

1978 DNR/AMAX FIELD LEACHING AND
RECLAMATION PROGRAM

Progress Report on the Leaching Study

January 29, 1979

Minnesota Department of Natural Resources
Division of Minerals
St. Paul, Minnesota

1978 DNR/AMAX FIELD LEACHING AND
RECLAMATION PROGRAM

Progress Report on the Leaching Study

January 29, 1979

Prepared by
Paul Eger
Bruce Johnson
Gary Hohenstein

Minnesota Department of Natural Resources
Division of Minerals
St. Paul, Minnesota

TABLE OF CONTENTS

	<u>Page</u>
List of Figures	iii
List of Tables	v
Foreward	vii
Abstract	viii
Overview	1
Introduction	6
1978 Field Program	
Methods	16
Phase I	
Results	20
Discussion	28
Summary & Conclusions	37
Phase II	
Results	38
Discussion	44
Summary & Conclusions	68
Future Analyses	69
Bibliography	72
Appendices	
Appendix I: Field Methods	73
Appendix II: Flow Calculations	78
Appendix III: Water Quality Data	82
Appendix IV: Computation of the Percent of Metals that are Retained in Test Piles	134
Appendix V: Rainfall Data	136
Appendix VI: Samples Used in Box Plot	144

Appendix VII: Quality Assurance	145
Appendix VIII: 1978 Sampling Season - General Events	154
Appendix IX: Reanalysis of Anomalous Values	156

LIST OF FIGURES

<u>Figure #</u>	<u>Title</u>	<u>Page</u>
1	Test Pile Construction	3
2	Test Pile Layout and Leachate Collection System	4
3	Flow Proportional Sampler	18
4	Rain pH, Amax 1978	25
5	Intensive Sampling of Rain Event of 6-23-78, Leach Pile 4, Concentration vs. Time	26
6	Intensive Sampling of Rain Event of 7-7-78, Leach Pile 4, Concentration vs. Time	27
7	Schematic of Stockpile Leaching Process	29-30
8	Intensive Sampling of Rain Event of 6-23-78, Leach Pile 4, Copper and Nickel Mass Loading vs. Time	33
9	Intensive Sampling of Rain Event of 6-23-78, Leach Pile 4, Sulfate Mass Loading vs. Time	34
10	Intensive Sampling of Rain Event of 7-7-78 and 7-8-78, Leach Pile 4, Mass Loading vs. Time	35
11	FL-1, 1977, Concentration vs. Time; Copper, Nickel, Sulfate, pH	46
12	FL-1, 1978, Concentration vs. Time; Copper, Nickel, Sulfate, pH	47
13	FL-2, 1977, Concentration vs. Time; Copper, Nickel, Sulfate, pH	48
14	FL-2, 1978, Concentration vs. Time; Copper, Nickel, Sulfate, pH	49
15	FL-3, 1977, Concentration vs. Time; Copper, Nickel, Sulfate, pH	50
16	FL-3, 1978, Concentration vs. Time; Copper, Nickel, Sulfate, pH	51
17	FL-4, 1977, Concentration vs. Time; Copper, Nickel, Sulfate, pH	52
18	FL-4, 1978, Concentration vs. Time; Copper, Nickel, Sulfate, pH	53
19	FL-5, 1977, Concentration vs. Time; Copper, Nickel, Sulfate, pH	54
20	FL-5, 1978, Concentration vs. Time; Sulfate	55
21	FL-5, 1978, Concentration vs. Time; Nickel, pH	56
22	FL-5, 1978, Concentration vs. Time; Copper, pH	57

23	FL-6, 1978, Concentration vs. Time; Sulfate	58
24	FL-6, 1978, Concentration vs. Time; Copper, Nickel, pH	59
25	Box Plot, Description	60
26	Box Plot, Sulfate	63
27	Box Plot, Copper	64
28	Box Plot, Nickel	65
29	Box Plot, pH	66
30	pH vs. Time, 1978	67
31	Passive Drip Sampler	74
32	Overview of Flow Proportional Sampler	77

LIST OF TABLES

<u>Table #</u>	<u>Title</u>	<u>Page</u>
I	Components of Field Leaching Piles	2
II	Mineralogical Composition of FL-1	8
III	Chemical Composition of FL-1	9-10
IV	Mineral Names, Abbreviations and Formulas	11-12
V	Mineralogical Composition of Semi-Massive Mineralized Rock Samples	13
VI	Chemical Composition of Semi-Massive Mineralized Rock Samples	14-15
VII	Characterization Data for Stockpiles	21
VIII	Soil Depth and Fertilizer Addition	22
IX	Regional Rainfall Averages	23
X	Rain pH	24
XI	Percent of Oxidized Metal that is Retained in Stockpile	32
XII	Mass Release Summary for Intensive Events - FL-4	36
XIII	Rainfall Events, April through October, 1978	39
XIV	Test Pile Area	40
XV	Flow Summary	41
XVI	Overall Runoff Calculation	42
XVII	Samples Used for Box Plot	61
XVIII	Water Quality Samples Collected in 1978	83
XIX	Amax Samples	85
XX	Water Quality Data, FL-1, 1978	87-92
XXI	Water Quality Data, FL-2, 1978	93-96
XXII	Water Quality Data, FL-3, 1978	97-100
XXIII	Water Quality Data, FL-4, 1978	101-121
XXIV	Water Quality Data, FL-5, 1978	122-127

XXV	Water Quality Data, FL-6, 1978	128-133
XXVI	Calculation of the Percent of Metals Retained in Test Pile	135
XXVII	Precipitation at Minnamax, April 1978	136
XXVIII	Precipitation at Minnamax, May 1978	137
XXIX	Precipitation at Minnamax, June 1978	138
XXX	Precipitation at Minnamax, July 1978	139
XXXI	Precipitation at Minnamax, August 1978	140
XXXII	Precipitation at Minnamax, September 1978	141
XXXIII	Precipitation at Minnamax, October 1978	142
XXXIV	Precipitation at Minnamax, November 1978	143
XXXV	Duplicate Samples	146
XXXVI	Quality Assurance Summary	149
XXXVII	Blanks	150
XXXVIII	Intralaboratory Quality Assurance	151
XXXIX	Hypalon Contamination Tests	152
XL	Pump Contamination Test	153
XLI	Reanalysis of Anomalous Value	157

FOREWORD

This progress report describes the leaching portion of the joint DNR/Amax leaching and reclamation study. It contains the raw water quality data collected during 1978. Some analysis of the data is presented, but more is needed and planned. Additional literature work is also planned. Supporting references will be cited in future reports and the discussion section will be expanded. Analysis plans are discussed in this report and additional results will be presented as they are completed.

This document is preliminary but it does serve as a starting point for continued discussion of the leaching program. Comments would be appreciated.

ABSTRACT

Runoff from lean ore and waste rock Duluth gabbro stockpiles may pose significant environmental problems. Water quality samples collected from gabbro stockpiles have contained elevated concentrations of trace metals (copper, nickel, cobalt and zinc.) Observed metal concentrations in leachate samples range from 10 to 10,000 times the natural background concentrations of streams in the area.

In 1978, a joint DNR/Amax program was established to study the leaching and reclamation of stockpiled gabbro. Six test piles (FL 1-6) were constructed in 1977. In 1978, two were covered with glacial till (piles 3,5) and one with topsoil (pile 2). These were then fertilized and planted.

Intensive sampling was conducted on FL-4 during two rain events, to determine the fluctuation in runoff concentration over the storm. Copper concentration remained essentially constant while nickel and sulfate concentration varied considerably. Mass release followed the runoff hydrograph, with the maximum release occurring at peak discharge.

Preliminary results indicate that there is a difference in the amount of runoff from each pile. Piles 5 and 6 yield about 65% runoff; piles 1,3 and 4, 50-55%; and pile 2, 35%. It appears that the glacial till treatment did little to control runoff, while the topsoil treatment reduced flow. Vegetation was sparse on the till pile but good growth was observed on the topsoil pile.

Both flow and concentration data indicate that pile 5 and 6 are different from piles 1 - 4. Pile 5 has produced acid leachate and the pH in pile 6 began to decline at the end of the field season. Metal concentrations in samples from piles 5 and 6 are one to two orders of magnitude higher than in samples from piles 1 - 4; the maximum nickel concentration observed was at pile 5, 83 mg/l. The median concentration values for pH, nickel sulfate are comparable for piles 1 - 4. Copper concentrations in samples collected from piles 2 and 3 increased in 1978. This increase appears to

be the result of increased copper mobility, rather than increased sulfide dissolution. Organic compounds removed from the overlying soil cover could produce a increase in copper mobility.

OVERVIEW

In 1974, Amax Exploration Inc. reached an agreement with Bear Creek Mining Company, and assumed Bear Creek's leases for properties located in T 60N R 12W, about 4 miles S.E. of Babbitt, Minnesota. As a significant proportion of the leases involved state land and state minerals, Amax requested permission from the State to construct an exploratory shaft.

In 1974, very little information existed on the potential environmental problems that might be associated with developing Minnesota's copper-nickel resources. The state and Amax agreed that the Amax project could serve as a pilot study. A comprehensive monitoring network was developed and an agreement was reached to conduct leaching tests on stockpiled materials.

In 1977, Amax constructed six (6) test piles containing lean ore material. The mass, grade, and completion date of each pile is given in Table I. Each pile was placed on an impervious liner (30 mil reinforced Hypalon) and all runoff is collected via a six (6) inch perforated drain line. The details of pile construction and pile layout are shown in Figures 1 and 2.

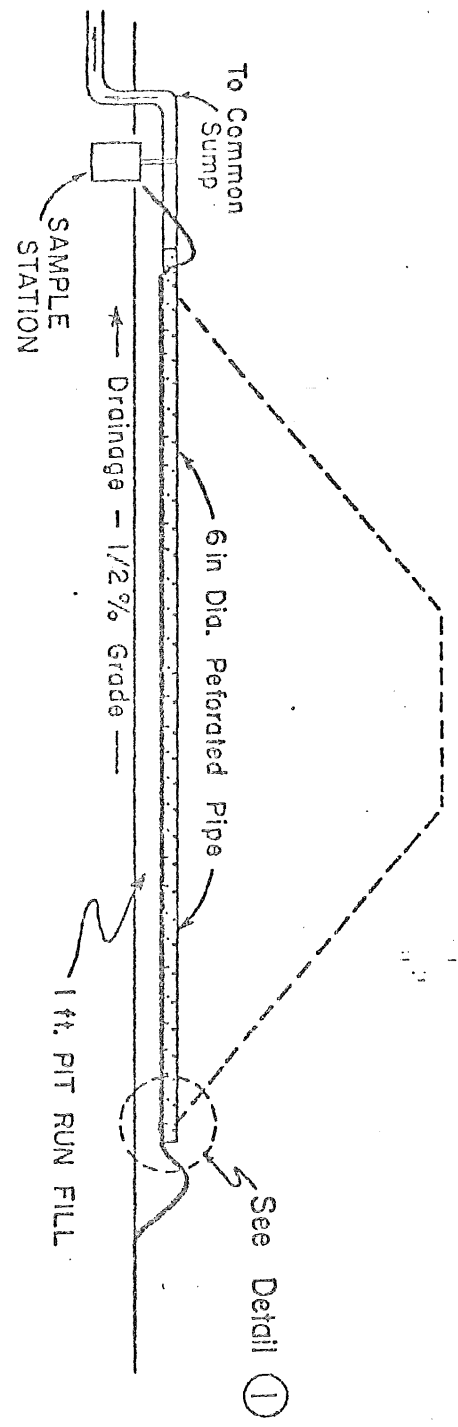
In 1977, Water quality data was collected periodically from each pile and has been present in a report "Field Leaching Summary Report 1977", prepared by Amax Environmental Services, Inc. May, 1978.

In 1978, a joint DNR/Amax program was initiated to study the leaching and revegetation of the lean ore test piles. This is a unique project not only from a scientific viewpoint but also from the stand point of industry-government cooperation. A concerted effort is being made by both the state and the company to identify significant environmental problems and to study methods of mitigation. In the joint program, Amax is responsible for the revegetation program and the DNR is responsible for the leaching aspects of the study. This is a preliminary progress

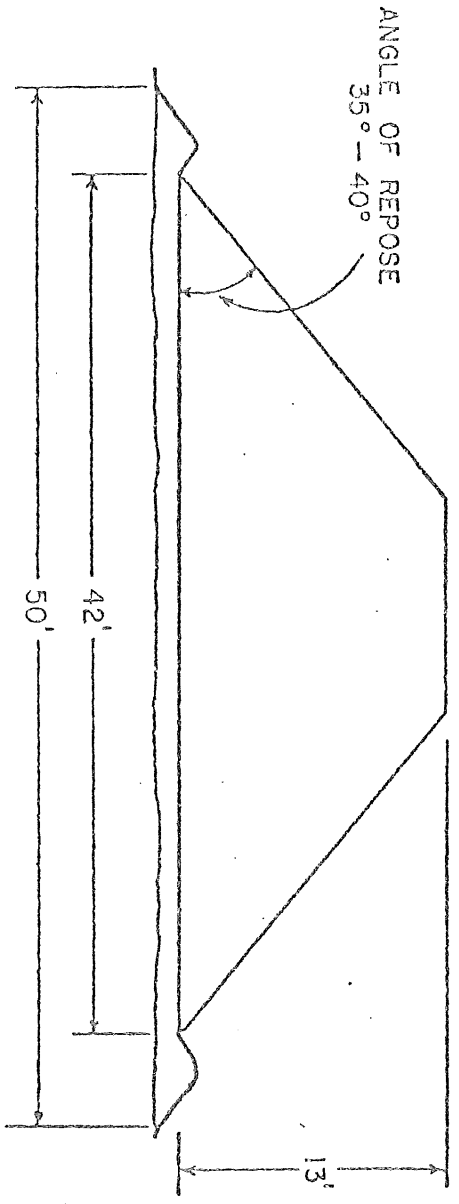
TABLE 1. COMPONENTS OF FIELD LEACHING PILES

<u>Pile No.</u>	<u>Size (Tons)</u>	<u>Completion Date</u>	<u>Average Mineral Content</u>			
			<u>% Cu</u>	<u>% Ni</u>	<u>% S</u>	
1	1766	April 20, 1977	.33-.35	.075	0.6	NONE
2	1766	April 20, 1977	.33-.35	.075	0.6	Trace of Ni
3	1766	April 20, 1977	.33-.35	.075	0.6	Trace of Ni
4	1765	April 20, 1977	.33-.35	.075	0.6	NONE
5	1951	Sept. 10, 1977	0.29	0.09	1.45	Trace of Ni
<u>6</u>	<u>1672</u>	Sept. 30, 1977	<u>0.38</u>	<u>0.09</u>	<u>0.83</u>	NONE
Total	Piles 1-6	10,686	0.33	0.08	0.79	

(ton is short ton = 2000 lbs)



SECTION B-B
 1" = 10'



SECTION C-C
 1" = 10'

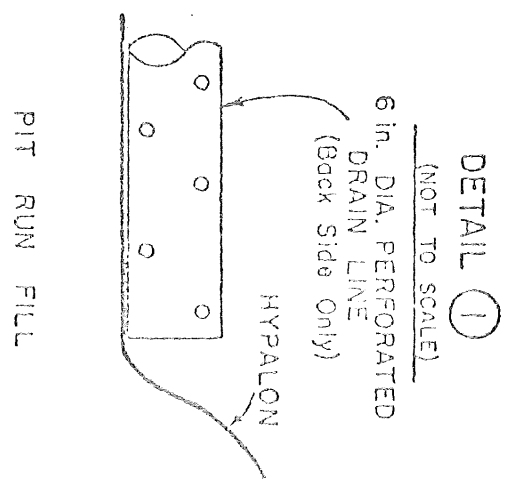
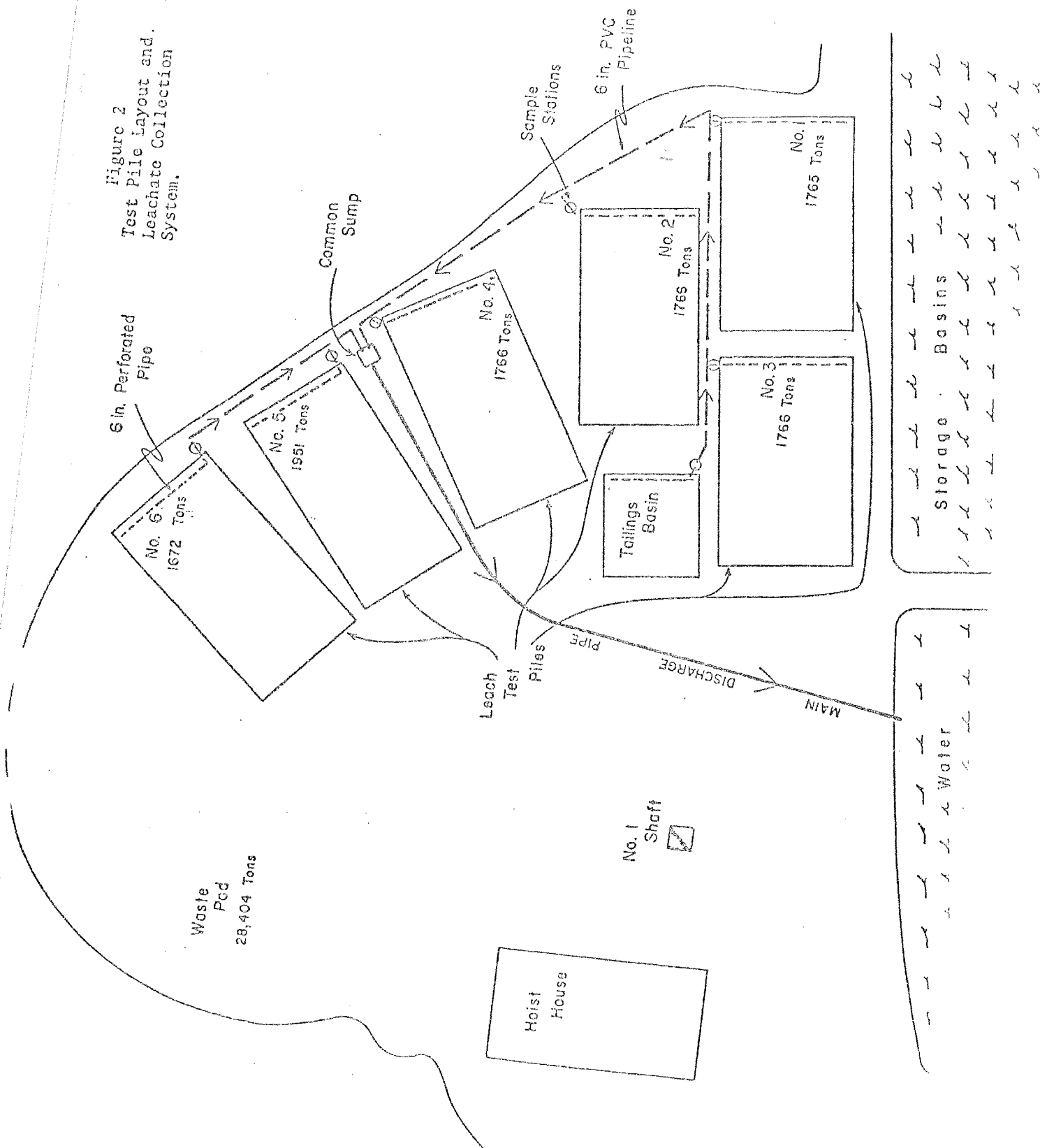


Figure 2
Test Pile Layout and
Leachate Collection
System.



) report on the leaching program. Water quality data, flow data and rainfall data that have been collected are presented. Some preliminary discussion of the results is provided. Data analysis is continuing and additional results will be included in future reports.

1 INTRODUCTION

Historically one of the major problems associated with the mining of metal sulfide deposits has been the release of toxic trace metals through the leaching of mining wastes (Hawley, 1972, Eisenreich et al, 1976). In most documented cases of leaching problems, the leachate is acidic, often with pH values as low as 2 to 3.

Most of the field studies reported in the literature involved materials that contained a high concentration of sulfide minerals. Hawley reports that acid leachate has been associated with materials that contain 2.5 to 70 percent sulfide. The Duluth gabbro is a low grade disseminated deposit. "Model" lean ore and waste rock concentrations developed by the Regional Copper Nickel Study (R. Stevenson, personal communication) range from .655 percent sulfur for lean ore to .207 for waste rock. Even though the gabbro is in general a low grade deposit, early water quality samples (1974) collected near stockpiled gabbro at Erie Mining Company's Dunka Pit, near Babbitt, MN, indicated elevated levels of trace metals. Studies conducted by the Regional Copper Nickel Study (Level II leaching report, soon to be released) have confirmed the findings of the early samples. Metal concentrations in leachate samples are 10 to 10,000 times the natural background concentrations.

Lean ore and waste rock stockpiles, unless controlled, may pose significant environmental problems. Not only is there evidence that stockpile runoff will contain elevated metal concentrations, but the mass of material that will be stockpiled is extremely large. For its open pit prospect, Amax has projected a stockpile area of 3400 acres, 500-600 feet high.

The Duluth gabbro complex contains a large percentage of silicate minerals. As part of the Regional Copper-Nickel Study, samples of the gabbro were collected

across the contact from Hoyt Lakes to Ely (more detail will be given in the Regional Copper Nickel report on geology and mineralogy). The mineralogy of these samples was determined and a complete chemical analysis was made on each sample. Five samples from the Amax area were analyzed, one of which was selected from leach pile FL-1. The mineralogical composition is shown in Table II and the chemical composition in Table III. A description of the mineral forms is given in Table IV. Over ninety percent of the rock is composed of silicate minerals, the three major groups being plagioclase, olivine, and pyroxene. The sulfides make up a very small percentage of the rock, approximately 0.655 percent.

Generally, most of the sulfides found in mining wastes are unwanted iron sulfides, either in the form of pyrite or pyrrhotite. The percent of iron sulfide in the test pile material is quite low (Table II) and this is generally true for the disseminated material across the region (R. Stevenson, personal communication). Only in pockets of massive or semi-massive ore are high concentrations of iron sulfides found. Tables V and VI include the analysis of a semi-massive sample collected from the Amax test shaft. This sample contained 10.5 percent sulfur, most of which was associated with the pyrrhotite which comprised 12.8% of the sample.

Table II MINERALOGICAL COMPOSITION OF FL-1 (volume %)

Plagioclase	59.112
Sericite	2.176
Olivine	10.510
Clinopyroxene	11.185
Orthopyroxene	3.716
Monocrystalline amphibole	3.567
Fibrous amphibole	0.288
Chlorite	1.136
Serpentine	0.257
Iddingsite	0.075
Talc	-
Biotite	1.738
Smectite	0.021
Celadonite	-
Opagues*	5.098
Chalcopyrite-cubanite	0.769
Pentlandite	0.037
Pyrrhotite	0.844
Ilmenite-magnetite	3.447
Graphite	-
Spinel	-
Myrmekite	-
Apatite	0.085
Epidote	0.953
Allanite	-
Calcite	0.056
Quartz	-
Cordierite	0.027

* The value shown for opaques is the sum of the five following values

Table III CHEMICAL COMPOSITION OF FL-1

<u>Element</u>		<u>Units</u>
Si (SiO ₂)	22.80 (48.81)	Pct
Al (Al ₂ O ₃)	8.98 (16.96)	Pct
Fe (Fe(O))	9.22 (11.86)	Pct
Mg (MgO)	4.31 (7.15)	Pct
Ca (CaO)	5.55 (7.76)	Pct
Na (Na ₂ O)	2.00 (2.70)	Pct
K (K ₂ O)	.32 (.39)	Pct
Ti (TiO ₂)	1.41 (2.35)	Pct
P (P ₂ O ₅)	.02 (.05)	Pct
Mn (MnO)	.12 (.16)	Pct
Cr (Cr₂O₃)	.03 (.05)	Pct
B	662.00	PPM
Ba	1173.00	PPM
Be	1.00	PPM
Sr	279.00	PPM
V	276.50	PPM
Th	6.40	PPM
Zr	80.00	PPM
S	.655	Pct
Cu	.306	Pct
Ni	.073	Pct
Fe (S)	.696	Pct
Co	.009	Pct
Zn	157.00	PPM
Pb	0	PPM
Ag	1.35	PPM
As	0	PPM
Hg	<1.00	PPB

Table III (cont'd) CHEMICAL COMPOSITION OF FL-1

<u>Element</u>		<u>Units</u>
Mo	.50	PPM
Cd	0	PPM

Pct = Weight percent
 PPM = parts per million by weight
 PPB = parts per billion by weight

Table IV. Mineral Names, Abbreviations and Formulas

LAG	Plagioclase	$\text{Na Al Si}_3 \text{O}_8 - \text{Ca Al}_2 \text{Si}_2 \text{O}_8$	a feldspar
ERCT	Sericite	$\text{K}_2 \text{Al}_4 \text{Si}_6 \text{Al}_2 \text{O}_{22} (\text{OH}, \text{F})_4$	a mica, alters from feldspar
OL	Olivine	$(\text{Fe}, \text{Mg}) \text{SiO}_4$	Fe-Mg silicate
CPX	Clinopyroxene	$\text{Ca} (\text{Fe}, \text{Mg}) \text{Si}_2 \text{O}_6$	a pyroxene, Fe-Mg silicate
OP	Orthopyroxene	$(\text{Fe}, \text{Mg})_2 \text{Si}_2 \text{O}_6$	a pyroxene, Fe-Mg silicate
AMP	Monocrystalline amphibole	$(\text{Na}, \text{K})_{0-1} (\text{Ca}, \text{Mg}, \text{Fe}^{+2}, \text{Fe}^{+3}, \text{Al})_7 (\text{Si}_{6-8} \text{Al}_{2-0}) \text{O}_{22} (\text{OH}, \text{F}, \text{Cl})_2$	amphibole with non-acicular morphology
FAMP	Fibrous Amphibole	$(\text{Na}, \text{K})_{0-1} (\text{Ca}, \text{Mg}, \text{Fe}^{+2}, \text{Fe}^{+3}, \text{Al})_7 (\text{Si}_{6-8} \text{Al}_{2-0}) \text{O}_{22} (\text{OH}, \text{F}, \text{Cl})_2$	amphibole with fibrous or acicular morphology
HLRT	Chlorite	$(\text{Mg}, \text{Fe}, \text{Al})_{12} (\text{Si}, \text{Al})_8 \text{O}_{22} (\text{OH})_{16}$	alters from Fe-Mg silicates
SEPPN	Serpentine	$\text{Mg}_3 \text{Si}_2 \text{O}_5 (\text{OH})_4$	alters from Fe-Mg silicates
TDNGT	Iddingsite	Serpentine + iron oxide phase	alters from olivine
TALC	Talc	$\text{Mg}_6 \text{Si}_8 \text{O}_{20} (\text{OH})_4$	alters from Fe-Mg silicates
BIOT	Biotite	$\text{K}_2 (\text{Mg}, \text{Fe}^{+2})_{6-4} (\text{Fe}^{+3}, \text{Al}, \text{Ti})_{0-2} (\text{Si}_{6-5} \text{Al}_{1-3}) \text{O}_{20} (\text{OH}, \text{F})_4$	a mica
MCTT	Smectite	$(\frac{1}{2} \text{Ca}, \text{Na})_{0.7} (\text{Al}, \text{Mg}, \text{Fe})_4 (\text{Si}, \text{Al})_8 \text{O}_{20} (\text{OH})_4 \cdot n\text{H}_2\text{O}$	a clay, alters from feldspar
LDNT	Celadonite	$\text{K Mg Fe}^{+3} \text{Si}_4 \text{O}_{10} (\text{OH})_2$	a mica, similar to glauconite
PQ	Opaque minerals, sum of following seven minerals*		
P-CB	*Chalcopyrite *Cubanite	Cu Fe S $\text{Cu Fe}_2 \text{S}_3$	undifferentiated
PN	*Pentlandite	$(\text{Fe}, \text{Ni})_9 \text{S}_8$	
	*Pyrrhotite	$\text{Fe}_7 \text{S}_8 - \text{Fe S}$	
RETIO	*Ilmenite	Fe Ti O_3	

	*Magnetite	$\text{Fe}_3 \text{O}_4$	contains appreciable titanium (20 wt%)
RPHT	*Graphite	C	present as flakes
PNL	Spinel	$\text{Mg Al}_2 \text{O}_4$	
MYRM	Myrmekitic intergrowths, generally between plagioclase and olivine		
APAT	Apatite	$\text{Ca}_5 (\text{PO}_4)_3 (\text{OH}, \text{F}, \text{Cl})$	
EPID	Epidote	$\text{Ca Fe}^{+3} \text{Al}_2 \text{Si}_3 \text{O}_{12} (\text{OH})$	(includes zeolites and prehnite $(\text{Ca}_2 \text{Al Al Si}_3 \text{O}_{10} (\text{OH}))$)
ALNT	Allanite	$(\text{Ca}, \text{Ce})_2 (\text{Fe}^{+2} \text{Fe}^{+3} \text{Al}_2 \text{Si}_3 \text{O}_{12} : \text{OH})$	borders radiating epidote
CAL	Calcite	Ca CO_3	
TZ	Quartz	Si O_2	
CORD	Cordierite	$\text{Al}_3 (\text{Mg}, \text{Fe}^{+2})_2 \text{Si}_5 \text{Al O}_{18}$	associated with hornfels

from R. Stevenson, Regional Copper-Nickel Study

Table V MINERALOGICAL COMPOSITION OF SEMI-MASSIVE, MINERALIZED ROCK SAMPLE (volume %)

Plagioclase	47.885
Sericite	0.091
Olivine	1.513
Clinopyroxene	2.656
Orthopyroxene	18.472
Monocrystalline amphibole	0.025
Fibrous amphibole	0.024
Chlorite	0.145
Serpentine	-
Iddingsite	-
Talc	-
Biotite	4.475
Smectite	-
Celadonite	-
Opakes*	19.239
Chalcopyrite-cubanite	3.231
Pentlandite	0.161
Pyrrhotite	12.816
Ilmenite-magnetite	2.564
Graphite	0.467
Spinel	-
Myrmekite	-
Apatite	0.118
Epidote	-
Allanite	-
Calcite	-
Quartz	0.037
Cordierite	5.350

* The value shown for opakes is the sum of the five following values

Table VI CHEMICAL COMPOSITION OF SEMI-MASSIVE, MINERALIZED ROCK SAMPLE

Element			Units
Si (SiO ₂)	18.15	(38.85)	Pct
Al (Al ₂ O ₃)	6.43	(12.15)	Pct
Fe (Fe(O))	7.71	(9.92)	Pct
Mg (MgO)	2.69	(4.46)	Pct
Ca (CaO)	3.44	(4.81)	Pct
Na (Na ₂ O)	1.18	(1.59)	Pct
K (K ₂ O)	.73	(.88)	Pct
Ti (TiO ₂)	.65	(1.08)	Pct
P (P ₂ O ₅)	.03	(.07)	Pct
Mn (MnO)	.11	(.14)	Pct
Cr (Cr ₂ O ₃)	.04	(.06)	Pct
B	428.00		PPM
Ba	310.00		PPM
Be	1.20		PPM
Sr	151.50		PPM
V	213.00		PPM
Th	0		PPM
Zr	59.50		PPM
S	10.500		Pct
Cu	1.155		Pct
Ni	.418		Pct
Fe (S)	13.885		Pct
Co	.036		Pct
Zn	185.00		PPM
Pb	0		PPM
Ag	0		PPM
As	0		PPM
Hg	<1.00		PPB

Table VI (cont'd)

CHEMICAL COMPOSITION OF SEMI-MASSIVE, MINERALIZED ROCK SAMPLE

<u>Element</u>		<u>Units</u>
Mo	5.50	PPM
Cd	0	PPM

Pct = Weight percent

PPM = parts per million by weight

PPB = parts per billion by weight

1978 FIELD PROGRAM

The overall goals of the joint leaching/reclamation program are measurement of the release of trace metals, sulfate, nutrients and chloride from the lean ore test piles and evaluation of the effect of various reclamation procedures on that release. To accomplish these goals the field program was separated into two phases.

The first phase was a characterization phase. Data was collected on the rock characteristics, top dressing characteristics (soil and fertilizer) and rainfall. In addition, the variability of leachate composition during a storm event was determined.

Phase II was a monitoring phase, in which data were collected to determine the total mass released from each pile. The total mass release will be used to evaluate the effectiveness of different reclamation procedures.

METHODS

As this was the first year of the program, a large effort was required to initiate the program, develop methodology, and provide instrumentation for the leach piles. The details of the problems encountered and the attempts to overcome them are given in Appendix I.

The critical parameters that had to be measured were 1-rainfall; the amount, duration, time of the event, and pH, 2-the discharge from individual piles and 3-a concentration representative of the runoff.

Rainfall

Rainfall is recorded by a standard rain gauge (Science Associates, Inc., NWS Spec. 450.230) and a recording rain gauge (Science Associates, Inc., NWS Spec. 450.220). The standard gauge is more accurate (± 0.01 inches) and is used to

determine the amount of rainfall while the recording gauge gives the duration and time of the rain event.

To collect samples for rainfall pH, a polyethylene funnel was attached to the outside of the weather instrument shelter. This funnel was connected by tygon tubing to a teflon bottle inside the shelter. The pH was recorded as soon as possible after rainfall ceased.

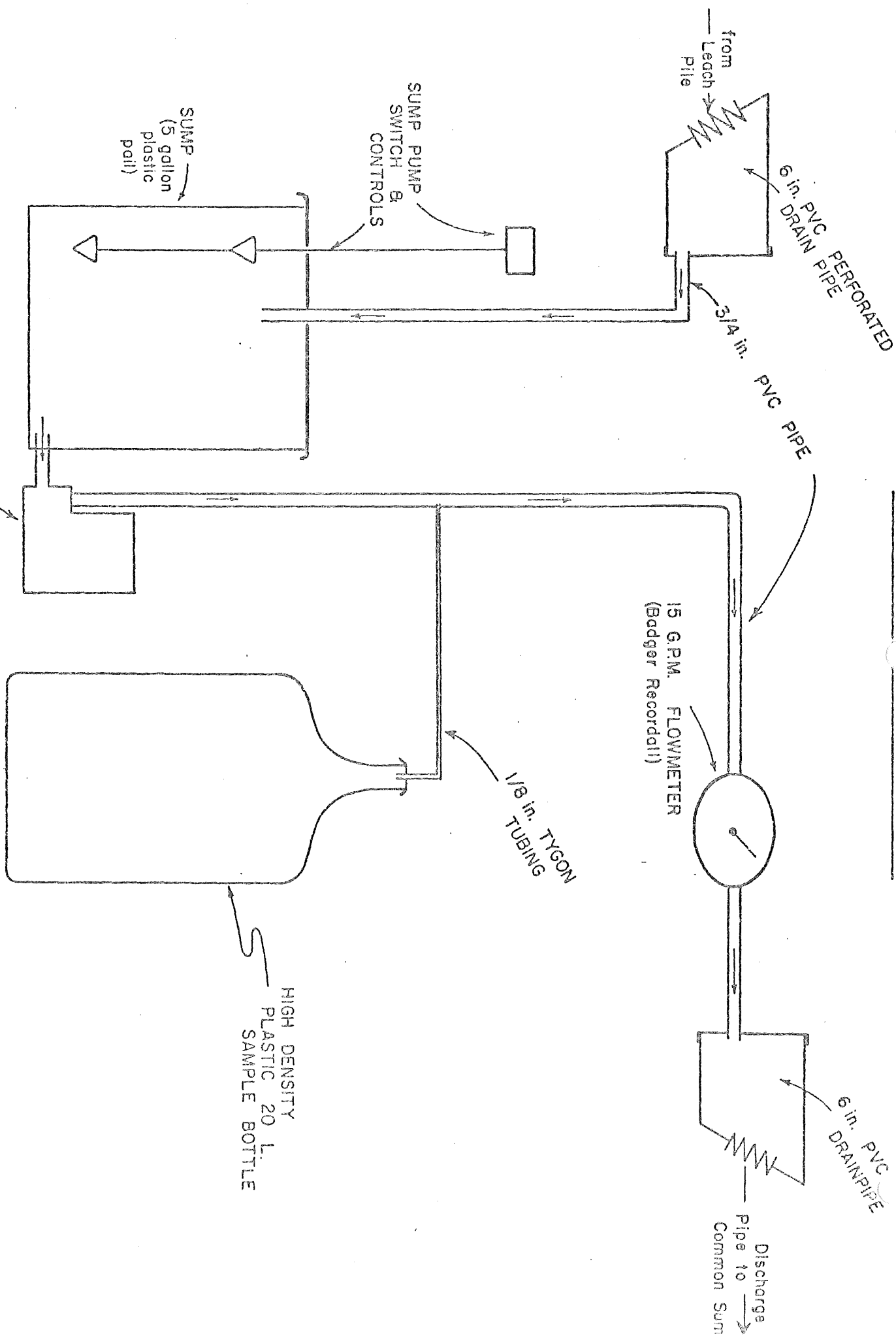
Flow

Daily volumetric flow measurements were made on each pile. Each pile is equipped with a flow meter (Badger Recordall Model 15). In July, fine mesh screens were installed upstream of the meters; and the slope was adjusted to increase the pressure drop through the meter. After these changes were made the meters worked satisfactorily at high flow, but failed to operate at low flow. Daily discharge from each pile was estimated using a combination of meter readings and volumetric measurements. Details and sample calculations are shown in Appendix II.

Water Quality Samples

The development of a satisfactory sampling device required a substantial amount of trial and error. As a result, the samples collected in 1978 are a mixture of composite and grab samples. A flow proportional sampler (Figure 3) was developed and tested on pile FL 4 and worked satisfactorily. This system provides a sample over an event that is weighted by flow. Concentrations have been shown to vary over a storm event (see Results-Phase I). In order to get an accurate measure of the total mass released from a pile, either a series of samples must be collected during each event or one flow weighted sample must be collected. The basic concept is that if 50% of the flow occurs in a 4 hour period then 50% of the volume of the sample should be collected in this period.

FLOW PROPORTIONAL SAMPLER



In our system, each time the pump discharges an aliquot of constant volume is placed in the sampling container. The higher the flow, the more often the pump discharges and the greater the volume of sample collected. This system has now been installed on all piles. (For more details refer to Appendix I).

RESULTS - PHASE I

Characterization

The objective of the characterization work is to provide information on all the test materials. Characterization data for the stockpiles are given in Table VII. Particle size distribution and surface area are estimates based on work done by the Regional Copper Nickel Study (Details of the calculation will be presented in the Level II Leaching Report). Piles 5 and 6 contain rock from the drifts which contain a higher degree of mineralization than the rock in the other four piles.

Additional mineralogical, chemical, and surface area information may be needed to clarify the differences between piles 1,2,3,4, and 5,6.

Top Dressing Characteristics

On May 11, test piles FL 3 & FL 5 were covered with glacial till and FL 2 with top soil. The volume and depth of soil cover for each pile is given in Table VIII. Composite samples of each soil type were collected. Each sample will be thoroughly mixed and split to obtain a representative sample. Particle size and total and extractable metal analysis will be performed by the Department of Natural Resources Laboratory in Hibbing. Soil classification, pH, and macro and micro nutrient analyses will be performed by the University of Minnesota Research Analytical Laboratory in St. Paul.

Fertilizer

Fertilizer was applied to test piles 2,3, and 5 on June 22. Sixteen kilograms (35.2 lbs) of a fertilizer with a guaranteed analysis of 10% NH_4NO_3 , 20% P_2O_5 , and 20% K_2O were applied to each pile. A composite sample of fertilizer was collected and will be analyzed for trace metal content.

TABLE VII. CHARACTERIZATION DATA FOR STOCKPILES

	Pile 1	2	3	4	5	6
Composition						
%S	.6	.6	.6	.6	1.45	.83
%Cu	.33-.35	.33-.35	.33-.35	.33-.35	.29	.38
%Ni	.075	.075	.075	.075	.09	.09
Mass (tons)	1766	1766	1766	1765	1951	1672
Collecting Area (ft. ²)	3173	3678	3178	3524	3648	3444
Surface area estimate) m ² /ton	90-820	90-820	90-820	90-820	90-820	90-820
Date constructed	(- - April 20 1977 - - - - -)				September 10 1977	September 3 1977
Stock source	shaft	shaft	shaft	shaft	drift	drift
Treatment	none	covered with topsoil and revegetated	covered with glacial till & revegetated	none	covered with glacial till & revegetated	none

* estimate based on an assumed particle size distribution (Detail of the calculation will be found in the Regional Copper Nickel Study Level II leaching report. This will be available soon.)

TABLE VIII.

SOIL DEPTH AND FERTILIZER ADDITION

1	Mean depth of soil cover (inches)	Mean width of pile (ft)	Length of pile (ft)	Volume of soil cover			NH ₄ added (g)	NO ₃ added (g)	P added (g)	K added (g)
				(ft ³)	(yds ³)	(m ³)				
2	7.14	56	92	3065	114	87	360	1239	1397	1582
3	11.3	51	88	4219	156	119	360	1239	1397	1582
5	10.9	56	90	4578	170	130	360	1239	1397	1582

Rainfall

During 1977-78 monthly bulk precipitation samples were collected by the Regional Copper Nickel Study. Bulk samples collect both wet and dry fall, so concentrations may tend to be slightly higher than if only rainfall was sampled. Table IX gives the regional average which was based on data collected at four sites across the copper-nickel study area. More information will be available in the Regional Copper Nickel Study Technical Report on air/water interactions. Concentrations of all constituents are generally quite low.

In 1978, rainfall samples were collected at Amax and pH was analyzed from fourteen separate events. The data is given in Table X and summarized in Figure 4. In general, the rain tends to be acidic. Recent studies conducted in the area have indicated that there is already a trend for increasing rainfall acidity (D. Thingvold, personal communication). The exact effect this increasing acidity will have on the release from stockpiled materials is not known, but if the pH in the pile is lowered more metals may be released.

Variability of Runoff Concentration Over a Storm Event

Intensive sampling was conducted on FL4 for two storm events (0.35 inches on June 23 and 1.53 inches on July 7). The complete set of data for these events is in Appendix III. Figure 5 and 6 illustrate the variation in concentrations of copper, nickel, and sulfate during the runoff. On June 23, there was no flow prior to the storm. Nickel and sulfate concentrations rose rapidly, and then leveled off, while copper concentrations remained essentially constant throughout the runoff period. On July 7, there was a small base flow prior to the rain event. Nickel and sulfate concentrations were high in the base flow, decreased rapidly with the initial rise in flow, increased slightly during the peak runoff, decreased on falling limb of the hydrograph, and then rose gradually as flow diminished.

TABLE IX. REGIONAL RAINFALL AVERAGES

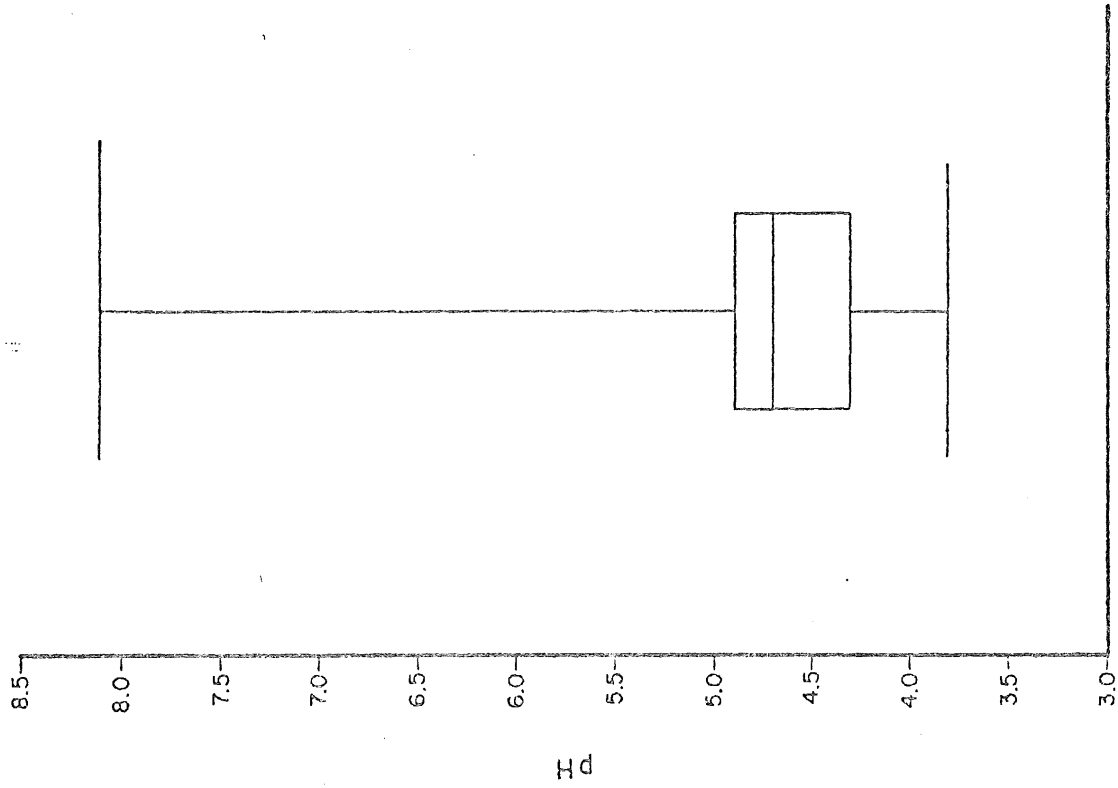
<u>Parameter</u>	
Specific Conductance, 25°C (umhos)	27
Suspended solids	12
Total dissolved solids, 180°C	10
NO ₂ , NO ₃	.27
Total Phosphorus	.04
Total organic Carbon	4.1
Alkalinity, CaCO ₃	< 10
Cl	< 1.9
Ca	1.6
Mg	< 1.6
Na	< 5
K (mg/l)	< .5
F (mg/l)	< .1
Ni (ug/l)	2
Cd (ug/l)	.45
Zn (ug/l)	8.1
Pb (ug/l)	10.9
Al (ug/l)	120
Fe (ug/l)	(~ 154)
As (ug/l)	< 1.6
Cu (ug/l)	1.5

All concentrations in mg/l except as noted.

TABLE X
Rain pH

[illegible]

Figure 4
RAINFALL pH, AMAX 1978

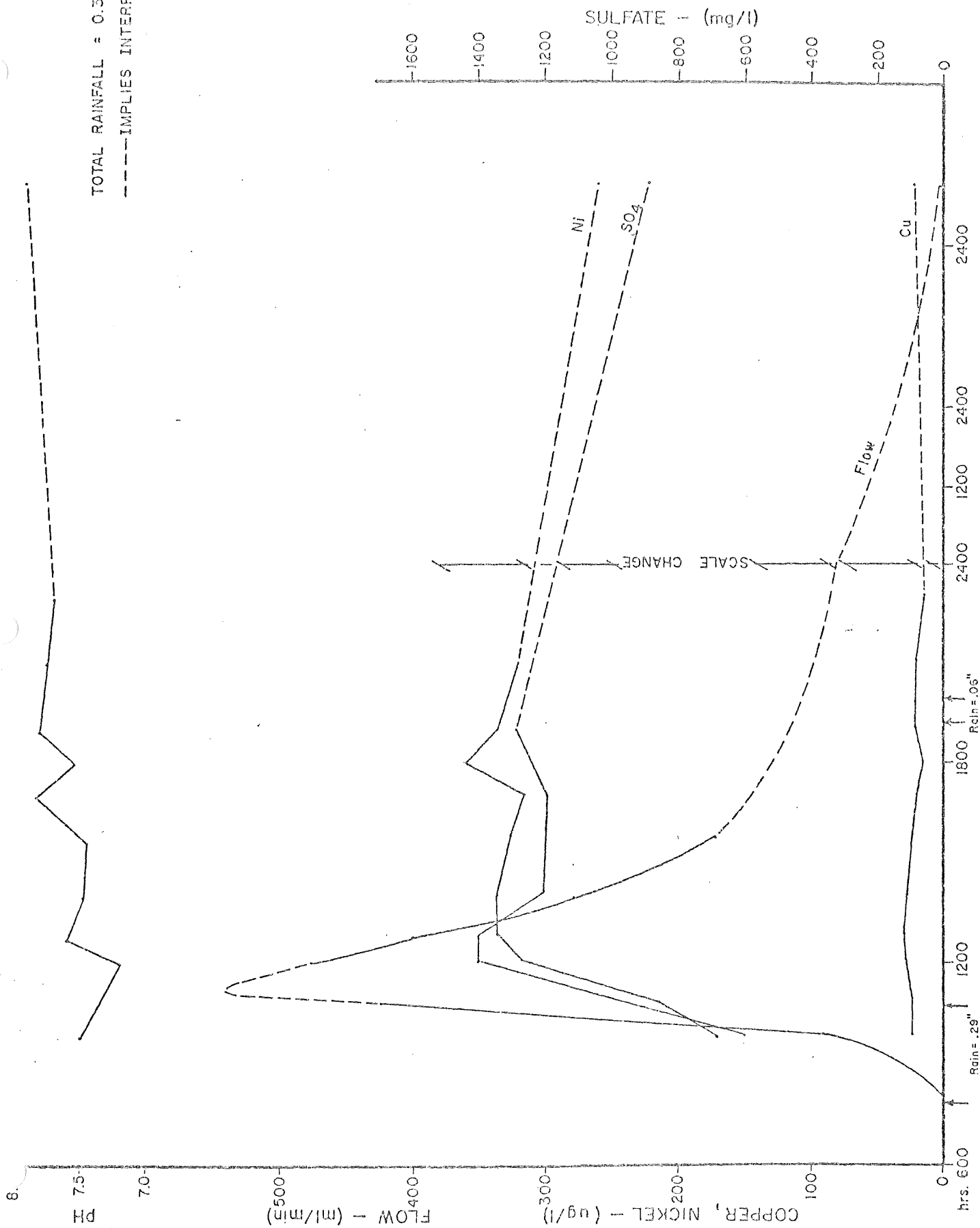


n = 14

Concentration vs Time

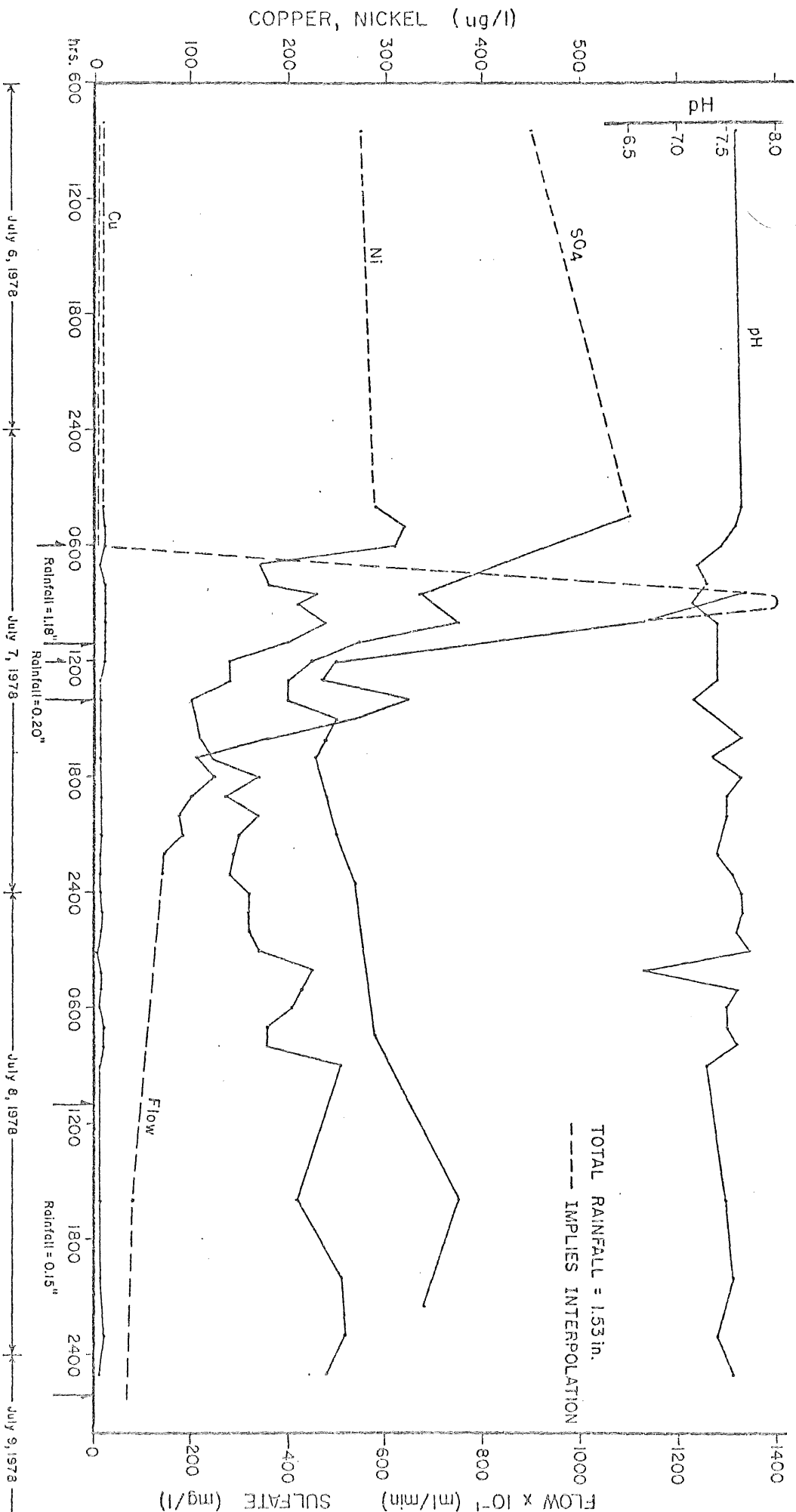
TOTAL RAINFALL = 0.55 in.

---IMPLIES INTERPOLATION



June 23 June 24 June 25 June 26

Figure 6
 INTENSIVE SAMPLING OF RAIN EVENT OF JULY 7 and JULY 8, 1978
 LEACH PILE 4
 Concentration vs Time



Copper concentrations essentially remained constant throughout the event.

DISCUSSION - PHASE I

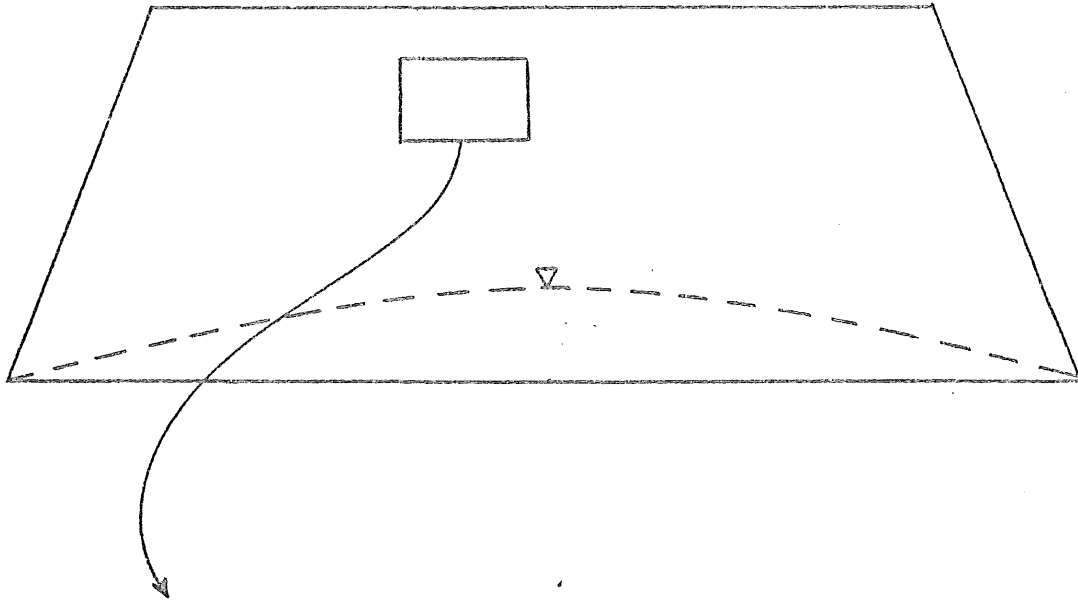
Leaching, as the term is generally used, is the net transfer of material from the solid phase to an environmentally observed aqueous phase. The net transfer is the complex result of a series of chemical and physical reactions that involve mineral dissolution and the transport of the dissolution products out of the stockpile. A schematic of the processes involved in the net transfer of material from the stockpile to an observation point is shown in Figure 7. A detailed discussion of each type of process will not be presented here, but will be provided in later reports as well as in the Regional Copper Nickel level II leaching report, and the technical report on the laboratory leaching experiments conducted at the University of Minnesota. Preliminary discussion can be found in earlier progress reports, (Eisenreich et al, 1977).

The two major considerations in leaching are 1) the reactivity of the specific mineral phase and 2) the mobility of the resulting chemical species; e.g. copper, nickel or sulfate. The reactivity of the mineral phase is a measure of how easily the mineral dissolves. Mobility is a measure of the tendency of an ion to remain in solution. It is the result of many competing reactions, and it is a function of the aqueous environment. Under acid pH conditions, mobility of most trace metals (e.g. copper) will be very high, while at neutral or basic pH, mobility may be low.

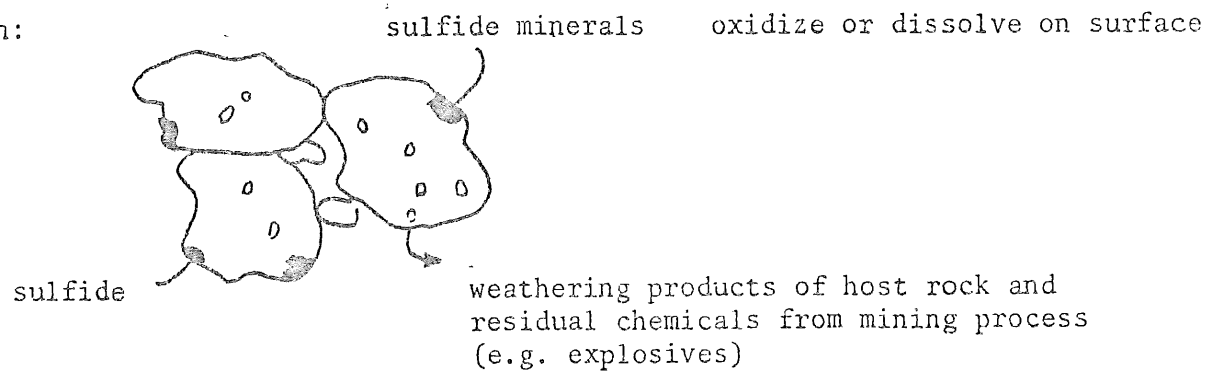
Although sulfate does undergo reactions in solution, under oxidizing conditions it is generally treated as a mobile ion. Therefore, it can be used as an indication of the dissolution of the metal sulfides in the pile. If it is assumed that the only source of the trace metals is the sulfide minerals and that the sulfate release is a measure of the total rate of sulfide mineral dissolution, then the percent of each metal that is transported out of the pile can be calculated. This

Figure 7

Schematic of Stockpile Leaching Process



Step 1: Reaction:



Step 2: Transport: A. reaction products are removed by percolating water

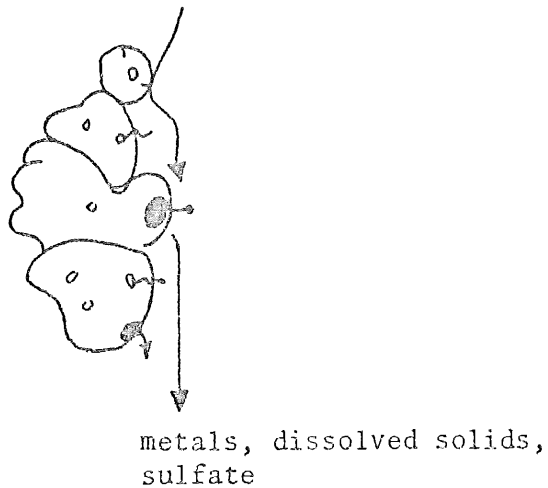
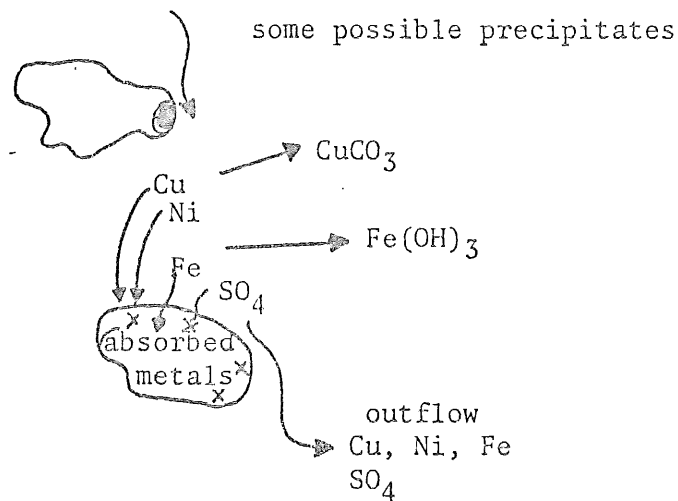


Figure 7 (cont'd.)

- B. Some of the metals are readsorbed onto the silicate mineral surface or form precipitates.



(In saturated zone the processes are essentially the same, although water is always available to transport the reaction products.)

The outflow from the stockpile is composed of the weathering products of 1) the sulfide minerals (the prime source of the trace metals; copper, nickel, zinc, cobalt; and sulfate) 2) the silicate minerals (major contributors of calcium, magnesium) and the residual chemicals that were on the rocks when they were stockpiled (primary source of nitrate).

is illustrated in Table XI using the 1977 data for leach pile FL 1. The details of the calculation are given in Appendix IV. The metals exhibit very low mobility. Under present environmental conditions, only a very small percentage of each metal that is released from the mineral phase is transported from the stockpile.

The mobility factor is important in discussing the different behavior of the release of copper and nickel from the test piles. The pH values of the samples collected during the rain events of 6-23 and 7-7 are shown in Figures 5 and 6. The mean pH was 7.56 on 6-23 and 7.44 on 7-7. At this pH, in the absence of complexing ligands, copper is not very mobile. It can form carbonate and hydroxide precipitates and be adsorbed onto the silicate surface of the gabbro or onto iron hydroxide precipitates. The result is that very little copper is transported from the test pile. The constant concentration over the rain event supports the concept that the copper release is controlled by its mobility.

In general, nickel is a more mobile ion than copper, particularly in the neutral pH range. As can be seen from Figures 5 and 6, the nickel concentration is more than an order of magnitude higher than the copper concentration. The nickel concentrations fluctuate over a factor of two during the storm of 7-7. The final concentration in solution is influenced not only by reaction equilibrium but also by the amount and rate of water moving through the pile. Further analysis of the fluctuations in concentration over the events is being conducted.

Figures 8,9,10, show the rate of mass release (mg/min) for copper, nickel and sulfate for the storms of 6-23 and 7-7. The general trend is that mass release follows the hydrograph with the maximum mass release occurring during the peak run-off. Table XII summarizes the total release from the pile for each storm.

Table XI. PERCENT OF OXIDIZED METAL THAT IS RETAINED IN STOCKPILE

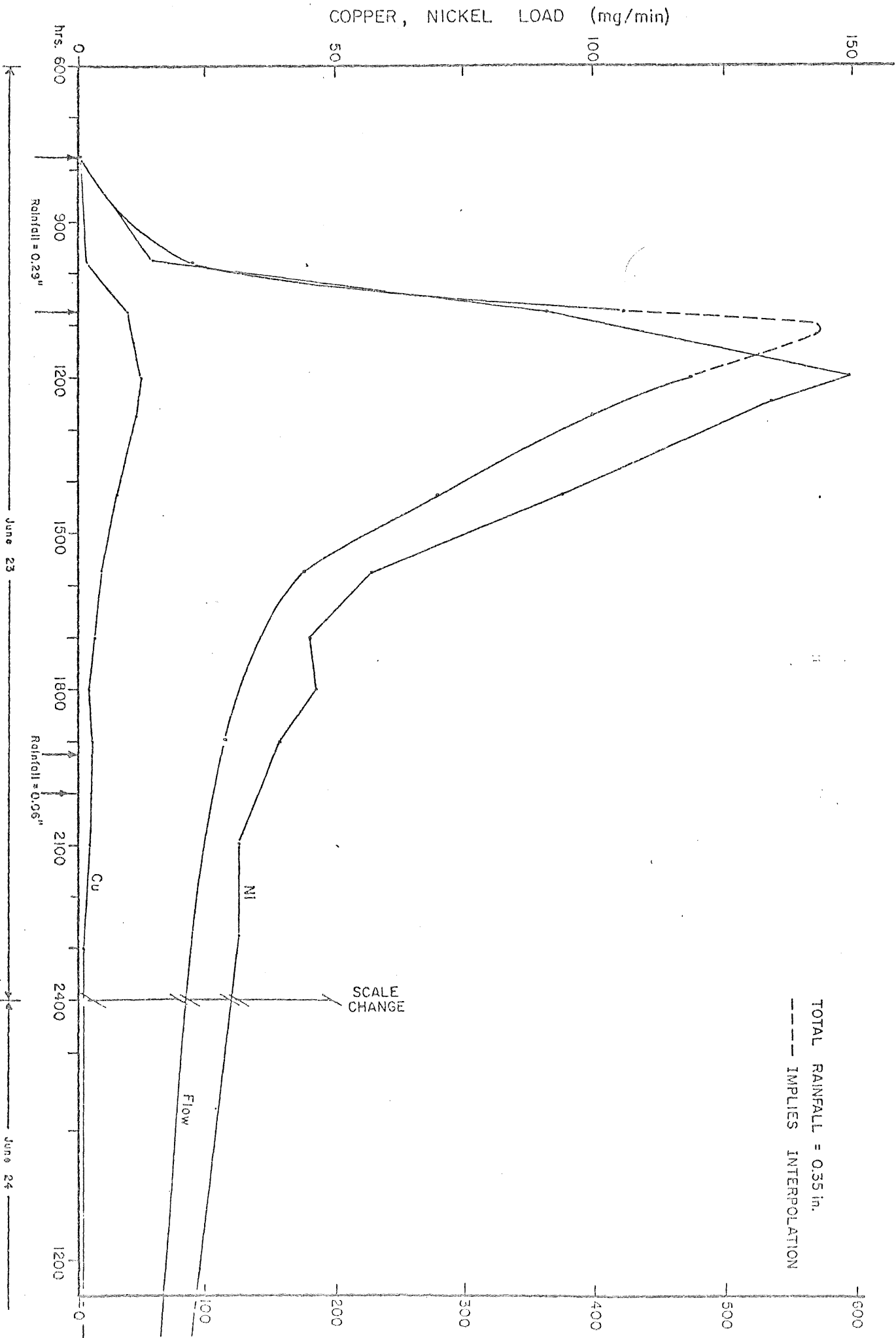
	Concentration (mg/l) predicted from chemical composition ¹	Concentration (mg/l) observed (median)	Percent of metal retained in pile
SO ₄	610 ¹ basis	610 ¹	0
Ni	22.7	.288	98.7
Cu	95.2	.03	99.97
Zn	5.0	.013	99.7
Co	2.8	.006	99.8
Fe	217	< .05	> 99.98

¹SO₄ is the basis of the calculation, it is assumed that SO₄ indicates total sulfide dissolution and that it is 100% removed from pile

INTENSIVE SAMPLING OF PAVN EVENT OF JUNE 23, 1978

LEACH FILE 4

Copper and Nickel Mass Loading vs Time



LEACH PILE 4
Sulfate Mass Loading vs Time

TOTAL RAINFALL = 0.35 in.
--- IMPLIES INTERPOLATION

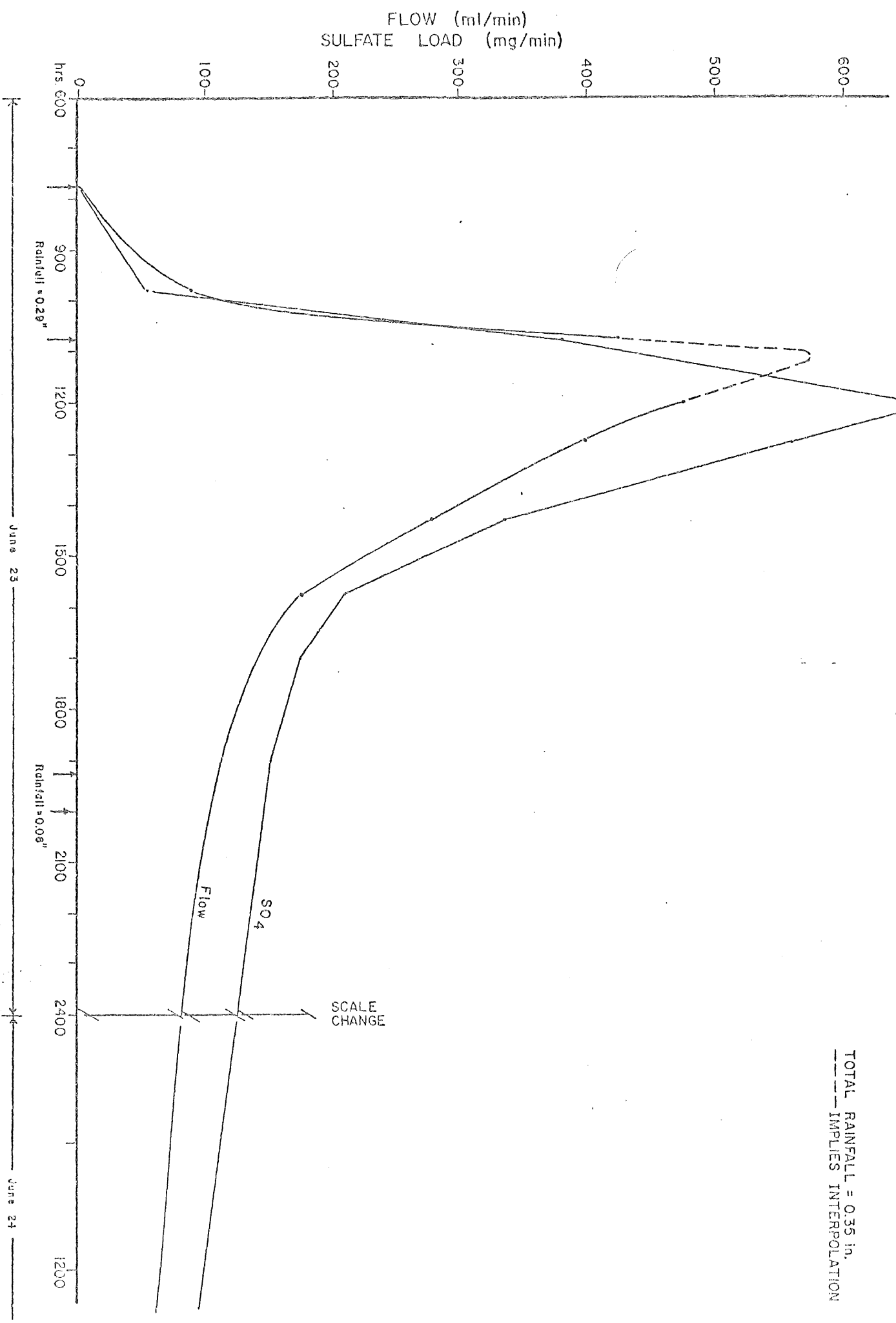


Fig. 2.10
INTENSIVE SAMPLING OF RAIN LEACH PILE 4
LEACH PILE 4
MASS LOADING VS TIME

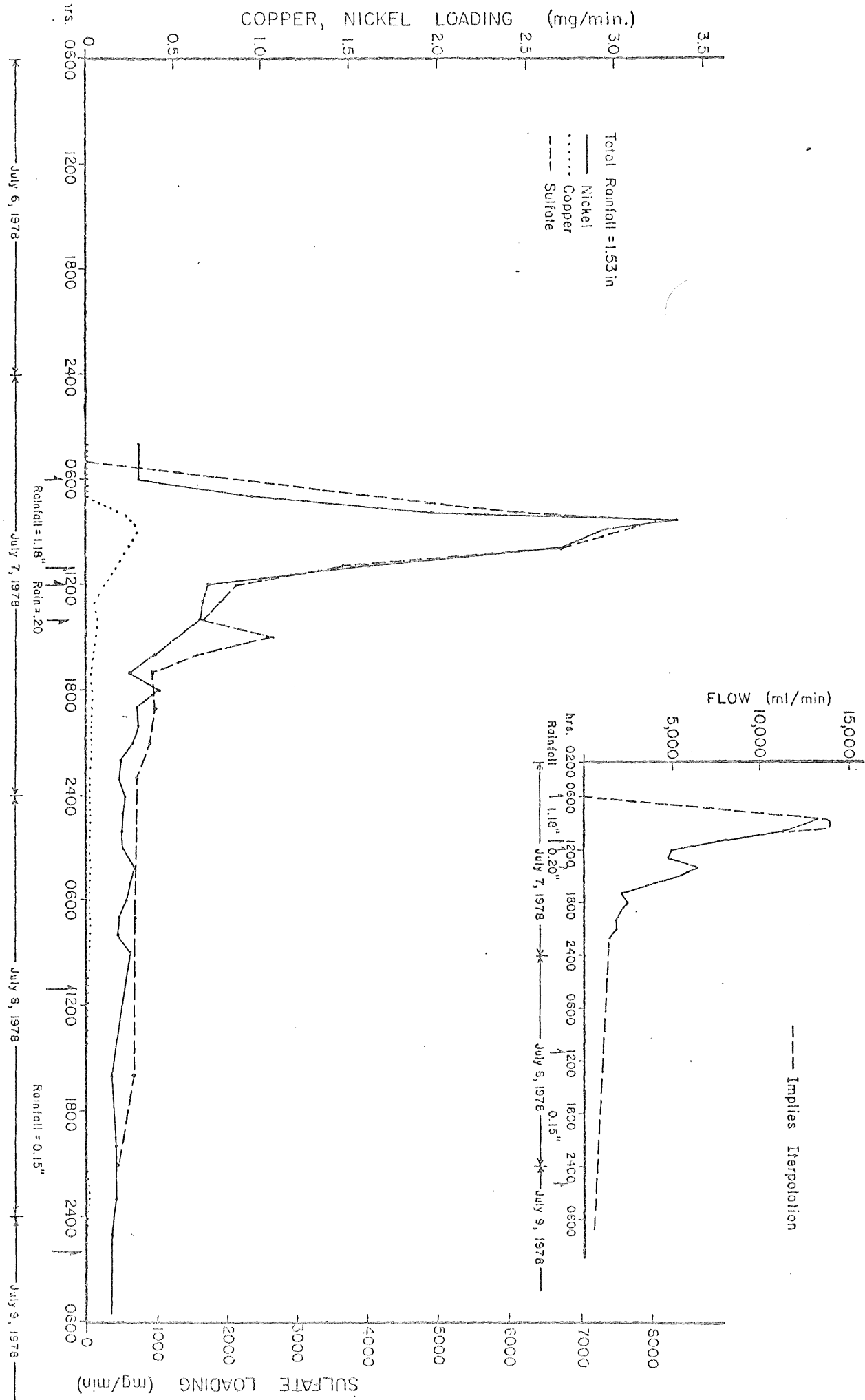


TABLE XII
MASS RELEASE SUMMARY FOR INTENSIVE EVENTS -- FL-4

<u>Parameter</u>	<u>6-23-78</u>	<u>7-7-78</u>
Cu released (mg)	6	107
Ni released (mg)	111	1441
SO ₄ released (g)	478	3738
Total Volume (l)	341	7599
Time Interval, Δt (min)	4415	4620
Total Rainfall (inches)	.35	1.53

how can rainfall $\frac{1.53}{0.35} \times 4620$
 $\frac{7599}{341} \times 22$?
 } volume

SUMMARY AND CONCLUSIONS

Copper concentration remains constant during runoff events, while concentrations of sulfate and nickel vary by more than a factor of two. Mass release for all parameters parallel the hydrograph, with the maximum release occurring at peak flow.

The possibilities of large variation in concentrations during storm events makes the collection of a composite sample a necessity. Grab samples will not adequately represent the concentration of all parameters during runoff. For some parameters, the mass calculations made on the basis of grab samples could be in error by more than a factor of two.

RESULTS - PHASE II

It will be recalled that the objective of Phase II is monitoring of the mass release and flow from each pile. The ultimate goal is the use of total mass release to measure the success of different reclamation efforts.

Rainfall

To calculate the total water input to each pile, the total rainfall and the collecting area of each pile must be known. Rainfall data was collected using a standard and a recording rain gauge. Complete rainfall data is given in Appendix V. Table XIII provides a monthly summary of the rainfall. The collecting area of each pile was measured with two sets of measurements taken for each pile and the results averaged. The results are summarized in Table XIV.

Flow Data

The problems encountered with obtaining the flow data have been discussed in Appendix I. Estimates of daily discharge from each pile were made using a combination of flow meter readings and volumetric discharge measurements. (Appendix II.)

The overall comparison between the total of the estimated flow for each pile and the sump flow is given in Table XV. The overall agreement is reasonably good.

The overall runoff relation for each pile is given in Table XVI. Preliminary data suggest that the percent runoff varies as $5 \approx 6 \times 4 \approx 3 \times 1 \times 2$. Monthly runoff coefficients were also computed for each pile. The results of these calculations indicated that even though the overall agreement between the estimated flows and the sump flow was good, the individual pile data needed to be re-examined. In the early part of the field season, the flow meters would periodically jam and produce backwater conditions in the pile. Some of the volumetric measurements were influenced by this backwater, and as a result the daily flows were overestimated.

TABLE XIII
Rainfall Events, April through October, 1978

Month	Total # of Events	# of Events $\geq$ 0.3 in.	Total Rain	Rain provided by events $\geq$ 0.3 inches in. %	
April	7	2	1.28	0.78	60.9
May	8	2	3.37	2.30	68.2
June	9	3	2.21	1.58	71.5
July	14	4	6.38	4.90	76.8
August	10	5	5.53	4.58	82.8
September	9	3	3.28	2.84	86.6
October	7	2	1.05	0.72	68.6
TOTAL	64	21	23.10	17.70	76.62

Note: Rainfall greater than or equal to 0.01 inches is an event.

Table XIV.
Test Pile Area

Pile	Total Collecting Area (ft ²)
1	3173
2	3678
3	3183
4	3524
5	3648
6	3444

Table XV. FLOW SUMMARY

Month	Rainfall	6 Pile Total	Sump Discharge	% Difference
April				
May	3.37	87,000	79,000	+9.4
June	2.49	82,000	81,000	+1.6
July	6.38	156,000	164,000	-4.6
August	5.53	129,000	123,000	+4.4
September	3.28	89,000	81,000	+9.4
October		12,000	12,000	
May - October		555,000	540,000	+2.8

$$+ \% \text{ difference} = \frac{6 \text{ pile} - \text{sump}}{\text{total}} \times 100$$

Table XVI. OVERALL RUNOFF CALCULATION

Pile	Total Collecting Area (ft ²)	Area of Exposed Hypalon (ft ²)	% of Area That Is Exposed Hypalon	Input liters/ in Rain	<u>TOTALS</u>		
					Input (l)	outflow (l)	runoff (%)
1	3173	96	3.0	7487	166,137	83,184	50
2	3678	243	6.6	8679	192,587	67,421	35 *
3	3183	36	1.1	7511	166,669	95,265	57 *
4	3524	528	15.0	8315	184,510	92,231	50
5	3648	160	4.4	8608	191,012	120,522	63 *
6	3444	371	10.8	8127	180,338	117,209	65

* Pile has been covered and seeded.

This was a particular problem with FL 3.

All flows will be recomputed. An attempt will be made to correlate flow data between periods of good flow records and then, based on these correlations, make necessary flow estimations. A preliminary examination of the problem time period indicates that the net result may be a reduction in the total flow from FL 3 and possibly FL 2. This would not change the overall relationship in percent runoff that was discussed previously.

Water Quality Data

All the 1978 water quality data are in Appendix III. The sampling procedures are discussed in Appendix I. The data are preliminary. Some of the concentration values appear to be anomalous and will have to be reanalyzed.

Since the major purpose of this report is to serve as a progress report, there is still a large amount of data analysis that remains to be done. The intent of this discussion is illustration of some of the general findings. More detailed analyses, which would include calculation of mass release, will be available in future reports.

Variation In Concentration With Time

To compute the mass release, the total flow for each pile must be computed and representative concentrations must be assigned. These calculations have not been completed. However, general comparisons have been made among the different test piles and between 1977 and 1978.

Figures 11 through 24 present the variation of copper, nickel, sulfate and pH with time for 1977 and 1978. These parameters were selected since they are the key components and products of the leaching reactions. The other parameters will be discussed in future reports. The data presented in these figures are the concentrations in the sample, no attempt has been made to produce a complete set

) of flow weighted or "representative" concentrations. The concentrations are a mixture of values; some from composite samples and some from grab samples which were collected both at high and low flow.

From the results of Phase I it is clear that concentrations vary during storm runoff. Therefore, the yearly concentration versus time graphs are useful for identifying long term general trends, but may not give an accurate representation of short time fluctuations. The variation between two samples may be the result of the differing flow conditions at which the samples were collected. Comparison of individual concentrations must be done with caution.

The box plot, or schematic diagram, (Figure 25) is a useful tool for summarizing data. In order to produce a meaningful summary of the concentration data, a uniform data set was selected. The objective was to choose a series of sampling dates on which a sample was collected from every pile. (Due to the start-up nature of the program, not all piles were sampled at the same frequency.) The set of samples that was chosen is listed in Table XVII. The concentrations obtained from this set are not necessarily representative of the entire year of the flow distribution but they do provide a basis for comparing the different test piles.

Since a smaller number of samples was collected in 1977, all the samples were used to provide a reasonable number of data points. There were not enough data to construct a box plot for piles FL 5 and 6 because they were not constructed until September, 1977. The resulting box plots are shown in Figures 26 through 29.

DISCUSSION

The results indicate that the piles tend to separate into two general groups: piles 1 through 4 and piles 5 and 6. Piles 1-4 were constructed from material from the shaft while the material in 5 and 6 came from the drifts. Piles 5 and 6 contain a higher percentage of sulfur (Table VII) and may have a finer particle size distribution (Amax, personal communication). These factors should tend to

enhance the reaction rate in these piles. (As mentioned previously, concentration alone is not a good indication of total release. Concentrations must be converted to mass before the total release can be calculated).

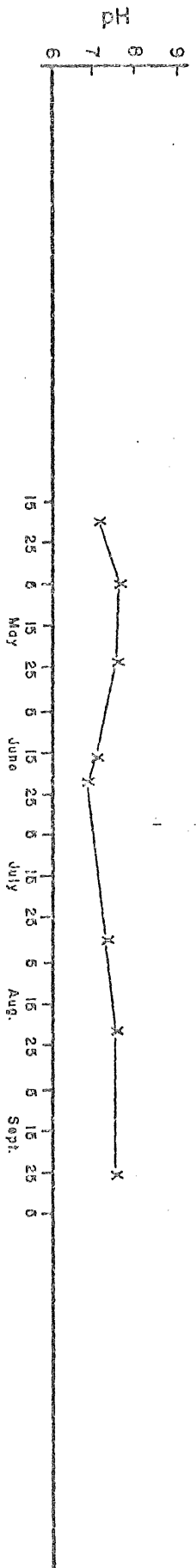
Piles 5 and 6 have higher median concentrations of copper, nickel, and sulfate than the other piles. Preliminary analysis of the flow data (Table XVI) indicates that these two piles also yield more water than the rest. It appears that the total mass release is higher in these piles. One of the major factors that affects the release is the pH. Figure 21 indicates the dramatic decline in pH observed for FL 5 and a corresponding increase in metal concentration. The exact cause of the pH decline is still being studied. Figure 30 shows additional pH data for pile 6. The pH dropped considerably in the last two months before freeze up. From Figure 30 it appears that the decline in pH began around the end of August. If this pH trend continues, acidic leachate may be produced. Nickel concentrations tended to increase throughout 1978. Concentration began to increase sharply about one month prior to the initiation of the decline in pH. This phenomenon can be seen in FL 5.

The rise in copper concentrations tend to correspond more closely to the decline in pH. Copper is not very mobile at pH values above 7, but its mobility increases as the pH declines. Preliminary examination of the sulfate data indicate no clear trend in concentration. The concentration is variable and there is no dramatic increase in 1978, as there is for the metals.

Since the release of sulfate can be used as a measure of the dissolution rate of the metal sulfides, the preliminary indication is that the overall rate of dissolution has not increased dramatically. The increase in metal concentration results from the increased mobility of the metals at the lower pH. From laboratory studies conducted by Lapakko, Eisenreich, and Hoffman (Eisenreich, et al 1977), an increased rate of sulfide dissolution was observed as pH decreased. It is also well

Figure 1
FL-1, 1977

CONCENTRATION VS TIME



X = grab sample
 — NICKEL
 COPPER
 --- SULFATE

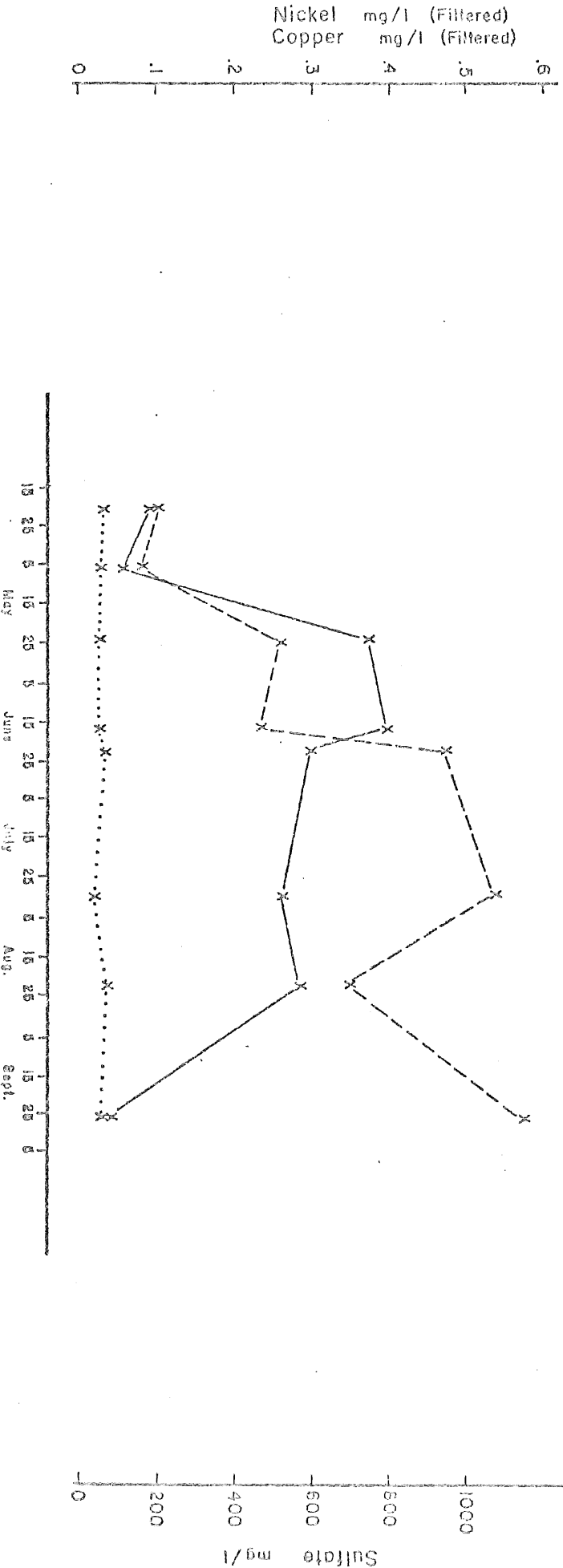
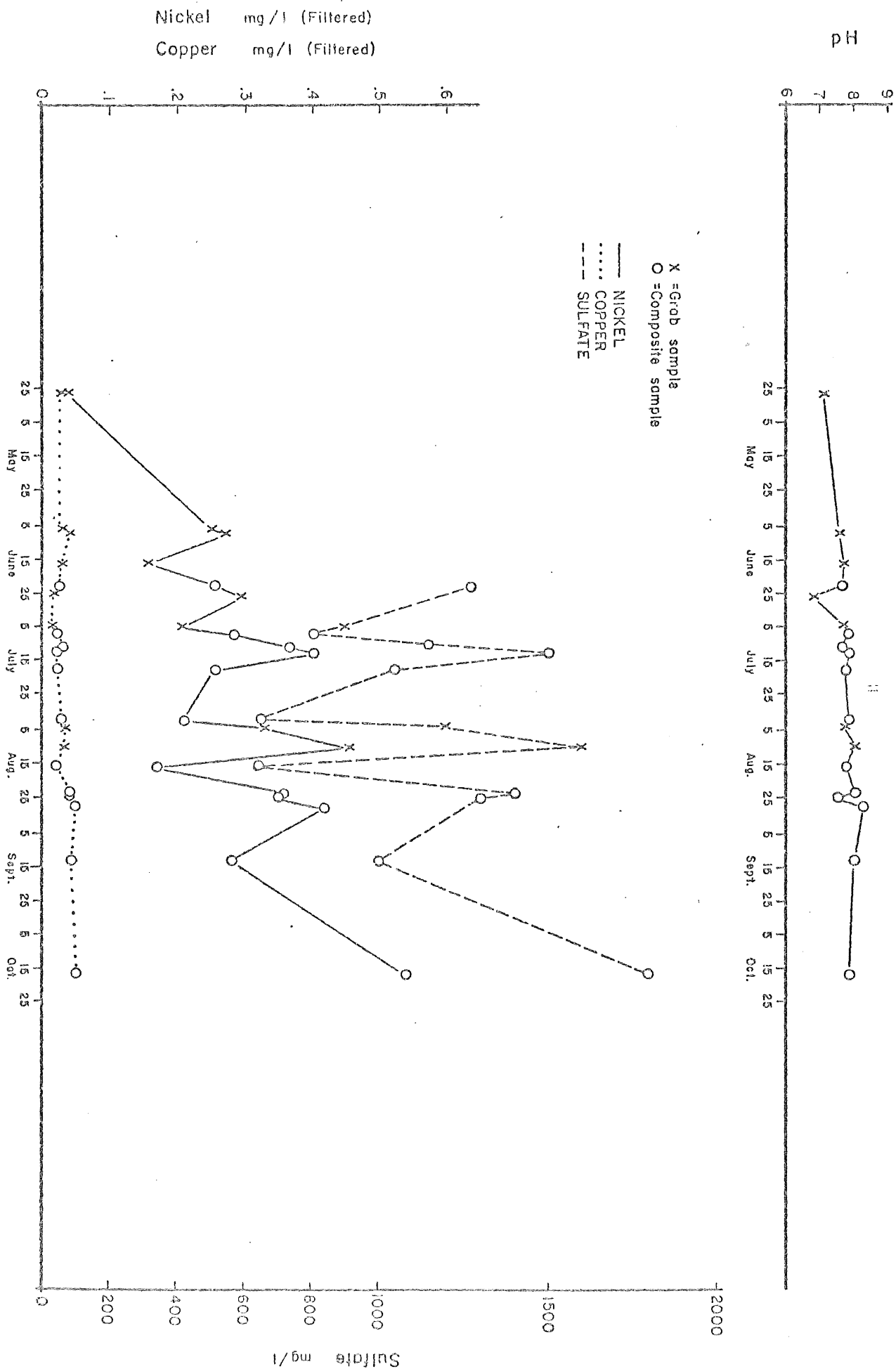
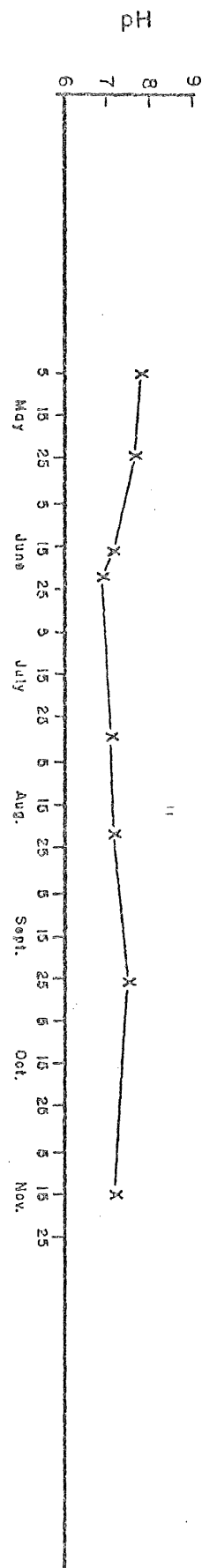


Figure 1
FL-1, 1978

CONCENTRATION VS TIME



CONCENTRATION VS TIME



X = grab sample
 — NICKEL
 COPPER
 --- SULFATE

Nickel mg/l (Filtered)
 Copper mg/l (Filtered)

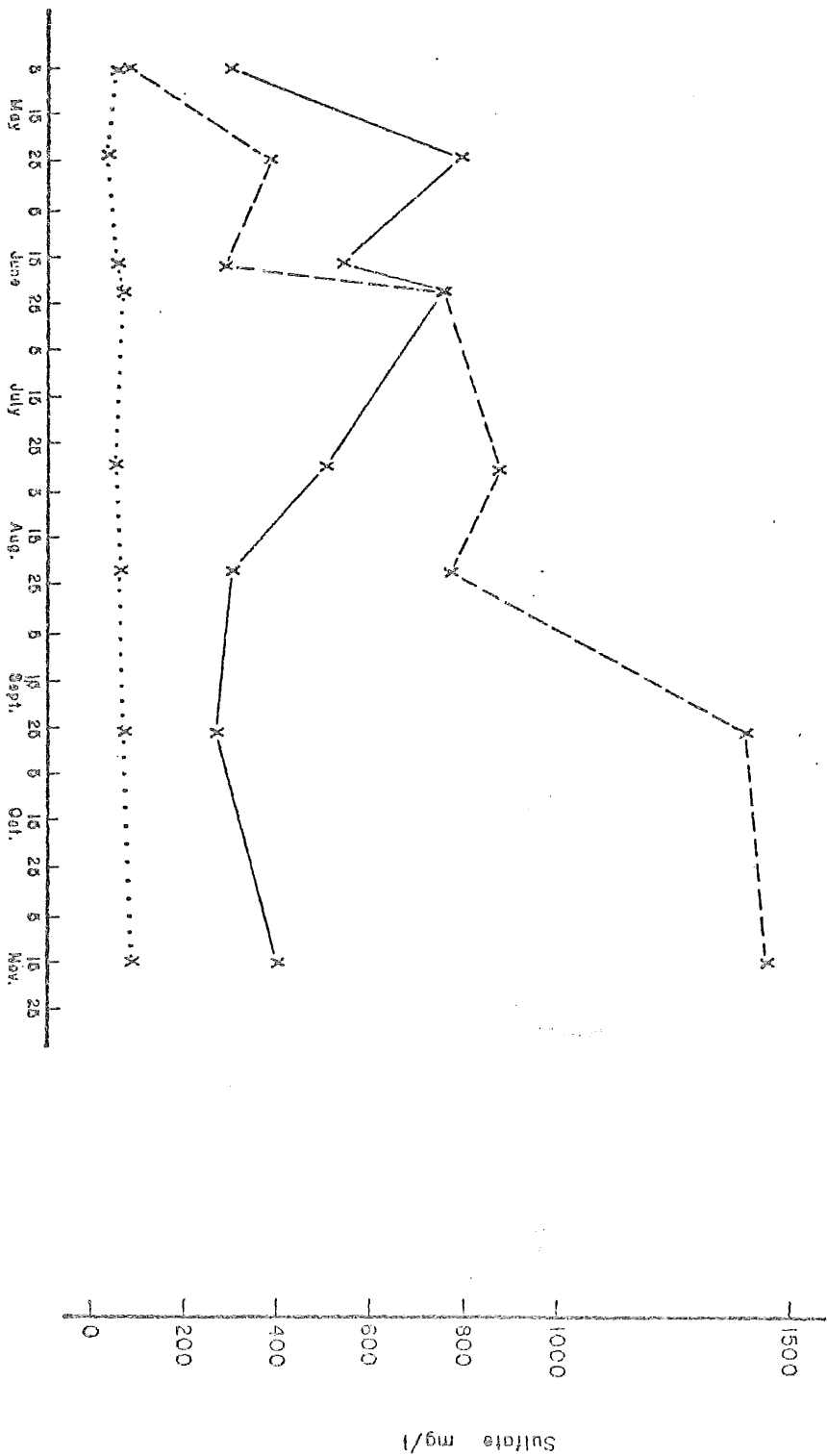


Figure 14
FL-2, 1978

CONCENTRATION VS TIME

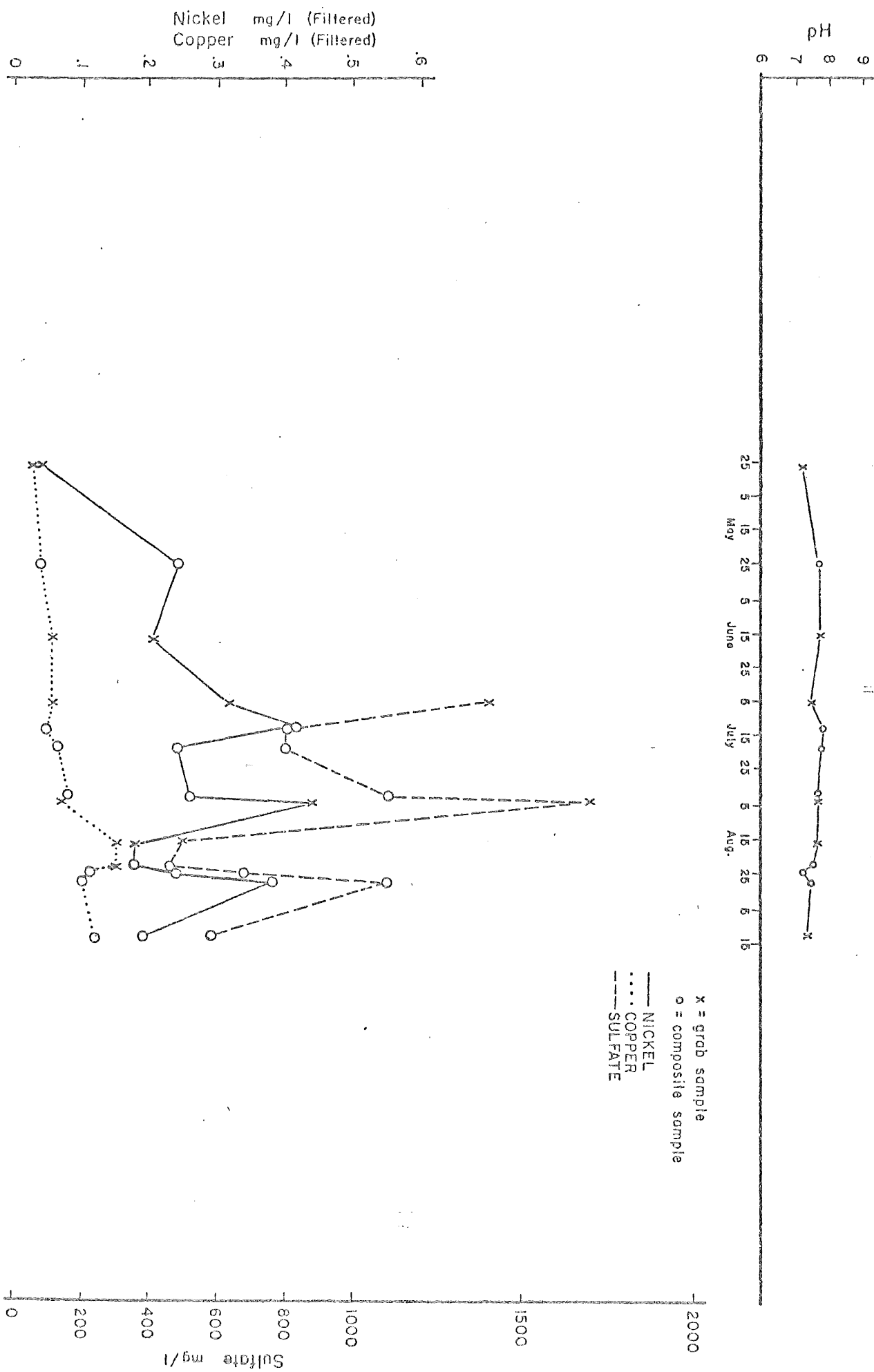
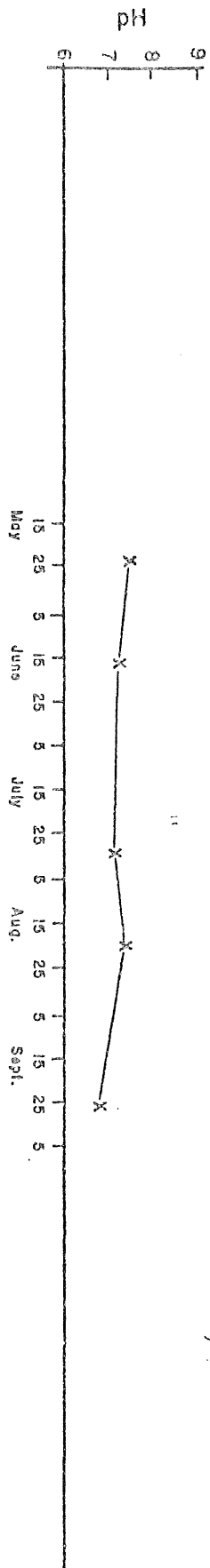


Figure 15
FL-5, 1977

CONCENTRATION VS TIME



X = grab sample
 — NICKEL
 COPPER
 --- SULFATE

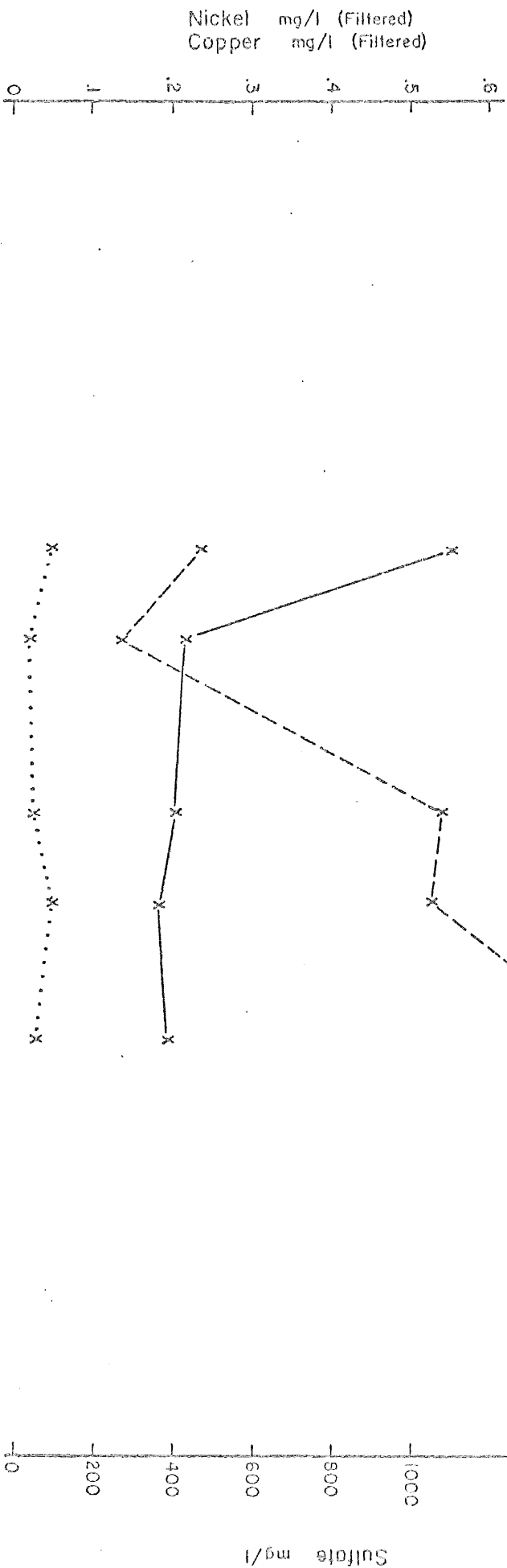
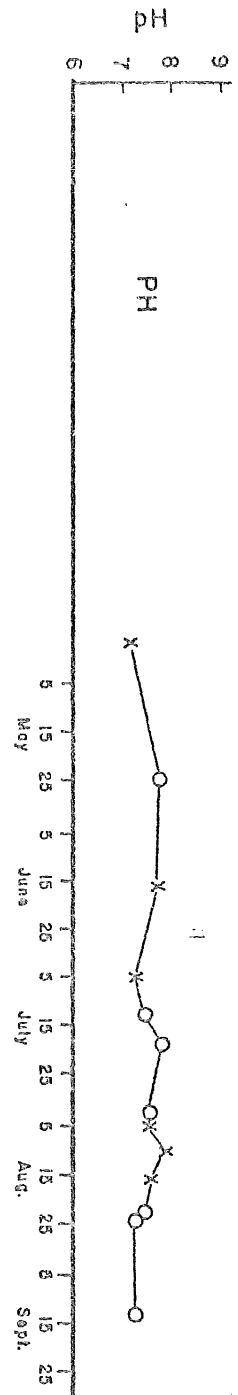


Figure 16
FL-3, 1978
CONCENTRATION VS TIME



O = grab sample
X = composite sample
— NICKEL
... COPPER
--- SULFATE

Nickel mg/l (Filtered)
Copper mg/l (Filtered)

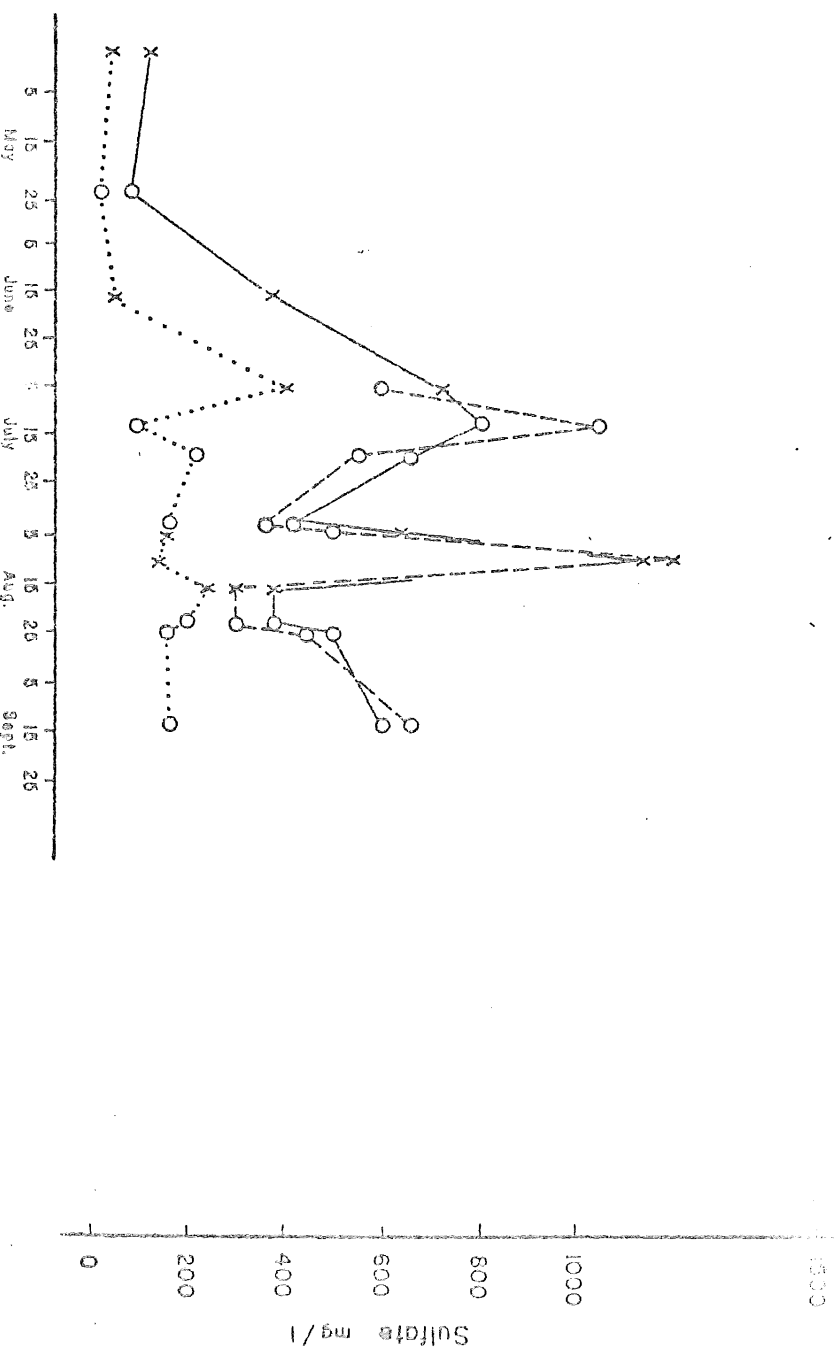
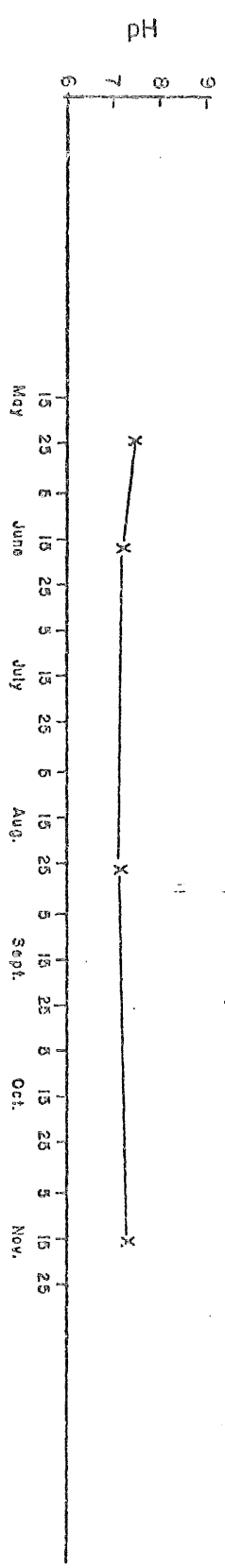


Figure
FL-4, 1977
CONCENTRATION VS TIME



X = grab sample
 — NICKEL
 COPPER
 --- SULFATE

Nickel mg/l (Filtered)
 Copper mg/l (Filtered)

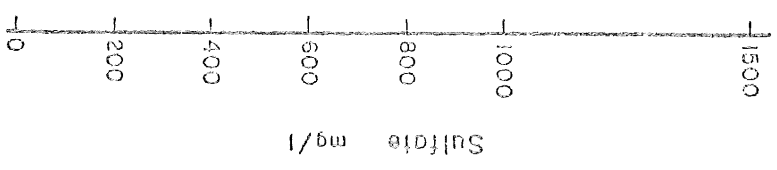
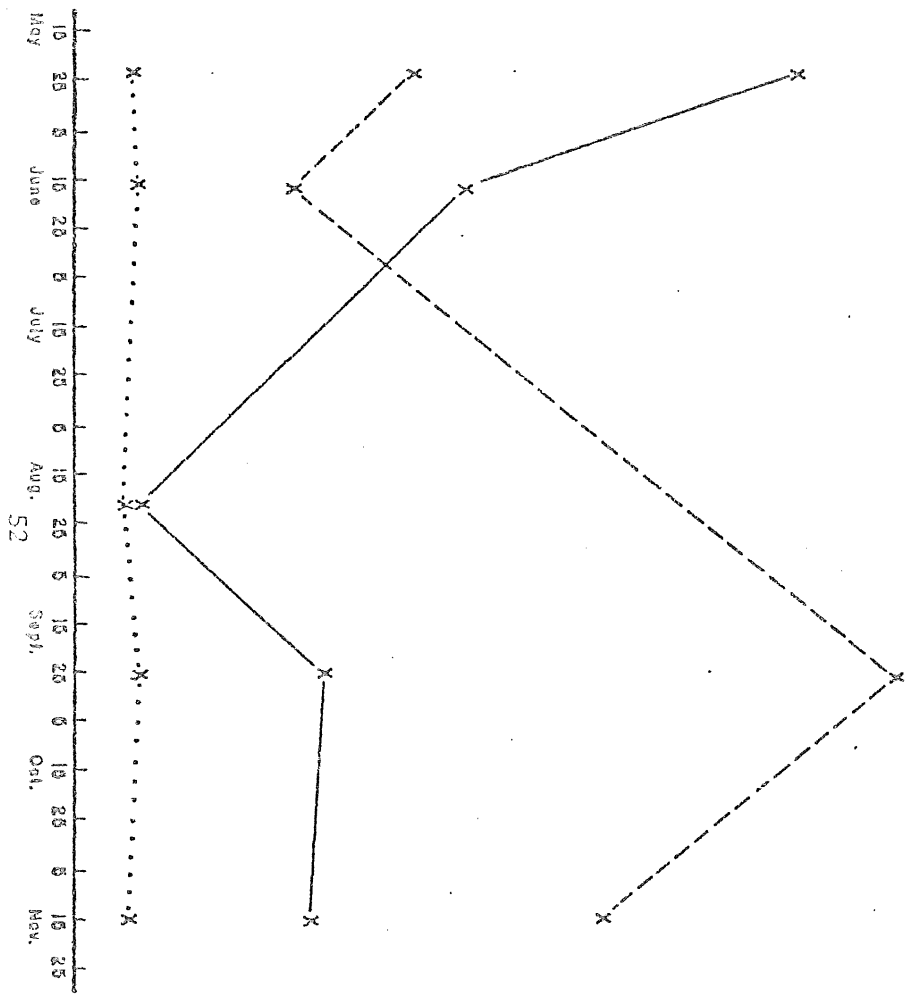
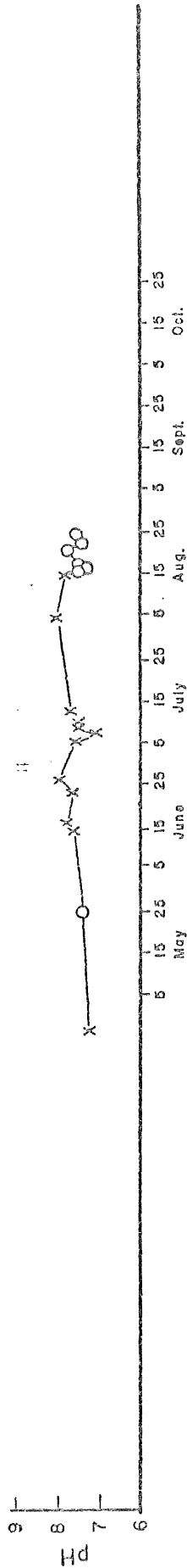


Figure 18
FL-4, 1978

CONCENTRATION VS TIME



X = grab sample
O = composite sample
— NICKEL
... COPPER
--- SULFATE

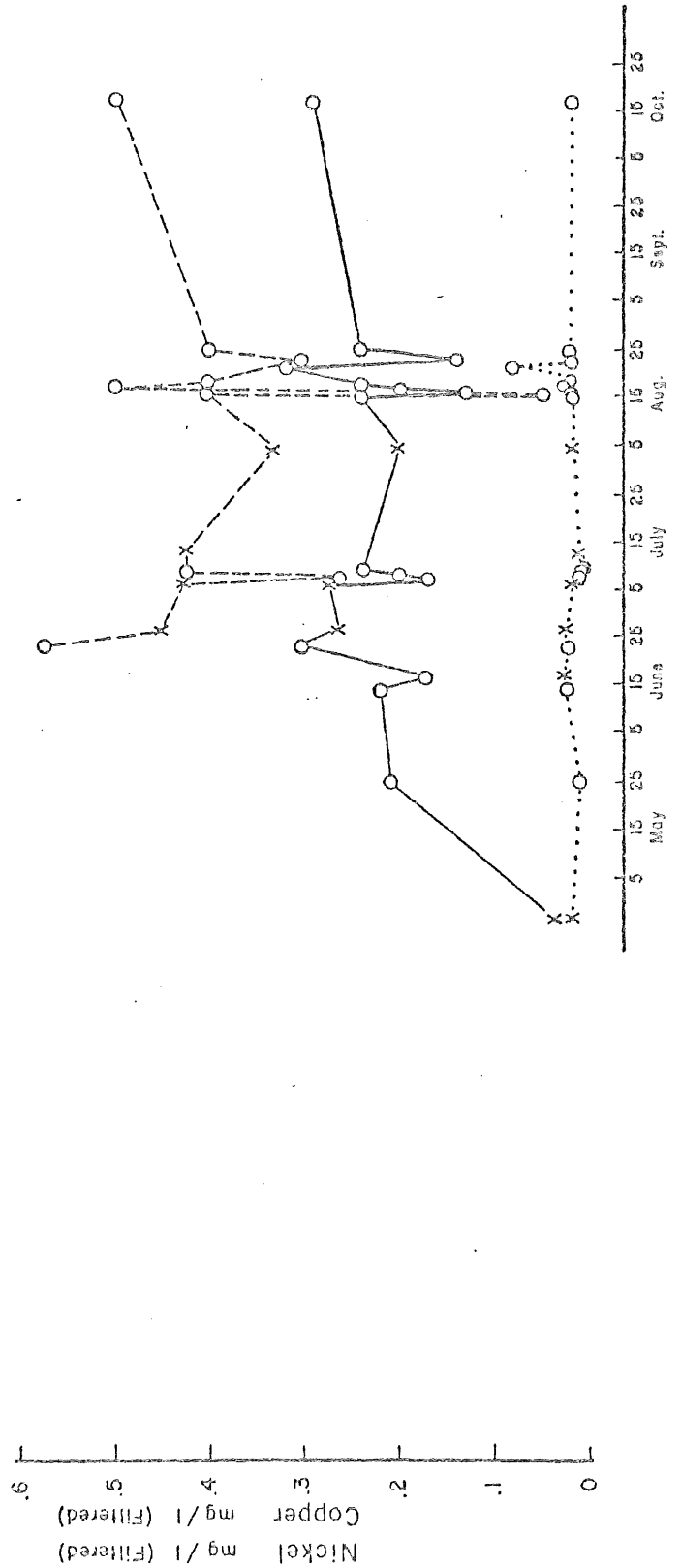
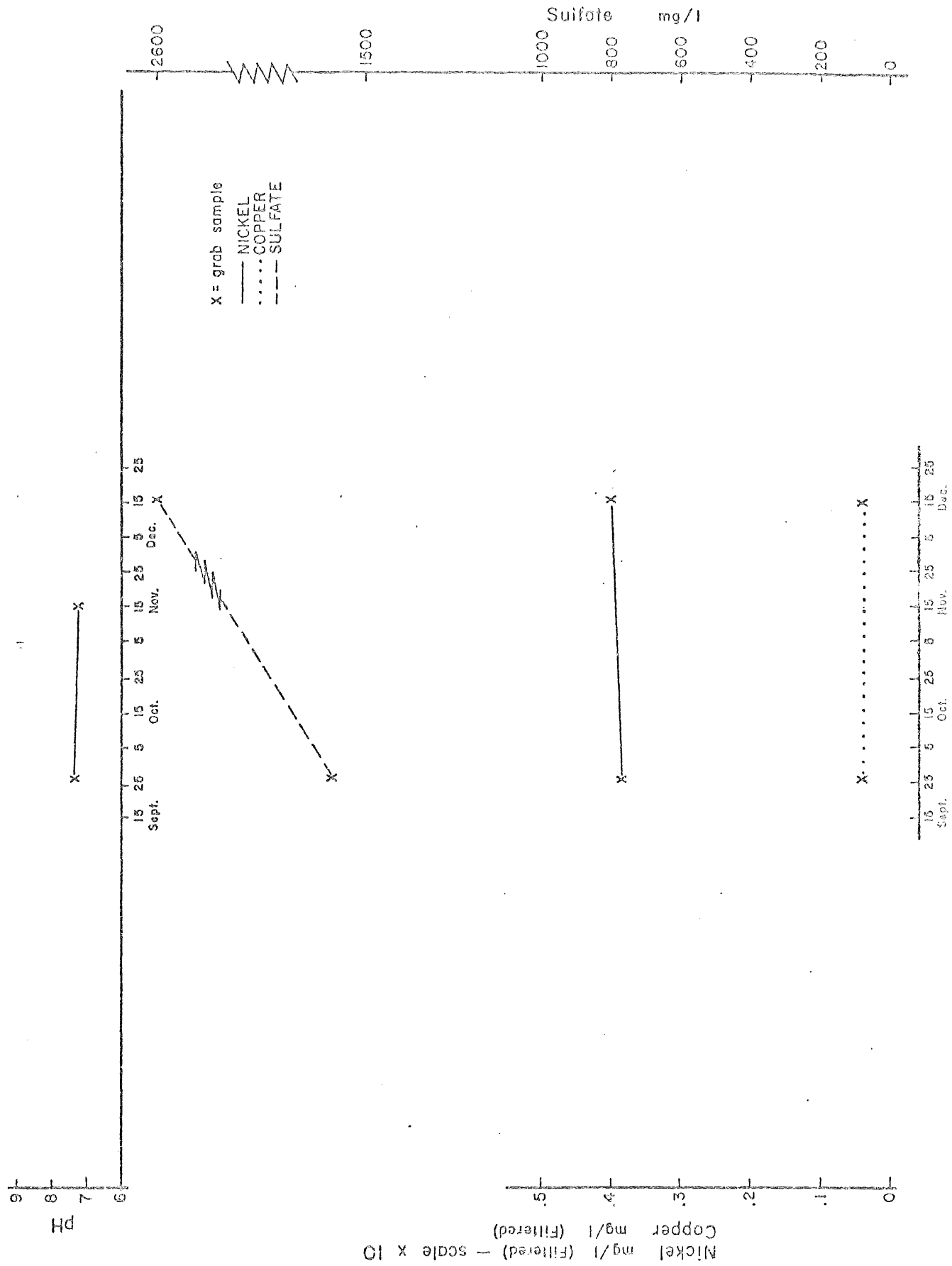


Figure 19
FL-5, 1977

CONCENTRATION VS TIME



SULFATE CONCENTRATION VS TIME



CONCENTRATION VS TIME, NICKEL, pH

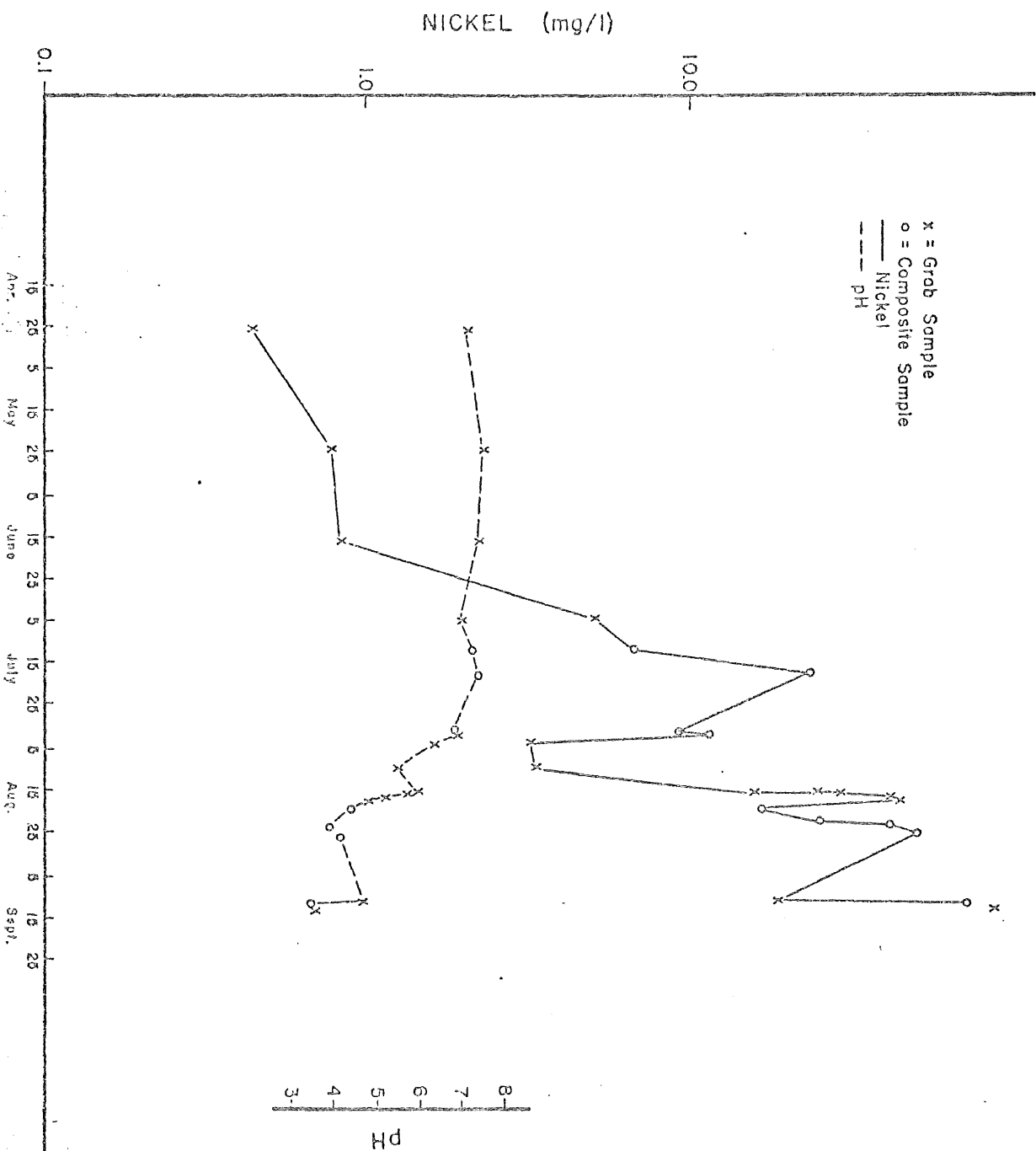
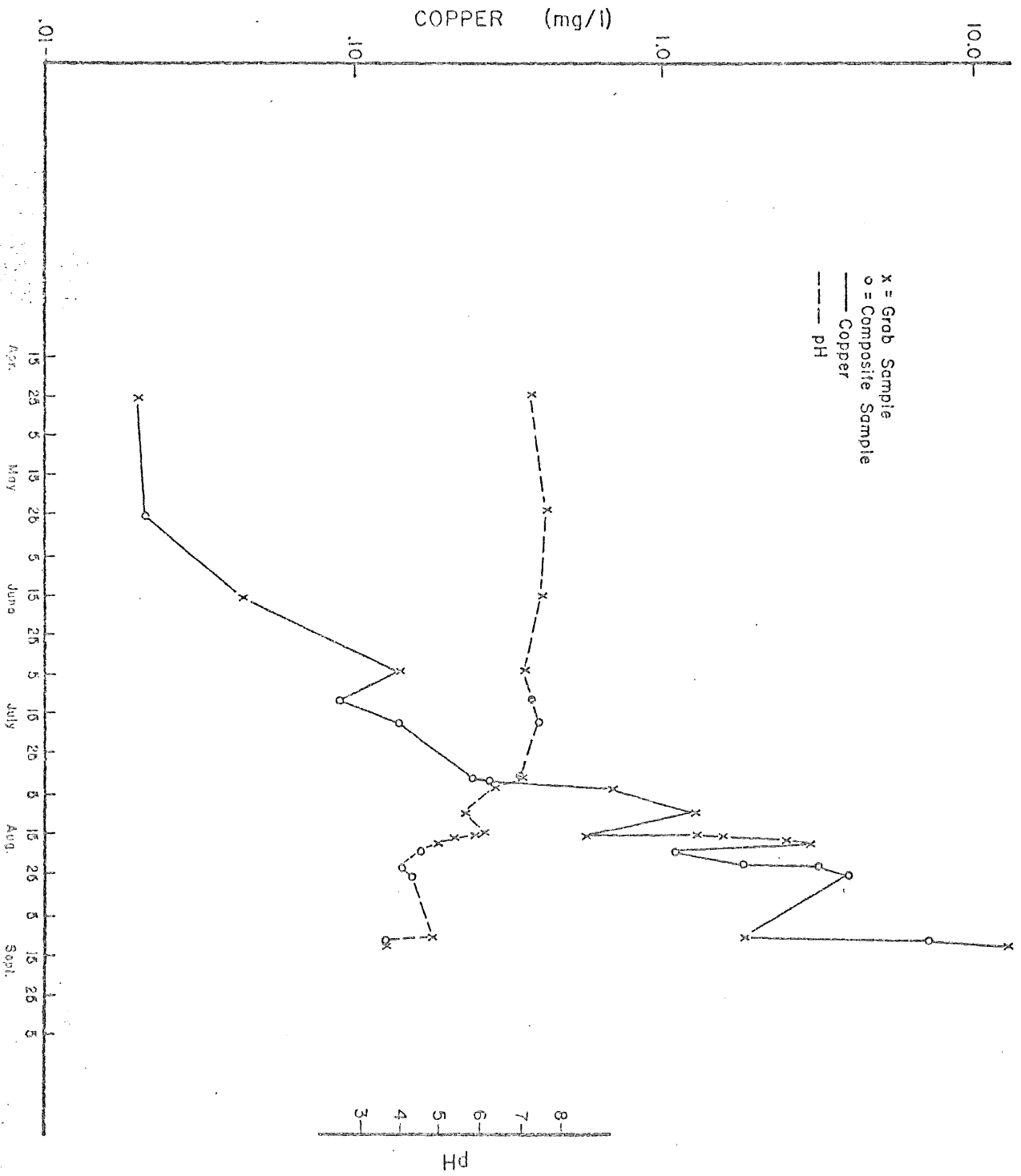
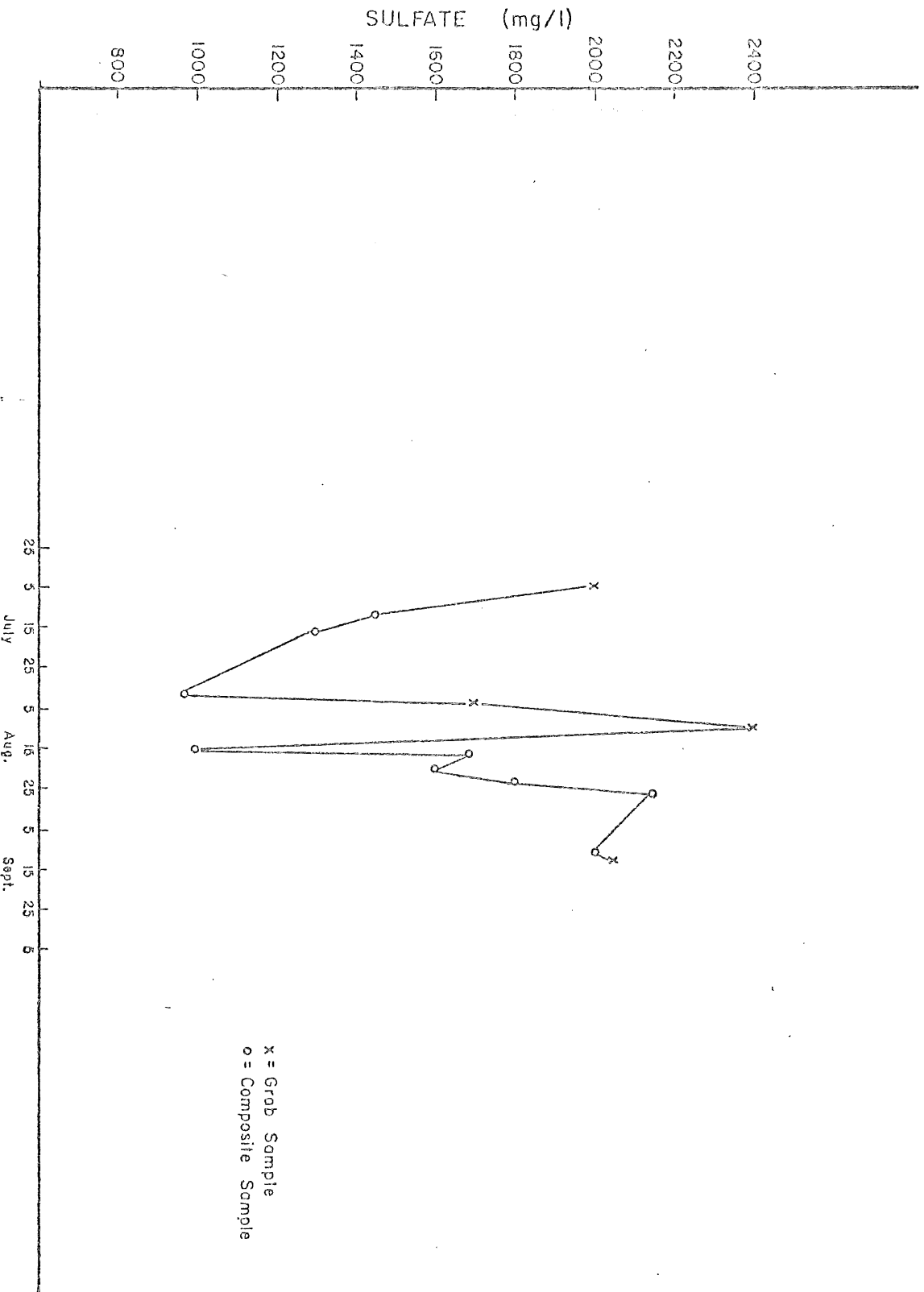


Figure 22
FL 03, 1978

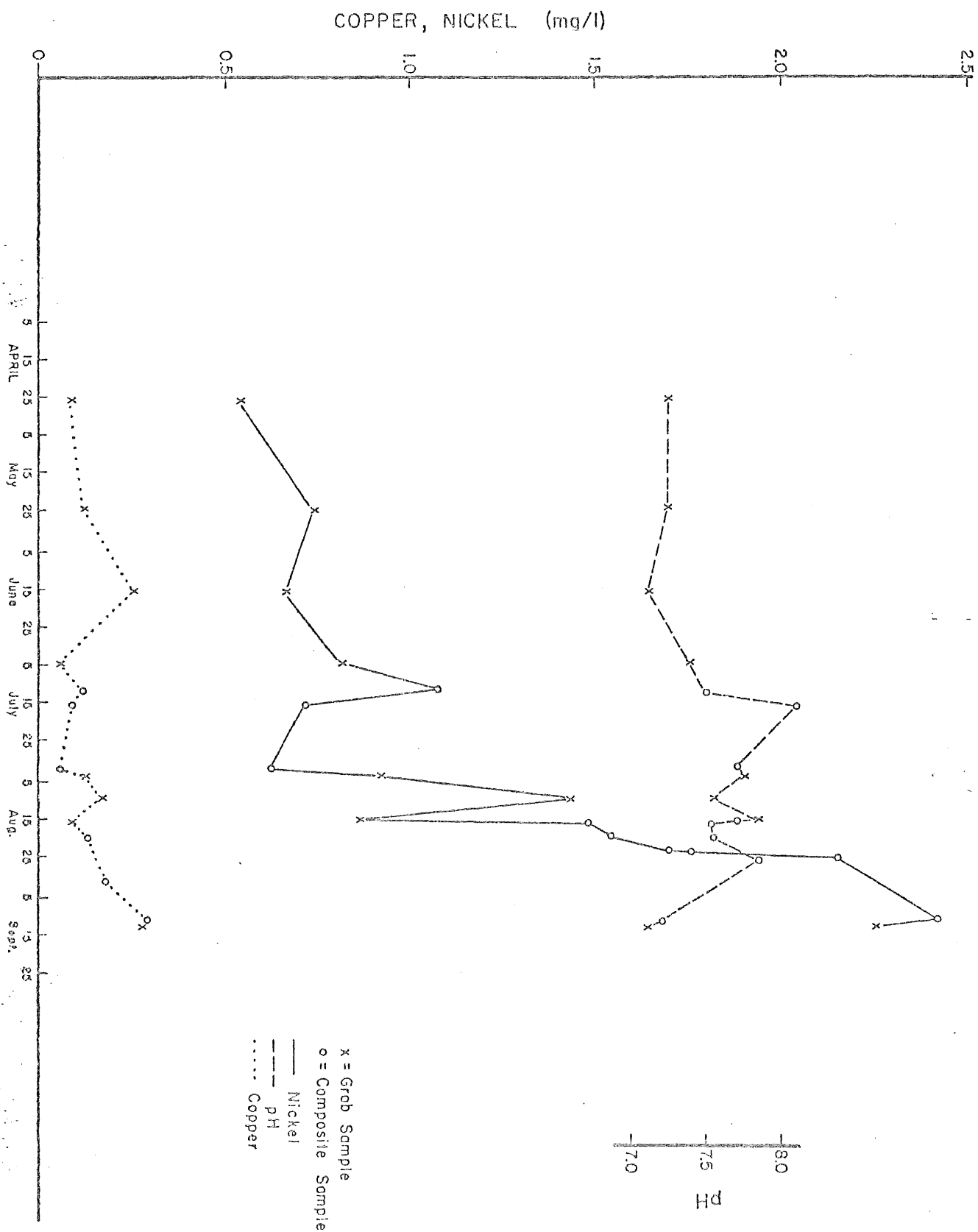
CONCENTRATION VS TIME, COPPER, pH



SULFATE CONCENTRATION VS TIME



FL 181 24 1978
 CONCENTRATION VS TIME, COPPER, NICKEL, pH



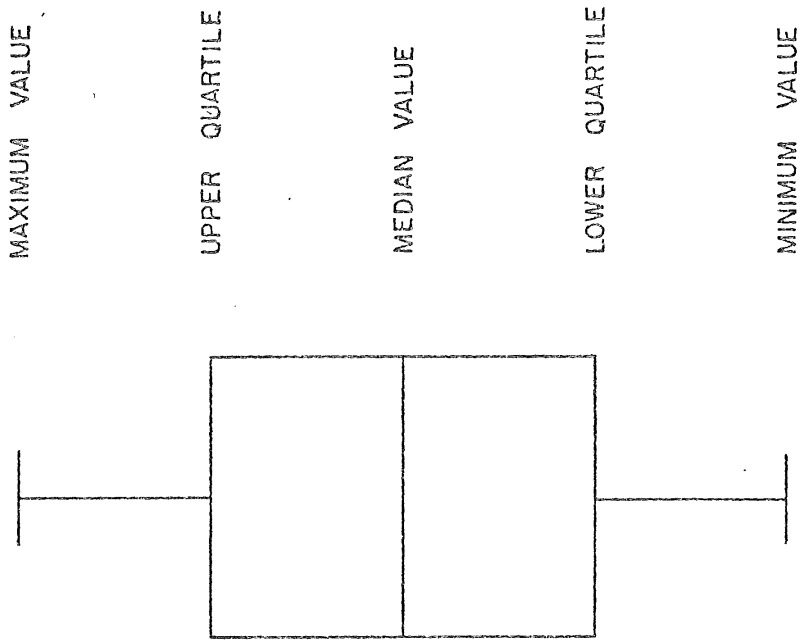


Table XVII. SAMPLES USED FOR BOX PLOT

<u>DATE</u>	<u>TYPE OF SAMPLE</u>	<u>CONDITION</u>
4-26	grab	low flow
6-16	grab	low flow
7-5	grab	tail of rain
7-12 to 7-13	composite	comp over rain for all, grab for FL4
7-14 to 7-19	composite	all piles except FL4
8-1 to 8-2	composite	over rain
8-4	grab	low flow
8-16	grab & composite	during & over rain event
8-23	composite	before and over rain
9-13	grab	tail of rain

more detailed information is given in Appendix V

documented that the oxidation of the metal sulfides results in acid production (Hawley, 1972; Eisenreich et al, 1976). Normally, the buffering capacity of the gabbro is sufficient to maintain the pH in the neutral to slightly basic range. If the oxidation rate increases or the buffering capacity decreases, the pH may drop. As pH decreases, the rate of metal transport from the stockpile increases. The drop in pH in FL 5, resulted in a 10 to 100 fold increase in metal transport.

With the exception of copper, the box plots indicate that piles 1-4 generally have comparable median concentrations. Median copper concentrations for piles 2 and 3 appear to have increased between 1977 and 1978, and the 1978 values are higher than those for piles 1 and 4. In 1977, the median copper concentration was comparable for all four piles. Median concentrations for piles 1 and 4 are essentially the same for 1977 and 1978. The fact that the median nickel concentrations are similar for all piles, both in 1977 and 1978, suggests that the overall release rate has not changed. A selective increase in copper release has occurred, due to increased copper mobility. Mobility could be increased by the introduction of organic compounds which have been washed out of the soil cover. Additional analysis is needed to determine the significance and the cause of this increase.

Median pH values for piles 1-4 increased slightly from 1977 to 1978. Comparison of the median sulfate data did not reveal any consistent pattern between the two years. Median sulfate concentrations decreased in FL 3 and 4, increased in FL 1 and essentially remained the same for FL 2.

Figure 26
BOX PLOT, SULFIDE

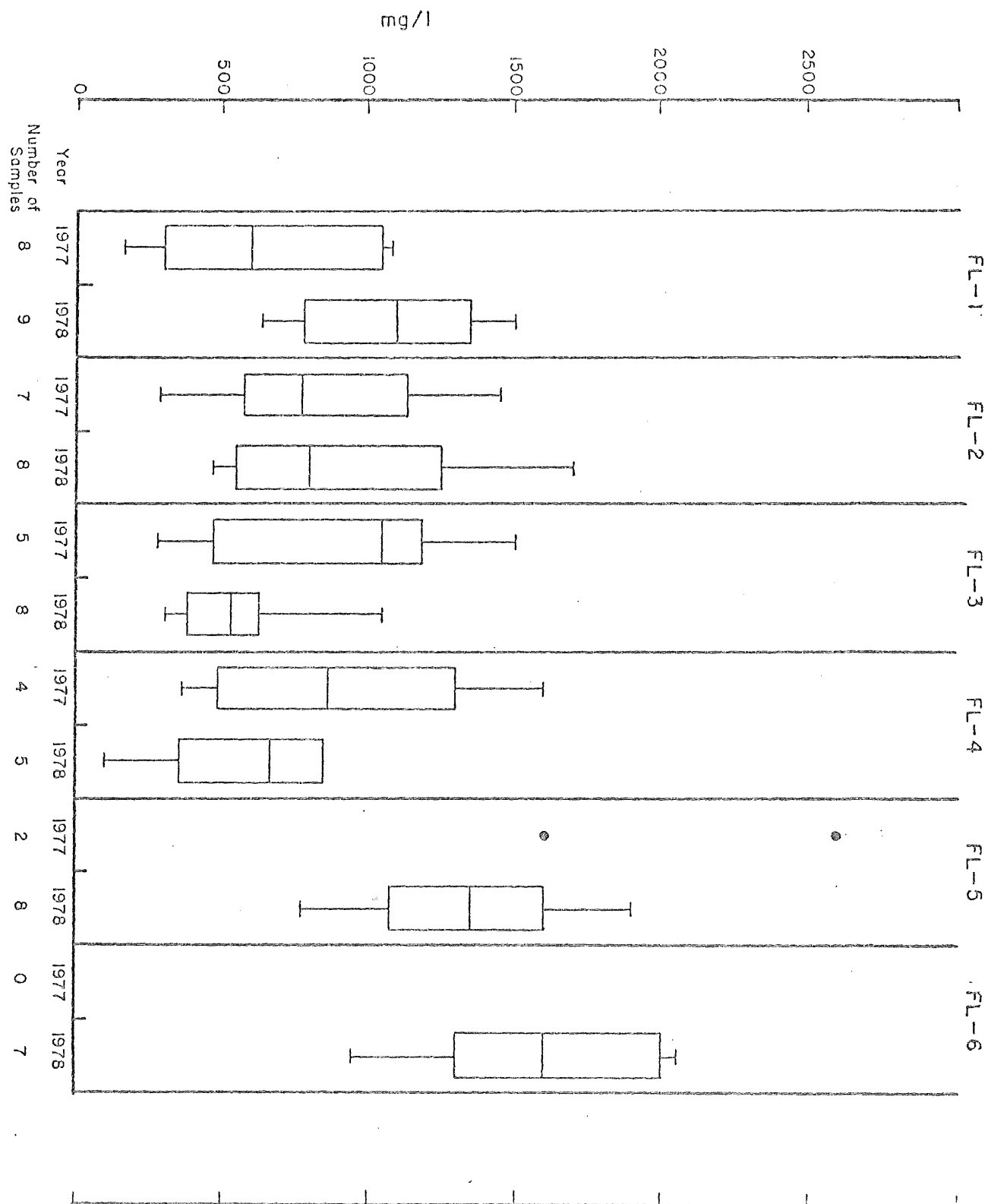


Figure 1
BOX PLOT, COPPER

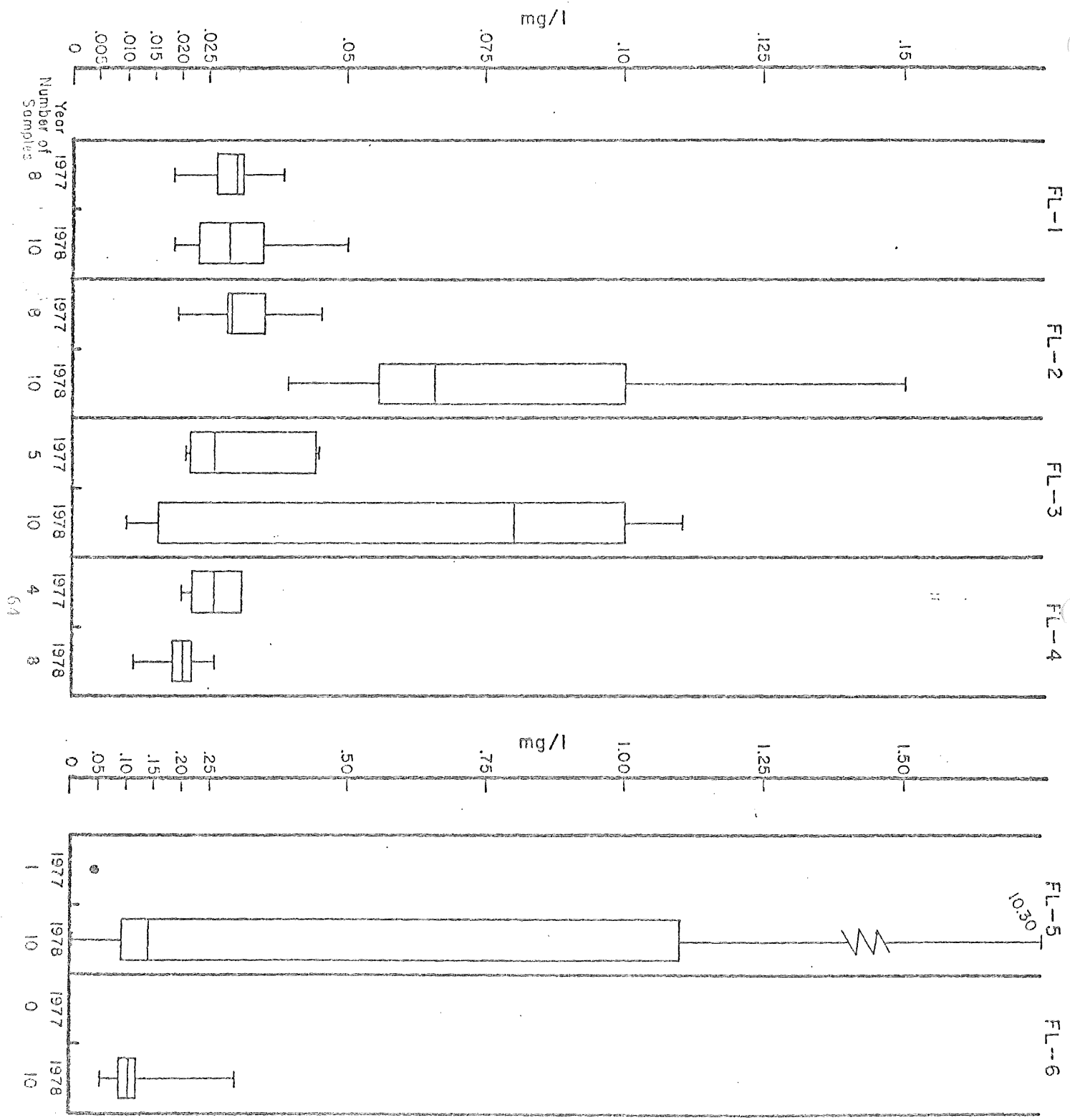


Figure 28
BOX PLOT, CK-L

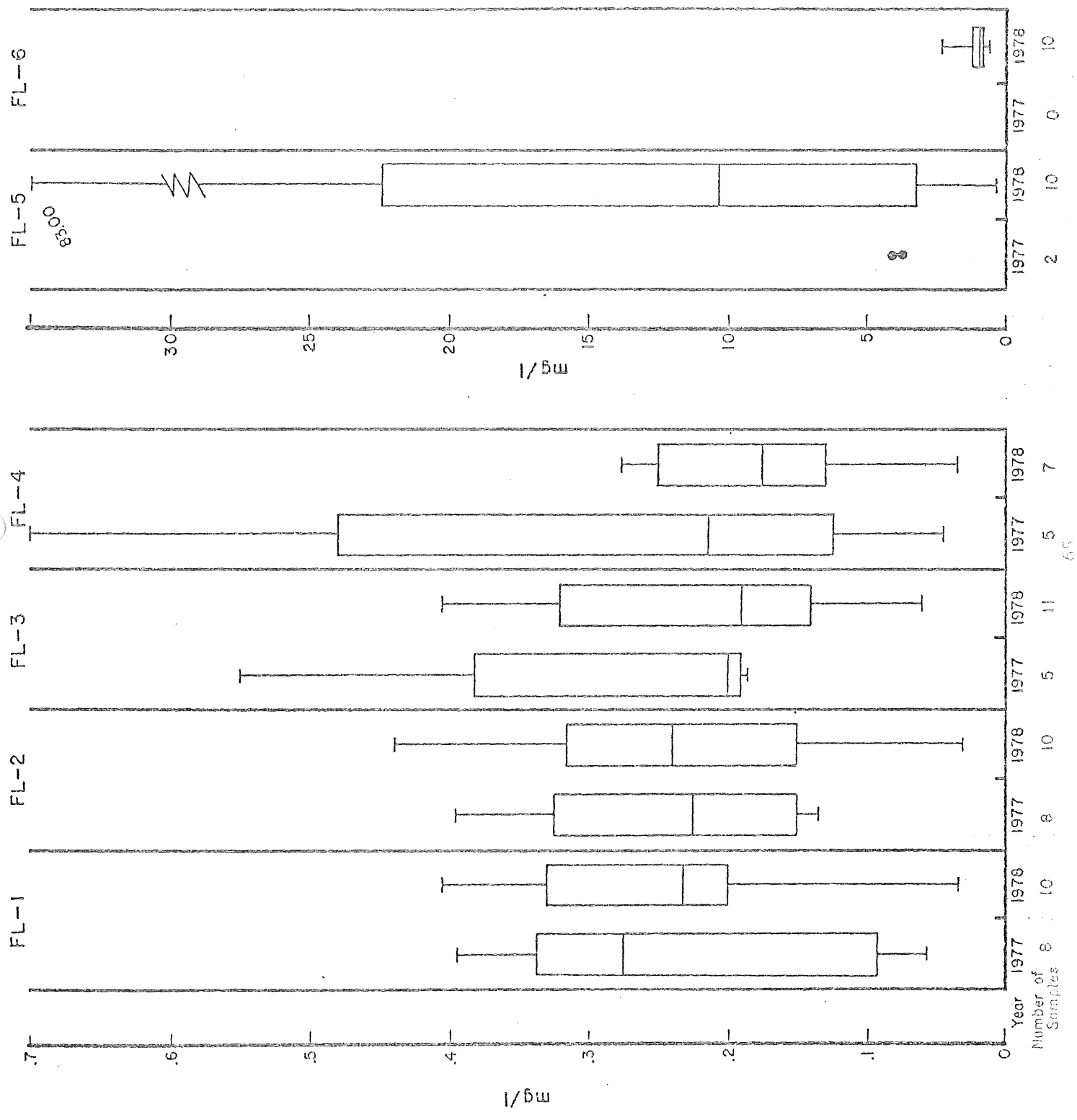


Fig. 29

BOX PLOT,

pH

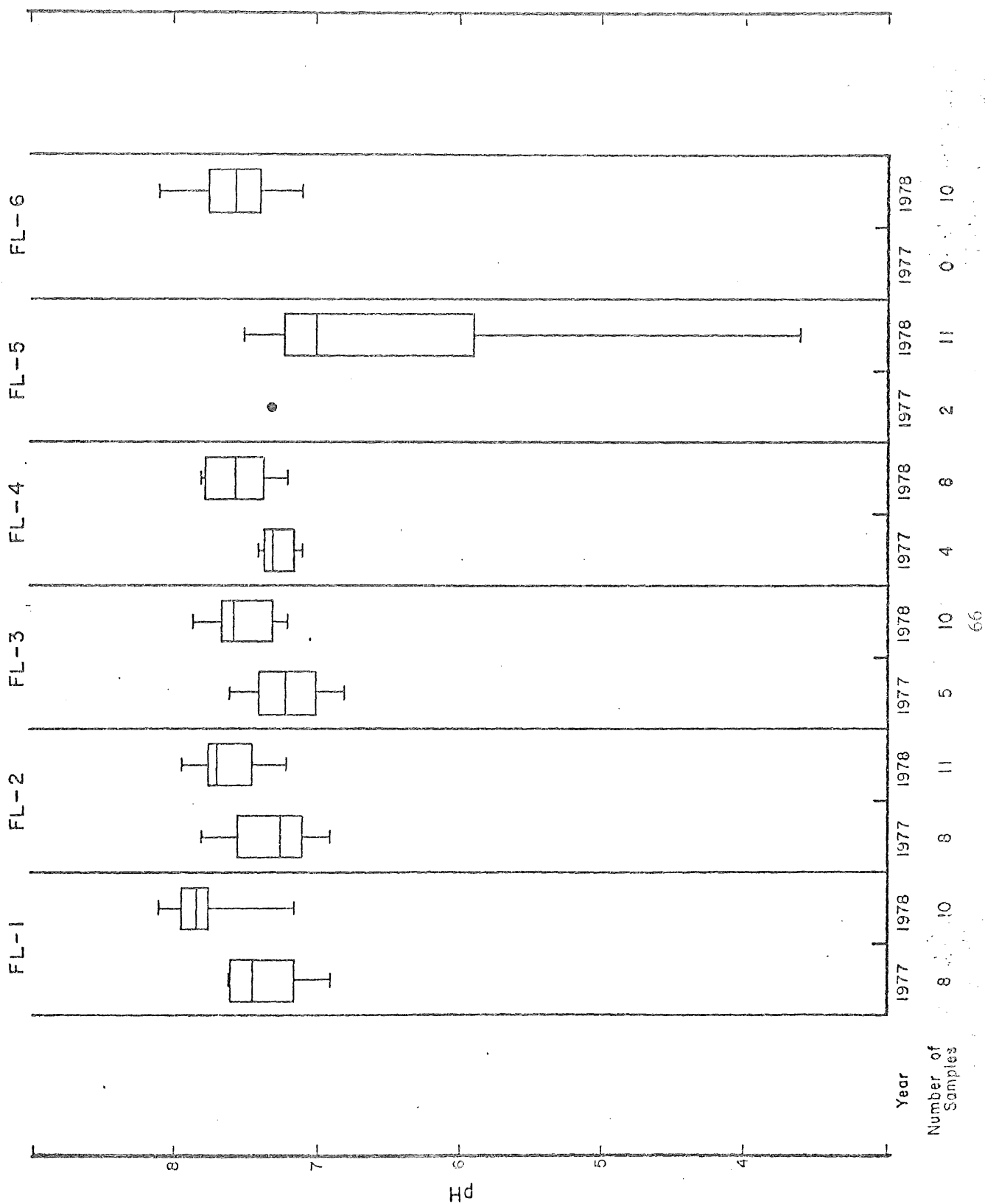
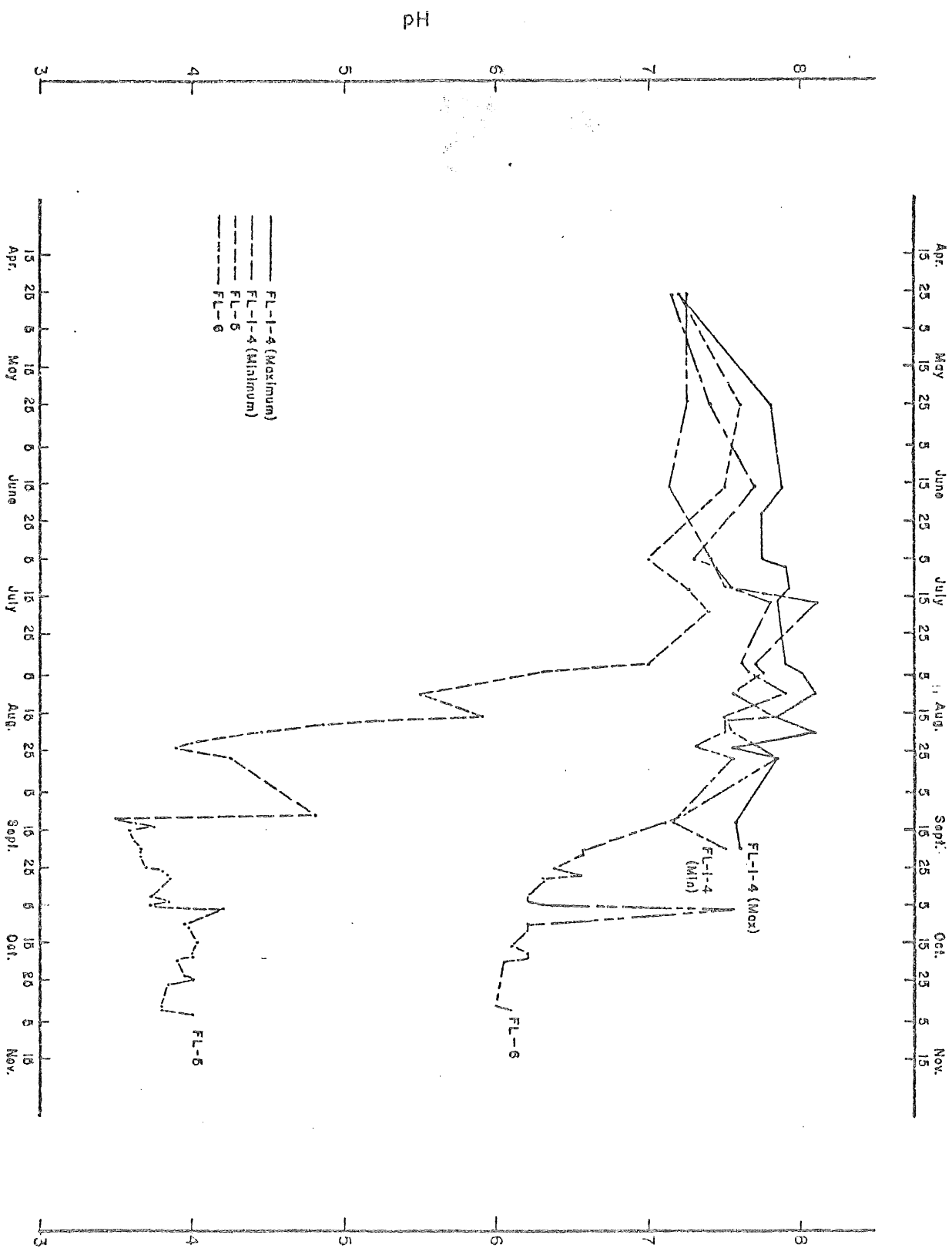


Figure 30
pH VS TIME



SUMMARY AND CONCLUSIONS

Preliminary analysis of the data indicates that for piles 1 through 4 median nickel concentrations in 1978 are comparable to those measured in 1977. There seems to be no significant differences in median nickel concentration among the first four piles.

Piles 2 and 3 exhibit increased copper concentration which appear to be the result of increased copper mobility. Organic compounds which are capable of complexing copper may have been washed out of the soil top cover, allowing more copper to remain in solution.

Piles 5 and 6 tend to behave differently than the first four. Pile 5 produced acidic leachate and the pH in pile 6 started to decrease before freeze up. When the pH declined, substantial amounts of metal were released in the leachate. The exact cause of the acidification is not known, but is being studied.

The overall runoff coefficients indicate that pile 2 had the least amount of runoff. Pile 2 was covered with topsoil and a good vegetative cover was established. Vegetative cover was sparse on the till covered piles and preliminary analysis suggests that the runoff from these piles was comparable to untreated piles. All conclusions are preliminary and analysis is continuing.

FUTURE ANALYSIS

An outline for future analysis is given below. Any recommendations or comments on the outline or suggestions for additional analyses would be appreciated.

I. Calculate mass release from each pile

A. flow calculations

1. flow records must be reanalyzed and daily flow estimates revised
2. flow records from periods of good record will be used to develop regression relations between the piles
 - a. these relationships will be used to examine periods of partial and estimated records.
 - b. readjustments in daily flows will be made
3. plot daily hydrographs
4. compute total outflow from each pile

B. assign "representative" concentrations

1. ideally, for each major event, there would be a flow weighted composite sample, then the mass released during that event would be
$$\begin{array}{lcl} \text{mass (mg)} & = & \text{total (liters)} \times \text{flow weighted} \quad (\text{mg/l}) \\ \text{released} & & \text{flow} \quad \text{concentration} \end{array}$$
2. due to the start up nature of the project, a flow weighted sample does not exist for each storm
 - a. concentration variation with time, flow, and rainfall will be studied
 - b. "representative" concentrations will be chosen and applied to different portions of the hydrograph

II. Factors affecting mass release

A. top dressing

1. is there a difference between the covered and uncovered piles
2. compare the mass released by each pile for each event

B. time between events

1. plot mass release vs time between events
2. is there a relationship - does mass release increase as time between events increases

C. rainfall

1. plot mass release versus
 - a. rainfall (in)
 - b. rainfall intensity (in/hr)
2. is there a relationship - does mass release increase as rainfall and/or intensity increase

D. PH

1. plot mass release vs pH for piles 5 and 6
2. compare SO₄ release with metals release - is there evidence for a large increase in sulfide dissolution

E. age of piles

1. is there a relationship between mass release and the total amount of rainfall that has fallen on the pile.

III. Other considerations

A. Acid forming potential

1. delineate the possible cause for the acidic conditions in FL5
2. check literature references and devise experimental tests to try and isolate the cause of the acidity.
3. compare the behavior of 5 and 6, is there a trend.

B. Peak runoff vs base flow

1. How much of the flow is "peak runoff" and how much "base flow"
2. On a yearly basis is most of the mass transported during peak flow or during base flow

C. Compute release rates for each pile (kg/ton yr)

1. how does the release rate vary between piles
 - a. is there a correlation with the % S in the rock
2. how do the release rates compare to other studies conducted on gabbro material
3. use major cations to estimate rates of host rock weathering - is this consistent with what is already known

IV. Redesign sampling plan

A. re-evaluate parameter list

1. are there some parameters which are not providing useful information

B. re-evaluate - sampling plan

1. should more or less samples be collected?

BIBLIOGRAPHY

- Eisenreich, S.J., Hoffman, M.R., Iwasaki, I., Bydalek, T.J., "Metal Sulfide Leaching Potential in the Duluth Gabbro Complex - A Literature Survey" 1976.
- Eisenreich, S.J., Hoffman, M.R., Lapakko, K., "Rates, Mechanism and Control of Metal Sulfide Leaching from Gabbro Mining Related Solids - Progress Report to the Copper Nickel Regional Task Force" January 10, 1977.
- Eisenreich, S.J., Hoffman, M.R., Lapakko, K., Carriker, N., Goldman, L., "Kinetics and Mechanism(s) of Metal Sulfide Release from Mining Drained Solids - A Progress Report to the Copper-Nickel Regional Study" July 1, 1977.
- Hawley, J.R., "The Problem of Acid Mine Drainage in Ontario", Ministry of the Environment, Toronto, 1972.
- Stevenson, R., personal communication - data will soon be published in Regional Copper Nickel report on geology and mineralogy.
- Thingvold, D., personal communication - more information will soon be published in Regional Copper Nickel report on air/water interactions

Appendix I Field Methods

Methods for sampling the field leach piles have undergone constant evaluation and change. Changes were made to produce a more representative sample. Documentation of these changes is necessary for proper interpretation of sample results.

From April 26 to May 24 no volumetric discharges were obtained from individual leach piles. Instead, the discharge from the common sump (Figure 2) of the 6 leach piles was used to obtain average flow from individual piles. This method was not satisfactory because flow, and thus mass loadings, from individual piles could not be accurately calculated.

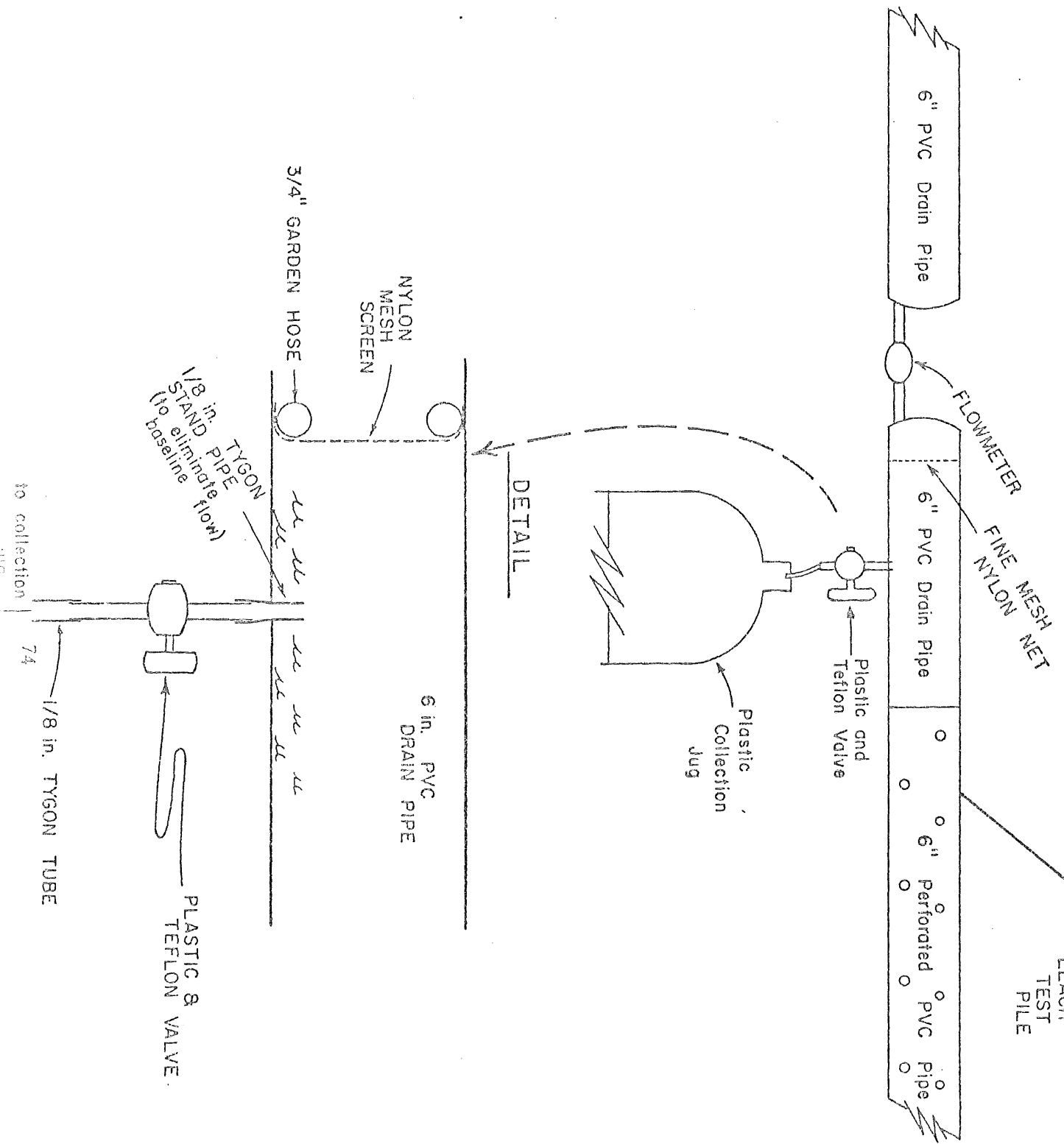
It was decided, therefore, to install low pressure, low volume flow meters in the discharge line of each leach-pile (Figure 3). The installation was completed on May 24. It soon became apparent that the flow meters were malfunctioning due to a combination of low water pressure and fine particulates. To correct this, two changes were made. A fine mesh nylon screen was installed upstream of the meter to filter particulates (Figure 31), and the position of the flow meter was lowered to give as much pressure drop as possible. These modifications were accomplished by July 14. Subsequently the meters functioned properly at high flows but continued to stop during low flows.

Release of metals is known to fluctuate with rain events, therefore, composite samples were needed to accurately estimate an average release for each rain event. To composite the flows a "passive drip sampler" (Figure 31) was developed and installed July 11. The passive drip sampler failed to operate as anticipated. Initially, the drip flow was expected to be proportional to the water level in the pipe; larger sample volumes being collected at high flow than at low flow. In practice, this did not work. The drip flow was difficult to regulate and showed very little response to the water level in the pipe. Since the drip rate did not

Figure 31

PASSIVE DRIP SAMPLER

LEACH
TEST
PILE



change significantly with the flow, the composite sample tended to oversample base flow. After the filter screens (for the flow meters) were installed a stand-pipe was added so that only flow above base flow would be sampled. Thereafter the drip flow did not always begin with rising flow and had to be readjusted manually. Additional problems occurred during backwater conditions. As the water backed up in the pipe, the drip flow continued and the sample did not represent the storm event. On several occasions, the backwater condition began during the night and by morning the five gallon collecting container had overflowed.

An attempt was made to solve both problems by developing a sump pump and a compositing system (Figures 3 and 32). The flow from the leach pile empties into a five gallon sump. The sump pump is controlled by a float switch in the sump. Each time the pump is activated the event is recorded on a Rustrak recorder. A flow meter installed on the pump outlet records total discharge. A small sample line has been installed in the pump discharge line. Each time the pump is activated a small aliquot is placed in the sampling container. This produces a flow weighted composite sample; more sample is collected at high flow since the pump is activated more frequently. This sampling and recording system was tested first on leach pile number 4 (installed August 11). The system operated well and it was decided to similarly instrument the remaining piles. By November 3 instrumentation was completed on leaching piles 1,2 and 5. Instrumentation of piles 3 and 6 is nearing completion.

LABORATORIES

Analytical services for the study are provided by Serco Laboratories, Roseville, Minnesota; DNR Minerals laboratory, Hibbing, Minnesota; DNR field laboratory at Minnana; and the Minnesota Department of Health laboratory in Minneapolis. The following is a list of the parameters analyzed by each laboratory.

Minnesota
Dept. of
Health

Dissolved
Organic
Carbon

Serco
Laboratories

Chloride
Nitrate
Ammonia
Total Phosphorus
Sulfate

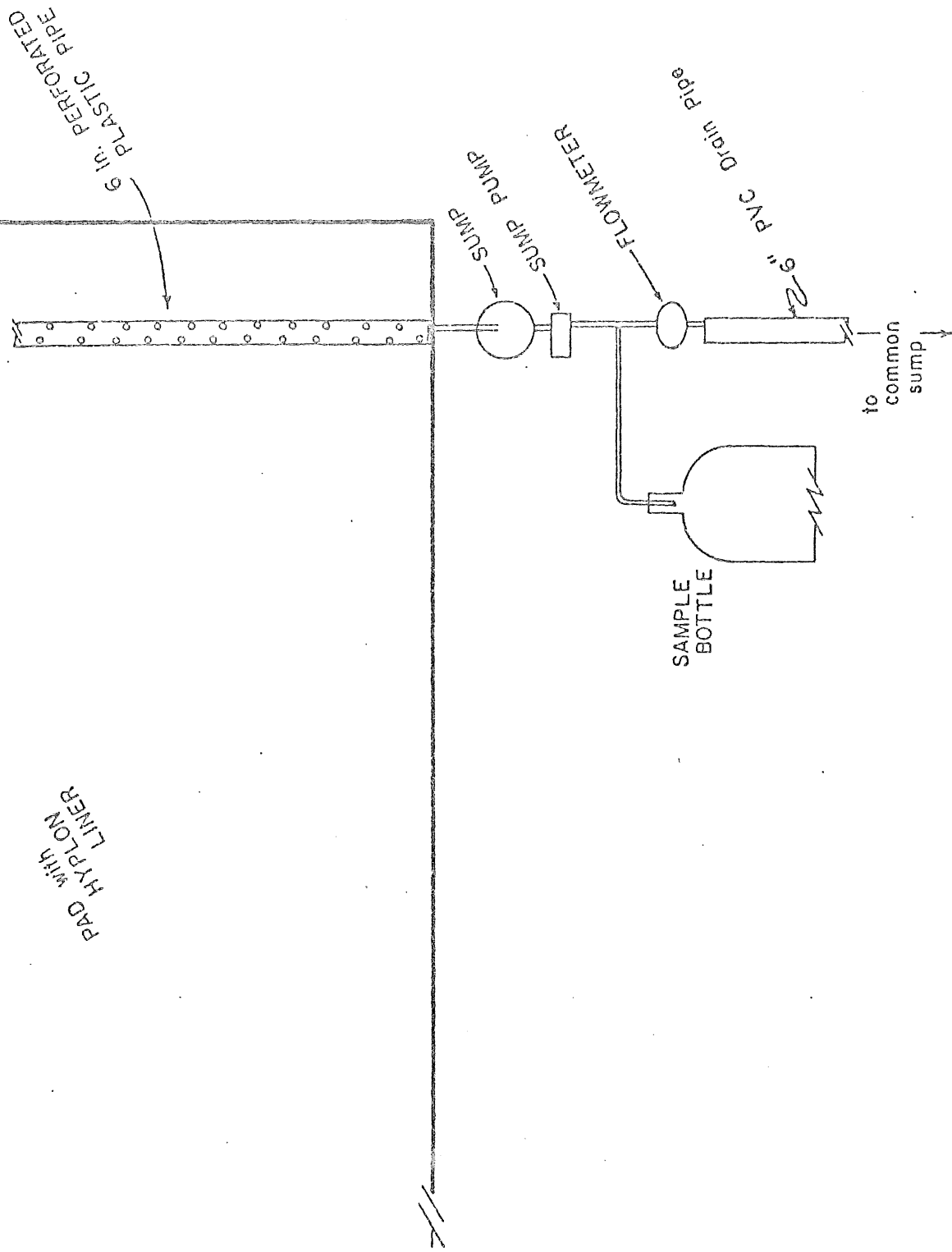
DNR Hibbing

Calcium
Magnesium
Sodium
Potassium
Copper
Nickel
Iron
Manganese
Cobalt
Zinc

DNR Field
Laboratory

pH
Specific Conductance
Temperature
Alkalinity
Dissolved Oxygen

Figure 32
OVERVIEW OF FLOW
PROPORTIONAL SAMPLER



Appendix II

FLOW CALCULATIONS

Flow meters were installed on each pile but did not always function satisfactorily. They were routinely read at 0800 and 1400-1600 every day during the week. The condition of the meter was noted (running, stopped, running but sticking). No readings were made on weekends and holidays.

After fine mesh screens were installed upstream of the meters, (July 14), the meters usually worked satisfactorily at high flows. Prior to July 14, the meters would sometimes jam during rain events and the flow would have to be estimated using volumetric flow measurements or through comparison with other piles. The meters rarely worked under low flow conditions. Base flows were generally computed using volumetric measurements. Normally the flow was measured between 1400-1600 and the recorded flow was assumed to be a good measure of the average daily flow rate.

Examples of the methods used to estimate daily flows are given in Table XVII.

The general approach that was used was:

- 1 - meter readings were used whenever possible
- 2 - if a meter was stopped prior to a storm event, the assumption was made that it began to record when the runoff from the storm began.
- 3 - if the meter was recording at 1600 and still running at 0800 the next day the total flow was divided strictly by time i.e. one half of the flow was assigned to the time period 1600-2400, one half was assigned to the period 2400-0800.
- 4 - Weekend flows
 - a - if no rain occurred during the weekend the flows would be interpolated from the Friday and Monday values.
 - b - if rain occurred, meter readings would be used. Sometimes meter readings would be used to represent peak flow and base flow would be estimated from the Friday and Monday values.
- 5 - when there was no rain, the daily flow was computed from the volumetric measurement.

- 6 - in the early spring before individual meters were installed and before volumetric measurements were taken, the sump outflow was used to estimate the flow from each pile. The sump output divided by the number of piles that were flowing at that time gave the daily flow for each pile.

(A refinement could be made by weighting each pile by its collecting area. However, since the time period when these estimates were needed was relatively short and total flows were small, this refinement is probably not necessary).

EXAMPLE OF FLOW CALCULATIONS

The data for pile FL4 is shown below

(s=meter stopped, r=running; s-r, running, but sticking)

Date	Time	Meter Reading (gal)	Volumetric Flow Rate ml/min	Rainfall in Time	Daily Flow, liters
7-14	0800	6413s			
	1500	6412.9s	300	0	432
7-15	no readings			.08	432
7-16	weekend			0	281
7-17	0800	6413s		0	
	1400	6413s	90		130
7-18	0800	meter under water		1.51	
	1435	7235.2r	1020	2400-0200	3758
7-19	0800	7548s-r		.24 1400-1600	
	1455	7620.3r	2325		1274
7-20	0800	7849r		0	836

The calculations were made as follows:

Date	Rainfall	Method
7-14	0	volumetric flow used as daily average
7-15	.08	this was a small rain, the assumption was made that it was enough rain to maintain the overall flow at a level comparable to 7-14
7-16	0	since this was a weekend, no meter or volumetric measurements were made. The average of the flow on 7-15, which was assumed to be the same as the flow on 7-14, and 7-17 was used.

(cont'd)

<u>Date</u>	<u>Rainfall</u>	<u>Method</u>
7-17	0	volmetric flow was used as daily average
7-18	2400-0200 1.51	the assumption was that the meter began to record at 2400 the total flow from 2400-1435 was obtained from the meter the flow from 1435-2400 was obtained by time weighting the total recorded flow between 1435 and 0800, i.e. 2400-1435 = total flow from meter = 3113 l 1435 - 0800 = total flow from meter = 1184 l $1435 - 2400 = \frac{9.5}{17.5} (1184) = 643$ total daily flow = 3113+643=3758 l
7-19	1400-1600 .24	1-the flow from 2400-0800 was obtained from the time weighted estimate as shown above 2-the flow from 0800-1500 was obtained from the meter 3-the flow from 1500-2400 was a time weighted estimate $2400-0800 \frac{8}{17.5} (1184) = 541 \text{ liters}$ 0800-1500 meter = 276 1500-2400 9/17 (867) = 457.1 Total Flow=541+276+457=1274

Appendix III

WATER QUALITY DATA

All the water quality samples that were collected by the DNR in 1978 are listed in Table XVIII. On April 24, one set of samples was collected by Amax and analyzed by Serco Laboratories (Table XIX). The results of all the samples are tabulated by pile and are presented in Tables XX - XXV.

Table XVIII

WATER QUALITY SAMPLES
COLLECTED IN 1978

C= composite sample

G= grab sample

DATE	FLOW CONDITIONS	PILES SAMPLED					
		1	2	3	4	5	6
4/26	Low Flow	G	G	G	G	G	G
5/24-26	Composite over rain		C	C	C	C	C
6/6	Peak	G					
6/7	After Peak	G					
6/14	Low Flow				2G		
6/16	Low Flow	G	G	G	G	G	G
6/23	Composite over rain	3G			13G		
6/26	Tail of rain	G			G		
7/5	Tail of rain	G	G	G		G	G
7/6	Low Flow				G		
7/7	Composite over rain				24G		
7/8	Composite over rain				13G		
7/9	Tail of rain				G		
7/6-7	Peak	C					
7/7-11	Tail of rain	C					
7/12-13	Peak	C	C	C		C	C
7/13	Tail of rain				G		
7/14-19	Composite over rain	C	C	C		C	C
8/1-2	Composite over rain	C	C	C		C	C
8/2	Tail of rain					C	
8/4	Low Flow	G	G	G	G	G	G
8/10	Low Flow	G		G		G	G
8/14-16	Composite over rain	C			C		
8/16	Composite over rain	G	3G	3G	C	4G	G,C
8/17	Tail of rain					G	
8/18	Tail of rain					G	

C= composite sample
G= grab sample

DATE	FLOW CONDITIONS	PILES SAMPLED					
		1	2	3	4	5	6
8/16-17	Tail of rain				C		C
8/17-18	Composite over rain				C		
8/18-21	Low Flow				C		
8/17-23	Composite over rain	C	C	C		C	C
8/21-23	Before Peak				C		
8/23	Peak				2C	C	
8/23-25	Tail of rain	C	C	C	C	C	C
8/25-28	Composite over rain	C	C		C	C	C
9/10-13	Composite over rain		C	C	C		
9/10-11	Composite over rain				C		C
9/11	Before Peak					G	
9/11-12	Peak and after peak					C	
9/12-13	After peak	C					
9/13	Tail of rain	G	G	G	2G	G	G
10/14-17	Composite over rain	C			C		C

Table XIX
Anax samples -- Serco

Date	4-24	4-24	4-24	4-24	4-24	4-24
Sample type	grab	grab	grab	grab	grab	grab
Time						
Site	FL-1	FL-2	FL-3	FL-4	FL-5	FL-6
Parameters						
Alkalinity	82	66	55	53	58	80
pH	7.8	7.8	7.6	7.5	7.7	7.7
Temperature						
Specific Conductance	967	819	642	776	1520	5150
Calcium	115	75	67	88	165	430
Magnesium	11	17	12	8.2	12	150
Sodium	110	90	58	63	162	516
Potassium	9.0	8.2	8.2	17	4.5	8.5
Copper	.025	.019	.013	.017	.039	.086
Nickel	.110	.095	.075	.090	.725	.960
Iron	.15*	7.5*	.35*	.20*	.25*	.45*
Manganese	.06	.06	.06	.09	.33	.66
Cobalt	.007	.006	.005	.007	.082	.042
Zinc	.033	.029	.017	.048	.021	.011
Sulfate	540	400	300	350	780	680
Chloride	3	3	2	5	32	569
Nitrate	2.7	4.3	3.1	1.5	28	460
Ammonia						
Total Phosphorus	0.1	.2	.1	.1	.1	0.1
Dissolved Organic Carbon	8.9	6.8	4.0	5.0	10	5.8

* Total Metal

Explanation of comment statements

1. Rain If the sample was collected during a rainfall event, the total amount of rainfall and its time of occurrence is given. If the sample was collected between events, the time and amount of the preceding rainfall is given.
2. Portion of the hydrograph sampled
If the sample was a grab sample, the general position of the sample relative to the peak in stockpile runoff is given. If the sample was a composite, the portion over which the sample was collected is given.
3. Other These comments refer to field observations on pile behavior, sample appearance, etc.

Table XX

WATER QUALITY DATA FL 1, 1978

FL-1 Date Sample type Time	4-26 grab	6-6 grab 2110	6-7 grab 0900	6-16 grab 1025	6-23 grab 0950	6-23 grab 1300	6-23 grab 1525	6-26 grab 0900
Parameters								
Alkalinity								
pH	7.15		7.60	7.84	7.49	7.82	7.85	6.35
Temperature	9.0	7.0		11.0	14.0	12.0	13.0	15.0
Specific Conductance	1120	1900	3325	2700	1775	2150	2200	2400
Calcium	112	216	253	244	189	180	181	195
Magnesium	11	19	23	22	18	17	17	20
Sodium	113	268	327	368	313	273	279	313
Potassium	13	20	23	22	23	21	20	21
Copper	.032	.030	.041	.028	.027	.024	.023	.024
Nickel	.037 ^a	.250	.272	.155 ^a	.274	.228	.250	.294
Iron	.20 ^a	.02	.03	.05	.02	.02	.03	.04
Manganese	.06	.13	.15	.14	.10	.09	.08	.09
Cobalt	.003	.009	.005	.001	.013	.012	.012	.014
Zinc	.017	.002	.030 ^a	.002	.004	.002	ND	.010
Sulfate - - -					1400	1400	1000	
Chloride					6	6	3	
Nitrate								
Ammonia								
Total Phosphorus								
Dissolved Organic Carbon								
Discharge at time of Sample (ml/min)	trickle	2558	-	120	175	207	127	59
Total Volume over composite (liters)	-	-	-	-	-	-	-	-

Comments

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho/cm

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. a = Value appears anomalous b = reanalysis

Comments

3. Rain

.75"	last rain	last rain	.35"	last rain
1730-2400	6-6	6-10		6-25
	0.75"	0.19"		.04"
	1730-2400	2300-2400	0745-1045	1800-1830
			1915-2000	
				.29"
				.06"

4. Portion of hydrograph sampled

low flow	Peak	After peak	low flow	Before peak	After peak	After peak	Tail of 0.4" rain
----------	------	------------	----------	-------------	------------	------------	-------------------

5. Other

Initial sample					Some gray matter in water
Snow					
Run off					

FL-1

Date Sample type Time	7-5 Grab 0830	7-7 Comp. 1600 on 7-6 to 1630 on 7-7	7-11 Comp. 1630 on 7-7 to 1525 on 7-11	7-13 Comp. 1200 on 7-12 to 0840 on 7-13	7-18 Comp. 1530 on 7-14 to 1400 on 7-19	8-2 Comp. 8-1 - 1700 - to 1515 on 8-2	8-4 Grab 1045	8-10 Grab 1340
<u>Parameters</u>								
Alkalinity								70
pH	7.75	7.90	7.70	7.92	7.80	7.90	7.80	8.10
Temperature	14.0	19				22	22	24
Specific Conductance	2100	1900	2450		1400	1100	1650	2400
Calcium	202	221	303 ^b	531 ^a	340	176	300	414
Magnesium	20	23	26	31	19	11	23	26
Sodium	206	222	286	395	220	127	209	317
Potassium	28	34	38	45	34	25	37	46
Copper	.018	.024	.024, .03 ^b	.027	.023	.027	.034	.03
Nickel	.206	.285	.408, .37 ^b	.405 ^a	.255	.21	.33	.46
Iron	.01	.04	.03	.01	.01	.01	.03	.02
Manganese	.09	.09	.14	.16	.11	.09	.13	.16
Cobalt	.007	.019	.022, .03 ^b	.026	.019	.010	.016	.025
Zinc	ND	.005	.01 ^b	.058 ^a	.003	.010	.013	.025
Sulfate	900	800	1150	1500	1050	650	1200	1600
Chloride	4	4	5	4	1	1	3	4
Nitrate		5.7	5.7	6.2	3.9	3.4	5.0	-
Ammonia		.44	.64	0.55	0.5	0.7	< 0.08	< 0.13
Total Phosphorus		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	177 (Q at 1535)						167	70
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite a = Value appears anomalous b = reanalysis

Comments	Last	1.38"	0.77"	1.51"	Last rain	Last	Last rain
4. Rain	rain 7-1	1.38"	from	from	8-1	rain 8-1	8-1
	7-2 1.36"	0600-	0600-	1400-	0001-		
	1400 on	1400	1400 on	1600 and	0200	0.95"	0.95"
	7-1 to		7-7;	2000-			
	1100 on		0.15"	2300 on			0.13" on
	7-2		from	7-12			8-10
			1100 7-8				time
			to 0200				1100-1200
			7-9				
5. Portion of hydrograph	Tail of 1.36" rain	Peak	Tail	Peak	Comp. over rain 7-18	Comp. over rain 8-1	Tail of 0.95" rain
6. Other			Comp. was 18165 mls		First of the pre-sent drip comps.		Low flow

FL-1

Date	8-16	8-16	8-24	8-25	8-28	9-13	9-13
Sample type	Grab	Comp.	Comp.*	Comp.	Comp.	Grab	Comp.
Time	1015	8-14 2030 to 1450 on 8-16	1025 on 8-17 to 1945 on 8-23	1945 on 8-23 to 0830 on 8-25	0830 on 8-25 to 0820 on 8-28	1020	1130 on 9-12 to 1020 on 9-13
<u>Parameters</u>							
Alkalinity		42	50	47	59	41	40
pH	8.00	7.70	8.10	7.55	7.85	7.6	7.55
Temperature	23	16		22		14	
Specific Conductance	1400	1675	2600	2500	2700	2175	2000
Calcium	190	149	302	300	308	254	238
Magnesium	15	13	26	26	26	20	18
Sodium	107	97	240	229	280	169	151
Potassium	28	22	40	43	40	41	38
Copper	.02	.02	.04	.04	.05	.05	.04
Nickel	.20	.17	.36	.35	.42	.27	.28
Iron	.02	.02	.06	.02	.04	.03	.03
Manganese	.07	.07	.14	.14	.15	.14	.10
Cobalt	.02	.02	.04	.03 ^b	.07 ^b	.02	.02
Zinc	.01	.02	.02	.02	.02	.01	.01
Sulfate		640	1400	1300		1100	1000
Chloride		2	1	1		1	2
Nitrate		2.5	5.0	4.6		-	-
Ammonia		-	-	0.40		-	-
Total Phosphorus		<0.1	<0.1	0.2		<0.1	<0.1
Dissolved Organic Carbon							
Discharge at time of sample (ml/min)	3441					426	
Total Volume over composite (liters)							

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite a = Value appears anomalous b = reanalysis

Comments	1.28"	1.28"	Last	Last	Last	Last rain 9-10,	
4. Rain	0400-	0400-	rain	rain	rain	11,12	2.46" total
	0800	0800	8-22,8-23	8-22,	8-27	1.00"	1200-1530
	.60" on	.60" on	1.75"	8-23	0.20"	9-10	
	8-14	8-14	2000 on	1.75"	1200-	1.31"	0830-1200
	.26" on	.26" on	8-22 to	2000 on	1400	9-11	
	8-15	8-15	1100 on	8-22 to		.15"	0300-1000
			8-23	1100 on		0-12	
				8-23			
5. Portion of hydrograph	Peak	Comp. over rain 8-16	Comp. over rain 8-22,23	Tail of 175" rain	Comp. over rain 8-27	Tail of 2.46" rain	After Peak
6. Other							
*Mean of duplicate samples							

FL-2 Table XXI Water Quality Data, FL2, 1978

Date	4-26	5-25	6-16	7-5	7-13	7-19	8-2	8-4
Sample type	Grab	Comp.	Grab	Grab	Comp.	Comp.	Comp.	Grab
Time			1120	0330	1155 on 7-12 to 0840 on 7-13	0810 on 7-18 to 1400 on 7-19	Start of rain to 0930 on 8-2	1030
Parameters								
Alkalinity								
pH	7.20	7.70	7.72	7.5	7.92	7.80	7.75	7.75
Temperature	4.0		11.0	12			19	22
Specific Conductance	1000	1900	4200	2700		1300	2000	2500
Calcium	99	177	323	218	491	291	191	341
Magnesium	13	23	47	33	43	24	21	42
Sodium	101	241	555	313	376	189	241	410
Potassium	12	15	23	28	37	28	26	33
Copper	.038	.040	.056	.057	.049	.062	.08	.07
Nickel	.030 ^a	.240	.200 ^a	.316 ^a	.410	.24 ^b	.26	.44
Iron	.82 ^a	.05	.03	.04	.03	.01	.04	.05
Manganese	.07	.16	.31	.22	.29	.16	.18	.28
Cobalt	.003	.008	.015	.021	.033	.01, .019	.01 ^b	.029
Zinc	.020	.028	.075	.084	.09 ^b	.033	.055	.113 ^a
Sulfate				1400	800 ^r	800 ^r	1100 ^r	1700
Chloride				34	30	41	14	19
Nitrate					23	24	19	26
Ammonia					.70	.55	.8	<.08
Total Phosphorus					<0.1	<0.1	<0.1	<0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	Trickle		192	133				100
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite
- r = Analysis rerun, see 10-5-78 memorandum from Serco.
- a = Value appears anomalous b = reanalysis

Comments		0.29"	Last	Last rain	0.77"	1.51"	Last	Last
4. Rain		0630-	rain 6-10	7-1,7-2	from	from	rain	rain
		0730	0.10"	1.36"	1400-	0001-	8-1	8-1
			2300-	1400 on	1600 &	0200 on	0.95"	0.95"
			2400	7-1 to	2000-	7-18;		
				1100 on	2300 on	0.24" on		
				7-2	7-12	7-19		
						(time unknown)		
5. Portion of hydrograph		Comp. over rain 5-25	Low flow	Tail of 1.36" rain	Peak	Tail of 1.51" rain on 7-18	Comp. over rain 8-1	Tail of 0.95" rain
6. Other	Initial sample					First of the pre-set drip comps.		

FL-2

Date Sample type Time	8-16 Grab 1010	8-16 Grab 1345	8-16 Grab 1655	8-23 Comp. 1000 on 8-17 to 1940 on 8-23	8-25 Comp. 1940 on 8-23 to 0840 on 8-25	8-28 Comp. 0840 on 8-25 to 0820 on 8-28	9-13 Grab* 1045	9-13 Comp. Rain on 9-10 to 1045 on 9-13
Parameters								
Alkalinity		38	41	31	35	48	41	17
pH	7.20	7.80	7.75	7.60	7.50	7.55	7.45	7.05
Temperature	23				23		15	
Specific Conductance	975	1100	1200	1100	1600	2300	1725	950
Calcium	100	108	116	103	170	253	182	84
Magnesium	12	15	16	15	24	34	22	10
Sodium	88	95	104	86	125	196	138	74
Potassium	17	16	17	18	28	32	30	23
Copper	.14, .17 ^b	.12, .14 ^b	.13, .14 ^b	.13, .15 ^b	.11	.10	.10	.14
Nickel	.15	.18	.21	.18	.24	.38	.26	.12
Iron	.05	.05	.04	.04	.01	.01	.02	.03
Manganese	.08	.10	.10	.10	.15	.23	.16	.06
Cobalt	.01 ^b	.02	.04	.02	.03	.05, .04 ^b	.02	.02
Zinc	.02	.02	.04	.02	.05	.09 ^b	.06	.03
Sulfate		500	500	460	680	1100	600	567
Chloride		17	17	15	25	34	18	6
Nitrate		10	11	9.4	17	24	13	-
Ammonia		-	-	-	0.64	-	<0.10	-
Total Phosphorus		0.1	0.8	< 0.1	< 0.1	0.1	< 0.1	< 0.1
Dissolved Organic Carbon		17						.
Discharge at time of sample (ml/min)	1500	632	420				130	
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus, and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

4. a = Value appears anomalous b = reanalysis

Comments

4. Rain

1.28" from 0400-0800 on 8-16 also: .60" from 2030-2400 on 8-14 .26" from 0001-0100 and 1000-1130 on 8-15	.23" on 8-18 0001- 0100 .60" on 8-22 2000-2400 1.15" on 8-23 0001-1100	Last rain 8-22 8-23 1.75" 2000 on 8-22 to 1100 on 8-23 rain	Last rain 8-27 0.20" 1200- 1400	Last rain 9-10,11, 12 2.46" total 1.00" 1200-1530 9-1 1.31" 0830-1200 9-1 .15" 0300-1000 9-12
--	---	---	--	---

5. Portion of
hydrograph

Peak	After Peak	After Peak	Comp. over rain 8-18, 22 8-23	Tail of 1.75" rain	Comp. over rain 8-27	Tail of 2.46" rain	Comp. over rain 9-10, 11,12
------	---------------	---------------	-------------------------------------	--------------------------	-------------------------------	--------------------------	-----------------------------------

6. Other

Water
was yel-
low
colored

*Mean of duplicate samples

Table XXII Water Quality Data, FL3, 1978

Date	4-26	5-25	6-16	7-5	7-13	7-19	8-2	8-4
Sample type	Grab	Comp.	Grab	Grab	Comp.	Comp.	Comp.	Grab*
Time			1205	0845	1210 on 7-12 to 0840 on 7-13	1530 on 7-14 to 1400 on 7-19	8-1 1800 to 1515 on 8-2	1100
Parameters								
Alkalinity								
pH	7.20	7.80	7.79	7.3	7.55	7.85	7.60	7.65
Temperature	4.5		6.0	9.0			22	22
Specific Conductance	675	1200	3000	1600		1000	650	950
Calcium	62	106	214	142	352	241	96	156
Magnesium	10	24	57	34	46	28	14	24
Sodium	52	122	372 ^a	102	207	-	60	88
Potassium	12	15	21	23	32	27	21	26
Copper	.023	.013	.026	.20 ^b	.049	.074, .11 ^b	.08	.08
Nickel	.06 ^b	.042 ^a	.185	.282, .36 ^b	.405	.140, .53 ^b	.21	.32
Iron	.70 ^b	.04	.06	< .02	.03	.01	.03	.02
Manganese	.05	.09	.24	.17	.24	.15	.16	.16
Cobalt	0	.050 ^a	.012	.017	.030	.020	.010	.020
Zinc	0	.020	.059	.037	.092	.055	.025	.044
Sulfate				600	1050 ^r	550 ^r	367 ^r	500
Chloride				78	34	35	12	17
Nitrate					12	10	8.0	11
Ammonia					1.0	0.75	0.2	<0.08
Total Phosphorus					<0.1	0.1	0.2	<0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	Trickle		496 ^{BW}	293				1000 ^{BW}
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite
- r = Analysis rerun, see 10-5-78 memorandum from Serco.
- a = Value appears anomalous b = reanalysis

Comments

4. Rain		0.29" 0630- 0730	Last rain 6-10 0.10" 2300- 2400	Last rain 7-1, 7-2 1.36" 1400 on 7-1 to 1100 on 7-2	0.77" from 1400- 1600 & 2000- 2300 on 7-12	1.51" from 0001- 0200 on 7-18; 0.24" on 7-19 (time unknown)	Last rain 8-1 0.95"	Last rain 8-1 0.95"
5. Portion of hydrograph		Comp. over rain 5-25	Low flow	Tail of 1.36" rain	Peak	Tail of 1.51" rain on 7-18	Comp. over rain 8-1	Tail of 0.95" rain
6. Other	Initial sample					First of the pre- set drip comps.; comp. didn't drip over rain period. Caught tail of rain from about 0810 on 7-18 to 1400 on 7-19		
*Mean of duplicate samples								
BW=backwater is present								

Date Sample type Time	8-10 grab 1340	8-16 grab 1025	8-16 grab 1400	8-16 grab 1640	8-23 Comp. 1050 on 8-17 to 1955 on 8-23	8-25 Comp. 1955 on 8-23 to 0835 on 8-25	9-13 grab 1030	9-13 Comp. Rain on 9-10 to 1020 on 9-13
<u>Parameters</u>								
Alkalinity	40		28	30	33	25	43	29
pH	7.90	7.60	7.65	7.60	7.50	7.30	7.3	7.30
Temperature	24	23	22	16		24	14	
Specific Conductance	1900	700	750	800	750	1150	1350	29
Calcium	348	79	89	83	75	115	147	120
Magnesium	51	13	15	16	14	23	24	19
Sodium	188	42	50	46	45	67	81	68
Potassium	49	17	20	16	17	23	28	27
Copper	.05, .07 ^b	.11, .12 ^b	.11, .13 ^b	.10, .13 ^b	.10	.08	.08	.09
Nickel	.56, .57 ^b	.20, .18 ^b	.24, .17 ^b	.23, .22 ^b	.19	.25	.30	.30
Iron	.01	.05	.08	.08	.07	.04	.04	.03
Manganese	.28	.07	.08	.09	.08	.10	.14	.10
Cobalt	.09	.02	.01	.02	< .02 ^b	.01	.01	.03
Zinc	.073	.02	.02	.02	.02	.03	.04	.03
Sulfate	1200		300		300	500	750	567
Chloride	48		10		7	11	8	6
Nitrate	-		5.3		3.6	8.5	5.5	-
Ammonia	< 0.13		1.1		-	1.3	< 0.08	-
Total Phosphorus	< 0.1		0.1		0.1	< 0.1	< 0.1	< 0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	30	14,195 ^d	2839	2103			451	
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

a = Value appears anomalous b = reanalysis

^d Backwater suspected

FL-3

Date

Sample type

	8-10 grab	8-16 grab	8-16 grab	8-16 grab	8-23 Comp. 1050 on 8-17 to 1955 on 8-23	8-25 Comp. 1955 on 8-23 to 0835 on 8-25	9-13 grab 1030	9-13 Comp. Rain on 9-10 to 1020 on 9-13
4. Rain	last rain 8-1 0.95"	1.28" from 0400-0800 on 8-16. Also: 0.60" from 2030-2400 on 8-14 0.26" from 0001-0100 and 1000-0130 and 1000-1130			.23" on 8-18 0001- 0100 60" on 8-22 2000-2400 1.15" on 8-23 0001-1100	last rain 8-22,23 1.75" 2000 on 8-22 to 1100 on 8-23	last rain 2.46 total 1.00" 1200-1530 9-1 1.31" 0830-1200 9-1 0.15" 0300-1000 9-1	
5. Portion of hydrograph	low flow	Peak	After peak	After peak	Comp. over rain 8-18,8-22, 8-23	Tail of 1.75" rain	Tail of 2.46" rain	Comp. over rain 9-10,11,12
6. Other								

Table XXIII Water Quality Data, FL4, 1978

Date	4-26	5-25	6-14	6-16	6-23	6-23	6-23	6-23
Sample type	Grab	Comp.	Grab*	Grab	Grab	Grab	Grab	Grab
Time			0745	0800	0950	1045	1200	1245
<u>Parameters</u>								
Alkalinity								
pH	7.20	7.40	7.60	7.70	7.49	7.35	7.2	7.59
Temperature	4.0		9.0	11	14.0	13.0	13.0	14.0
Specific Conductance	1100	1750	2500	2600	1300	1775	2575	2800
Calcium	121	204	228	247	134	151	207	223
Magnesium	11	20	29	30	17	19	28	31
Sodium	84	165	262	277	154	192	275	308
Potassium	27	35	57	41	27	30	39	43
Copper	.018	.012 ^a	.024	.026	.022	.023	.026	.028
Nickel	.035 ^a	.210	.220	.175	.172	.216	.314	.336
Iron	.42 ^a	.02	.04	.04	.01	.06	.05	.05
Manganese	.10	.19	.21	.26	.16	.17	.22	.23
Cobalt	.004	.012	.016	.015	.009	.015	.025	.028
Zinc	.048	.112	.128	.120	.017	.042	.124	.174
Sulfate					600	900	1400	1400
Chloride					17	20	27	30
Nitrate								
Ammonia								
Total Phosphorus								
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	Trickle		125	94	90	423	475	400
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

4. a = Value appears anomalous

Comments								
4. Rain		0.29"	Last rain	Last rain	Total rainfall on 6-23 = 0.35"			
		0630-	6-10	6-10	.29" from 0745 - 1045			
		0730	0.10"	0.10"	.06" from 1915 - 2000			
			2300-	2300-				
			2400	2400				
5. Portion of hydrograph	Low flow	Comp. over rain 5-25	Low flow sample just prior to rain.	Low flow				
6. Other	Initial sample				Some cloudy grey when filtered on surface of unit.	Water grey in color prior to filtering	Water not as turbid as previous sample.	
*Mean of duplicate samples.								

Sample type	6-23 Grab 1420	6-23 Grab* 1540	6-23 Grab 1700	6-23 Grab 1800	6-23 Grab 1900		6-23 Grab* 2100	
Parameters								
Salinity	7.45	7.45	7.82	7.55	7.8		7.75	
Temperature	14.0	14		7.0				
Specific Conductance	2650	2650	2650	2500	2625		2500	
Calcium	225	223	215	228	220		216	
Sodium	31	30	29	32	30		30	
Potassium	300	296	291	306	293		292	
Magnesium	43	42	41	43	43		42	
Copper	.026	.024	.020	.015	.020		.020	
Nickel	.336	.325	.314	.360	.336		.320	
Chromium	.03	.02	.02	.03	.01		< .02	
Manganese	.23	.22	.20	.24	.23		.22	
Iron	.026	.026	.022	.026	.023		.022	
Zinc	.156	.152	.170	.173	.160		.154	
Sulfate	1200	1200	1200		1300			
Chloride	28	21	31		30			
Nitrate								
Ammonia								
Total Phosphorus								
Dissolved Organic Carbon								
Discharge at time of sample (gal/min)	280	175						
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus, and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

Comments					
4. Rain		Total rainfall on 6-23 = 0.35" 0.29" from 0745 - 1045 0.06" from 1915 - 2000			
5. Portion of hydrograph					
6. Other	Clear water	Isco #2 pH taken 6-26 1350; filtered 6-26; added to Isco #3 for SO ₄ Cl	Isco #3	Isco #4 pH taken 6-26 1340; filtered 6-26; added to Isco #5 for SO ₄ and Cl	Isco #6 pH taken 6-26 1555; filtered at 1445 on 6-26; kept separate for SO ₄ Cl
* Mean of duplicate samples.					

Date	6-23	6-26	7-6	7-7	7-7	7-7	7-7	7-7
Sample type	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab
Time	2300	0920	0830	0400	0500	0600	0700	0800
<u>Parameters</u>								
Alkalinity								
pH	7.7	7.90	7.58	7.65	7.60	7.45	7.2	7.3
Temperature		17	17					
Specific Conductance	2400	2150	1825	2050	2050	2050	1200	1400
Calcium	213	186	212	234	242 ^b	234	132	166
Magnesium	29	24	25	25	24 ^b	27	15	17
Sodium	278	260	190, 173 ^b	201	220 ^b	239	137	156
Potassium	41	41	52	45	43 ^b	42 ^b	20 ^b	29 ^b
Copper	.013	.021	.019	.017	.02	.02	.01	.02
Nickel	.36 ^b	.260	.275	.290	.32	.31	.17	.18
Iron	.01 ^b	0 ^a	.03	.03	.01	.02	.04	.01
Manganese	.22	.18	.18	.20	.19	.19	.12	.13
Cobalt	.025	.019	.019	.022	.06	.06	.02	.04
Zinc	.147	.084	.073	.132	.13	.12	.06	.07
Sulfate		900	850 ^r		1000 ^r			550
Chloride		28	11		17			9
Nitrate								
Ammonia								
Total Phosphorus			0.1		< 0.1			< 0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)		5	88					
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

5. r = Analysis rerun, see 10-5-78 memorandum from Serco.

4. a = Value appears anomalous b = reanalysis

Comments

4. Rain

Last
rain 6-25
.04" 1800
-1830

Last
rain
7-1, 7-2
1.36"
1400 on
7-1 to
1100 on
7-2

Total rainfall on 7-7 = 1.58"
from 0600 - 1400

5. Portion of
hydrograph

Tail of
.04" rain

Low flow
after
1" rain

6. Other

Isco #8
pH taken
6-26
1540;
filtered
6-26
added to
Inco #7
for SO₄
and
Cl

Isco
filtered
1450

Isco
filtered
1455

Isco
combined for
SO₄ #Cl

Isco
filtered
1520 com-
bined with
0900 for
general
parameters

Date	7-7	7-7	7-7	7-7	7-7	7-7	7-7	7-7
Sample type	Grab	Grab	Grab	Grab	Grab*	Grab	Grab	Grab
Time	0830	0900	1000	1100	1200	1300	1400	1500
<u>Parameters</u>								
Alkalinity								
pH	7.20	7.15	7.40	7.40	7.40	7.40	7.15	
Temperature					11	11	11	
Specific Conductance	1000	1450	1550	1275	1125	1050	950	
Calcium	176	172	179	145	126	115 ^b	104	
Magnesium	18	18	19	15	13	10 ^b	10	
Sodium	161	157	164	122	110	88 ^b	80	
Potassium	1363 ^a	29 ^b	33 ^b	268 ^a	607 ^a	22 ^b	20 ^b	
Copper	.02	.02	.02	.02	.02	.01	.01	
Nickel	.25	.21	.24	.20	.14	.14	.10	
Iron	.03	.07	.05	.01	.02	.02	.02	
Manganese	.12	.13	.12	.10	.08	.08	.07	
Cobalt	.02	.02	< .01	.02	.02	.01	< .02	
Zinc	.07	.07	.08	.05	.04	.04	.04	
Sulfate	600	550	600 ^r	450	450	400	250 ^r	500
Chloride	9	9	11	8	6	6	5	5
Nitrate	2.0				1.8		1.4	
Ammonia	.76				1.1		.96	
Total Phosphorus	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	13,360		11,238	8,051	5,002	4,732	6,489	5,344
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite
- r = Analysis rerun, see 10-5-78 memorandum from Serco.
- a = Value appears anomalous b = reanalysis

Comments

4. Rain

Total rainfall on 7-7 = 1.38"
from 0600 - 1400

5. Portion of
hydrograph

6. Other

Isco
filtered
1530
combined
with 0800
for G.P.

*Mean of duplicate samples.

FL-4

Date	7-7	7-7						
Sample type	Grab	Grab						
Time	1600	1700						
Parameters								
Alkalinity								
pH	7.65	7.35						
Temperature	11	11						
Specific Conductance	950	1100						
Calcium	144	119						
Magnesium	11	11						
Sodium	84	89						
Potassium	22 ^b	24 ^b						
Copper	.01	.01						
Nickel	.11	.12						
Iron	.01	.03						
Manganese	.08	.09						
Cobalt	<.01	<.01						
Zinc	.04	.05						
Sulfate	430 ^r	450 ^r						
Chloride	5	5						
Nitrate								
Ammonia								
Total Phosphorus	< 0.1	0.1						
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	3586	2074						
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite 5. r = Analysis rerun, see 10-5-78 memorandum from Serco.
- a = Value appears anomalous b = reanalysis

Comments

4. Rain

Total rainfall on
7-7 = 1.38" from
0600 - 1400

5. Portion of
hydrograph

6. Other

Date	7-7	7-7	7-7	7-7	7-7		7-7	7-7
Sample type	Grab	Grab*	Grab	Grab	Grab		Grab	Grab
Time	1800	1900	2000	2100	2200		2300	2400
<u>Parameters</u>								
Alkalinity								
pH	7.65	7.50	7.50	7.45	7.40		7.55	7.65
Temperature	11	11	11	11	11			
Specific Conductance	1125	1150	1175	1200	1200		1175	1200
Calcium	129	128	134	136	139		132	189
Magnesium	12	12	14	14	13		13	15
Sodium	97	92	110	111	99		96	114
Potassium	35	26 ^b	38	37	28 ^b		32	40
Copper	.012	.015	.012	.014	.01		.01	.009
Nickel	.170	.135	.170	.150	.14		.14	.160
Iron	.05	.02	.02	.02	.02		.02	.02
Manganese	.10	.10	.10	.10	.10		.09	.11
Cobalt	.011	.01	.011	.011	< .01 ^b		.01	.011
Zinc	.049	.05	.047	.056	.04		.05	.050
Sulfate		480		500			540	
Chloride		5		5			5	
Nitrate		1.5		1.5				
Ammonia		.44		.40				
Total Phosphorus		< 0.1		< 0.1			< 0.1	
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	2469	2055	1747	1822	1431			
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

4. a = Value appears anomalous b = reanalysis

Comments

4. Rain

Total rainfall on 7-7 = 1.38" from
0600 - 1400

5. Portion of
hydrograph

6. Other

Filtered immedi- ately	Isco #1 filtered 7-10 1330	Isco #2 filtered 7-10 1330	Isco #3 filtered 7-10 1330

*Mean of duplicate samples.

Sample type	7-8 Grab 0100	7-8 Grab 0200	7-8 Grab 0300	7-8 Grab 0400	7-8 Grab 0500	7-8 Grab 0600	7-8 Grab 0700	7-8 Grab 0800
Parameters								
Alkalinity	7.65	7.60	7.72	6.65	7.60	7.50	7.50	7.60
Temperature								
Specific Conductance	1225	1250	1275	1350	1325	1325	1350	1400
Calcium	194	212	210	224	233	245	159 ^a	168, 175 ^b
Magnesium	15	16	15	12	16	16	16	17
Sodium	111	121	118	116	121	124	113	119
Potassium	39	43	40	40	41	42	34	38
Copper	.014	.012	.007	.014	.012	.009	.02	.02
Nickel	.160	.160	.170	.225	.215	.205	.18	.18
Iron	.02	.04	.07	.04	.03	.01	.02	.04
Manganese	.12	.12	.12	.12	.13	.14	.11	.12
Alt	.011	.015	.013	.015	.015	.015	.02	.04 ^b
Zinc	.049	.049	.055	.053	.061	.056	.05	.06
Sulfate							650 ^r	
Chloride							6	
Nitrate								
Ammonia								
Total Phosphorus							< 0.1	
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)								
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus, and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

5. r = Analysis rerun, see 10-5-78 memorandum from Sere

4. a = Value appears anomalous

114 b = reanalysis

Comments

4. Rain

1.38" From 0600 - 1400 on 7-7, 0.15" from 1100 on 7-8 to 0200 on 7-9

5. Portion of hydrograph

6. Other

Isco #4	Isco #5	Isco #6	Isco #7	Isco #8	Isco #9	Isco #10	Isco #11
Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered
7-10	7-10	7-10	7-10	7-10	7-10	7-10	7-10
1330	1330	1330	1530	1530	1530	1530	1530
					Lack of H ₂ O		

FL-4

Date	7-8	7-8	7-8	7-8	7-9	7-13	8-4	8-15
Sample type	Grab	Grab	Grab	Grab*	Grab	Grab	Grab	Comp.
Time	0900	1600	2000	2300	0100	1130	1010	8-14 to 0930 on 8-15
<u>Parameters</u>								
Alkalinity								39
pH	7.3	7.48	7.55	7.40	7.55	7.65	8.00	7.30
Temperature							22	21
Specific Conductance	1425	1600	1650	1700	1550		1100	1275
Calcium	303	167, 177 ^b	302	212, 222 ^b	300	273	191	201
Magnesium	20	16	21	21	20	18	13	19
Sodium	153	121	155	152	149	153	115	158
Potassium	49	37	48	42	46	44	43	39
Copper	.012	.01	.012	.02	.009	.012	.020	.02
Nickel	.255	.21 ^a	.255	.26	.240	-	.20 ^a	.24
Iron	.01	.01	.02	.02	.02	.02	.02	.02
Manganese	.16	.12, .16 ^b	.18	.16	.16	.14	.14	.15
Cobalt	.019	.03 ^b	.019	.03	.017	.015	.010	.01 ^b
Zinc	.064	.06	.064	.07	.005 ^a	.004 ^a	.052	.07
Sulfate		950		950 ^r		850	660	800
Chloride		8		7		7	3	6
Nitrate						2.2	1.2	1.2
Ammonia						0.90	< 0.08	1.2
Total Phosphorus		< 0.1		< 0.1		< 0.1	< 0.1	< 0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)							95	
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite 5. r = Analysis rerun, see 10-5-73 memorandum from Serco.

4. a = Value appears anomalous

b = reanalysis

Comments

4. Rain	1.38" from 0600 - 1400 on 7-7, 0.15" from 1100 on 7-8 to 0200 on 7-9					0.77" from 1400-1600 and 2000-2300 on 7-12	Last rain 8-1 0.95"	.60" from 2050-2400 on 8-14; .26" from 0001-0100 1000-1150 on 8-15
5. Portion of hydrograph						Tail of 0.77"	Tail of 0.95"	Comp. over rain 8-14, 15
6. Other	Isco #12 Filtered 7-10 1530	Isco #19 Filtered 7-11 1520	Isco #23 Filtered 7-11 1520	Isco #26 Filtered 7-11 1515	Isco #28 Filtered 7-11 1515			

*Mean of duplicate samples.

Date Sample type Time	8-16 Comp. Start of rain to 1435 on 8-16	8-17 Comp. 1435 on 8-16 to 0800 on 8-17	8-18 Comp. 0800 on 8-17 to 1500 on 8-18	8-21 Comp. 1500 on 8-18 to 0830 on 8-21	8-23 Comp. 0830 on 8-21 to 0800 on 8-23	8-23 Comp. 0800 on 8-23 to 1440 on 8-23	8-23 Comp. 1445 on 8-23 to 1925 on 8-23	8-25 Comp. 1925 on 8-23 to 0835 on 8-25
Parameters								
Alkalinity	28	29	36		29	30	31	33
pH	7.50	7.29	7.60	7.75	7.65	7.05	7.70	7.55
Temperature						25		23
Specific Conductance	825	1175	1850	2050	1400	1000	1250	1750
Calcium	118	355	219	271	155	111	147	216
Magnesium	11	41	21	27	16	11	18	21
Sodium	60	158	110	142	102	67	85	115
Potassium	26	12	42	50	31	30	36	46
Copper	.02	.03	.02	.08	.02	.02	.02	.02
Nickel	.13	.20	.24	.32	.18	.11	.14	.24
Iron	.03	.04	.02	.46 ^a	.01	.01	.04	.01
Manganese	.09	.12	.16	.20	.11	.08	.10	.14
Cobalt	.02	.02	.04	.04 ^b	.03	.02	.02	.03
Zinc	.03	.05	.07	.10 ^b	.05	.03	.03	.06
Sulfate	100 ⁷	1000	800		700	500	610	800
Chloride	1	13	3		3	1	3	2
Nitrate	1.2	2.2	1.4		1.5	1.5	1.4	1.4
Ammonia	-	-	-		0.96	1.2	-	1.0
Total Phosphorus	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)								
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

4. a = Value appears anomalous

b = reanalysis

Comments

4. Rain

1.28"	Last rain	0.25"	Last rain	.60" from 2000-2400 on	Last rain
0400-	8-16 1.28"	0001-	8-18	8-22 1.15" from 0001 -	1.75"
0800	0400-	0100	0.23"	1100 on 8-23	2000 on
.60" on	0800		0001-		8-22 to
8-14			0100		1100 on
.26" on					8-23
8-15					

5. Portion of hydrograph

Comp. over rain 8-16	Tail of 1.28" rain	Tail of 1.28" rain; Comp. over rain 8-18	Low flow	Before peak	Peak	After peak	Tail of 1.75" rain
----------------------------	--------------------------	--	-------------	----------------	------	---------------	-----------------------

6. Other

FL-4

Date	8-28	9-11	9-15	9-15	9-15			
Sample type	Comp.*	Comp.	grab	grab	Comp.			
Time	0835 on 8-25 to 0815 on 8-28	9-10 to 0835 on 9-11	1100	1100	9-10 rain to 1100 on 9-15			
<u>Parameters</u>								
Alkalinity	41.8	35	34	34				
pH	7.55	7.30	7.40	7.40	6.9			
Temperature			12	12				
Specific Conductance	2350	2300	1875	1875	1200			
Calcium	280	256	226	226	125			
Magnesium	29	26	21	21	11			
Sodium	187	219	120	119	83			
Potassium	60	59	51	52	30			
Copper	.03	.03	.03	.03	.01			
Nickel	.34	.34	.25	.25	.13			
Iron	.02	.06	.08	.03	.06			
Manganese	.19	.20	.16	.16	.09			
Cobalt	.04	.05	.05	.04	.01			
Zinc	.10	.08	.06	.07	.03			
Sulfate	1250	1200		1070	633			
Chloride	2	10		2	3			
Nitrate	2.4	-		1.4	-			
Ammonia	-	-		<0.08	-			
Total Phosphorus	< 0.1	< 0.1		< 0.1	< 0.1			
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)								
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite

Date	8-28	9-11	9-13	9-15	9-13	
Sample type	Comp.*	Comp.	grab	grab	Comp.	
Time	0855 on	9-10 to	1100	1100	9-10	
	8-25 to	0835 on			rain to	
	0815 on	9-11			1100 on	
	8-28				9-13	
4. Rain	Last rain	~1.00"	Last rain	9-10,11,		
	8-27	from 1200	12	2.46" total		
	0.20"	-1530 on	~1.00"	1200-1530		
	1200-	9-10	9-10			
	1400		~1.31"	0830-1200		
			9-11			
			~.15"	0300-1000		
			9-12			
5. Portion of Hydrograph	Comp. over rain 8-27	Comp. over rain 9-10	Tail of 2.46" rain	Comp. over rain 9-10,11,12		
6. Other			Total Metals	Took 150 mls of each of 3 comp. and added together 9-10 to 9-11 0855 9-11 0835 to 9-11 1145 9-11 1145 to 9-13 1100	filtered metals	

* Mean of duplicate samples

Date Sample type Time	4-26 grab	5-25 Comp.	6-16 grab 1115	7-5 grab 0800	7-15 Comp. 1150 on 7-12 to 0850 on 7-15	7-19 Comp. 0900 on 7-18 to 1400 on 7-19	8-2 Comp. 8-1 1700. to 0900 on 8-2	8-2 Comp. 0900 on 8-2 to 1450 on 8-2
Parameters								
Alkalinity								
pH	7.20	7.6	7.5	7.05	7.22	7.40	6.95	7.05
Temperature	6.0		13	15			20	22
Specific Conductance	1750	2500	3300	2950		2050	1850	1600
Calcium	190	279	366	325	357 ^b	565, 596 ^b	264	288
Magnesium	11	21	26	29	27	29	19	21
Sodium	153	273	336	231	248	245	139	150
Potassium	6	10	15	13	14	16	14	12
Copper	.020	.021	.044	.14 ^b	.090	.141	.25	.28
Nickel	.445	.780	.835	5.100	6.7 ^b	21.5	9.22 ^b	11.54 ^b
Iron	.17 ^a	.02	.03	.02	.04	.02	.04	.05
Manganese	.27	.89	1.40	1.29	1.67	2.40	1.94	2.22
Cobalt	.045	.136	.160	.195	.81	1.9, 2.42	1.22, 1.07 ^b	1.39, 1.23 ^b
Zinc		.096	.174	.257	.250	.596	.579	.420
Sulfate				1800	1300	1500	700	850
Chloride				78	50	59	25	25
Nitrate					39	54	43	90
Ammonia					13	12	4.6	6.3
Total Phosphorus					< 0.1	< 0.1	.4	< 0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	trickle		192	370				
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = μmho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

a = Value appears anomalous

b = reanalysis

FL-5

Date Sample type) Time	4-26 grab	5-25 Comp.	6-16 grab 1115	7-5 grab 0800	7-15 Comp. 1150 on 7-12 to 0850 on 7-13	7-19 Comp. 0900 on 7-18 to 1400 on 7-19	8-2 Comp. 8-1 1700 to 0900 on 8-2	8-2 Comp. 0900 on 8-2 to 1450 on 8-2
4. Rain		0.29"	Last rain 6-10 0.10" 2300-2400	Last rain 7-1, 7-2 1.36" 1400 on 7-1 to 1100 on 7-2	0.77" from 1400-1600 and 2000- 2300 on 7-12	1.51" from 0001-0200 on 7-18; 0.24" on 7-19 1400	Last rain 8-1 0.95"	Last rain 8-1 0.95"
5. Portion of hydrograph		Comp. over rain 5-25	Low flow	Tail of 1.36" rain	Peak	Tail of 1.51" rain on 7-18; First of the present drip compositors	Comp. over rain 8-1	Tail of 0.95" rain
6. Other								

FL- 5

Date	8-4	8-10	8-16	8-16	8-16	8-17	8-18	8-23
Sample type	grab	grab*	grab*	grab	grab	grab	grab	Comp.
Time	1000	1320	0945	1330	1700	0815	1500	1100 on 8-17 to 0910 on 8-23
<u>Parameters</u>								
Alkalinity		7		6	10	5	4	
pH	6.30	5.50	6.10	5.80	5.80	5.25	4.85	4.45
Temperature	22	22	15	22	16		16	
Specific Conductance	2350	4000	1150	1750	1575	2100	5100	1750
Calcium	483	636	202	264	270	400 ^b	550 ^b	200
Magnesium	32	47	20	27	31	40 ^b	44 ^b	23
Sodium	238	338	97	111	106	178 ^b	554	112
Potassium	17	20	9	11	9	33	8	9
Copper	.7, .13 ^b	1.28 ^b	.58 ^a	1.30	1.59	2.53	2.98	1.10
Nickel	3.23 ^b	3.31 ^b	15.26 ^b	24.07 ^b	28.05 ^b	40.58 ^b	42.21	15.98
Iron	.05	.12	3.38	9.75	10.78	11.54	5.28	.26 ^b
Manganese	3.32	4.29	2.18	3.15	5.85	5.14	5.87	2.58
Cobalt	1.77, 1.94	1.96, 2.43 ^b	2.63	4.05	4.69	6.73	7.22	2.86
Zinc	.774	1.18, 1.25 ^b	.42	.66	.79	1.24	1.45	.59
Sulfate	1400	2000		900	800	800	800	1400
Chloride	44	52		19	20	27	34	17
Nitrate	83	-		38	44	55	67	35
Ammonia	7.5	8.5		4.0	-	-	-	4.0
Total Phosphorus	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	333	147	11,356 ^x	3785	2704	1714 ^x	498	
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

* mean of duplicate samples ^x Backwater suspected
a = Value appears anomalous (124) b = reanalysis

FL-5

Date
Sample type
Time

	8-4 grab	8-10 grab*	8-16 grab*	8-16 grab	8-16 grab	8-17 grab	8-18 grab	8-23 Comp. 1100 on 8- to 0910 on 8-
4. Rain	Last rain 8-1 0.95"	Last rain 8-1 0.95" 0.13" on 8-10 1100- 1200	1.23" from 0400-0800 on 8-16 also: 0.60" from 2030-2400 on 8-14 0.26" from 0001-0100 and 1000-0100 and 1000-1130			Last rain 8-16 1.28" 0400-0800	0.23" 0001-0100	.25" on 8- 0001-0100 .60" on 8- 2000-2400 1.15" on 8- 0001-1100
5. Portion of hydrograph	Tail of 0.95" : rain	Low flow	Peak	After peak	After peak	Tail of 1.28" rain	Tail of 0.23" rain	Before peak
6. Other								

FL-5

Date Sample type Time	8-23 Comp. 0910 on 8-23 to 1930 on 8-23	8-25 Comp. 1930 on 8-23 to 0855 on 8-25	8-28 Comp. 0855 on 8-25 to 0815 on 8-28	9-11 grab 1145	9-12 Comp. 1200 on 9-11 to 1455 on 9-12		9-15 grab 1100	
<u>Parameters</u>								
Alkalinity								
pH	4.00	3.90	4.25	4.80	5.50		5.62	
Temperature		21		17			15	
Specific Conductance	1800	2800	3250	1475	2650		3250	
Calcium	207	344	395	140	260		512	
Magnesium	26	42	50	20	50		65	
Sodium	102	177	220	79	135		183	
Potassium	11	15	18	9	17		21	
Copper	1.80	3.15	3.95	1.81	7.28		10.50	
Nickel	24.5	39.40	48.00	18.00	67.00		83.00	
Iron	7.75	2.78	2.58	.75	24.00 ^b		25.00	
Manganese	3.40	5.40	6.47	2.90	10.00		15.00	
Cobalt	3.94	6.36	7.76	1.51	4.88		6.17	
Zinc	.66	1.18	1.49	.56	1.75		2.46	
Sulfate	700	1200	1500	700	1550		1900	
Chloride	16	22	30	8	9		15	
Nitrate	34	54	64	-	-		46	
Ammonia	-	8.3	-	-	-		0.1	
Total Phosphorus	< 0.1	< 0.1	< 0.1	0.2	< 0.1			
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)				8801 ^c			721	
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

4. a = Value appears anomalous

b = reanalysis

c Average value computed from flow meter readings over time interval 0945-1545

(126)

FL-5

Date
Sample type
Time

8-23 Comp. 0910 on 8-23 to 1930 on 3-25	8-23 Comp. 1830 on 8-23 to 0855 on 3-25	8-28 Comp. 0855 on 8-25 to 0815 on 8-28	9-11 grab 1145	9-12 Comp. 1200 on 9-11 to 1455 on 9-12	9-13 grab 1100	9-15 grab 1100
4. Rain	.25" on 8-18 0001-0100 .60" on 8-22 2000-2400 1.15" on 8-23 0001-1100	Last rain 8-22, 23 1.75" 2000 on 8-22 to 1100 on 8-23	Last rain 8-27 0.20" 1200-1400	1.31" 0830-1200 Also: 1" from 1200-1530 9-10	Last rain 9-10, 11, 12 2.46" total 1.00" 1200-1530 1.31" 0830-1200 0.15" 0500-1000	9-10 9-11 9-12
5. Portion of hydrograph	Peak and after peak	Tail of 1.75" rain	Comp. over rain 8.27	Before Peak	Peak and after peak	Tail of 2.46" rain

6. Other

Total
metals

Filtered
metals
split with
Amax

Date Sample type Time	4-26 grab	5-25 Comp.	6-16 grab 1120	7-5 grab 0830	7-13 Comp. 1145 on 7-12 to 0830 on 7-13	7-19 Comp. 1530 on 7-14 to 0900 on 7-19	8-2 Comp. Start of rain to 1435 on 8-2	8-4 grab 0930
Parameters								
Alkalinity								
pH	7.25	7.25	7.12	7.4	7.49	8.1	7.70	7.75
Temperature	4.0		15.0	12		18	25	22
Specific Conductance	>5000		8860	4610		5700	2600	4150
Calcium	478	840	1028	435 ^b	794	540	258	451
Magnesium	139	152	206	141 ^b	124	95	61	120
Sodium	535	862	1106	491 ^b	685	508	260	
Potassium	12	18	22	17 ^b	16	12	9	12
Copper	.088	.121	.258	.060	.118	.092	.06	.11, .13 ^b
Nickel	.540	.740	.665	.65, .82 ^b	1.03 ^b	1.0, .72 ^b	.63	.95
Iron	.28	.12	.12	.02	.03	.05	.05	.04
Manganese	.60	1.14	1.64	.70	.95	.75	.62	1.04
Cobalt	.030	.062	.059	.051	.067	.052	.035	.17, .11 ^b
Zinc	.022	.003	.033 ^a	.006	.014	.006	.020	.030
Sulfate				2000	1450	1500	950	1700
Chloride				420	607	512	180	320
Nitrate					400	160	48	210
Ammonia					100	100	70	100
Total Phosphorus					<0.1	1.9	0.1	0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	Trickle		135	223				287
Total Volume over composite (liters)								

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

4. a = Value appears anomalous

b = reanalysis

FL-6

Date Sample type Time	4-26 grab	5-25 Comp.	6-16 grab 1120	7-5 grab 0800	7-15 Comp. 1145 on 7-12 to 0830 on 7-13	7-19 Comp. 1550 on 7-14 to 0900 on 7-19	8-2 Comp. Start of rain to 1435 on 8-2	8-4 grab 0930
4. Rain		0.29"	Last rain 6-10 0.10" 2300-2400	Last rain 7-1, 7-2 1.36" 1400 on 7-1 to 1100 on 7-2	0.77 from 1400-1600 and 2000- 2300 on 7-12	1.51" from 0001- 0200 on 7-18; 0.24" on 7-19 (time un- known)	Last rain 8-1 0.95" Comp. over rain 8-1	Last rain 8-1 0.95" Tail of 0.95" rain
5. Portion of Hydrograph		Comp. over rain 5-25	Low flow	Tail of 1.36" rain	Peak	Before peak and peak		
6. Other								

HL- 6

Date Sample type Time	8-10 Grab 1315	8-16 Grab 1000	8-16 Comp. Start of rain to 1440 on 8-16	8-17 Comp. 1440 on 8-16 to 1405 on 8-17	8-23 Comp. 1405 on 8-17 to 1935 on 8-23	8-25 Comp. 1935 on 8-23 to 0840 on 8-25	8-28 Grab 0840 on 8-25 to 0815 on 8-28	9-15 Grab 1600
<u>Parameters</u>								
Alkalinity	47		40	46	30	40	57	25
pH	7.55	7.85	7.71	7.52	7.55	7.40	7.85	7.1
Temperature	24	22				25		13
Specific Conductance	6840	2200	2250	4600	4320	4750	5290	3400
Calcium	748	231	269	396	368	375	481	367
Magnesium	178	70	78	46	112	119	135	125
Sodium	700	236	278	200	396	432	681	395
Potassium	22	6	6	14	12	12	15	14
Copper	.17	.09	.10	.13	.13	.15	.18	.28
Nickel	1.43	.87	1.00	1.48	1.54	1.70	2.15	2.25
Iron	.15	.03	.08	.05	.05	.07	.07	.06
Manganese	1.68	.75	.89	1.38	1.40	1.53	1.82	2.12
Cobalt	.28	.14	.18	.27	.24	.27	.39	.21
Zinc	.050	.03	.03	.05	.05	.05	.07	.12
Sulfate	2400		1000	1700	1600	1800	2150	2050
Chloride	600		150	190	280	220	390	180
Nitrate	-		140	120	170	140	230	-
Ammonia	160		-	-	-	98	-	-
Total Phosphorus	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)	77	28390						
Total Volume over composite (liters)								667 (Q at 1135)

1. All parameters in mg/l except as follows.

a. Temperature = °C

b. Specific Conductance = umho

c. Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.

2. All metal values are filtered, unless otherwise specified.

3. Comp. = Composite

Comments

4. Rain

Last rain	1.23"	1.28"	Last rain	Last rain	Last rain	Last rain	Last rain
8-1	0400-	0400-	8-16	8-22,	8-22,	8-27	9-10,11,12
0.95"	.60" on	.60" on	1.28"	8-23	8-23	0.20"	2.46" total
0.13" on	8-14	8-14	0400-	1.75"	1.75"	1200-	1.00" 1200-
8-10	.26" on	.26" on	0800	2000	2000 on	1400	1530 9-10
1100-	8-15	8-15		on 8-22	8-22 to		4.31" 0830-
1200				to	1100 on		1200 9-11
				1100 on	8-23		2.15" 0300-
				8-23			1000 9-12

5. Portion of hydrograph

Low flow	Peak	Comp. over rain	Tail of 1.28" rain	Comp. over rain	Tail of 1.75" rain	Comp. over rain	Tail of 2.46" rain
		8-16		8-22, 8-23		8-27	

6. Other

PL- 6

Date	9-13							
Sample type	Comp.							
Time	9-10							
	rain							
	to							
	1135 on							
	9-13							
Parameters								
Alkalinity	26							
pH	7.21							
Temperature								
Specific Conductance								
Calcium	408							
Magnesium	115							
Sodium	498							
Potassium	14							
Copper	.29							
Nickel	2.42							
Iron	.04							
Manganese	2.16							
Cobalt	.23							
Zinc	.12							
Sulfate	2100							
Chloride	360							
Nitrate	-							
Ammonia	-							
Total Phosphorus	0.1							
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)								
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite

Comments

4. Rain

Last
rain
9-10, 11,
12 2.46'
total
1.00"
1200-
1530
9-10
1.31"
0830-
1200
9-11
.15"
0300-
1000
9-12

5. Portion of
hydrograph

Comp. over
rain
9-10, 11,
9-12

6. Other

Appendix IV

COMPUTATION OF THE PERCENT OF METALS THAT ARE RETAINED IN THE TEST PILES:

Assumptions: SO_4 is completely mobile and it is a measure of the total amount of sulfide dissolution that has occurred. The goal is to compute the total sulfide dissolution rate and based on the percent of each metal sulfide in the pile, calculate the amount of each metal sulfide that has reacted. The inherent assumption is that all the sulfides are oxidized at the same rate.

The 1977 data from FL1 are used. Chemical data from Amax, as well as detailed chemical information from the regional copper nickel study are available (Tables I and III).

Filtered data was used for the metals, so that the influence of particulates could be eliminated. Since the piles are small, have fine material in them, and the samples are collected directly from the pile, fine particles may be in suspension. These particles could tend to bias the results to unusually high values.

It is assumed that all iron in solution comes from the sulfide minerals (Iron exists in the silicate minerals as well).

The calculations are shown in Table XXVI. The first column is the composition of the rock as given in Table III. The second column (Mole % of s) gives the distribution of each metal sulfide, i.e. 6.08 percent of the total sulfides contain nickel. Values in Column III were calculated by assuming all the sulfides are present as simple sulfides, i.e. NiS , CuS etc. and the amount of dissolution that would occur to yield a SO_4 concentration of 1000 mg/l was calculated.

Table XXVI Calculation of Metals Retained in Test Pile

<u>Parameter</u>	<u>% determined from sample Ax 9001</u>	<u>Mole % of S</u>	<u>Concentration at base 1000 mg/1SO₄</u>	<u>At Base of 610 mg/l</u>	<u>Observed Median Concentration mg/l</u>
S-SO ₄	.655	100	1000	610	610
Ni	.073	6.08	37.2	22.7	.288
Cu	.306	23.6	156	95.2	.03
Zn	.016	1.20	8.18	5.0	.013
Co	.009	.750	4.60	2.8	.006
Fe(s) *	.697	61.3	356	217	4.05

* This is the iron that is in the sulfide minerals only, it does not include the iron that is in the silicates.

Table XXVII

April, 1978

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.00		
2	.02		
3	.20		
4	.00		
5	.00		
6	.47		
7	.00		
8	.00		
9	.31		
10	.00		
11	.15		
12	.00		
13	.10		
14	.00		
15	.00		
16	.00		
17	.00		
18	.00		
19	.00		
20	.00		
21	.00		
22	.00		
23	.00		
24	.03		
25	.00		
26	.00		
27	.00		
28	.00		
29	.00		
30	.00		

From 4/1 - 5/2, rain was recorded from A.M. to A.M. with a standard rain gauge; rain during weekends would be added to the Monday rain figures.

From 5/2 on, all times midnight to midnight.

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.00		
2	.00		
3	.00		
4	.00		
5	.00		
6	.00		
7	.32	0300-0815	
8	.00		
9	.00		
10	.00		
11	.00		
12	.00		
13	.00		
14	.00		
15	.00		
16	.00		
17	.00		
18	.00		
19	.21	1830-2115	
20	.00		
21	.00		
22	.00		
23	.00		
24	.29	0630-0730	
25	.00		
26	.25	0500-0600	Quantity is an estimate.
27	.10	0800-0900	Quantity is an estimate.
28	1.92	0700-0830=1.86;1300-1400=.06	0700-0830 is an estimate.
29	.08	1215-1530	
30	.20	1830-2400	
31			

From 4/1 - 5/2, rain was recorded from A.M. to A.M. with a standard rain gauge; rain during weekends would be added to the Monday rain figures.

From 5/2 on, all times midnight to midnight.

Table XXIX

June, 1978

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.48	2400-0300=.30; 1815-1845=.18	
2	.02		Not traceable on the recorder
3	.00		
4	.00		
5	.00		
6	.75	1730-2400	
7	.21	0001-0900	
8	.00		
9	Trace		
10	.10	2300-2400	
11	.00		
12	.00		
13	.00		
14	.00		
15	.00		
16	.00		
17	.00		
18	.00		
19	.00		
20	.00		
21	.00		
22	.00		
23	.35	0745-1045=.29; 1915-2000=.06	
24	.00		
25	.06	1800-1830	
26	.11	1730-2030	
27	.00		
28	.13	1630-1900	
29	.00		
30	.00		

From 5/2 on, all times midnight to midnight.

Table XXX

July, 1978

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.12	1400-2400	15
2	1.24	0001-1100	
3	.00		
4	.00		
5	.00		01
6	.00		
7	1.38	0600-1100=1.18"; 1200-1400=.20"	11
8	.09	2300-2400 heavy	
9	.06	2400-0200 light	
10	.00		
11	.00		15
12	.77	1400-1600, 2000-2300	
13	.00		
14	.00		
15	.00		
16	.20		22
17	.00		
18	1.51	midnight-0200, heavy	
19	.24		
20	.00		
21	.01		15
22	.29	1500-1600	
23	.00		
24	.26	1300-1600	
25	.00		
26	.10	2100-2200	12
27	.00		
28	.11	2000-2100	
29	.00		
30	.00		
31	.00		

From 5/2 on, all times midnight to midnight.

Table XXXI

August, 1978

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.95		21
2	.00		
3	.00		
4	.00		
5	.00		
6	.00		
7	.00		
8	.00		
9	.00		
10	.13	1100-1200	45
11	.00		
12	.13	0600-0630	
13	.00		
14	.60	2030-2400	
15	.26	2400-0100, 1000-1130	47
16	1.28	0400-0800	
17	.00		
18	.23	2400-0100	
19	.00		
20	.00		
21	.00		
22	.60	2000-2400	
23	1.15	0001-1100	
24	.00		
25	.00		
26	.00		
27	.20	1200-1400	
28	.00		
29	.00		
30	.00		
31	.00		

From 5/2 on, all times midnight to midnight.

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.00		
2	.00		
3	.00		
4	.00		
5	.00		
6	.00		
7	.00		
8	.00		
9	.00		
10	1.00	1200-1530	quantity is an estimate
11	1.31	0830-1200	quantity is an estimate
12	.15	0300-1000	quantity is an estimate; Exact total 9/10-9/12 = 2.46"
13	.00		
14	.53	0001-0600	
15	.03	0810-1200	
16	.00		
17	.00		
18	.09		
19	.06	1700-1800	
20	.00		
21	.00		
22	.00		
23	.00		
24	.00		
25	.00		
26	.03	1500-1700	
27	.00		
28	.08	1900-2000	
29	.00		
30	.00		

From 5/2 on, all times midnight to midnight.

Table XXXIII

October, 1978

PRECIPITATION AT MINNAMAX

Date	Net ppt (Inches)	Time of Rain	Remarks
1	.05"	2300-2400	
2	.17"	0001-0100=.02"; 0200-0400=.15"	
3	.00		
4	.00		
5	.32	0400-1700, drizzle	
6	.00		
7	.00		
8	.00		
9	.00		
10	.00		
11	.04	1200-1300	
12	.00		
13	.00		
14	.00		
15	.40	0800-1100	
16	.00		
17	.00		
18	.00		
19	.00		
20	.00		
21	.00		
22	.00		
23	.00		
24	.00		
25	.00		
26	.02	0800-1200	
27	.00		
28	.05	0600-1030	quantity is an estimate
29	.00		
30	.00		
31	.00		

From 5/2 on, all times midnight to midnight.

Appendix VI Samples Used In Box Plot

Date	1	2	3	4	5	6
4-26	grab	grab	grab	grab	grab	grab
6-16	grab at 1025	grab at 1120	grab at 1205	grab at 0800	grab at 1115	grab at 1120
7-5	grab at 0830	grab at 0830	grab at 0845	grab from 7-6	grab at 0800	grab at 0800
7-13	composite from 1200 on 7-12 to 0840 on 7-13	composite 1155 on 7-12 to 0840 on 7-13	composite from 1210 on 7-12 to 0840 on 7-13	grab at 1130 on 7-13	composite 1150 on 7-12 to 0830 on 7-13	composite from 1145 on 7-12 to 0830 on 7-13
7-18	composite from 1530 on 7-14 to 1400 on 7-19	composite 0810 on 7-18 to 1400 on 7-19	composite 1530 on 7-14 to 1400 on 7-19	no sample	composite 0900 on 7-18 to 1400 on 7-19	composite 1530 on 7-14 to 0900 on 7-19
8-2	composite 1700 on 8-1 to 1515 on 8-2	composite 1415 on 7-24 to 0930 on 8-2	composite 1800 on 8-1 to 1515 on 8-2	no sample	composite mean of two samples 1-1700 on 7-1 to 0900 on 8-2 2-0900 on 8-2 to 1450 on 8-2	composite
8-4	grab at 1045	grab at 1030	grab at 1100	grab at 1010	grab at 1000	grab at 0930
8-16	grab at 1015	grab at 1010	grab at 1025	composite	mean of 3 grabs, at 0945, 1330 1700	grab at 1000
8-23	composite 1025 on 8-17 to 1945 on 8-23	composite 1000 on 8-17 to 1940 on 8-23	composite 1050 on 8-17 to 1955 on 8-23	combined composite 1-0830, 8-21 to 0800, 8-23 2-0800, 8-23 to 1440, 8-23	composite 1100 8-17 to 0910, 8-23	composite 1405, 8-17 to 1935, 8-23
9-13	grab at 1020	grab at 1045	grab at 1030	grab at 1100	grab at 1100	grab at 1135

Appendix VII

QUALITY ASSURANCE

Duplicate, Blank Samples, Intralaboratory Splits

Six percent of all the water quality samples were masked duplicates. The data for the duplicate samples are given in Table XXXV. The results are summarized in Table XXXVI.

Distilled deionized water blanks were also analyzed as part of the quality assurance program. Table XXXVII summarizes the results.

Partial results for the intralaboratory study are given in Table XXXVIII.

Except for zinc, the agreement is satisfactory.

HYPALON TESTS

The contamination potential of the Hypalon liner was evaluated in two tests. Runoff samples were collected from the tailings plot area prior to the deposition of tailings. In the second test a piece of Hypalon was soaked in distilled deionized water for 4 weeks. Some low level zinc contamination was observed (Table XXXIX).

PUMP TESTS

Distilled deionized water was passed through the compositing pumps.

The results shown in Table XL indicate some low level zinc contamination.

Duplicate Samples

Table XXXV

Date	7-7	7-7	7-8	7-8	8-28	8-28
Sample type	grab	grab	grab	grab	Composite	Composite
Sample No.	73	74	93	94	181	184
Time	1900	1900	2300	2300	0835 on 8-25	to 0815 on 8-23
	FL-4	FL-4	FL-4	FL-4	FL-4	FL-4
<u>Parameters</u>						
Alkalinity					41.8	41.8
pH	7.50	7.50	7.40	7.40	7.55	7.55
Temperature	11	11				
Specific Conductance	1150	1150	1700	1700	2350	2350
Calcium	129	127	211	212	287	274
Magnesium	12	12	21	21	30	28
Sodium	93	90	152	153	180	194
Potassium	348	111	43	42	57	64
Copper	.02	.01	.02	.02	.03	.03
Nickel	.15	.12	.25	.26	.33	.34
Iron	.02	.01	.03	.01	.01	.03
Manganese	.09	.10	.16	.16	.19	.19
Cobalt	.02	0	.02	.04	.03	.06
Zinc	.05	.05	.07	.07	.09	.10

Duplicate Samples

Date	8-16	8-16			6-14	6-14
Sample type	grab	grab			grab	grab
Sample number	135	138			14	15
Time	0945	0945			0745	0745
Site	FL-5	FL-5			FL-4	FL-4
<u>Parameters</u>						
Alkalinity						
pH	6.10	6.10			7.60	7.60
Temperature	15	15			9.0	9.0
Specific Conductance	1150	1150			2500	2500
Calcium	203	201			222	234
Magnesium	21	20			28	29
Sodium	98	96			256	267
Potassium	9	9			36	38
Copper	.59	.57			.025	.023
Nickel	15.26	15.25			.220	.219
Iron	3.44	3.31			.03	.05
Manganese	2.17	2.18			.21	.21
Cobalt	2.61	2.65			.016	.016
Zinc	.42	.42			.130	.125
<u>Parameters</u>						
Alkalinity						
pH	7.45	7.45	7.75	7.75	7.40	7.40
Temperature	14	14			11	11
Specific Conductance	2650	2650	2500	2500	1125	1125
Calcium	232	214	215	217	126	125
Magnesium	32	28	30	30	13	13
Sodium	310	283	292	291	110	111
Potassium	44	40	41	44	576	638
Copper	.07	.024	.020	.019	.02	.01
Nickel	.336	.314	.314	.325	.14	.14
Iron	.01	.02	.01	0	.04	.01
Manganese	.23	.21	.22	.22	.08	.08
Cobalt	.027	.025	.022	.021	.02	.03
Zinc	.169	.134	.153	.154	.04	.04

FL- Duplicate Samples

Date	8-24	8-24	9-13	9-13	8-4	8-4	8-10	8-10
Sample type	Comp.	Comp.	Grab	Grab	Grab	Grab	Grab	Grab
Sample #	166	168	191	193	121	122	128	130
Time	1025 on 8-17 to 1945 on 8-23		1500	1500	1100	1100	1320	1320
Site	FL-1	FL-1	FL-2	FL-2	FL-3	FL-3	FL-5	FL-5
<u>Parameters</u>								
Alkalinity	50	50	41	41			7	7
pH	8.10	8.10	7.45	7.45	7.65	7.65	5.50	5.50
Temperature			15	15	22	22		22
Specific Conductance	2600	2600	1725	1725	950	950	4000	4000
Calcium	305	300	181	182	156	157	634	638
Magnesium	26	25	21	22	23	25	43	51
Sodium	243	238	139	137	88	88	336	339
Potassium	41	39	30	29	26	26	20	21
Copper	.04	.04	.10	.11	.08	.08	1.28	1.27
Nickel	.38	.35	.27	.25	.33	.32	3.31	3.31
Iron	.05	.06	.03	.02	.01	.04	.15	.08
Manganese	.14	.14	.16	.16	.16	.16	4.32	4.26
Cobalt	.05	.02	.03	.02	.023	.017	1.96	1.96
Zinc	.02	.01	.06	.06	.044	.044	1184	1180
Sulfate								
Chloride								
Nitrate								
Ammonia								
Total Phosphorus								
Dissolved Organic Carbon								
Discharge at time of sample (ml/min)								
Total Volume over composite (liters)								

- All parameters in mg/l except as follows.
 - Temperature = °C
 - Specific Conductance = umho
 - Nitrates and ammonia are mg/l as nitrogen, total phosphorus is mg/l as phosphorus and dissolved organic carbon is mg/l as carbon.
- All metal values are filtered, unless otherwise specified.
- Comp. = Composite

Table XXXVI

QUALITY ASSURANCE SUMMARY

$$\% \text{ error} = \frac{\frac{X_1 - X_2}{(X_1 + X_2) / 2}}{\times 100\%}$$

<u>Parameter</u>	<u>Number of Samples</u>	<u>Median</u>	<u>Maximum</u>	<u>Minimum</u>
Ca	12	.96	8.1	0
Mg	12	4.4	13.3	0
Nq	12	2.1	9.8	0
K	12	5.1	19.2	0
Cu	12	2.9	66.6	0
Ni	12	3.05	22	0
Zn	12	0.17	66.6	0
Co	12	3.0	200	0
Fe	12	66.3	200	0
Mn	12	0	10.5	0

Table XXXVII

BLANKS

Parameter	High mg/l	Low mg/l	Median	Mean	σ
Co	.02	0	0	.001	.005
Cu	1.01	0	0	.067	.252
Ni	0	0	0	0	0
Zn	0	0	0	0	0
Ca	31	0	0	2.07	7.73
Fe	.01	0	0	.001	.002
K	3	0	0	.200	.56
Mg	10	0	0	.667	2.49
Mn	0	0	0	0	0
Na	34	0	0	2.2	8.50

Blanks without #172

Co	.02	0	0	.0014	.004
Cu	0	0	0	0	0
Ni	0	0	0	0	0
Zn	0	0	0	0	0
Ca	.06	0	0	.0043	.015
Fe	0	0	0	0	0
K	0	0	0	0	0
Mg	.01	0	0	.0007	.001
Mn	0	0	0	0	0
Na	0	0	0	0	0

15 Samples

Table XXXVIII

INTRALABORATORY QUALITY ASSURANCE

Date		Co	Cu	ug/l Ni	Zn	Ca	Fe	Mg/l K Mg		Mn	Na
9/11	Eml DNR	20	10	550	910	91	.03	5	72	.04	44
	Eml Serco	1	8.0	450	23	115	.05	4.1	81	.03	44
	Eml Erie										
	% Diff. Sero DNR	+100	20	18	+100	26	40	18	11	25	0
9/13	FL5 DNR	6170	10300	83000	2460	312	23	21	65	13	183
	FL5 Serco	7500	9500	78000	2480	380	20	20	76	12	200
	% Diff.	18	7.7	6.0	.81	18	13	4.8	14	7.7	8.5
7/13	FL4 Serco	12	15	150	64					.12	
	FL4 DNR	15	12		4					.14	
	% Diff.	20	20		100+					14	

Table XXXIX

HYPALON CONTAMINATION TESTS

<u>Parameters</u>			
Calcium	< .02	< .02	.70
Magnesium	< .01	< .01	.71
Sodium	< .01	< .01	.94
Potassium	< .01	< .01	.07
Copper	< .01	< .01	< .01
Nickel	< .02	< .02	< .02
Iron	< .02	< .02	< .02
Manganese	< .02	< .02	< .02
Cobalt	< .01	< .01	< .01
Zinc	< .01	< .01	.02
	Rainwater Runoff From Hypalon-covered Pad		1.4 cm by 1.7 cm Hypalon Section immersed in water for 28 days

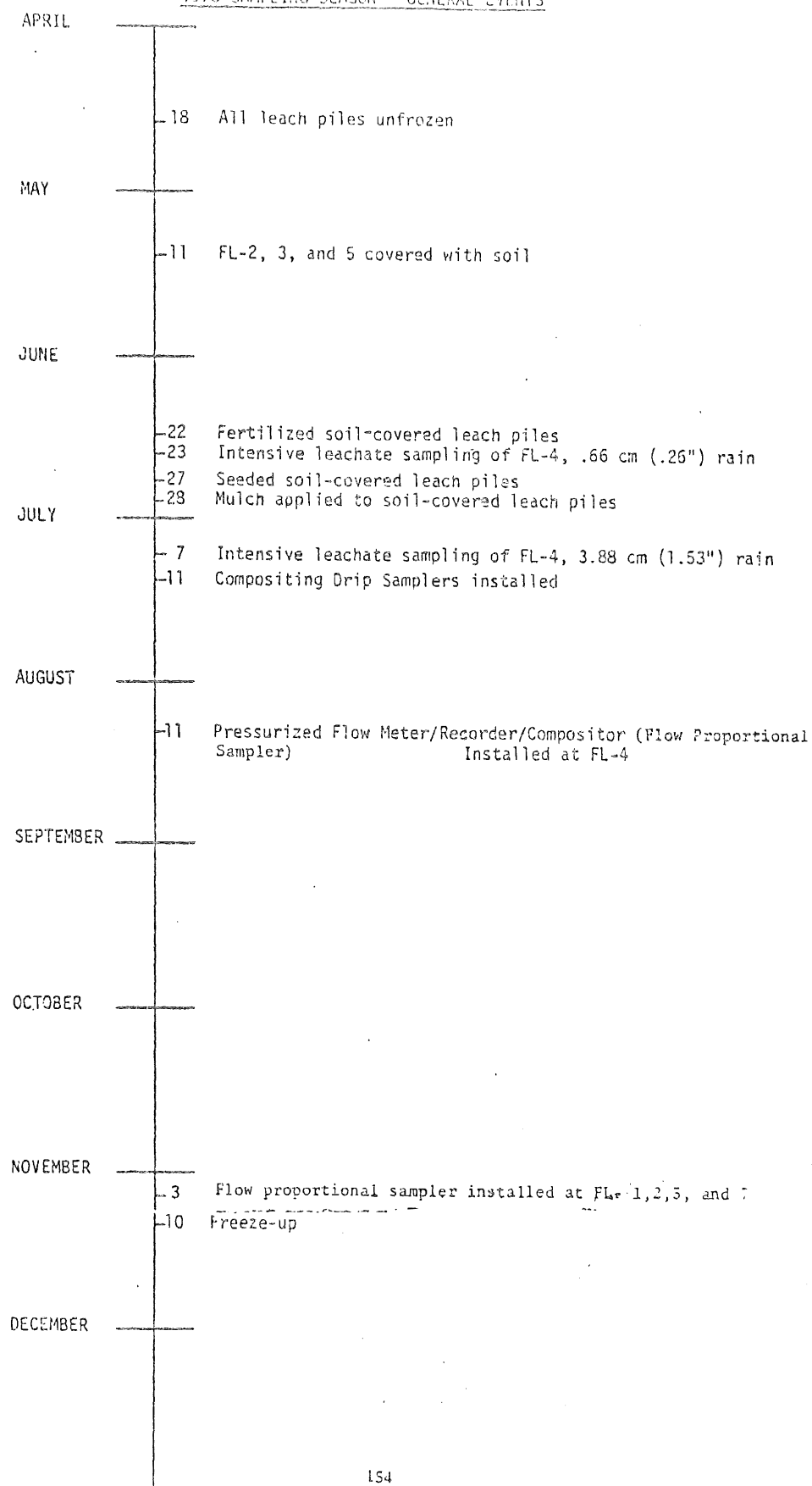
Table XL

PUMP CONTAMINATION TESTSeptember 29, 1978

<u>Parameters</u>	<u>FL1</u>	<u>FL2</u>	<u>FL3</u>	<u>FL5</u>	<u>FL6</u>	<u>Blank*</u>
Calcium	< .02	< .02	< .02	< .02	< .02	< .02
Magnesium	< .01	< .01	< .01	< .01	< .01	< .01
Sodium	< .01	< .01	< .01	< .01	< .01	< .01
Potassium	< .01	< .01	< .01	< .01	< .01	.01
Copper	.02	.02	< .01	< .01	< .01	< .01
Nickel	< .02	< .02	< .02	< .02	< .02	< .01
Iron	< .02	< .02	< .02	.10	< .02	< .02
Manganese	< .02	< .02	< .02	< .02	< .02	< .02
Cobalt	< .010	< .010	< .01	< .01	< .01	< .01
Zinc	.01	.02	.02	.02	.02	.01

*Distilled, deionized water

All values in mg/l

1978 SAMPLING SEASON - GENERAL EVENTS

1977 - 1978

DETAILED EVENTS

4/20/77 FL-1, 2, 3, and 4 Constructed.
9/10/77 FL-5 Constructed.
9/30/77 FL-6 Constructed
4/18/78 All piles unfrozen.
4/26/78 First Sampling, 1978
5/02/78 Recording rain gauge started.
5/11/78 FL-3, 5, and 2 covered with soil.
5/24/78 Flow meters attached to pipelines.
5/25/78 Hand-made flow weighted composite FL-4.
6/13/78 Lowered FL-1 discharge pipe and adjusted flow meters to have more hydraulic head.
6/22/78 Fertilized soil-covered piles with 16,000 g/pile.
6/23/78 Intensive sampling FL-4 .89 cm (.35 inches) rain, also hydro-graph obtained from FL-1.
6/27/78 Soil-covered piles seeded.
6/28/78 Soil-covered piles mulched.
7/07/78 Intensive sampling FL-4 3.88 cm (1.53 inches) rain, also hydro-graphs from FL-1, 2, 3, 4, 5, and 6.
7/11/78 Compositing drip samplers installed.
7/14/78 Filter screens placed above all flow meters.
8/11/78 Pressurized flow meter and flow Proportional Sampler Samplers) attached to FL-4; also Rustrack recorder attached
8/18/78 Pipe between FL-3 and FL-1 lowered.
9/21/78 First hard frosts.
11/03/78 Flow Proportional Sampler installed at FL-1,2,5, and 7
11/10/78 First snow.
11/14/78 Heat tapes put on drains of piles.

Appendix IX

Reanalysis of Anomalous Values

Certain values in the original water quality data appeared anomalous. The anomalous values were reanalyzed, if a sufficient amount of the sample remained. The results of the reanalysis (performed in December) are given in Table XLI.

FL 1

Table XII. Reanalysis

Sample #	Date		Para- meter	original value mg/l		rerun value mg/l		
95	7-11		Ca	419		303		
			Cu	.024		.03		
			Ni	.405		.37		
			Co	.022		.03		
			Zn	.074		.01		
129	8-10		Co	.06		.03		
147	8-16		Co	.06		.02		
166	8-24		Co	.04		.04		
168	8-24		Co	.04		.04		
173	8-25		Co	.05		.03		
180	8-28		Co	.06		.07		
FL 2								
101	7-13		Zn	.008		.09		
108	7-19		Ni	20.5		.24		
			Co	.019		.01		
112	8-2		Co	40		.01		
			Zn	.055		.05		
137	8-16		Cu	.14		.17		
			Co	0		.01		
143	8-16		Cu	.12		.14		
150	8-16		Cu	.13		.14		
169	8-24		Cu	.13		.15		
183	8-20		Co	.05		.04		
			Zn	.09		.09		
			(157)					

FL 3

	Date		Para- meter	original value mg/l	rerun mg/l			
3	4-26		Ni	0	.06			
			Fe	.7	.7			
48	7-5		Cu	1.0	.20			
			Ni	.282	.36			
			Fe	0	<.02			
110	7-19		Cu	.074	.11			
			Ni	.140	.33			
131	8-10		Cu	.05	.07			
			Ni	.56	.57			
139	8-16		Cu	.11	.12			
			Ni	.20	.18			
142	8-16		Cu	.11	.13			
			Ni	.24	.17			
149	8-16		Cu	.10	.13			
			Ni	.23	.22			
167	8-24		Co	0	<.02			

FL 4

44	6-23		Ni	.116	.36			
			Fe	0	.01			
52	7-6		Na	190	173			
60	7-7		Ca	118	242			
			Mg	12	24			
			Na	103	220			
			K	225	43			
			(158)					

FL 4 (cont.)

	Date		Para- meter	original value mg/l	rerun mg/l			
61	7-7		K	135	42			
62	7-7		K	1393	20			
63	7-7		K	348	29			
64	7-7		K	1363	no sample left			
65	7-7		K	356	29			
66	7-7		K	278	33			
1100	7-7		K	268	no sample			
58	7-7		K	295	22			
			Na	243	88			
			Mg	27	10			
			Ca	233	115			
68	7-7		K	148	20			
70	7-7		K	95	22			
71	7-7		K	248	24			
73	7-7		K	230	29			
74	7-7				24			
77	7-7		K	289	28			
			Co	0	2.01			
90	7-8		Ca	168	175			
			Mg	17	16			
			Co	0	.04			
91	7-8		Ca	167	177			
			Mn	.12	.16			
			Co	0	.03			
93	7-8		Ca	212	222			
			(159)					

EL 4 (cont.)

sample #	Date		Parameter	Original	rerun			
133	8-15		Co	.03	.01			
156	8-21		Co	.06	.04			
			Zn	1.0	.10			
			Fe	.46	missed			
FL 5								
49	7-5		Cu	.90	.14			
103	7-13		Ca	533	357			
			Ni	12.50	6.70			
			Co	1.1	.81			
128	7-19		Ca	565	596			
			Co	1.9	2.42			
			Zn	.396	1.24			
			Ni	22.5	missed			
113	8-2		Ni	2.88	9.22			
			Co	1.22	1.07			
114	8-2		Ni	3.02	11.34			
			Co	1.39	1.28			
124	8-4		Cu	.7	.13			
			Ni	3.23	3.23			
			Co	1.77	1.94			
128	8-10		Ni	3.31	3.31			
130	8-10		Co	1.96	2.43			
			Zn	1.18	1.25			
135	8-16		Ni	15.26	15.26			
			(160)					

FL 5 (cont)

[illegible]

**Water Quality Modeling Results for
Copper (Cu), Lead (Pb), and Sulfate
(SO₄) at Plant and Mine Sites,
Northmet (PolyMet) Project**

**Supplemental Draft EIS
2013**

**A Sulfide-Ore Copper/Nickel Mine
Proposed to be Developed in the
Duluth Complex of Minnesota**

**Mitigation will be required for at
least 200 years at the Mine Site and
500 years at the Processing Site**

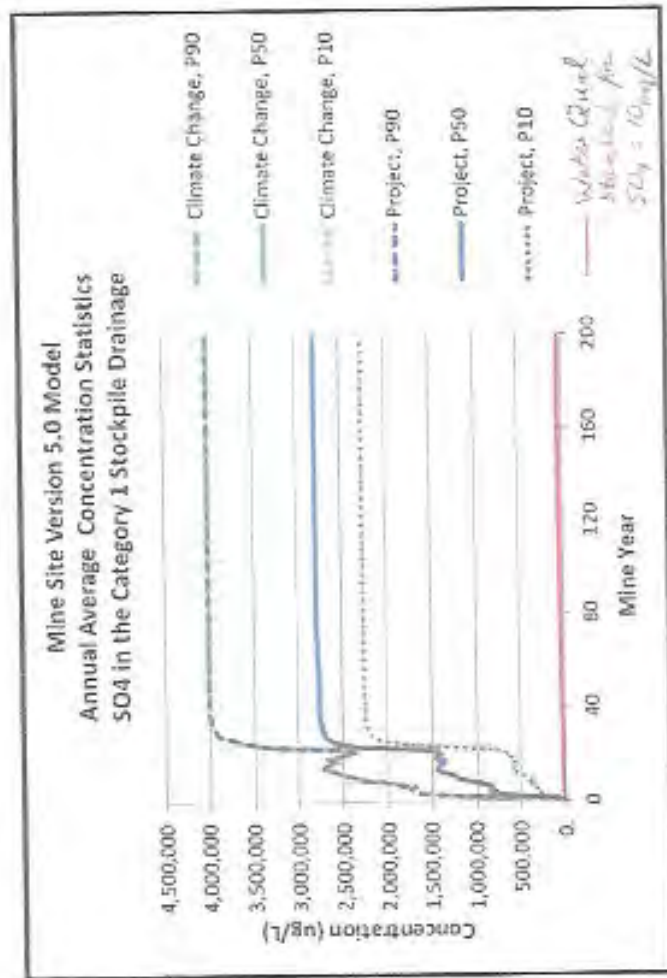


Figure 6-169 Sulfate in the Category 1 Waste Rock Stockpile drainage: with and without modeled Climate Change

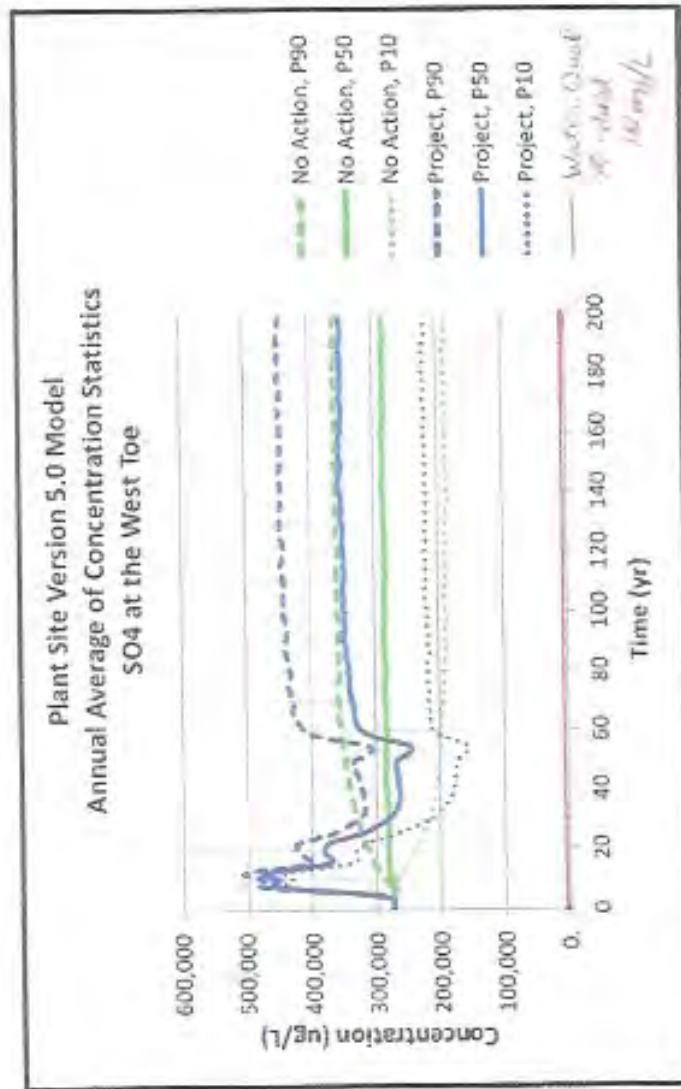


Figure 6-42 Sulfate Concentrations at the West Toe; No Action vs. Project

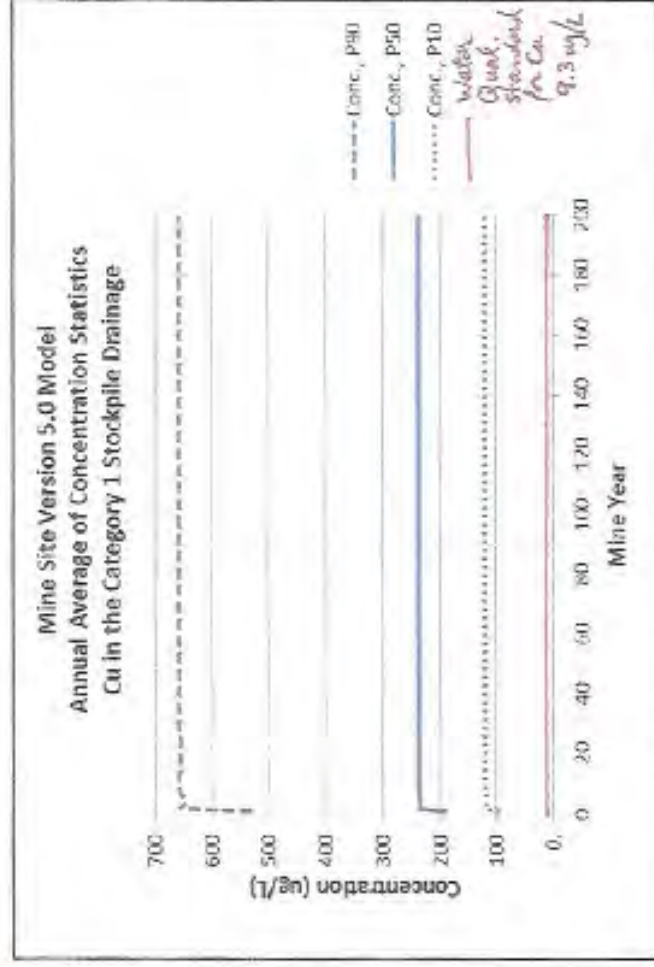


Figure 6-33 Estimated Copper Concentrations in the Category 1 Stockpile Drainage

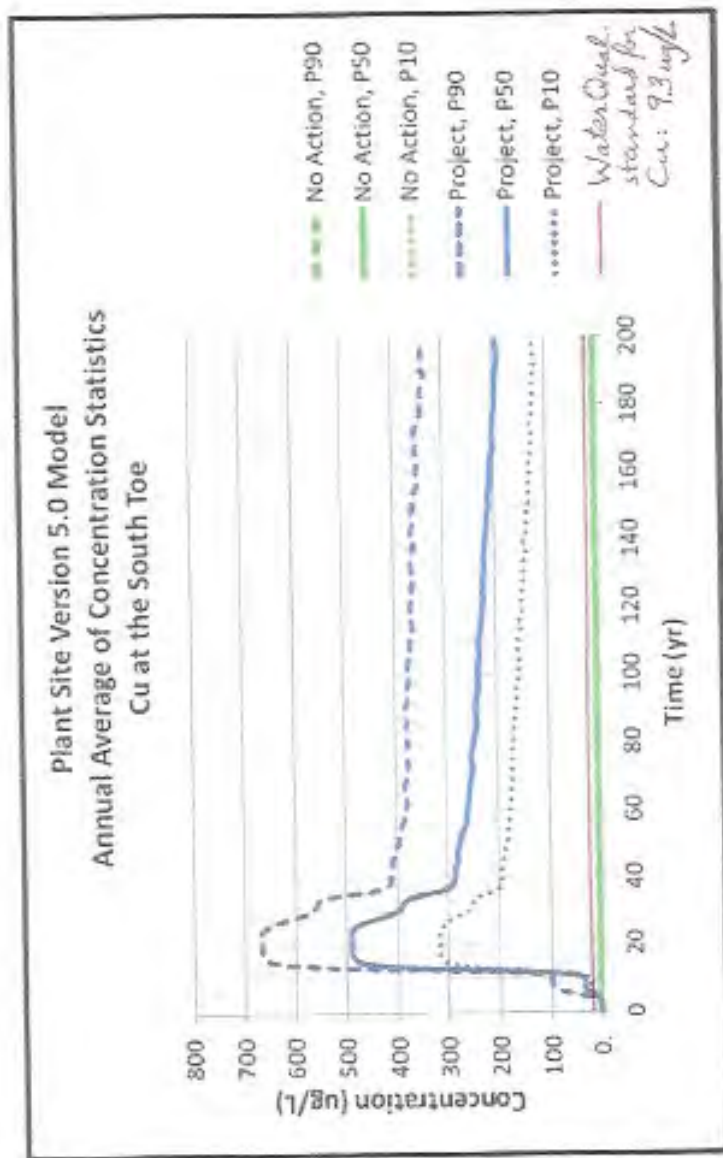


Figure 6-49 Copper Concentrations at the South Toe; No Action vs. Project

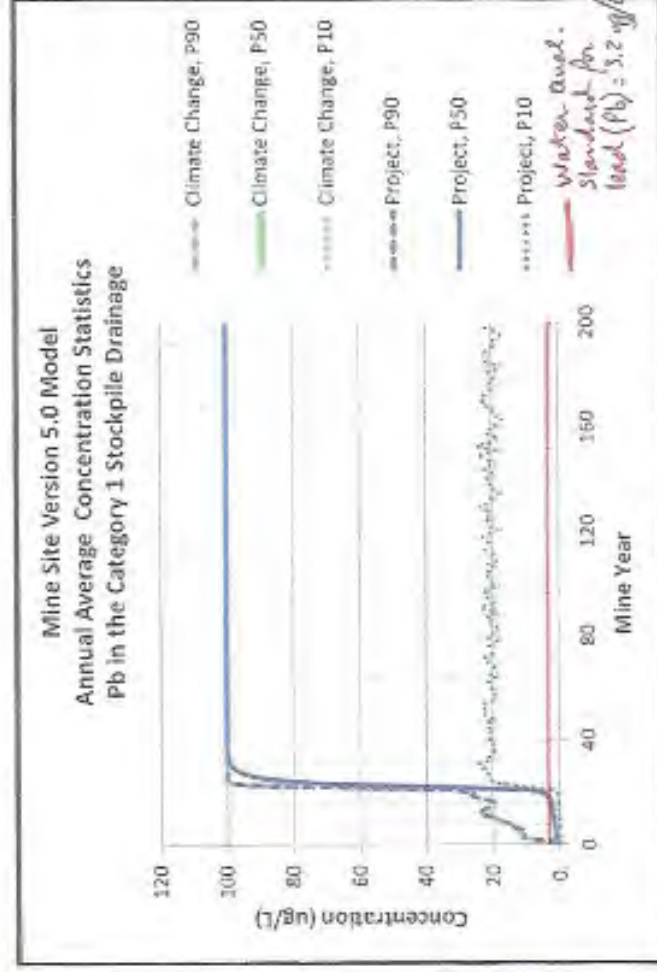


Figure 6-168 Lead in the Category 1 Waste Rock Stockpile drainage with and without modeled Climate Change

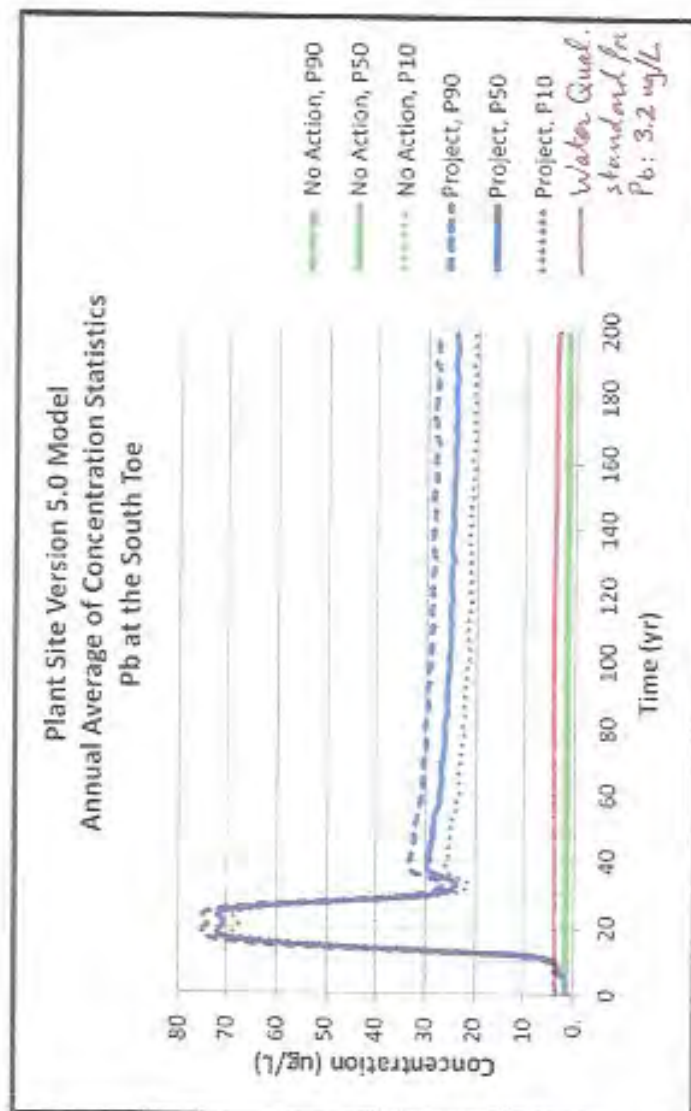


Figure 6-50 Lead Concentrations at the South Toe; No Action vs. Project

the TIMBERJAY



60° Partly Cloudy Complete Forecast

Wednesday, October 14, 2015

Search

BUSINESS DIRECT

CLASSIFIEDS/LEGALS

MINING AND THE ENVIRONMENT

Mining vs. water

Dunka site exposes breakdown in mine regulation



The Dunka Mine is located about three miles southeast of Babbitt.

Marshall Helmberger
Posted 10/7/15

ATTACHMENTS

[MPCA responses 2.pdf](#)[MPCA responses to
Timberjay questions.](#)

SUPERIOR NATIONAL FOREST—As state and federal regulators work to finalize the environmental review on PolyMet Mining's proposed NorthMet copper-nickel mining operation, impacts to water remain near the top of the list of concerns.

Unlike other mining in northeastern Minnesota, the ore that PolyMet proposes to mine is part of what's known as the Duluth Complex, a zone of sulfide-bearing rock that stretches from southeastern St. Louis County in an arc through central Lake and Cook counties. The sulfide rock contains copper, nickel, platinum and other valuable metals, but it is also known to leach acid, metals, sulfates, and other potentially toxic chemicals when exposed to air and water. To critics, this process, known as acid rock drainage, has come to symbolize the dangers associated with the mining of sulfide ores.

While NorthMet would be the first copper-nickel mine in northeastern Minnesota, it wouldn't be the first time that a significant amount of low-grade sulfide-bearing rock was exposed as part of a mining operation in the region.

For 30 years, beginning in 1964, LTV Steel operated the Dunka Mine, located just three

miles southeast of Babbitt. While LTV mined taconite at the site, a layer of the Duluth Complex lay on top of the iron ore along one end of the mine. In exposing the iron ore, LTV removed an estimated 50 million tons of sulfide-bearing rock that it stockpiled at the mine site, where it remains to this day.

When state regulators and PolyMet officials say they can mitigate the risks of acid rock drainage at NorthMet, Dunka provides a good example of the challenges and the economic and political pressures that regulators could face when proposals outlined in the NorthMet Supplemental Draft Environmental Impact Statement, or SDEIS meet realities on the ground.

At first glance, the story of Dunka looks encouraging. When state regulators realized back in the 1970s that the stockpiled ore was leaching highly toxic levels of copper, nickel, and other contaminants into a nearby creek that drained into Birch Lake's Bob Bay, they took action. After conducting experiments at the site to better understand the degree of acid drainage actually taking place at Dunka and how best to contain it, officials with the Department of Natural Resources and the Pollution Control Agency required LTV to cap the top of the sulfide-bearing waste rock piles. They also required the company to install a water treatment plant and a series of engineered wetlands that were designed to capture metals and other contaminants.

And even environmentalists, like Paula Maccabee, an attorney for WaterLegacy who has fought hard for better enforcement of pollution rules at Minnesota mines, acknowledge that the work, completed mostly in the 1990s, reduced to some degree the level of toxic metals being discharged from the Dunka site. Indeed, an analysis conducted by the DNR in 2000 found that the capping of the sulfide rock stockpiles, by itself, reduced runoff by 55 percent and decreased nickel discharges by 82 percent.

However, as Maccabee points out, the water treatment plant built in the 1980s has been closed for decades and existing manmade wetlands, by themselves, still do not bring Dunka's discharge in compliance with Minnesota water quality standards.

Even so, Richard Clark, of the Minnesota Pollution Control Agency's Metallic Mining sector, states that Cliffs Natural Resources, which assumed ownership of Dunka after acquiring LTV assets following the company's 2001 bankruptcy, has been in consistent compliance with the terms of its wastewater permit for Dunka.

A review of monitoring data as well as Cliffs' wastewater permit by the Timberjay shows that both Maccabee and Clark are right. Cliffs has complied with its permit, yet its discharges don't comply with water quality standards. In fact, the mine's discharge regularly fails to meet water quality standards for several contaminants, including nickel, sulfates, and hardness, often by significant amounts.

These two seemingly incongruous facts are at the heart of what former state regulator Bruce Johnson sees as a fundamental breakdown in Minnesota's regulatory process as it pertains to metallic mining. Cliffs can both violate water quality rules at Dunka and simultaneously meet the terms of its wastewater permit for Dunka, issued by the MPCA in 2000, because the permit includes no effluent limits in most cases. For most of the mine's discharge, Cliffs' permit only requires that the company monitor the pollution and file monthly reports with the MPCA.

That might be a surprise to most members of the general public, but it's all too common according to Johnson, a biologist by training who spent decades working for the MPCA and the Minnesota Department of Natural Resources. Johnson was one of the lead DNR researchers on the 1970s-era copper-nickel study and he was involved in the development of the remediation plan for the Dunka Mine, so he's as knowledgeable as anyone in the state about the science and the regulatory history of Dunka. According to Johnson, permits like the one currently regulating Dunka, which only require companies to monitor their pollution output and report it to the MPCA, do little to protect water quality and it's one of the reasons he's grown disenchanted with the state of environmental regulation in Minnesota. Johnson and his wife Maureen, herself a chemist by training who worked for the MPCA for years to clean up Superfund sites in Minnesota, both now serve as volunteer science advisors for Maccabee's WaterLegacy. "We're spending millions of dollars funding the MPCA," said Johnson. "I think the public would be surprised at what's going on."

Maccabee said she was stunned when Johnson first explained to her what was happening to the state's regulatory process, particularly as it relates to mining. She said the current permitting process for the state's mines is focused primarily on protecting mining companies from legal liability for their pollution, not on protecting the environment. "A permit like we see for Dunka protects the company even if their discharges violate water quality standards," she said. "If they put it in the permit that all they have to do is monitor, then they don't have to comply with the water quality rules."

Clark acknowledges that Cliffs complies with its permit simply by monitoring and reporting its pollution discharges, but he says the data that Cliffs is collecting will help the agency as it works towards the issuance of a new permit.

Maccabee says that's slim comfort considering that Cliffs' current permit for Dunka expired a decade ago. And, at this point, agency officials say that they have no timeline for when a new draft permit might be proposed, much less when a final permit might ultimately be approved.

One thing, however, is certain. It's going to take years. And it may never happen at all.

In the meantime, says Maccabee, the old permits provide Cliffs with legal protection, helping to keep the courts and the public from weighing in on behalf of clean water.

It's just such situations, repeated across the Iron Range, that prompted WaterLegacy to petition the Environmental Protection Agency earlier this year to rescind the MPCA's regulatory authority over the mining industry. Maccabee, in WaterLegacy's petition, noted that virtually every mine on the Iron Range is operating on expired permits, in some cases with permits that have been expired for a quarter century. In those cases, companies are allowed to operate under rules that date back in many cases to the 1970s or 80s, before Congress updated the Clean Water Act in the 1990s.

Routine violations of standards

Because the MPCA requires Cliffs to provide monthly reports of their discharges from various points in and around the Dunka Mine, the actual effluent levels are publicly available. And even though capping of the waste rock stockpiles has significantly reduced the flow of metals like copper and nickel, monitoring reports show that discharges of those metals, particularly nickel, still routinely exceed a number of the limits written in state law and enforced under federal law. The mine includes seven known surface discharge points and most violate a number of water quality standards, often by significant amounts.

One of the worst is a discharge point labeled SD-009, located about midway along the mine's southeast flank. According to the discharge monitoring reports that Cliffs routinely files with the MPCA, SD-009 routinely discharges water into the environment that would be in gross violation of state water quality standards for metals like copper and nickel, says Johnson, if the MPCA followed state and federal rules.

The water from SD-009 always exceeds standards for other pollution parameters, says Johnson, including hardness and conductivity, sometimes by as much as four times the allowable limits under either federal or state rules. Sulfate discharges are extremely high as well, averaging approximately 1,800 milligrams per liter (mg/l), but reading as high as 2,450 mg/l at times. That compares to the 10 mg/l sulfate standard currently in state rules for wild rice waters, a list that includes Birch Lake. The MPCA has since proposed a flexible sulfate standard for wild rice waters, but even if this proposal were adopted, it is highly unlikely that such high levels of sulfate would ever be allowed.

The MPCA, back in 2000, issued Cliffs a permit variance that allows the company to continue to discharge excess pollutants from SD-009 and a second point, known as SD-008. The permit and the variance both expired in 2005, but under permitting rules the mine can continue discharging under the old variance until its application for a new permit is acted upon by the MPCA.

The effects of the contaminant discharges at Dunka are apparent beyond the mine itself. Most of the mine's contaminants discharge into Unnamed Creek, a natural stream that flows north to the southern tip of Birch Lake's Bob Bay. Cliffs maintains a monitoring point, known as SW-001, at the mouth of the creek, where it enters Bob Bay, which is located about a mile downstream of the mine. While the dilution of the mine's discharge by other uncontaminated runoff in the Unnamed Creek watershed helps reduce the contaminate concentration, the water entering Bob Bay is still far from meeting water quality standards under state and federal law. The monitoring reports filed by Cliffs show routine violations for nickel, hardness, conductivity and sulfates. Sulfate levels in the water entering Bob Bay have run as high as 1,840 mg/l per liter according to the reports.

The monitoring reports show some of the highest pollution readings during the winter months, and Johnson said two factors account for that trend. For one, stream flow is generally lowest during winter, which means there's less water to dilute the steady discharge of contaminants that do escape the mine site. In addition, engineered wetlands at the site that are supposed to capture contaminants do not function during the winter, according to Johnson, which means the mine's discharges are released essentially untreated. The MPCA acknowledges the higher pollutant concentrations in

winter, and responded by writing allowances for the higher discharges into Cliff's permit variance.

Calcium also

a concern

The monitoring reports also show very high levels of calcium in the mine's discharge, and some of that may be attributable to the engineered wetland, which uses limestone as a way to reduce the toxicity of metals, like copper. While calcium is not typically considered a serious pollutant by itself, the recent spread of invasive mollusks, such as zebra mussels, into lakes across Minnesota, has raised concerns about calcium levels, particularly for lakes north of the Laurentian Divide, where traditionally low calcium levels are believed to provide a natural protection against the survival of zebra mussels. Like most shellfish, zebra mussels require sufficient calcium in order to grow their protective shells. In most Minnesota lakes, natural calcium comes from limestone deposits formed in ancient seabeds. But the last glaciers scraped the Canadian Shield nearly bare of limestone, leaving little calcium behind. Research on the mollusks show that they require calcium levels of at least 20-25 mg/l in order to mature and reproduce. Most lakes in northern St. Louis and Lake counties fall well below that level, which may be one reason zebra mussels haven't proven to be a problem in Canadian Shield lakes in Minnesota, at least so far.

Yet monitoring reports from 2013-2014 show that the water entering Bob Bay at SW-001 contains calcium ranging from a low of 30.6 mg/l to a high of 405 mg/l, with an average reading of approximately 100 mg/l. Whether that discharge has raised the calcium levels in Bob Bay or elsewhere in Birch Lake isn't known, since the MPCA hasn't tested the waters of the bay since the 1980s.

Impacts to aquatic environment

The question remains, however, whether the mine's discharges are negatively affecting the aquatic environment. The MPCA's Clark says there's little sign of it. "The most recent biological monitoring for the Dunka site suggests a healthy aquatic system in Unnamed Creek," he said. As part of their permit, Cliffs is required to undertake biological assessments of the aquatic life in Unnamed Creek, and Clark maintains those assessments indicate the presence of pollution intolerant species, like caddisflies. "These measures suggest an appropriately healthy and diverse population of aquatic insects is present in Unnamed Creek," said Clark.

Johnson strongly disputes that claim, noting that the only way to adequately determine the health of a creek is to compare it with other un-impacted streams in the area. Clark acknowledges that the MPCA doesn't require Cliffs to assess aquatic life in other nearby streams, which, according to Johnson, makes any conclusions derived from Cliffs' sampling suspect.

Johnson notes that state researchers did undertake such comparisons as part of the 1970s-era copper-nickel study, and those comparisons demonstrated at the time that the diversity of aquatic insects in Unnamed Creek (which was already receiving Dunka discharges) was more than 40 percent less than in unpolluted streams in the vicinity.

Among more sensitive families and genera of aquatic insects, the comparison found even greater impacts. The diversity of mayflies, for example, was reduced from the average of 11 different genera in neighboring streams, to just four in Unnamed Creek, a reduction of 64 percent. Such dramatic impacts to aquatic species violates the intent of the Clean Water Act, said Johnson. Federal rules indicate that receiving streams should maintain at least 95 percent of their species diversity.

In the 1970s, DNR researchers speculated that discharges from mine dewatering might have contributed to the disappearance of a number of species of more sensitive invertebrates in Unnamed Creek. But, according to Johnson, more recent data gathered by Cliffs, suggests it's the ongoing contaminant discharge from waste rock runoff that's causing the problem.

While Cliffs' studies suggest there's been no further reduction in species diversity in Unnamed Creek in recent years, Johnson said there should be evidence of actual recovery if the pollution problem was under control. So far, he notes, there's no sign of that.

As for the caddisflies cited by Clark, Johnson notes that the copper-nickel study found them to be less sensitive to pollution than other insect varieties living in the area.

The MPCA does cite other evidence, including bio-assays, that agency officials believe points to lower levels of contaminants coming from the mine. Bio-assays are essentially experiments in which researchers add increasing concentrations of water from a tested lake or stream—in this case, Unnamed Creek—to a sample of uncontaminated water, to determine at what level the conditions might prove toxic to certain aquatic insects or minnows, like fatheads, known to be sensitive to pollution. Cliffs is required to conduct such bioassays on a regular schedule as part of its current permit and, to date, Clark explains, only one of 11 such tests run since 2012 indicated a level of toxicity harmful to certain stream organisms. And even that test passed when run a second time, notes Clark. Meanwhile, none of the tests indicated toxicity to fathead minnows, a fish species known to be sensitive to pollution.

Johnson takes issue with those findings as well. He notes that when one of the bio-assays showed toxicity last summer, the testing company re-ran the test using water with a higher level of hardness, about 200 mg/l. Johnson said that makes a difference, since increased hardness makes metals like copper and nickel less toxic. He said the tests should be using water with the level of hardness found in Birch Lake, which is the receiving water for contaminants in Unnamed Creek. "Hardness in Birch Lake is about 46 milligrams per liter," said Johnson. "According to the rules, the hardness should be based on natural conditions." He calls the bio-assays, as conducted by Cliffs, "strategic advocacy, rather than science."

Perhaps the larger question is whether the discharges, particularly the very high levels of sulfates, are affecting Bob Bay or Birch Lake as a whole. Research conducted for the state's copper-nickel study in the 1970s, showed that fish and clams in Bob Bay exhibited very high levels of copper and nickel, although there was some evidence those levels may have been higher than normal even prior to mining at Dunka.

In addition, other more recent research, including studies on the Iron Range, suggest a strong connection between sulfate levels and the conversion of elemental mercury into the more highly toxic methyl mercury, which is responsible for fish consumption advisories on many lakes in northeastern Minnesota. Sulfate discharges from Dunka into Bob Bay are among the highest on the Iron Range. But despite these well-documented excesses, Clark says he's unaware of any sampling of water or fish tissues in Bob Bay, at least by state officials, since the initial state remediation work back in the 1980s.

Who pays for

pollution?

The state's mining industry has fought for years for relief from some of Minnesota's environmental laws, which are among the strictest in the country—at least on paper. Mining company representatives and their political supporters argue that the cost of cleaning up some of the industry's longstanding pollution problems is too high in an era of intense global competition in the iron ore industry.

Such political pressure has, more than once, stood in the way of enforcement of clean water rules on the state's mining industry. Indeed, earlier this year, the Legislature, led by the Iron Range delegation, blocked the MPCA from issuing a draft permit for U.S. Steel's Minntac tailings basin after company officials told top state officials they wouldn't accept enforcement of the standard as written.

While political pressure is one way that companies can avoid the cost of environmental clean-up, bankruptcy is another. LTV's 2001 bankruptcy left the clean-up of Dunka in a legal limbo until Cliffs Natural Resources purchased LTV's northeastern Minnesota mining property in later that year.

But Cliffs is facing extreme financial challenges of its own given a high debt load and the recent plunge in iron ore prices. The company's stock has fallen dramatically in the past four years, from a high of \$99.86 in July of 2011, to just \$2.75 a share this past week. Industry analysts have been speculating for months about a possible bankruptcy of the heavily indebted company.

Given the company's financial difficulties, there's reason to believe that the MPCA will continue to delay any action on a new permit. The MPCA and Cliffs can avoid compliance with the federal Clean Water Act at present, because the company is operating under expired permits that were originally issued prior to enactment of current clean water laws and rules. But those rules require that any new permit that the MPCA issues, must come into compliance with current standards—and that would almost certainly require a major new investment in pollution control facilities at Dunka. MPCA's Clark notes that the current wastewater treatment plant at Dunka isn't designed to address all of the documented pollution at the site, so a new facility would likely be required. Reducing sulfate levels, in particular, would almost certainly require construction of a reverse

osmosis facility, a water treatment method that is expensive to build and comes with ongoing operational costs. Would Cliffs, which inherited the pollution problems at Dunka, be willing to invest millions of dollars in such a clean-up effort? So far, neither the Legislature nor regulatory agencies in Minnesota have shown a willingness to force the issue against a politically-powerful mining industry.

Maccabee says the state needs to show it can truly regulate the taconite industry before it can credibly undertake a new and environmentally risky form of mining in the region. "Minnesota regulators need to act now and require a clean-up of Dunka mine pollution," Maccabee said. "At least as important, Minnesota needs to learn the lessons of the Dunka mine project before embarking on copper-nickel mining in the Duluth Complex. Bankruptcy, volatile prices and the undue political influence of the mining industry all increase the risk of long-term violations of water quality standards."

Cliffs Natural Resources was provided a draft of this story in advance and offered an opportunity to comment. The company did not respond.

the TIMBERJAY



56° Partly Cloudy Complete Forecast

Wednesday, October 14, 2015

Search

BOOKS

The lesson of Dunka

Minnesotans can't rely on state regulators to protect our waters

Posted 10/7/15

If the Pike River were discharging over 1,000 milligrams per liter of sulfates into the waters of Lake Vermilion on a regular basis, property owners on the lake would rightfully be up in arms.

So what's kept property owners on Birch Lake quiet, as Unnamed Creek discharges water containing as much as 1,800 mg/l of sulfates emanating from sulfide-bearing waste rock at the former Dunka Mine? It's an easy question to answer. They didn't know.



As Minnesotans, we've long prided ourselves on the idea that we take care of our environment. We tell ourselves all the time that we have the toughest environmental rules anywhere. We assume, quite naturally, that we can rely on our state regulators to enforce those strict rules and that we can rest comfortably knowing our waters are protected.

But as our front-page story on the Dunka Mine reveals, perception doesn't always match up with reality. As Minnesotans, we could well be excused for believing that when our Pollution Control Agency issues a permit to a mining company, that the permit actually controls pollution. Imagine our surprise to learn that the permit for the Dunka Mine, now in the hands of Cliffs Natural Resources, contains no effluent limits in most cases. For contaminants like copper, nickel, and sulfates, as well as other pollution parameters, such as hardness and conductivity, the current permit allows Cliffs to essentially discharge any amount of pollution. To comply with its permit, the company is required merely to collect water samples once a month, have those samples tested, and report the results to the MPCA.

MPCA officials acknowledge that those test results show routine violations of water quality standards. And yet nothing changes as the years go by.

MPCA officials say the data will be useful when the agency issues a new permit for Dunka. That permit, under federal rules, will need to eventually bring Dunka into compliance with water quality standards. But Dunka's current permit expired over a decade ago and there's no timeline for when a new one might actually be issued. Which means the agency will continue to quietly document Dunka's violations, while doing nothing to actually clean up the water.

Certainly, the fault here doesn't only lie with the MPCA. Agency officials are subject to the dictates of the Legislature and the Governor. When the agency proposed to issue a new draft permit for Minntac's tailings basin earlier this year, the Legislature, led by legislators from the Iron Range, stepped in and blocked the move because it would have required the company to eventually meet Minnesota's strict sulfate standard of 10 mg/l.

This is what it looks like when a major industry captures the workings of government. In places like Texas and Louisiana, state regulators look the other way while the oil and chemical industries foul the air and water in those states. In West Virginia, state regulators are equally toothless when it comes to regulating coal mining. In North

Dakota, Wyoming, and Montana, it's the same story with coal mining as well as oil and gas development.

Resource extraction means big money for some, and jobs for others, and it all equals immense political clout in the hallways of state capitals. In the face of that, politicians routinely choose political expediency and put environmental protection on the back burner.

We can argue about the choice the politicians make, but we can't reasonably argue about the utter disconnect between the promise of Minnesota's tough environmental laws and the reality of environmental regulation in the state.

Dunka, more than anything, should be a wake-up call. We may have enacted strong environmental laws back in the 1970s, but our political leaders today lack the will to enforce them. For those who care, the time for complacency is over.

[EMAIL](#)

[Tweet](#)

6

[G+](#)

0

[Share](#)

2

Comments

[REPORT THIS](#)

[HOME](#) | [ABOUT US](#) | [PRIVACY POLICY](#) | [SUBSCRIBE](#)

© Copyright 2015, Timberjay.com, all rights reserved. Powered by: Creative Circle Advertising Solutions

TECHNICAL DOCUMENT

ACID MINE DRAINAGE PREDICTION

December 1994

U.S. Environmental Protection Agency
Office of Solid Waste
Special Waste Branch
401 M Street, SW
Washington, DC 20460



DISCLAIMER AND ACKNOWLEDGEMENTS

This document was prepared by the U.S. Environmental Protection Agency (EPA). The mention of company or product names in this document is not to be considered an endorsement by the U.S. Government or by the EPA.

This technical document consists of a brief review of acid forming processes at mine sites, followed by a summary of the current methods used to predict acid formation, selected state regulatory requirements, and case histories. This report was distributed for review to the U.S. Department of the Interior's Bureau of Mines and Bureau of Land Management, the U.S. Department of Agriculture's Forest Service, the Interstate Mining Compact Commission, the American Mining Congress, the Mineral Policy Center, representatives of state agencies, and public interest groups. EPA is grateful to all individuals who took the time to review this technical document.

The use of the terms "extraction," "beneficiation," and "mineral processing" in this document is not intended to classify any waste stream for the purposes of regulatory interpretation or application. Rather, these terms are used in the context of common industry terminology.

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
1.1 Oxidation of Metal Sulfides	4
1.2 Source of Acid and Contributing Factors	5
2. ACID GENERATION PREDICTION	9
2.1 Sampling	11
2.2 Static Tests	13
2.2.1 Acid-Base Accounting (ABA)	16
2.2.2 Modified Acid Base Accounting	16
2.2.3 British Columbia Research Initial Test (BC)	17
2.2.4 Alkaline Production Potential : Sulfur Ratio (APP:S)	17
2.2.5 Net Acid Production Test	17
2.3 Kinetic Tests	18
2.3.1 Humidity Cell Tests	18
2.3.2 Soxhelet Extraction Tests	19
2.3.3 Column Tests	21
2.3.4 British Columbia Research Confirmation Test	21
2.3.5 Batch Reactor (Shake Flask) Tests	22
2.3.6 Field Scale Test	22
2.4 Application of Test Results in Prediction Analysis	23
2.4.1 Some Experience With Static and Kinetic Tests	24
2.5 Mathematical Modeling of Acid Generation Potential	25
2.5.1 Overview of Existing Models	25
2.5.2 Empirical Models	26
2.5.3 Deterministic Models	27
2.6 Conclusions	28
3. CURRENT REGULATORY REQUIREMENTS	28
4. CASE HISTORIES	32
4.1 Newmont Rain Facility, Elko County, NV	33
4.1.1 Introduction	33
4.1.2 Waste Rock	33
4.1.3 Acid Generation Prediction	34
4.1.4 Treatment	34
4.2 Cyprus Thompson Creek, Challis, ID	35
4.2.1 Introduction	35
4.2.2 Waste Rock	36
4.2.3 Acid Generation Prediction	36
4.2.4 Tailings	37
4.2.5 Acid Generation Prediction	37
4.2.6 Treatment	37
4.3 LTV Steel Mining Company, The Dunka Site, Minnesota	38
4.3.1 Introduction	38
4.3.2 The Acid-Generating Duluth Complex	39

4.3.3	Acid Rock Drainage Prediction Methods	39
4.3.4	Environmental Risks	40
4.3.5	Treatment	40
4.4	California Gulch	40
4.5	Clear Creek/Central City	41
4.6	Iron Mountain Mine	42
4.7	Silver Bow Creek/Butte Area Site	42
5.	REFERENCES	44

LIST OF TABLES

	<u>Page</u>
Table 1. Comparison of Acid Rock Drainage Factors In Waste Rock Piles and Tailings Impoundments	3
Table 2. Partial List of Sulfide Minerals	4
Table 3. Sulfide Ore Bacteria and Their Growth Conditions	5
Table 4. Sources of Information on Acid Generation Potential for New and Operating Mines	10
Table 5. Summary of Static Test Methods, Costs, Advantages, and Disadvantages	15
Table 6. Summary of Some Kinetic Test Methods, Costs, Advantages, and Disadvantages	20
Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994)	29

ACID MINE DRAINAGE PREDICTION

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA), the states, and the Federal Land Management Agencies all need better tools to manage acid mine drainage at mine sites. This report examines acid generation prediction methods as they apply to non-coal mining sites. Following a brief review of acid forming processes at mine sites, the report summarizes the current methods used to predict acid formation including sampling, testing, and modeling. Selected State requirements for testing the potential of mining wastes to generate acid are summarized. Case histories from active mining sites and sites on the Superfund National Priorities List (NPL) are also presented. It is hoped that this report will assist states and the mining industry in their use of predictive methods. The Agency has not yet determined whether any one method is more accurate than another. This report also does not incorporate material presented at the Third International Conference on the Abatement of Acidic Drainage, held in Pittsburgh, Pennsylvania, in April 1994. The Agency is preparing additional reports to update this information, including a document containing extended summaries of selected papers presented at the conference.

The formation of mine acid drainage and the contaminants associated with it has been described by some as the largest environmental problem facing the U.S. mining industry (U.S. Forest Service 1993, Ferguson and Erickson 1988, Lapakko 1993b). Commonly referred to as acid rock drainage (ARD) or acid mine drainage (AMD), acid drainage from mine waste rock, tailings, and mine structures such as pits and underground workings is primarily a function of the mineralogy of the rock material and the availability of water and oxygen. Because mineralogy and other factors affecting the potential for AMD formation are highly variable from site to site, predicting the potential for AMD is currently difficult, costly, and of questionable reliability. The U.S. Forest Service sees the absence of acid prediction technology, especially in the context of new mining ventures, as a major problem facing the future of metal mining in the western United States (U.S. Forest Service 1993).

Acid mine drainage from coal and mineral mining operations is a difficult and costly problem. In the eastern U.S., more than 7,000 kilometers of streams are affected by acid drainage from coal mines (Kim et al. 1982). In the western U.S., the Forest Service estimates that between 20,000 and 50,000 mines are currently generating acid on Forest Service lands, and that drainage from these mines is impacting between 8,000 and 16,000 kilometers of streams (U.S. Forest Service 1993). In addition to the acid contribution to surface waters, AMD may cause metals such as arsenic, cadmium, copper, silver, and zinc to leach from mine wastes. According to the Forest Service, the metal load causes environmental damage, and is of greater concern than the acidity in environmental terms.

Acid mine drainage prediction tests are increasingly relied upon to assess the long-term potential of acid generation. This concern has developed because of the lag time at existing mines between waste emplacement and observation of an acid drainage problem (Univ. of California, Berkley 1988). The issue of long-term, or perpetual care of acid drainage at historic mines and some active mines has focussed attention on the need for improving prediction methods and for early assessment of the potential during the exploratory phase of mine development. In addition to many other mines, examples of three mine sites where the potential to generate acid was either not considered or not expected but later developed include: Cyprus Thompson Creek in Idaho; the Newmont Gold Company's Rain Mine in Nevada; and the LTV Dunka Mine in Minnesota. Case studies for these mines are presented in Section 4.0 of this report. Also included are short case studies of four sites on the NPL due, in part to acid drainage (U.S. EPA 1991).

Wastes that have the potential to generate acid as a result of metal mining activity include mined material such as spent ore from heap leach operations, tailings, and waste rock units, including overburden material. While not wastes or waste management units, pit walls in the case of surface mining operations, and the underground workings associated with underground mines and subgrade ore piles, also have the potential to generate ARD.

As mineralogy and size variables change, the ability to accurately predict the acid potential becomes quite difficult (Brodie, et al. 1991). Waste rock piles and subgrade ore piles, when left onsite, are both characterized by wide variation in mineralogy and particle size. Changes in these variables appear to influence drainage water quality (Doepker 1993). Coarse grain material allows air circulation; however, fine grain material exposes more surface area to oxidation (Ferguson and Erickson 1988). Drainage water quality from waste rock piles at several mines in British Columbia have demonstrated wide variability. Research at these sites focussed on variables affecting the frequency of acid effluent observed in permit-related monitoring (British Columbia AMD Task Force, 1990). The results reflect the diurnal and seasonal fluctuations in drainage quality as well as variation in mineralogy and particle size common to waste rock piles. In contrast, drainage from tailing impoundments are more likely to carry a more uniform contaminant load due to their more uniform mineralogy and texture. Table 1

Table 1. Comparison of Acid Rock Drainage Factors In Waste Rock Piles and Tailings Impoundments

Acid Generation Factors Affecting	Waste Rock Piles	Tailings Impoundment
Sulphide Source	• Variable in concentration and location. • Conditions may vary from sulphide rich to basic over short distances.	• Conditions uniform, often with very high sulphide content.
Particle Size	• Average rock size typically greater than 20 cm (but highly variable).	• Tailings may be 100% less than 0.2mm.
pH Variation	• Highly variable conditions over short distances.	• Fairly uniform conditions with a few major horizontal zones.
Initiation Of Rapid Oxidation	• Usually starts immediately after first rock is placed (in "trigger" spots).	• Usually starts after tailings placement ceases at end of mine life.
Oxygen Entry	• Seepage along preferential flow paths. • Seasonal variations in flow path "flushes" out stored products resulting in concentration peaks.	• Seepage slow and uniform. • Reduced flow path variation and stored product "flushing."
ARD Releases	• Large infiltration resulting in large seepage from toe and to groundwater. • Rapid release following generation, sometimes with both neutralized and acid ARD seeps.	• Large early top surface ARD runoff. • Lower infiltration. • Gradual transition in seeps from process water to neutralized ARD to low pH ARD.

(Source: Brodie et al., 1991) to S

compares acid rock drainage factors of waste rock piles and tailings impoundments. In examining this table, it is important to note that diffusion of oxygen into water is slow and, therefore, oxidation of iron sulfide is inhibited until the water level drops, which can occur periodically or seasonally in some cases.

1.1 Oxidation of Metal Sulfides

Acid is generated at mine sites when metal sulfide minerals are oxidized. Metal sulfide minerals are present in the host rock associated with most types of metal mining activity. Prior to mining, oxidation of these minerals and the formation of sulfuric acid is a function of natural weathering processes. The oxidation of undisturbed ore bodies followed by release of acid and mobilization of metals is slow. Discharge from such deposits poses little threat to receiving aquatic ecosystems.

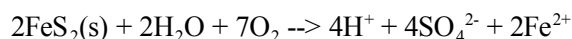
Extraction and beneficiation operations associated with mining activity increase the rate of these same chemical reactions by exposing large volumes of sulfide rock material with increased surface area to air and water.

The oxidation of sulfide minerals consists of several reactions. Each sulfide mineral has a different oxidation rate. For example, marcasite and framboidal pyrite will oxidize quickly while crystalline pyrite will oxidize slowly. For discussion purposes, the oxidation of pyrite (FeS_2) will be examined (Manahan 1991). Other sulfide minerals are identified in Table 2.

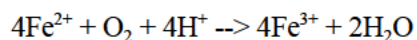
Table 2. Partial List of Sulfide Minerals

Mineral	Composition
Pyrite	FeS_2
Marcasite	FeS_2
Chalcopyrite	CuFeS_2
Chalcocite	Cu_2S
Sphalerite	ZnS
Galena	PbS
Millerite	NiS
Pyrrhotite	Fe_{1-x}S (where $0 < x < 0.2$)
Arsenopyrite	FeAsS
Cinnabar	HgS

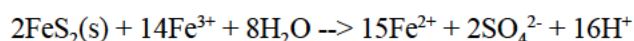
(Source: Ferguson and Erickson 1988)



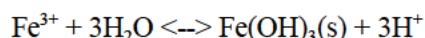
In this step, S_2^{2-} is oxidized to form hydrogen ions and sulfate, the dissociation products of sulfuric acid in solution. Soluble Fe^{2+} is also free to react further. Oxidation of the ferrous ion to ferric ion occurs more slowly at lower pH values:



At pH levels between 3.5 and 4.5, iron oxidation is catalyzed by a variety of *Metallogenium*, a filamentous bacterium. Below a pH of 3.5 the same reaction is catalyzed by the iron bacterium *Thiobacillus ferrooxidans*. Other bacteria capable of catalyzing the reaction are presented in Table 3. If the ferric ion is formed in contact with pyrite the following reaction can occur, dissolving the pyrite:



This reaction generates more acid. The dissolution of pyrite by ferric iron (Fe^{3+}), in conjunction with the oxidation of the ferrous ion constitutes a cycle of dissolution of pyrite. Ferric iron precipitates as hydrated iron oxide as indicated in the following reaction:



$Fe(OH)_3$ precipitates and is identifiable as the deposit of amorphous, yellow, orange, or red deposit on stream bottoms ("yellow boy").

Table 3. Sulfide Ore Bacteria and Their Growth Conditions

Microorganism	pH	Temp., °C	Aerobic	Nutrition
<i>Thiobacillus thioparus</i>	4.5-10	10-37	+	autotrophic
<i>T. ferrooxidans</i>	0.5-6.0	15-25	+	"
<i>T. thiooxidans</i>	0.5-6.0	10-37	+	"
<i>T. neapolitanus</i>	3.0-8.5	8-37	+	"
<i>T. denitrificans</i>	4.0-9.5	10-37	+/-	"
<i>T. novellus</i>	5.0-9.2	25-35	+	"
<i>T. intermedius</i>	1.9-7.0	25-35	+	"
<i>T. perometabolis</i>	2.8-6.8	25-35	+	"
<i>Sulfolobus acidocalderius</i>	2.0-5.0	55-85	+	"
<i>Desulfovibrio desulfuricans</i>	5.0-9.0	10-45	-	heterotrophic

(Source: Thompson 1988)

1.2 Source of Acid and Contributing Factors

The potential for a mine to generate acid and release contaminants is dependent on many factors and is site specific. Ferguson and Erickson identified primary, secondary, and tertiary factors that control acid drainage. These factors provide a convenient structure for organizing the discussion of acid formation in the mining environment. Primary factors involve production of the acid, such as the oxidation reactions. Secondary factors act to control the products of the oxidation reaction, such as reactions with other minerals that consume acid. Secondary factors may either neutralize acid or react with other minerals. Tertiary factors refer to the physical aspects of the waste management unit (e.g., pit walls, waste rock piles, or tailings impoundments) that influence the oxidation reaction, migration of the acid, and consumption. Other downstream factors change the character of the drainage by chemical reaction or dilution (Ferguson and Erickson 1988). These downstream factors are beyond the scope of this paper and are not discussed herein.

Primary factors of acid generation include sulfide minerals, water, oxygen, ferric iron, bacteria to catalyze the oxidation reaction, and generated heat. Some sulfide minerals are more easily oxidized (e.g., framboidal pyrite, marcasite, and pyrrhotite) and hence, may have a greater impact on timing and magnitude during acid prediction analysis compared to other metal sulfides. Also important is the physical occurrence of the sulfide mineral. Well crystallized (euhedral) minerals will have smaller exposed surface areas than those that are disseminated.

Both water and oxygen are necessary to generate acid drainage. Water serves as both a reactant and a medium for bacteria in the oxidation process. Water also transports the oxidation products. A ready supply of atmospheric oxygen is required to drive the oxidation reaction. Oxygen is particularly important to maintain the rapid bacterially catalyzed oxidation at pH values below 3.5. Oxidation of sulfides is significantly reduced when the concentration of oxygen in the pore spaces of mining waste units is less than 1 or 2 percent. Different bacteria are better suited to different pH levels and other edaphic factors (edaphic factors pertain to the chemical and physical characteristics of the soil and water environments). The type of bacteria and their population sizes change as their growth conditions are optimized (Ferguson and Erickson 1988). Table 3 identifies some of the bacteria involved in catalyzing the oxidation reactions and their growth conditions.

The oxidation reaction is exothermic, with the potential to generate a large amount of heat, and therefore thermal gradients within the unit. Heat from the reaction is dissipated by thermal conduction or convection. Research by Lu and Zhang (undated) on waste rock using stability analysis indicates that convective flow can occur because of the high porosity of the material. Convection cells formed in waste rock would draw in atmospheric air and continue to drive the oxidation reaction. Convection gas flow due to oxidation of sulfide minerals depends on the maximum temperature in the waste rock. The maximum temperature depends on ambient atmospheric temperature, strength of the heat source, and the nature of the upper boundary. If the sulfide waste is concentrated in one area, as is the case with encapsulation, the heat source may be very strong.

Secondary factors act to either neutralize the acid produced by oxidation of sulfides or may change the effluent character by adding metals ions mobilized by residual acid. Neutralization of acid by the alkalinity released when acid reacts with carbonate minerals is an important means of moderating acid production. The most common neutralizing minerals are calcite and dolomite. Products from the oxidation reaction (hydrogen ions, metal ions, etc.) may also react with other non-neutralizing constituents. Possible reactions include ion exchange on clay particles, gypsum precipitation, and dissolution of other minerals. Dissolution of other minerals contributes to the contaminant load in the acid drainage. Examples of metals occurring in the dissolved load include aluminum, manganese, copper, lead, zinc, and others (Ferguson and Erickson 1988).

Some of the tertiary factors affecting acid drainage are the physical characteristics of the material, how acid generating and acid neutralizing materials are placed, waste, and the hydrologic regime in the vicinity. The physical nature of the material, such as particle size, permeability, and physical weathering characteristics, is important to the acid generation potential. Particle size is a fundamental concern since it affects the surface area exposed to weathering and oxidation. Surface area is inversely proportional to particle size. Very coarse grain material, as is found in waste dumps, exposes less surface area but may allow air and water to penetrate deeper into the unit, exposing more material to oxidation and ultimately producing more acid. Air circulation in coarse material is aided by wind, changes in barometric pressure, and possibly convective gas flow caused by heat generated by the oxidation reaction. In contrast, fine-grain material may retard air and very fine material may limit water flow; however, finer grains expose more surface area to oxidation. The relationships between particle size, surface area, and oxidation play a prominent role in acid prediction methods. As materials weather with time, particle size is reduced, exposing more surface area and changing physical characteristics of the unit. Though difficult to weigh, each of these factors influences the potential for acid generation and are therefore important considerations for the long-term (Ferguson and Erickson 1988, Lu and Zhang undated).

The hydrology of the area surrounding mine workings and waste units is also important in the analysis of acid generation potential. When acid generating material occurs below the water table, the slow diffusion of oxygen in water retards acid production. This is reflected in the portion of pits or underground workings located below the water table. Where mine walls and underground workings extend above the water table, the flow of water and oxygen in joints may be a source of acid. A similar relationship is evident with tailings, which are typically fine grained and disposed of subaqueously; the slow diffusion of oxygen inhibits formation of acid. However, since tailings are placed in either raised or valley impoundments, they are likely to remain saturated for only a limited period of time during mine operation. Following mine closure, the free water surface in the impoundment may be drawn down substantially, favoring AMD conditions.

The spatial distribution of mining wastes in units, or waste placement, affects acid generation potential. For example, the distribution of acid generating wastes with neutralizing wastes may be controlled by the stacking sequence. Calcareous material may be mixed with or placed above sulfidic wastes to buffer acid production or provide alkalinity to infiltrating solution prior to contact with acid generating wastes. An alternative to layering or mixing is encapsulation. This technique attempts to isolate acid generating wastes from oxygen

and water, thereby reducing its potential to produce acid. It is unclear if encapsulation is feasible over the long-term.

Wetting and drying cycles in any of the mine workings or other waste management units will affect the character of any acid drainage produced. Frequent wetting will tend to generate a more constant volume of acid and other contaminants as water moves through and flushes oxidation products out of the system. The build-up of contaminants in the system is proportional to the length of time between wetting cycles (Ferguson and Erickson 1988, Doepker 1993). As the length of the dry cycle increases, oxidation products will tend to accumulate in the system. A high magnitude wetting event will flush accumulated contaminants out of the system. This relationship is typical of the increase in contaminant load observed following heavy precipitation for those areas having a wet season.

2. ACID GENERATION PREDICTION

The objectives of predictive testing are to: (1) determine if a discrete volume of mining waste will generate acid and (2) predict the quality of the drainage based on the rate of acid formation measured (California Mining Association 1991). There are two important points that must be considered when evaluating the acid generation potential of a rock material. The first is how to collect samples from the field for use in analytical testing. The second is which analytic test method should be used. Both points have a profound impact on the reliability of analytical tests. Results from any analytical test are only as reliable as the samples used for the test. Once the sampling strategy is selected, an appropriate analytical method (or methods) can be selected. Methods used to predict the acid generation potential are classified as either static or kinetic. Factors affecting the selection of the sampling regime and analytical method include an existing knowledge of the geology, costs, and length of time available to conduct the test. This section will examine sample methodology and analytic tests used to predict acid generation potential.

The following list of components describes the solid phase composition and reaction environment of sulfide minerals. Potential contaminants are included to indicate their importance in the scope of acid generation. These components should be kept in mind while evaluating information on acid generation potential.

Components affecting the total capacity to generate acid are characterized by:

- Amount of acid generating (sulfide) minerals present [Note: assumes total reaction of sulfide minerals]
- Amount of acid neutralizing minerals present
- Amount and type of potential contaminants present.

Components affecting the rate of acid generation include:

- Type of sulfide mineral present (including crystal form)
- Type of carbonate mineral present (and other neutralizing minerals, as appropriate)
- Mineral surface area available for reaction
 - Occurrence of the mineral grains in the waste (i.e., included, liberated)
 - Particle size of the waste
- Available water and oxygen
- Bacteria.

Analytical tests used to assess a material's acid generation potential are either static or kinetic in nature. A static test determines both the total acid generating and total acid neutralizing potential of a sample. The

capacity of the sample to generate acidic drainage is calculated as either the difference of the values or as a ratio of the values. These tests are not intended to predict the rate of acid generation, only the potential to produce acid. Static tests can be conducted quickly and are inexpensive compared to kinetic tests. Kinetic tests are intended to mimic the processes found at mining sites, usually at an accelerated rate. These tests require more time and are considerably more expensive than static tests. Data from the tests are used to classify wastes or materials according to their acid generating potential. This information can be collected and evaluated during the economic analysis of mines in their exploratory phases. Based on this information, decisions can be made with respect to specific mitigation practices for existing mines.

In this discussion, it will be useful to keep in mind sources of information needed to assess acid potential. Some of the primary and secondary factors that affect the drainage character from waste management units are presented in Table 4. The variables identified may be appropriate when considering other than waste units, such as mine pits and underground workings.

Table 4. Sources of Information on Acid Generation Potential for New and Operating Mines

Information Type	New Mine	Operating Mine
Mine Rock Classification	• Outcrop exposures • Exploration drill samples, logs • Geological sections • Core assays	• Outcrop and excavation exposures • Drill core • Production sampling • Core assays • Specific sampling from working areas and piles
Mine Rock Distribution	• Mine planning	• Mine planning • Mine rock placement records • Pit and underground plans and exposures • Pile surveys • Pile drilling and sampling • Site personnel
Acid Generation, Leaching Potential	• Static testing • Short term leach extractions • Mineralogy • Site comparisons	• Observation of old cores • Field sampling • Static testing of distinct sub-units from working areas
Drainage Water Quality	• Kinetic testing • Background water quality	• Regular monitoring • Seep surveys • Kinetic testing • Leach extraction

(Source: Modified from Robertson and Broughton, undated)

Efforts by both the mining industry and state regulatory agencies to develop the best protocols for sampling and/or analytical methods to predict acid generation potential have demonstrated that site specific conditions (e.g., climate and geology) dictate a case-by-case approach when evaluating acid potential. This is complicated by the fact that a variety of research efforts on different methods by the Bureau of Mines, EPA,

and the Canadian Mine Environment Neutral Drainage (MEND), as well as those used by mining companies and their consultants, make comparison of data difficult. Several authors have conducted comparative evaluations of predictive tests (Lapakko 1992, Bradham and Caruccio 1990, Coastech 1989). Kim Lapakko of the Minnesota Department of Natural Resources has conducted comparative evaluations of static and kinetic test methods using a range of rock types. Bradham and Caruccio conducted a comparative study on tailings.

When evaluating the acid generation potential, a phased testing plan selects samples appropriate for the detail needed (California Mining Association 1991). This approach allows investment in acid prediction testing to be commensurate with a deposit's economic potential and saves time and expense associated with unnecessary tests. Sampling and testing should be an iterative process, collecting, testing, and evaluating a small amount of information to establish the acid generation potential. Based on the preliminary findings, subsequent sampling and testing can be selected to refine the information as needed.

The typical steps in predicting the acid forming potential, as described in summary documents on the subject, are listed below (California Mining Association 1991, British Columbia AMD Task Force 1989):

1. Define the geologic (or lithologic) units that will be encountered during mining. Describe the geology and mineralogy of these units in detail.
2. Develop a sampling plan based on understanding of geology (rock mass, etc.). Collect samples to represent ranges of compositional variation within a rock unit (see Lapakko 1988, 1990a).
3. Select static or kinetic tests and evaluate potential for acid formation.
4. Evaluate sampling criteria and conduct additional kinetic tests as required.
5. Develop a model as appropriate.
6. Based on findings, classify geologic (lithologic) units as acid, non-acid forming, or uncertain. (Note: the potential to produce acid may vary within a given geologic unit.)

2.1 Sampling

Selection of samples has important implications for subsequent acid prediction testing. The purpose of testing rock material is to allow classification and planning for waste disposal based on the predicted drainage quality from that material. Samples must be selected to characterize both the type and volume of rock materials and also account for the variability of materials that will be exposed during mining. When to collect samples for testing is an equally important consideration. Researchers agree that sampling and testing should be concurrent with resource evaluation and mine planning (Lapakko 1990a, British Columbia AMD Task Force 1989). Sampling techniques used to evaluate recoverable mineral resources (assay samples) are similar to those required for prediction of acid generation potential. Active mining operations for which

predictive tests were not conducted in advance of mining lack the advantage of front end planning; however, these mines can still use these samples and other information collected to establish the acid generating potential.

The pressure is increasing for new operations or those in the exploratory phase to accurately predict future drainage water quality. By comparison, the acid drainage potential at old mines may be well established. Examples of information needed from existing operations are the quantity of existing acid products, the potential and stage of acid generation in each of the waste units, and the acid forming potential of future wastes to be generated (see Table 4). Broughton and Robertson recommend that the first two stages of an acid prediction analysis for either new or existing mines are (1) to review the geology and mineralogy and (2) classify the rock and collect samples (Robertson and Broughton, undated; Broughton and Robertson, 1992).

Sample collection for prediction tests for both old and new mines should consider both geologic and environmental factors. Geologic factors for sample selection are primarily a good understanding of the local geology. If available, this may include information from mines, core logs, or other sources in the immediate area. The exploration geologist or mine geologist is probably the best resource for understanding and describing the mine's geology in detail. This information is important to both the sampling program and application of test results. Environmental factors include consideration of the potential environmental contaminants in the rock and climatic variables. A quality assurance/quality control program should be developed and coordinated with the mine plan for sample collection and acid generation testing.

There are many opinions concerning the number of samples to be collected in a fixed-frequency sampling program. One mining consulting firm recommends about 8 - 12 samples of each significant rock type or 1 sample for each 1 million tons, at a minimum (Schafer 1993). In this case a significant rock type represents one or two percent of the total mine rock volume. Gene Farmer of the U.S. Forest Service suggests that one sample (about 1,500 grams) be collected per 20,000 tons of waste rock, or about 50 samples for each 1 million tons (USDA Forest Service 1992). These samples would be collected by compositing from individual drill hole cuttings prior to blasting. The British Columbia AMD Task Force recommends a minimum number of samples based on the mass of the geologic unit. Their recommended minimum sample number is 25 for a 1 million ton geologic unit, or one sample for every 40,000 tons. Using the British Columbia method, as waste volume increases, the number of samples decreases. For example, for a unit of 10 million tons, the minimum sample number is 80, or one sample for every 125,000 tons (British Columbia AMD Task Force 1989).

There are reservations to prescribing a fixed number of samples for collection per volume of material. This is particularly true for existing mines when collecting samples from waste rock dumps for acid generation potential tests. Waste rock dumps are usually constructed by end-dumping of rock from trucks, creating heterogeneous deposits that are very difficult to sample with confidence. Tailings are comparatively more uniform due to milling and depositional methods used, and it is easier to characterize their variability. Fixed-frequency sampling does not encourage the use of best judgement on the part of the sample collector

(typically a mining company). It also does not provide the statistical basis to account for variability among samples. The determination of how many samples should be taken at any one time appears to be dependent on variability of the site's geology and how the mine will be developed. Due to general uncertainty regarding AMD predictive methods, it may be prudent to sample wastes or material throughout the life of the mine.

Factors to consider in a sampling program for existing or planned mines include the method of sample collection, length of time samples are to be (or have been) stored, and the sample storage environment. Each of these can affect the physical and chemical characteristics of a sample. Samples collected from cores exposed to the environment may be physically and/or chemically altered. If samples are collected from drill core, contamination may be a problem if a lubricant was used. At existing mines, tailings samples should be taken over a variety of depths to determine if oxidation of sulfide minerals is occurring. The influence of lime addition during milling may maintain alkaline conditions. Collecting samples of waste rock is difficult because of the variability inherent in these waste units. Drilling is considered to be the preferred method for collecting samples from waste rock piles (Ferguson and Morin 1991).

Since individual samples will be used to test and classify larger volumes of waste, it is important to consider how representative samples are to be collected. Compositing is a common practice used to sample large volumes of material. Typically, composite samples are collected from drill hole cuttings on benches prior to blasting. However, compositing merges information about the variation of sample that would be identified if more samples were collected and analyzed. Therefore, information about sample variability is lost (British Columbia AMD Task Force 1990, Robertson and Broughton undated). Composite sampling of tailings may be useful as a "first look" for characterizing tailings; compositing with stratification by lithology and alteration can help to avoid the problems of simple composite samples (Schafer 1993).

2.2 Static Tests

Static tests predict drainage quality by comparing the sample's maximum acid production potential (AP) with its maximum neutralization potential (NP). The AP is determined by multiplying the percent of total sulfur or sulfide sulfur (depending on the test) in the sample by a conversion factor ($AP = 31.25 * \%S$). NP is a measure of the carbonate material available to neutralize acid. The value for NP is determined either by adding acid to a sample and back titrating to determine the amount of acid consumed or by direct acid titration of the sample; the endpoint pH is usually 3.5 (Ferguson and Morin 1991, Lapakko 1993a). Lapakko (1992) reported that using an endpoint pH of 3.5 measures a sample's acid neutralizing potential below 6.0, but noted that a drainage pH in the range of 3.5 may not be environmentally acceptable. The net neutralization potential (NNP), or acid/base account (ABA) is determined by subtracting the AP from the NP ($NNP = NP - AP$). A ratio of NP to AP is also used. An NNP of 0 is equivalent to an NP/AP ratio of 1 (Ferguson and Morin 1991). Units for static test results (AP, NP, and NNP) are typically expressed in mass (kg, metric ton, etc.) of calcium carbonate ($CaCO_3$) per 1000 metric tons of rock, parts per thousand.

If the difference between NP and AP is negative then the potential exists for the waste to form acid. If it is positive then there may be lower risk. Prediction of the acid potential when the NNP is between -20 and 20 is

more difficult. If ratios are used, when the ratio of a sample's neutralization potential and acid production potential is greater than 3:1, experience indicates that there is lower risk for acid drainage to develop (Brodie et al. 1991). For ratios between 3:1 and 1:1, referred to as the zone of uncertainty, additional kinetic testing is usually recommended. Those samples with a ratio of 1:1 or less are more likely to generate acid.

Prediction of drainage quality for a sample based on these values requires assumptions that reaction rates are similar and that the acid consuming minerals will dissolve (Lapakko 1992). When reviewing data on static tests, an important consideration is the particle size of the sample material and how it is different from the waste or unit being characterized.

Information on these and other static acid prediction tests, including summaries of test results, is available (Coastech 1989, Lapakko 1993b). The following descriptions are excerpted from Lapakko (1993b).

Lapakko (1992) has also conducted comparison tests of static methods using mine waste samples from different mines. Additional summaries of static tests have been completed by Coastech (1989) as part of the MEND Project, and the California Mining Association (1991). Five static tests will be summarized here and in Table 5.

Table 5. Summary of Static Test Methods, Costs, Advantages, and Disadvantages

Acid Base Accounting (Sobek et al, 1978)	MODIFIED Acid Base Accounting (Coastech, 1989)	BC RESEARCH INITIAL (Duncan and Bruynesteyn, 1979)	Alkaline Production Potential: Sulfur (Caruccio et al, 1981)	Net Acid Production (Coastech 1989)
ACID PRODUCTION DETERMINATION				
Acid Producing Potential = 31.25 * Total S	Acid Producing Potential = 31.25 * Total S	Total Acid Production = 31.25 * Total S	Total S used as indicator	300 mL H ₂ O ₂ added to 5 g rock to directly oxidize sulfides present
NEUTRALIZATION POTENTIAL DETERMINATION				
-60 mesh (0.24 mm) sample add HCl as indicated by fizz test, boil one minute than cool titration endpt pH 7.0 cost: 34-110	-60 mesh (0.24 mm) sample add HCl as indicated by fizz test agitate for 23 hours at room temperature pH 1.4 - 2.0 required after six hours agitation titration endpt pH 8.3 cost: 34-110	-300 mesh (0.038 mm) sample titrate sample to pH 3.4 with 1.0 N H ₂ SO ₃ titration endpt not applicable cost: 65-170	-0.023 mm sample 20 mL 0.1 N HCl to 0.4g solid for 2 hours at room temperature titration endpt pH 4.0 cost: 34-110	particle size not presented acid produced by iron sulfide oxidation dissolves buffering minerals titration endpt pH 7.0 cost: 25-68
ADVANTAGES AND DISADVANTAGES				
simple and short time ^{1,3} no special equipment and easy interpretation ¹ many samples can be tested ³ does not relate to kinetic ² assumes parallel acid/alkaline release ^{2,3} if APP and NP are close, hard to interpret and different particle size not reflected ³	simple, short time, no special equipment, and easy interpretation ¹ does not relate to kinetic ² assumes parallel acid/alkaline release ^{2,3} if AP and NP are close, hard to interpret and different particle size not reflected ³	simple and fairly short time ^{1,3} no special equipment and easy interpretation ¹ many samples can be tested ³ assumes parallel acid/alkaline release, different particle size not reflected, and if APP and NP are close, hard to interpret ³	simple, short time, and no special equipment moderate interpretation ¹	simple, short time, no special equipment, and easy interpretation ¹ limited reproducibility ⁴ uncertain if extent of sulfide oxidation simulates that in field

1 = Coastech 1989, as referenced in Lapakko 1993

2 = Bradham and Caruccio 1990, as referenced in Lapakko 1993

3 = Ferguson 1984, as referenced in Lapakko 1993

4 = Lawrence 1991, as referenced in Lapakko 1993

(Source: Lapakko 1993b)

2.2.1 Acid-Base Accounting (ABA)

The acid-base accounting test, a form of static testing, was developed in 1974 to evaluate coal mine waste and was modified by Sobek et al. in 1978. The acid production potential (APP) is determined from the total sulfur content as follows:

$$31.25 \times \text{percent S} = \text{APP}$$

and assumes that two moles of acid will be produced for each mole of sulfur. Units for APP are tons of acidity per ton of rock. Neutralization Potential (NP) is determined first by a simple fizz test to select the acid strength to use in the next step. Based on this information, hydrochloric acid is added to the sample and the sample is boiled until the reaction stops. The resulting solution is back titrated to pH 7 with sodium hydroxide to determine the amount of acid consumed in the reaction between HCl and the sample.

The net neutralizing potential (NNP) is determined by subtracting the APP from the NP and is a measure of the difference between the neutralizing and acid forming potentials. The value for NNP may be either positive or negative. Tests conducted by Ferguson (reported by Lapakko 1993b) indicate that NNP values less than 20 (kg CaCO₃/ton) are likely to form acid. Those with NNP values greater than 20 were not likely to form acid. For NNP values between -20 and 20 it was difficult to determine the acid potential.

Assumptions of the test are that all the sulfur in the sample is reactive. This assumption does not take into account the presence of gypsum and other non-reactive sulfur minerals. A shortcoming of the technique is the potential to overestimate NP in one or more of the following ways: (1) use of strong acid may dissolve minerals that would not otherwise react to maintain drainage pH within an environmentally acceptable range; (2) use of boiling acid may cause an overestimation of NP by reacting with iron and manganese carbonates, which would not otherwise factor in the natural NP (this observation is problematic with samples that contain large quantities of these carbonates); (3) the NP may be underestimated by contribution from metal hydroxides that precipitate during the titration with sodium hydroxide.

2.2.2 Modified Acid Base Accounting

The Modified Acid Base Accounting method is similar to the previous method with some exceptions. It calculates APP on the sulfide sulfur content (Lawrence 1990). This is different from the total sulfur calculation used in the ABA test in that the sulfur contribution from non-sulfide sources is not included. Determination of NP uses a longer (24-hour) acid digestion at ambient temperature, rather than boiling hydrochloric acid as used in the ABA method. When back titrating with sodium hydroxide to determine the acid consumed in the digestion, an endpoint of 8.3 is used instead of 7.

This modified method assumes that sulfur present as sulfate is not acid producing, and therefore may underestimate available APP if jarosite or other acid producing sulfate minerals are present. Conducting the

acid digestion at standard temperature may reduce the contribution of iron carbonate minerals when determining the NP.

2.2.3 British Columbia Research Initial Test (BC)

The B.C. Research Initial Test, as developed by Duncan and Bruynesteyn (1979), is similar to the ABA test in that it calculates APP based on total sulfur. Consequently, similar concerns should be kept in mind for the APP values. NP (or acid consuming capability) is determined by titrating the sample with 1.0 normal sulfuric acid to pH 3.5. Coastech (1989) notes that this requires more sophisticated equipment (i.e., automatic titrator) than the ABA procedure and is more time consuming. Samples are crushed to minus 400 mesh. Data for APP and NP are compared by difference or ratio, as described above. If a sample is determined to be potentially acid generating, the B.C. Confirmation kinetic test may be conducted. This test is presented in the next section.

2.2.4 Alkaline Production Potential : Sulfur Ratio (APP:S)

The Alkaline Production Potential : Sulfur Ratio test was developed by Caruccio et al. (1981) and modified by Coastech (1989) to measure the acid forming potential of coal waste. Like the ABA and B.C. initial tests, the APP:S test uses total sulfur to determine the total acid potential. Again, similar problems exist for the APP:S test as were experienced with these other tests. A change in nomenclature should be noted here. The acid consuming potential (NP in the previous tests) is referred to as the Alkaline Production Potential. The value is determined by grinding a 500 mg sample to minus 23 micron and adding 20 mL of 0.1N HCl and allowing it to react for 2 hours at ambient temperature. The sample and solution are then titrated to pH 5 to determine the alkaline production potential.

Samples representative of the geologic variation at the site are collected as in other tests and the Alkaline Production Potential is determined. Results from the alkaline production potential test are plotted with the results for total sulfur content of the same samples. Samples of several APP:S ratios are selected for kinetic testing to determine which will be acid producing. With this calibration, the acid producing potential of future samples from the various geologic units can be projected based on the APP:S ratio, rather than depending on kinetic tests, which require more time.

Because this test uses total sulfur, similar to the ABA, to determine acid production, it also tends to overestimate potential acid production for samples containing sulfate minerals. Coastech (1989) noted the shorter exposure to less concentrated acid used in the digestion reaction would tend to underestimate Alkaline Production Potential (NP), and preclude the complete reaction of all buffering carbonates present.

2.2.5 Net Acid Production Test

In the Net Acid Production Test, hydrogen peroxide is used to accelerate the oxidation of sulfide (Lawrence et al. 1988). For the test, five grams of material are oxidized by 100 mL of 15 percent hydrogen peroxide to

oxidize the metal sulfide minerals. The reaction generates acid which in turn reacts with the buffering minerals in the sample. The reaction is allowed to continue for one hour after all visible signs of reaction have ended. The pH of the solution is determined and then titrated to pH 7. This gives a value for the Net acid or neutralizing potential of the sample. This test is different from static tests described above in that it mimics the reaction of APP and NP and determines a single value, NNP. One potential limitation of the test was noted. If the extent of oxidation in the field setting is greater than in the test, the potential exists for the test to underestimate acid production, creating the possibility that some acid producing waste may be incorrectly classified as non-acid-producing.

2.3 Kinetic Tests

Kinetic tests are distinguished from static tests in that they attempt to mimic natural oxidation reactions of the field setting. The tests typically use a larger sample volume and require a much longer time for completion than for static tests. These tests provide information on the rate of sulfide mineral oxidation and therefore acid production, as well as an indication of drainage water quality. Of the different kinetic tests used, there is no one test that is preferred. The preference for tests changes with time as experience and understanding increase. In a 1988 summary article by Ferguson and Erickson, the B.C. Research Confirmation Test was considered to be the most widely used. A similar 1991 article by Ferguson and Morin stated that the use of modified humidity cells was becoming more common. From information reviewed for this report, there does seem to be a trend toward the preference for modified humidity cell and column type tests.

Kinetic tests can be used to assess the impact of different variables on the potential to generate acid. For example, samples may be inoculated with bacteria (a requirement for some tests); temperature of the sample environment may also be controlled during the test. Most tests require the sample particle size to be less than a specified sieve size (e.g., minus 200 mesh). Larger sample volumes and test equipment may examine acid potential from coarse particles. Acid drainage control mechanisms, such as increasing alkalinity by adding lime, may also be examined using kinetic tests.

It is helpful to supplement kinetic tests with an understanding of empirical data characterizing the sample. Examples include analysis of specific surface area, mineralogy, and metals. Such information may affect the interpretation of test data and are important when making spatial and temporal comparisons between samples based on the test data. As with static tests, it is important to consider the particle size of the test sample, particularly when comparing test results with field scale applications.

Seven kinetic tests are summarized primarily from Lapakko's (1993b) review and the BC AMD Task Force, Draft Technical Guideline, Volume I (1989). Other sources are noted in the text. Brief descriptions of the kinetic tests discussed are also presented in Table 6.

2.3.1 Humidity Cell Tests

Both Standard and Modified Humidity Cell Tests are used to determine the rate of acid generation. Tests are conducted in a chamber resembling a box with ports for air input and output. The modified humidity cell uses crushed samples and resembles a column. There is no standard for either humidity cell test.

The Humidity Cell Test, as conducted by Sobek (1978), leaches a 200 g sample crushed to minus 2.38 mm in an enclosed plastic container. The test is typically run for ten weeks and follows a seven day cycle. The sample may be inoculated with bacteria. During the seven day cycle, dry air is passed through the sample container for the first three days and humidified air for the next three days. On the seventh day the sample is rinsed with 200 mL of distilled water. The solution may be analyzed for pH, acidity, alkalinity, and specific conductance; redox potential (the oxidation-reduction potential of an environment), sulfate, and dissolved metals may also be tested. The humidity cell test method is very similar to the column test described below.

Depending on the sample, the test duration may need to be extended. Monitoring sulfate and dissolved metal loads is important to track both the oxidation reaction and metal mobility. Two points are important when using this and other kinetic tests: (1) if the sample was allowed to react before testing began (e.g., in storage) there may be a build up of oxidation products in the sample—this would be flushed out in the early water rinses, and (2) neutral drainage may lead to an incorrect prediction of acid potential if the test period is not long enough.

2.3.2 Soxhlet Extraction Tests

This test simulates geochemical weathering using a soxhlet extraction apparatus to recirculate solution through the sample. The sample is placed in a thimble in the unit and solution is circulated from a reservoir. Two procedures are used—one is the standard test described by Singleton and Lavkulich (1978); the other is the modified test described by Sobek et al. (1978). In the standard test the sample is leached using a 70 °C solution of acetic acid or distilled water over a period of six weeks (duration of the procedure may vary). The modified test uses only distilled water at 25 °C.

Research by Coastech (1989) determined that use of acetic acid yielded unrealistic results. Soxhlet extraction test conditions are more extreme than other kinetic tests. However, it is a shorter test and may be useful in simulating long weathering trends in a relatively short test time. Drawbacks include the complex equipment required and the more complex nature of the test in general.

Table 6. Summary of Some Kinetic Test Methods, Costs, Advantages, and Disadvantages

HUMIDITY CELLS (Sobek et al., 1978)	SOXHELET EXTRACTION (Singleton and Lavkulich, 1978; Sullivan and Sobek, 1982)	COLUMN TESTS (Bruynesteyn and Hackl, 1982; Hood and Oertel, 1984)
SUMMARY OF TEST METHOD		
-2.38 mm particle size 200g of rock exposed to three days dry air, three days humidified air, and rinsed with 200 mL on day seven cost: 425-850	particle size not presented T=70 °C (Singleton and Lavkulich, 1978) T=25 °C (Sullivan and Sobek, 1982) water passed through sample is distilled and recycled through sample cost: 212-425	variable particle size columns containing mine waste are leached with discrete volumes or recirculating solutions cost: dependent upon scale
ADVANTAGES AND DISADVANTAGES		
models AP and NP well and models wet/dry ³ approximates field conditions and rate of acidity per unit of sample moderate to use, results take long time, and some special equipment ⁴ moderate ease of interpretation ^{1,3} large data set generated ²	simple, results in short time, and assessment of interaction between AP and NP ³ moderate to use and need special equipment ⁴ moderate interpretation ^{1,3} in developmental stage and relationship to natural processes not clear	models AP and NP, models effect of different rock types, models wet/dry, and models different grain sizes ³ difficult interpretation, not practical for large number of samples ² large volume of sample ² lots of data generated, long time, and potential problems: uneven leachate application, channelization ^{2,3}

(Source: Lapakko 1993b)

BC RESEARCH CONFIRMATION (Duncan and Walden, 1975)	BATCH REACTOR (Halbert et al., 1983)	FIELD TESTS (Edger and Lapakko, 1985)
METHOD		
-400 mesh particle size 15-30g added to bacterially active solution at pH 2.2 to 2.5, T=35°C if pH increases, sample is non acid producer if pH decreases, 1/2 original sample mass is added in each of two increments cost: 170-340	-200 mesh particle size sample/water slurry is agitated 200g/500 mL ¹ cost: 425-850	field scale particles 800 to 1300 metric ton test piles constructed on liners flow and water quality data collected tests began in 1977 and are ongoing cost: initial construction is expensive, subsequent costs are comparable
ADVANTAGES AND DISADVANTAGES		
simple to use, low cost, assesses potential for biological leaching ³ moderate to use, longer time needed, and some special equipment needed difficult interpretation if pH change is small, does not model initial AP step, and long time for pH to stabilize ²	able to examine many samples simultaneously and relatively simple equipment ⁴ subject to large sampling errors and lack of precision ⁴	uses actual mine waste under environmental conditions can be used to determine drainage volume mitigation methods can be tested expensive initial construction long time

(Source: Lapakko 1993)

1 = Coastech 1989, as referenced in Lapakko 1993

2 = Bradham and Caruccio 1990, as referenced in Lapakko 1993

3 = Ferguson 1985, as referenced in Lapakko 1993

4 = Babij et al. 1980, as referenced in Lapakko 1993

2.3.3 Column Tests

Column Tests are conducted by stacking the waste or material in a cylinder or similar device. Wetting and drying cycles are created by adding water and then allowing the column to dry. Each of the cycles may occur over a period from several days to a week or more, though they typically last for three days each. Care must be taken to avoid piping along the sample-wall interface when packing the column. Water added to the column is collected and analyzed to determine the current oxidation rate, sulfate production, metal release, and other parameters.

Column test equipment, like humidity cells, is a relatively simple apparatus compared to a soxhlet extraction device. It is easily modified to test control options, such as the addition of limestone, the influence of bacteria, and water saturation (Water Resources Control Board 1990). Results from research indicate that column tests of well sorted tailings material greater than 0.5 cm in diameter accurately represents field test conditions (Bradham and Caruccio 1990). Tests of waste rock material were not reported. Some of the disadvantages of column type tests are that the long time required, the associated high costs, and as mentioned above, the potential for channeling.

2.3.4 British Columbia Research Confirmation Test

Originally developed by Duncan and Bruynesteyn (1979), this test is intended to confirm results of the B.C. Initial (static) Tests; specifically, it is intended to determine if bacteria can catalyze enough reactions to satisfy their acid demands. As described in the Draft Technical Guide, Volume I (1989), sulfuric acid is added to a sample volume to a pH of 2.5. Although not identified in the Draft Technical Guide, other researchers use sample volumes in the range of 15 to 30 g of material passing a 400 mesh screen (Lapakko 1993b). The sample is shaken for four hours and acid is added to maintain a solution pH between 2.5 and 2.8. The sample is then inoculated with *Thiobacillus ferrooxidans* and the flask weighed. The flask is plugged with cotton, incubated at 35°C, and shaken continuously. The pH and metals in solution are monitored for the first three days and the pH maintained below 2.8. Distilled water is added to maintain constant weight. When the pH is established below 2.8, monitoring for pH and the metal is performed every second day until microbiological activity stops. This occurs when pH and metal values remain constant. Additional sample material is then added to the flask and this is shaken for 24 hours. When tested, if the pH is 3.5 or higher, the test is terminated. If the pH of the solution is less than 3.5, more of the sample is added and is shaken for 24 hours. The pH is tested; if it is greater than 4 or less than 3.5, the test is terminated. If the pH is less than or equal to 4, or greater than or equal to 3.5, the sample is shaken for 48 more hours and a final pH reading is taken (British Columbia AMD Task Force 1989).

If the bacteria are sustained in the sample, there is a strong possibility that acid drainage will be generated in the waste unit being characterized (British Columbia AMD Task Force 1989). If insufficient acid is produced, the solution pH will approach the natural pH (above 3.5), and the sample is determined to be non-acid producing. If the solution remains below 3.5 then there is a strong possibility that the sample will be an acid producer.

The initial acidification of the sample in this test presents conditions significantly different than in a typical waste unit. The test does not examine mineral/bacterial reactions above a pH of 2.5 (2.8 as described above). Reactions above these levels may be a major influence in determining if acid drainage is generated (Lapakko 1993b). Other disadvantages are that the test ignores neutralization potential and sulfide oxidation rates (British Columbia AMD Task Force 1989).

2.3.5 Batch Reactor (Shake Flask) Tests

In the Batch Reactor test, like the British Columbia Confirmation test, a mine sample and water are slurried together in a flask. The solution is usually distilled water, however, nutrients may be added. Sample size and solution volume are determined by the user. Coastech (1989) conducted tests using 250 g of waste and 500 mL of distilled water. Flasks are shaken continuously during the test. Water samples are taken at regular intervals to determine water quality parameters such as pH, sulfate, and metals in solution. Sampling for water quality analysis during longer tests may require addition of water to maintain volume. This would complicate interpretation of test data. Data from the tests are used to estimate the rate of sulfide mineral oxidation and release of contaminants, such as metals.

The batch reactor is relatively simple and allows examination of multiple factors, such as pH and temperature, which can be tested simultaneously. The influence of bacteria and control measures may be used as test parameters. The primary difficulty with the method is that the duration of the test may not exceed the lag time prior to acid formation (Lapakko 1993b). Other concerns are that the water volume in the flask may inhibit acid formation and bacteria may not acclimate in the test conditions (British Columbia AMD Task Force 1989).

2.3.6 Field Scale Test

Field Scale Testing, similar to On-site Rock Piles described by B.C. AMD Task Force, use large volumes of material to construct test cells in ambient environmental conditions, typically at the mine site in question. These tests are very different from laboratory tests where the experiment is conducted under controlled conditions. Sample size varies and may be as much as 1000 metric tons or more, depending on space availability. Particle size of the test material is not usually reduced for the test to better approximate field conditions. The sample is loaded on to an impervious liner to catch solutions and a vessel is used to collect the leachate. The volume of solution is determined and an aliquot is analyzed for pH, sulfate, dissolved metals, and other parameters.

Consideration of climatic conditions is important when evaluating results from field scale tests. Climatic effects must be distinguished from the rate of sulfide oxidation, acid generation, neutralization, and metal dissolution as determined by analysis of the leach solution. This is necessary because climatic effects, especially precipitation, determine the flushing rate but do not influence either reaction rate or the subsequent chemical composition of the leachate (British Columbia AMD Task Force 1989).

Lapakko (1988) demonstrated that carefully constructed kinetic tests in the laboratory could be extrapolated to field scale tests. That research is summarized in Section 5.3 of the report.

Field scale tests have the advantage of being conducted under the same environmental conditions as the waste or other units they are simulating. They also allow monitoring of the influence of bacteria and control measures. Drawbacks to field tests are that they require long test durations. Unlike other kinetic tests, field tests do not accelerate environmental conditions, which tend to assess the potential to generate acid more quickly. Consequently, field tests will provide information on acid generation potential for a mine waste unit for that amount of time that they are started before waste emplacement begins. For some operations this may be 10 years or more and test results may be used to optimize reclamation design (Lapakko 1993b).

2.4 Application of Test Results in Prediction Analysis

Results from static and kinetic tests are used to classify mine wastes on the basis of their potential to generate acid. Static tests yield information about a sample's ability to neutralize and generate acid. The difference or ratio of these values becomes the basis of the classification. As discussed, for samples with NNP values greater than 20 tons CaCO_3 /1000 tons of waste (ratio of 3:1), the potential to generate acid is low (Smith and Barton-Bridges 1991). For NNP values between -20 and 20 (ratios between 1:1 and 3:1), the potential for acid generation remains, and uncertainty will exist. It is important to note that each of these values are generalities and can be affected by the relative availability of surface areas of iron sulfides and calcium-magnesium carbonates.

The determination of AP based on estimated or reactive sulfur content in the sample has some inherent limitations. When total sulfur is used as the basis to estimate sulfide content, this uncertainty may be attributable to possible errors in: (1) assessment of true acidity and neutralization in the sample; (2) calculated acidity based on total sulfur conversion value; and (3) analytical error. Similar errors exist for static tests that determine reactive sulfide mineral concentrations. Estimating long-term reactive sulfide based on short-term tests may result in uncertainty due to difficulties in making oxidation rate predictions (British Columbia AMD Task Force 1989).

Acid base accounting tests conducted on an iterative basis, where the initial sample set is small, are helpful when establishing boundaries between lithologic units. As data from static tests is collected and evaluated, the sampling selection can be refined. The goal of sampling is to collect representative samples that define the variability of the lithologies present. If significant variability in the acid generation or neutralization potential is identified in the initial sample test results, additional sampling to refine lithologic boundaries is necessary (California Mining Association 1991).

Kinetic tests are often conducted to confirm results of static tests and estimate when and how fast acid generation will occur. The test provides insight on the rate of acid production and the water quality potentially produced and is used to evaluate treatment and control measures. Unlike static tests, there is no standardized method for evaluating test results. Data are examined for changes through time and water

quality characteristics. Kinetic tests tend to accelerate the natural oxidation rate over those observed in the field. This may have the advantage of condensing time, and providing earlier insight into the potential for acid generation.

Generally, kinetic tests are evaluated for changes in pH, sulfate, acidity and a host of potential metals. According to the B.C. AMD Task Force (1989), samples with pH values less than 3 are considered strongly acid; between 3 and 5 the sample is acid generating and there may be some neutralization occurring; at pH values >5, the sample is not significantly acid, or an alkaline source is neutralizing the acid. Sulfate is a by-product of sulfide oxidation and can be used as a measure of the rate of oxidation and acid production. When evaluating test data it is important to examine the cumulative sulfate production curve as an indicator of sulfide oxidation, in addition to other parameters. An analysis of metals in the sample solution serves as an indicator of contaminant load but is not a good indicator of acid generation.

Based on test data, decisions with respect to the mine plan are made. Similar to static tests, kinetic tests are refined to address variability of the geology. Information collected from kinetic tests, such as oxidation rates and water quality, are more commonly being used as inputs to models, which are discussed in the following section.

2.4.1 Some Experience With Static and Kinetic Tests

Ferguson estimated that for about 50 percent of the mines it is easy to determine whether acid generation is a problem, and noted that predicting the potential for the other 50 percent is more difficult (U.S. EPA 1992a). When data collected from static and kinetic tests is inconclusive it may be necessary to extrapolate from existing data using oxidation rates and other factors and project how a sample may react. The soundness of the extrapolation is dependent on the representativeness of the sample, accuracy of the tests data, and the interpretation of the data.

Ferguson and Morin (1991) found that samples with an NP/AP ratio of less than 0.1 tended to produce acid during typical laboratory timeframes. They expected that if laboratory tests were conducted for longer time periods the NP/AP ratio would shift closer to 1 and did not speculate on what the values for NNP and NP/AP would be in the future. Extrapolating a sample's ability to generate acid was divided into short (less than one year), medium (a few years), and long-term (many years) time frames. Short term projections are based on laboratory data. Medium term projections require knowledge of the neutralization process, primarily consumption of carbonate. Long-term extrapolations of acid generation potential will require an understanding of weathering rinds and diffusion of oxygen into and reaction products out of that rind. Long-term projections were identified as being extremely problematic.

Researchers in British Columbia, Canada, have examined results of static and kinetic tests conducted on tailings and waste rock (Ferguson and Morin 1991). The results are based on a study of 20 active or abandon mines in British Columbia. Their findings indicate that for tailings, only those samples having a negative NNP produced acid. The test method was not identified and the limitations are therefore not discussed here.

According to this report, waste rock data from static tests is very limited and demonstrates the variability expected with these waste units. They observed that samples of waste rock that had weathered for one month (prior to sample collection) needed to be flushed initially to remove existing oxidation products.

Lapakko (1990b) used solid phase characterization of the sample in conjunction with acid base accounting data and the rates of acid production and consumption to extrapolate information beyond the timeframe of kinetic tests. The rates of acid production and consumption were based on kinetic test results over a 20 week period. The time required to deplete sulfide and carbonate minerals was determined using rates established from kinetic tests. Based on these observations the time required to deplete the iron sulfide content was 950 weeks and the time to deplete the carbonate content was 40 weeks. This prediction agreed with an observed drop in pH between week 36 and week 56 from 8.7 to 6; after another 20 weeks the pH dropped below 5. This research appears to indicate that kinetic tests should be run for periods of at least 20 weeks in length.

2.5 Mathematical Modeling of Acid Generation Potential

As the preceding discussion indicates, static and kinetic testing provide only a partial picture of the potential of mine wastes to produce ARD. Static testing estimates the ultimate APP and NP of waste material but is generally silent with regard to the rates of generation of acidic and alkaline flows in actual waste matrices. Kinetic testing is more helpful with regard to estimating the rates of oxidation and neutralization. As discussed above, actual waste units can be very non-homogenous and anisotropic with respect to the distributions of mineral types, particle size, hydrologic conditions and so forth. Thus, while a given kinetic test may well approximate the potential for ARD in a portion of a waste unit, the result may not be representative of the "global" potential for ARD. Equally important is the practical limitation on the duration of kinetic tests: because kinetic tests are generally short-lived with respect to the potential period of persistence of AMD, they inadequately mimic the evolutionary nature of the process of acid generation.

To overcome the uncertainties inherent in short-term testing, as well as avoid the prohibitive costs of very long-term testing, some researchers have developed mathematical models to aid in predicting the long-term effects on water quality of acid generating wastes. Predictive modelling offers the hope of providing tools for estimating the potential extent of acid generation prior to its occurrence. Ideally, such information may be compared for scenarios entailing alternative management options to identify the design, operating, and closure methods that best meet economic and environmental objectives. As a practical matter, existing AMD models fall short of the ideal. Nevertheless, these models may provide valuable information for planning purposes, and may have an important role in understanding and predicting AMD.

2.5.1 Overview of Existing Models

A number of distinct approaches to modelling ARD have emerged to date. In general, all the models attempt to describe the time-dependant behavior of one or more variables of a mine waste geochemical system in terms of observed behavior trends (empirical models) or chemical and/or physical processes that are believed to control ARD (deterministic models). Empirical models extrapolate values for the desired output variables

(e.g., acid generation) from laboratory or field data (British Columbia AMD Task Force 1989).

Deterministic models simulate the changes in system values according to the causal mechanisms relating each element of the system to the others.

It is important to remember that all ARD models are simplifications of reality. Simplification is required by incomplete understanding of all factors influencing ARD. Simplification can substantially reduce the cost and time required to model the system under study. However, simplifying assumptions can lead to incorrect conclusions if they result in the omission of important causal mechanisms. For instance, failure to consider the presence of neutralizing materials in a waste pile could result in an overestimation of the rate of acid generation. Similarly, failure to consider hydrogeochemical conditions within a waste pile may preclude consideration of adsorption/precipitation reactions involving metals, thereby miscalculating the potential for metals loading in effluent streams. Because the importance of any given controlling factor may vary from site to site, the significance of a simplifying assumption for any particular modelling effort must be weighed carefully.

2.5.2 Empirical Models

As stated above, empirical models extrapolate values of sulfide oxidation from existing laboratory and field test data. The method of extrapolation typically involves determination of the "best-fit lines" through test data points (British Columbia AMD Task Force 1989). The equations so derived may then be solved to provide, for instance, the acid generation rate of a particular waste unit at some time in the future. Using the projected acid generation rate as an input to a separate hydrogeochemical model that accounts for attenuation of seepage constituents in soils and dilution in receiving waters, the estimated constituent loading rates and consequent receiving water quality at time T may be estimated (Broughton and Robertson 1991).

Empirical models generally do not explicitly consider the causal mechanisms driving oxidation of sulfides and neutralization of seepage. Rather, such models assume that the operation of such controls is accurately represented in the test data. Therefore, the accuracy of empirical models in predicting AMD depends heavily on the quality of the test data used in the models. Principle sources of uncertainty may be expected to include variations in the spatial and particle size distribution of sulfide and alkaline minerals not captured by the data due to insufficient spacial distribution of samples; changes in the distribution of particle sizes throughout the waste unit (due to weathering) not captured by the data; and failure to accurately calibrate the model to reflect the actual quantity and type of materials disposed of (British Columbia AMD Task Force 1989).

It is important to note that empirical models, by their nature, are site-specific. Because the models rely on actual trends observed at a specific site, rather than generic causal mechanisms, the best fit lines for one site can not be assumed to be representative for another site. Further, significant changes in waste unit composition, geometry, or controls over time may invalidate previous representativeness of empirical models. Nevertheless, empirical models may provide cost-effective and reasonably reliable estimations of short-term future AMD conditions for sites with sufficient spatial and temporal data.

2.5.3 Deterministic Models

Deterministic models simulate AMD by solving systems of equations that represent the various controlling factors in the waste reaction process (Broughton and Robertson 1991). The simulation approach allows the users to examine the potential sulfide oxidation rate and resulting seepage quality over periods of tens to hundreds of years in the future. The greatest promise of deterministic models is that they may allow the user to predict AMD as it evolves over time under the changing influence of rate controlling factors. Existing models have built upon earlier work on acid releases from coal mine spoils as well as work on leachate quality in metals heap leach operations (Nicholson 1992). The models may rely solely on the causal relationships described in the equations, or may include empirical data as exogenous drivers (outside the model structure) to solve for certain aspects of the system (Nicholson 1992; Broughton and Robertson 1991). The most important differences between the models lie in the particular causal mechanisms (e.g., oxygen diffusion, changing particle size, temperature variations due to exothermic reactions) addressed within each model structure.

Nicholson presents a review of AMD models. In that review, Shumate (1971)¹ is credited with first recognizing that diffusion of oxygen within mine rock limits the overall rate of oxidation of sulfides (Nicholson 1992). The first working models to incorporate this process (Morth 1972¹, Rica and Chow 1974¹) used the acid generation rate to calculate resulting drainage water quality. Rittchie (1977)¹ added to this concept by explicitly accounting for the removal of oxidized sulfur from the store of available unreacted sulfide. Other models have included convection as a means of oxygen transport within waste piles (Lu and Zhang undated). Convection may be influenced by changes in barometric pressure or by the release of heat from the exothermic oxidation of sulfides. Some researcher's have modelled the feedback mechanisms operating between temperature and biological and chemical oxidation rates, noting that the mechanism is only significant where waste permeabilities are high enough to allow convective oxygen transport to occur (Nicholson 1992).

More recent models have addressed the hydrologic and geochemical conditions in waste unit matrices, as well as reaction product transport, to more realistically represent changes in seepage quality (Nicholson 1992). Bennett (1990)¹ and others found that water flow through the waste pile strongly influences sulfide oxidation rates by acting as a heat sink and removing heat produced by oxidation.

Jaynes et al. (1986)¹ and Schafer (1991)¹ have incorporated chemical equilibrium relationships of varying complexity to model the mobilization and attenuation of oxidation and dissolution products within the waste pile. These relationships drive the residence times of various constituents within "mixing cells" of the waste matrix, and, along with allowing for consumption of acid by alkaline materials, result in changes in effluent chemistry as conditions within the matrix evolve (Nicholson 1992).

¹As cited in Nicholson 1992.

Model developments such as those listed above have significantly contributed to understanding of the processes controlling AMD. For instance, explicit consideration of oxygen diffusion reveals that, in instances where diffusion is restricted, fast processes such as biologically catalyzed oxidation can be unimportant to the overall rate of oxidation. Similarly, consideration of hydrologic flow within the waste matrix shows that the rate of release of oxidation products from waste piles depends strongly on the flow characteristics within the wastes (Nicholson 1992). More recent models have corroborated the proposition that waste dump geometry can be important to oxidation rates by influencing the surface area exposure and air infiltration rates (Nicholson 1992).

2.6 Conclusions

Notwithstanding the understanding that existing models have provided, AMD models to date have not found extensive applications in predicting oxidation rates and effluent quality at operating or proposed sites (Ferguson and Erickson 1988). As stated above, models are simplifications of reality, and consequently are subject to a high degree of uncertainty. Among the sources of uncertainty are incomplete or invalid model structure; natural variability of certain parameters; and lack of parameter calibration and model verification (British Columbia AMD Task Force 1989).

Among the greatest concerns facing the reliability of predictive deterministic models are model calibration and validation. Model parameters must be adjusted to match the conditions prevailing at an actual site. Therefore, reliable waste characteristics, hydrologic and geochemical data must be collected and incorporated into the model structure. Validation requires comparison of model predictions with actual field sampling results. To date, the availability of field data for validation is very limited.

CURRENT REGULATORY REQUIREMENTS

Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994) (Continued)

Regulations/Guidance	Sampling	Analysis
Nevada⁵		
Regulations address process components, Nevada regulations, § 445.242	Wasterock and overburden must be evaluated for its potential to release pollutants and its acid generation potential. (NDEP 1990)	The Meteoric Water Mobility Procedure should be used to determine the potential release of pollutants from samples. Consult NDEP's "Meteoric Water Mobility Procedure", dated September 19, 1990 for specifics regarding the procedure requirements. Acid generation potential must be evaluated using the Static Test, Acid/Base Accounting procedure, to determine neutralization potential (NP). (NDEP 1990)
Guidance documents include the Nevada Division of Environmental Protection's (NDEP's) "Waste Rock and Overburden Evaluation" document, dated September 14, 1990.	Drill core samples should be collected during initial orebody definition, and used to characterize materials. Samples should be sent to an assay lab. During active mining operations, samples can be collected from remaining, saved, assayed materials to be "representatively composited" (not defined) on a quarterly basis for on-going evaluations. Samples are also required of waste materials that were not subject to assaying. (NDEP 1990)	Acidification potential (AP) should be determined based on two alternatives: (1) determining total sulfur content, or (2) determining peroxide oxidizable sulphur. For alternative (1), compare results to NP. If NP exceeds AP value by 20%, material is considered non-acid generating. If less than 20%, determine total sulfide sulfur content according to <u>Standard Methods of Chemical Analyses</u> or equivalent procedure. If NP is less than 20% greater than AP, kinetic testing must be initiated. For alternative (2), if NP value exceeds value by 100%, material is non-acid generating. If less than 100%, initiate kinetic testing. (NDEP 1990)
This evaluation document requires the use of the Meteoric Water Mobility Test (MWMT) to determine a sample's potential to release pollutants. This test does not test for AGP, but is required as a precursor to acid generation tests. Procedural requirements for the MWMT are provided in NDEP's September 19, 1990 guidance document titled, "Meteoric Water Mobility Procedure," dated September 19, 1990.	A representative sampling program must consider lithological and mineralogical variation, the extent of "sulfide" mineralization, color variation, degree of fracturing and of oxidation, and extent of secondary mineralization. (NDEP 1990)	Operating facilities with positive acid generating results from static testing, must notify the NDEP and begin kinetic testing within 10 days. Kinetic testing is required to be conducted according to procedures identified in attachment I. If kinetic testing confirms acid generating potential, containment/neutralization methods must be evaluated on site specific basis and proposed to the NDEP for approval. (NDEP 1990)

(Source: Based on phone conversations with State personnel and collected documents)

(Source: ¹Humphries, 1994)

(Source: ²Lapakko, 1994)

(Source: ³Schuld, 1994)

(Source: ⁴Miller, 1994)

(Source: ⁵Gaskin, 1994)

Regulatory programs for five states were reviewed for their requirements concerning acid generation prediction. A summary of the regulatory requirements for California, Minnesota, Idaho,

Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994)

Regulations/Guidance	Sampling	Analysis
California¹		
Regulations: Waste classification under §2571C of Chapter 15, of the California Mining Code. No other requirements specified.	No specific requirements indicated. Each site is considered on a case-by-case basis.	California is considering adoption of new regulations. These new regulations require testing of rock using a procedure for predicting AMD. Neither specific static or kinetic testing procedures are identified. Test results would be analyzed and interpreted by the mining company or its contractor. The state sets a trigger level at a 3:1 ratio (NP/AP) with a 95 percent confidence interval. If samples do not meet this requirement, kinetic tests are required, or the mine has the option to develop a management plan for waste disposal.
Minnesota²		
Regulations: Under §6132.1000 Mine Waste Characterization:	Sample types include material generated from exploration, pre-production sampling, and process testing. An outline of chemical and mineralogical analyses and laboratory tests must be conducted and presented to the commissioner for use in evaluating mining and reclamation plans. Mine waste characterization data submitted must include laboratory tests describing acid generation and dissolved solids release from mine waste. (Minnesota §6132.100)	Based on results of analyses and tests, additional mine waste characterization may be required. May include laboratory dissolution tests to describe a material's acid-producing and acid consuming mineral content. (Minnesota §6132.100) Results of mine waste characterization data should be submitted throughout the life of the operation to regulatory agencies establishing water quality and compliance monitoring standards. (Minnesota §6132.100)
Idaho³		
Regulations: There are no formal policies or regulations that specifically address AMD. Under Chapter 47-1513 of Idaho's Surface Mining Act and Dredge and Placer Mining Act reclamation and operating plans are required that are protective of Idaho's water resources. (Schuld 1993) Protocols based on BC Acid Mine Task Force Report "Acid Rock Drainage Technical Guide Also, a proposed "Policy Guidance Memorandum" has been submitted to the DEQ but has not been signed by Administrator as of April 1993. (Schuld 1993) Under this policy, Idaho may request Federal land managers (BLM, USFS) to determined AGP for sites on Federal lands.	Sampling should begin during exploration. The state requires that exploration plans stipulate that half the samples collected should be kept in storage. Storage should minimize potential for sample contamination, weathering. Materials selected for sampling should include waste rock, overburden, and ore/subore. Composites of core samples should be obtained as samples. "The number of samples obtained for AMD prediction testing should be based on the size of probable ore reserves and overburden. Consult "Acid Rock Drainage Guide" or other technical guidance document, in addition to best professional judgement, to determine minimum number of samples. (Schuld 1993) The sampling interval is based on lithology and changes in units. Reporting should occur prior to excavation and continue after mining has commenced. Results of static tests must be reported in order to prepare permit.	Idaho does not require the use of a specific static or kinetic test, however, the state must be informed of, and approve, the test methodology selected. Tests are conducted by U.S. EPA approved CLP laboratories only. Idaho uses BMPs in place of monitoring requirements to prevent any contact of AMD with groundwater or surface waters of the State. BMPs must function to avoid AMD generation, or should collect and treat AMD until it no longer exists. Future goals for BMPs will include (1) Leachate Detection/Collection Systems, (2) Closure requirements and monitoring, and (3) Bonding. If the ratio of acid potential (AP) to neutralization potential (NP) is greater than 2:1, the State requires a kinetic test to be performed. If State waters are impacted, an NOV and/or Consent Order may be issued, and other site specific requirements may be imposed.

Table 7. Summary of State Regulations for Acid Generation Prediction Testing (August 1994) (Continued)

Regulations/Guidance	Sampling	Analysis
Montana⁴		
Regulations: Under Title 82, "Metal Mine Reclamation", § 82-4-336 (7), reclamation plans are required to provide for "...reclamation of disturbed land to comparable utility and stability,...". The State interprets this to mean both chemical and physical stability. Review and approval of reclamation plans gives the State the authority to reject plans that do not adequately assess AMD potential. Guidance: DRAFT, "Geochemical Characterization Checklist", Montana Department of State Lands. This provides specific recommendations that are only summarized in this table.	Sample collection is preferred during the advanced exploration of project. This allows data to be compiled and long term leachate extraction tests to be performed before submittal for a mining permit. Information requested includes descriptions of climate, topography, hydrology, vegetation, geology, mineralogy especially iron sulfide and total element content for mineralized and unmineralized lithologies. The number of samples to collect is dependent on the variability of the lithology/alteration assemblage. The British Columbia Draft Task Force Guide (SRK, 1989) and the Saskatchewan Mine Rock Guidelines (SRK, 1992) are used as references for a rough guide to methods and sample sizes needed to characterize mine waste. Samples should not be composited if possible. Samples should be split 4 ways. For each sample please record: sample location, sample description including mineralogy/petrology especially sulphur fractionation and carbonates, grain size and crystal form of iron sulfides, particle size distribution, paste pH, and slaking characteristics after Brodie et al, 1991. Two suites of samples should be collected. 1) Collect representative samples from each lithology for a reference suite. This suite should incorporate samples from unmineralized areas to establish regional background. The "representativeness" of each sample should be determined by the geologist who is most familiar with the site. This sample set will be biased. 2) Collect random samples over the entire deposit to limit bias. This sample set will be much larger than the representative suite. At least 8 samples should be analyzed for each lithology or alteration assemblage. A statistical analysis of the data should be compiled.	For splits from each sample provide analyses for: total element or trace element and any static test. After data is reviewed and compared to average crustal abundances and/or regional background values, a carefully picked subset of samples should be analyzed using any humidity cell test method and/or any field leachate extraction method to help establish limits for suitable and unsuitable material. The definition of "suitable" and "unsuitable" may vary with each site depending on the regional geology. Any laboratory and/or method may be used but must be approved by the agency prior to use. Rationale must be given as to why certain methods were used. After all information has been compiled and reported for each suite, decisions are made as to what materials are suitable for reclamation purposes and which materials are unsuitable and need to be isolated. The above mentioned testing sequence will not predict whether a material will produce contaminants. It will define which lithologies/alteration assemblages are suspect with respect to contaminant production and should be segregated from the suitable waste materials. Independent interpretations of the data set can be forwarded but the agencies' interpretation will comprise the effective recommendation. Testing should be ongoing throughout mine life to better substantiate preliminary conclusions made during the permitting process. More detail and references are given in "Permitting Guidelines for Mine Rock Characterization" available from the Department of State Lands, Hard Rock Bureau, 1625 11th Ave, Helena, MT 59620. (406) 444-2074. References: Brodie, 1991; Steffen et al, 1989; Steffen et al, 1992)

. In addition, the U.S. Forest Service is developing a protocol. In the meantime, the acid generating potential associated with mines on Forest Service land is considered on a case-by-case basis as part of their review of proposed plans of operation.

3. CASE HISTORIES

Presented below are selected case studies for mines where acid drainage from mine wastes or mine works has occurred. Both active sites and sites on the National Priorities List are described. The active sites were selected to represent sites where the potential to generate acid was either not considered, or not expected, but later developed. Case histories for the Newmont Rain facility in Nevada, Cyprus Thompson Creek in Idaho, and the LTV Steel Mining Company Dunka site in Minnesota are presented below in Sections 4.1, 4.2, and 4.3, respectively. EPA visited each of these sites to further its understanding of the mining industry. Each site has experienced acid generation problems; however, it is important to note that each is also taking corrective action to mitigate the problem. The companies are working with appropriate State and Federal agencies to determine long-term treatment needs.

The EPA (1991) has prepared National Priorities List (NPL) Site Summary Reports for the mining sites on the NPL. NPL sites were selected from these reports if acid generation was identified as a problem. Using this criteria, seven of 56 mining-related sites were selected for review. The purpose of the review was to determine if acid generation predictive tests were conducted at individual sites, and if such tests were conducted, how the data were used. The review included examination of available literature on each site and interviews with each site's Remedial Project Manager (RPM). Based on incomplete information for the seven sites studied, tests for either acid prediction or pH prediction have not been conducted at Silver Bow Creek, Eagle Mountain Mine, Tar Creek, and Whitewood Creek. Eagle Mountain Mine and Silver Bow Creek have not conducted prediction tests because acid generation is such a clear and extreme problem (Taylor 1993, Forba 1993, and Overbay 1993).

Sites that have assessed the acid generation potential include Clear Creek/Central City, California Gulch, and Iron Mountain. At Clear Creek acid/base potentials were calculated for waste materials and potential acid generation testing is being required by the City of Clear Creek for any new development that disturbs the ground. Both the RPM and State contact for Iron Mountain indicate that acid generation predictive tests have been done while mucking out tunnels. Acid generation prediction has also occurred at California Gulch. Further details on the sampling and analytical methods used to predict acid generation have not been obtained. Sections 4.4 through 4.7 provide details on acid generation prediction experiences at these three NPL sites (Fliniau 1993, Hyman 1993, and Sugarek 1993).

3.1 Newmont Rain Facility, Elko County, NV

3.1.1 Introduction

EPA visited Newmont Gold Company's Rain facility in September of 1991 (U.S. EPA 1992b). The facility is located on approximately 627 acres, 9 miles southeast of Carlin in Elko County, Nevada. The facility is a mining-milling-leaching operation for beneficiating disseminated gold ore. Ore and waste rock are mined from an open pit. Of the ore removed from the mine, over forty percent is milled and beneficiated by the carbon-in-leach method at a current rate of about 840,000 tons per year (TPY). The remaining ore (about 1,000,000 tons per year) is leached using a modified heap method referred to as a valley leach. An average of 35,000 tons of material was being removed from the mine each day as of late 1991. Of this, 5,500 tons was ore grade, 29,500 tons was waste rock. This rate varies between 7,000 and 40,000 tons per day, respectively.

Most of the ore-grade material is taken from the oxidized sediments of the Webb Formation, proximal to the Rain fault. Gold concentrations in this material range from 0.01 to 0.15 ounces of gold per ton of rock. According to Newmont, sulfide-bearing rock does not contain gold in sufficient quantity to be economically recoverable, and is therefore disposed of as waste rock.

3.1.2 Waste Rock

Projected waste rock tonnage was estimated to be 41.4 million tons by the end of 1990, and 62.5 million tons during the life of the mine. In late 1991, the waste rock dump covered 211 acres north and east of the pit. Waste rock production from the pit averaged 29,500 tons per day. Of this, 7,500 tons were sulfidic and 22,000 tons oxide. Newmont had estimated that by mine closure in 1995, there will be 62.5 million tons of waste rock; of this, 77.8 percent was expected to be mostly oxidized mixed sedimentary material of the Webb Formation (some of which will contain sulfide mineralization), 15.4 percent carbonaceous and potentially sulfidic, 4.3 percent limestone of the Devil's Gate Formation, and 2.5 percent alluvium from surface deposits.

Prior to the spring of 1990, sulfide, oxide, and calcareous waste rock were disposed of together. On May 8, 1990, acid drainage was observed flowing from the base of the waste rock dump and into the unnamed drainage above Emigrant Spring, toward Dixie Creek. Inspection of the drainage downstream of the dump revealed that approximately two miles of the channel contained a red-brown precipitate. Discharge to the drainage was estimated by Newmont to be 3 gpm. According to Newmont, snow removed from the roads was disposed of on the waste dump. As the snow melted, it infiltrated the waste rock pile, oxidizing sulfur-bearing minerals and generating acid. The solution migrated along pre-mining topography and discharged at the toe of the dump.

Surface-water samples were taken along 5 points in the drainage above and below Emigrant Spring in May, June, and July of 1990. They showed pH values ranging from 2.37 to 3.21 near the base of the waste rock at the discharge point, and from 6.5 to 8.64 about 4,000 feet downstream. Arsenic levels near the effluent point

were 46 ppm in May and 1.5 ppm in July; at the distant sampling point, arsenic levels were 0.023 ppm in May and 0.005 ppm in July. Mercury levels near the discharge point were 0.19 ppm in May and 0.0019 ppm in July; at the distant sampling point, mercury levels were <0.0001 ppm in May and 0.0003 ppm in July.

3.1.3 Acid Generation Prediction

Following detection of the acid generation in 1991, Newmont's Rain facility Water Pollution Control Permit was revised. As part of the revised Permit, Newmont is required to report quarterly on results of Meteoric Water Mobility testing and Waste Rock Analysis. The meteoric water mobility test is an extraction procedure that determines moisture content of the waste, percent of a sample passing -200 mesh, pH of deionized water, and final pH of extract (following 24-hour extraction time). Following the meteoric water mobility test, total carbon, organic-carbon, and sulfur assays are obtained on the composite waste sample by combustion-infrared analysis to measure sulfur and sulfide contents, and to estimate carbonate content. Acid neutralization potential is then measured using titration. The extracted solution is analyzed for nitrate, phosphorous, chloride, fluoride, total dissolved solids, alkalinity, sulfate, and metals. Waste rock analysis is intended to determine the net acid generation potential of the material placed in the waste rock dump during the quarter.

Data for the third and fourth quarters of 1990 and the first quarter of 1991 were examined by EPA following the site visit (U.S. EPA 1992b). Third quarter results for the waste rock analysis indicated a net acid generation potential of -10.6 tons of CaCO_3 for each 1,000 tons of waste. This suggests that the wastes generated during this quarter had sufficient buffering capacity to neutralize any acid solution generated by sulfidic material. Fourth quarter results showed a large shift, with an acid generating potential of 5.35 tons of CaCO_3 for each 1,000 tons of waste. The total acid generating potential of waste rock disposed during this quarter was equivalent to the amount of acid neutralized by 5.35 tons of CaCO_3 for each 1,000 tons of waste rock. For the first quarter of 1991, waste rock analysis data showed a net acid generating potential of 8.57 tons. In these circumstances, Newmont is required to perform kinetic testing according to State of Nevada protocol. Results of this analysis were not available; however, in the third Quarterly Monitoring Report for 1991, Newmont indicated that column studies were underway to fulfill this requirement.

3.1.4 Treatment

In response to the drainage, Newmont took the following actions. By May 9 (one day after the drainage was noted), a small pond was constructed to collect the flow from the dump. On May 11, an HDPE liner was installed in the pond, and on May 18, Newmont constructed a cutoff trench across the channel downstream of the collection pond to collect subsurface solution. The trench was twenty feet deep and forty feet across and included a HDPE liner. Inflow to this trench was pumped to the collection pond and then trucked to the tailings impoundment for disposal.

The State and BLM approved Newmont's long-term mitigation plan with construction beginning in November of 1990, and completed in March of 1991. The solution collection and return system consists of

surface and subsurface water collection and recovery system. Surface water is collected in a ditch and drains to a sump located at the toe of the waste rock pile. Drainage collected in the sump drains by gravity to a 200,000-gallon capacity, double-lined pond. Subsurface flow is recovered in an HDPE-lined trench and also drains to the double-lined pond. Flows average 23.8 gpm with a maximum of 183 gpm. In the event of a power failure, the pond has a capacity to retain in excess of 65 hours of inflow at the maximum projected flow rate. In addition, storm water from the surface of the waste rock dump and surrounding area is collected in a single-lined, 600,000-gallon pond located just below the double-lined pond. Solution from both ponds is pumped to the mill area and added to the tailings pipeline.

As a long-term mitigation/prevention measure, Newmont began encapsulating sulfidic waste rock within oxidized and/or calcareous waste rock that has either no net acid generating potential or some acid neutralizing potential. As of late 1991, this was being accomplished by placing a pervious layer of coarse oxidized waste rock on the native soil. On this, five feet of compacted oxidized ore was placed. Additional oxide ore was placed against the natural hillslope to act as a barrier. These layers were to act as barriers to water movement into and out of the sulfidic waste rock. Following these steps, sulfidic waste rock was placed on and in front of the oxide ore. Several lifts were expected to be added to the sulfidic waste pile. In addition, haul trucks follow random routes during construction to compact the material, thereby reducing its permeability. Eventually, the front edge and top will be covered with 15 feet of oxidized material to complete the encapsulation. Prior to encapsulation, sulfide waste rock will be mixed with oxidized material or the limited quantity of calcarious material available to buffer any acidic solution generated. The sulfidic materials are fine to coarse grain sedimentary rocks extracted primarily from the Webb Formation.

Neither the draft nor the final Environmental Assessment prepared for the Rain Facility discussed the potential for sulfidic material to generate acid drainage.

3.2 Cyprus Thompson Creek, Challis, ID

3.2.1 Introduction

EPA conducted a site visit of the Cyprus Minerals Corporation Thompson Creek (Cyprus) facility in September 1991 (U.S. EPA 1992c). Cyprus mines molybdenite (molybdenum disulfide, MoS_2) from an open pit mine near Challis in central Idaho. Cyprus staked its first mineral claims at Thompson Creek in 1967. In 1981, mining operations began and the first concentrates were produced in 1983. In late 1991, the Cyprus Thompson Creek Mine site consisted of (1) an open pit mine and two waste rock dumps; (2) a primary in-pit crusher; (3) a mill with grinding and flotation, and (4) a tailings impoundment.

Cyprus has been conducting a study to investigate the potential for the waste dumps and the tailings impoundment to generate AMD. The results of the AMD study of the waste rock and tailings were to be provided to USFS by March 1, 1992. Proposed revisions to the facility's reclamation plan were also to be submitted to the U.S. Forest Service (U.S.FS). According to USFS personnel, the revisions to the Plan of Operations were to be subjected to the environmental review requirements of National Environmental Policy

Act (NEPA). This review may include preparation of a supplemental Environmental Impact Statement (U.S. EPA 1992c). The AMD study has been requested.

3.2.2 Waste Rock

When mining began in 1981, approximately 130 million tons of overburden were initially removed as "pre-production stripping." Most of the overburden was placed in two waste rock dumps (the Buckskin and Pat Hughes dumps) located adjacent to the pit. In 1990, approximately 16.2 million cubic yards of waste rock were generated, consisting mainly of metasediment, quartz monzonite, Challis volcanics, and clayey rock (i.e., decomposed volcanics).

3.2.3 Acid Generation Prediction

Both intrusive and metasedimentary rocks have high sulfur content (up to 1.13 and 1.66 percent, respectively). Therefore, in 1990, Cyprus began a study of the potential for AMD generation from the waste rock and tailings, using both static and kinetic test methods. As of late 1991, static testing had been performed on twenty intrusive rock, and 58 metasedimentary rock samples collected from both the lower and upper benches of the pit. For each sample, Cyprus calculated the neutralization potential (NP) and the acid generation potential (AP) to determine the net neutralization potential (NNP) and the NP/AP ratio. The NNP represents the neutralization potential (the tons of calcium carbonate required to neutralize 1,000 tons of waste rock) minus acid generation potential (calculated based on the total sulfur content). According to Cyprus personnel, waste rock with an NP/AP ratio in excess of 3:1 was considered non-acid generating. According to USFS personnel, a NP/AP ratio of at least 5:1 should be required before a material is determined to be non-acid forming (U.S. EPA 1992c).

Static testing of eight intrusive rock samples from the lower benches of the pit, close to the ore zone, yielded an average net neutralization potential (NNP), and neutralization ratio (NP/AP) of 0.53 and 1.88:1, respectively. These results exhibited more AMD potential than the average NNP (4.93) and average NP/AP (3.80:1) values obtained from 12 intrusive rock samples from the upper bench. They indicate a greater potential for AMD with intrusive waste rock in the vicinity of the ore zone. The AMD potential decreased with distance from the ore zone. The difference between intrusive rock samples collected from the upper and lower benches was believed to be caused by a relatively predictable pattern of mineralization and alteration zoning around the ore body.

According to Cyprus, the metasedimentary rocks did not appear to be sources of AMD. Cyprus has performed static testing on the metasedimentary rock in the lower benches and found average NNP and NP/AP values of 24.95 and 3.11:1, respectively. It should be noted that, while the metasedimentary rocks are considered non-acid forming by Cyprus (NP/AP greater than 3:1), the average NP/AP ratio is less than the minimum (5:1) ratio suggested by the USFS. Metasedimentary rock samples obtained from the upper benches showed average NNP and NP/AP values of 19.02 and 8.52:1, respectively. Though the average

NNP value did not increase in samples from the upper bench, the NP/AP ratio increased significantly, supporting the theory that AMD potential decreases with distance from the ore zone.

Kinetic testing of intrusive and metasedimentary rock was ongoing in 1991 for those static test samples showing acid generating potential. Results of these tests were to be incorporated into the AMD study as they became available.

3.2.4 Tailings

During the ongoing acid drainage study, indications of acid generation were found in the tailings. As of late 1991, the tailings impoundment covered a total of approximately 150 acres with the embankment covering about 60-70 acres and the tailings pond behind the embankment approximately 90 acres. According to Cyprus personnel, tailings oxidation to a depth of several feet had been evident for over two years (U.S. EPA 1992c).

3.2.5 Acid Generation Prediction

In October 1990, ten hollow stem auger borings were completed in the tailings embankment. Samples collected from these borings were subjected to humidity cell testing, and showed that the average sulfur content of the tailings sands was 0.79 percent and the pH ranged from 3.5 to 7.3 s.u. (Analyses of tailings sands have shown pH levels as low as 3.0 s.u.) In addition, of eight samples tested, six produced elevated iron and sulfate concentrations, and associated increased acidity, within a 15-week test period. The kinetic tests affirm the reactive nature of the tailings found in static test results.

According to Cyprus personnel, the tailings pond and the seepage return pond were not a problem (pH > 5.7 s.u.). However, in 1991, Cyprus conducted a water quality trend analysis for six surface water quality monitoring locations in the tailings impoundment area. These locations included the main drain of the rock toe, springs located on the left and right abutments of the rock toe, the discharge from the rock toe, the sump below the seepage return pond dam, and Bruno Creek (immediately downstream of the sump). This analysis found that during the period 1981-1990, (1) pH decreased at four locations (but not at the left and right abutment springs), (2) sulfate had increased at all locations, (3) iron had increased at four locations (not at the left and right abutment springs), and (4) no trends in zinc, copper, or arsenic were recognized. The increase in sulfate concentrations was attributed to tailings oxidation and acid generation.

3.2.6 Treatment

Cyprus applied trisodium phosphate (TSP) to tailings embankment sand to address the AMD problem. Previous column testing had found that TSP addition increased the pH, and reduced iron concentrations in leachate samples. According to Cyprus's consultant, two TSP tests, humidity cell tests and large scale tests, were being conducted in 1991 to determine TSP's effectiveness in controlling AMD from the embankment, and maintaining impoundment water quality. However, because the tailings impoundment unit has no

discharge and water from the impoundment, seepage return pond, and pump back system is returned to the mill, the TSP application were expected to cause elevated phosphorus levels in the reclaim water. Cyprus personnel indicated these levels may adversely affect flotation operations and that this issue was being studied.

Cyprus' original plan for reclamation of the tailings impoundment indicates that Cyprus initially anticipated that water quality standards could be met by diluting impoundment seepage with natural runoff. No water treatment beyond sediment control was expected to be required. However, the original reclamation plan did not consider the AMD issue. According to Cyprus personnel, the AMD problem could extend well beyond the life of the mine and perpetual care/treatment may be necessary. Therefore, Cyprus was evaluating remedial alternatives (other than perpetual care) and was preparing to submit a revised tailings pond reclamation plan (as a modification to their operating plan).

Alternatives to be considered included installing an additional flotation unit to remove pyrite and/or in-place treatment of tailings with trisodium phosphate as a buffer. Preliminary flotation tests have been conducted to investigate the possibility of removing sulfides from the tailings prior to disposal in the impoundment. Test results indicated that a high percentage of pyrite may be recovered. Limited static testing performed on a whole tailings sample from which pyrite was recovered indicated a NP/AP ratio in excess of 4:1 compared to an average value of 0.84:1 for all tailings analyses.

According to Cyprus personnel, oxidation had only been found to occur in the top two to three feet of tailings (despite the results of analyses of the 1990 borehole samples that showed oxidation at all depths down to 150 feet). Therefore, an additional alternative under consideration was to encapsulate the tailings. Information on specific types of cover materials was not provided. Additionally, Cyprus was investigating the potential use of wetlands treatment.

3.3 LTV Steel Mining Company, The Dunka Site, Minnesota

3.3.1 Introduction

EPA visited the LTV's Dunka site in August 1991 (U.S. EPA 1992d). The site is located approximately 20 miles northeast of LTV Steel Mining Company's (LTV SMC Co.) Hoyt Lakes facility. The site is on private, State, Bureau of Land Management, and U.S. Forest Service lands; LTV SMC Co. holds surface and mineral leases for the area. The Dunka pit is part of the eastern-most extension of the Biwabik iron formation and is one of the smaller pits on the Mesabi Range at three miles in length. Although additional material may be removed from the pit for beneficiation, in 1991, plans called for no further exploration activity at the site or enlargement of the pit.

3.3.2 The Acid-Generating Duluth Complex

The taconite ore at the Dunka site contacts Duluth Complex material (DCM), which must be removed to reach portions of the taconite ore deposit. The Duluth Complex is a sulfur-containing, mafic intrusive rock unit, considered to be one of the largest known sources of copper and nickel resources. As of late 1991, LTV SMC Co. had removed and placed in "gabbro" stockpiles approximately 50 million tons of Duluth Complex material containing an average of more than 0.2 mass percent copper oxides and/or 0.05 mass percent nickel oxides as gabbro stockpiles.

The remaining Duluth Complex material stockpiles were categorized as waste rock stockpiles and are made up of material containing less than 0.2 percent copper oxide and less than 0.05 percent nickel. Since these waste rock stockpiles were constructed in 1976, monitoring of drainage from the piles has revealed a decrease in pH levels, as well as an increase in trace metal concentrations. Copper and nickel concentrations as high as 1.7 and 40 mg/L, respectively, were observed in seepage/runoff from Duluth Complex waste rock stockpiles at the site. In addition, during sampling conducted by the Minnesota Department of Natural Resources between 1976 and 1980, pH values as low as 5.0 at Seep 1 were reported.

3.3.3 Acid Rock Drainage Prediction Methods

To address this drainage, the Minnesota Department of Natural Resources in conjunction with LTV SMC Co., constructed full scale test piles of the Duluth Complex material to monitor its acid generation potential. The MDNR continues to monitor the test piles and study acid generation. Lapakko (1988) conducted kinetic tests of Duluth Complex material using a humidity cell. Nine samples were selected from core material and one sample from a test stockpile. This experimental method was selected based on ongoing field test results, which demonstrated a strong correlation between sulfur content, trace metal mobility, and acid production. Laboratory scale tests provided better control and simplified analysis. Sulfur content was identified as the independent variable. Samples that had variable sulfur content were selected. Part of the study was to determine the feasibility of extrapolating laboratory results to operational conditions.

Each cell was loaded with 75 gram rock samples passing 100 mesh but less than 270 mesh. Samples were rinsed with 200 ml of distilled-deionized water, which was allowed to remain in contact with the sample for five minutes. Rinse water was collected and filtered through a 45 micron filter. At the beginning of the experiment, the samples were rinsed five times to remove oxidation products generated during sample preparation. Two rinses were used each week during the remainder of the experiment. Between the weekly rinsings, the samples were stored in a box fitted with temperature and humidity controls.

The laboratory study found that drainage pH decreased as the sulfur content of the sample increased. Drainage pH also decreased as the experiment time increased. Both of these findings are consistent with field observations on pH variation correlated with sulfur content and time. Based on the data, Lapakko (1988) concluded that the small particles (<2.0 mm) have a large influence on field stockpile drainage quality. The weighted average sulfur content for particles in this fraction is 1 percent compared to 0.6 percent in the bulk

rock. Most of the sulfur occurs as pyrrhotite. The higher sulfur content combined with the higher surface area of these particles make this fraction susceptible to more intense oxidation reactions.

3.3.4 Environmental Risks

Toxicity testing of the leachate showed that copper and nickel concentrations exceeded the 48-hour lethal concentration (LC50) for *Daphnia pulicaria*; nickel concentrations also exceeded the 96-hour LC50 for fathead minnow. Concentrations of calcium, magnesium, and sulfate in the stockpile drainage were also elevated. According to LTV SMC., there was some question whether the metals were the toxic agent.

Most of the seepage from waste rock piles at the Dunka site has historically been discharged to Unnamed Creek. Unnamed Creek flows into Bob Bay, a part of Birch Lake. In a 1976-1977 study of trace metals in Bob Bay, it was found that concentrations of copper, nickel, cobalt, and zinc in the waters of the Bay were higher than the regional average concentrations and decreased with distance from the mouth of Unnamed Creek. Elevated metal concentrations were also observed in the sediments, as well as in aquatic plant and clam tissue. In the study, it was estimated that the total discharge from the Dunka watershed into Bob Bay through Unnamed Creek was 500 million gallons per year. Unnamed Creek contributes more than 90 percent of the trace metals load to Bob's Bay. Annual loading is over one ton of nickel. Less than 40 percent of this nickel load was found to be removed from the system through natural lake processes. According to LTV SMC., carbon dating of sediment samples from Bob Bay indicates significant metal concentrations which predate mining.

3.3.5 Treatment

As of late 1991, the State and LTV SMC. were working to develop technologies to mitigate leachate generation and release of trace metals associated with stockpile drainage. The technologies being tested and employed included pile capping/channeling to limit infiltration, active treatment in a neutralization pond to lower pH and remove metals, and use of artificial wetlands to remove metals. The ultimate goal was a passive treatment system that would require little or no maintenance (U.S. EPA 1992d).

3.4 California Gulch

The California Gulch NPL site is located in the upper Arkansas River Valley in Lake County, Colorado. It is bounded by the Arkansas River to the west and the Mosquito Mountains to the east, and is approximately 100 miles southwest of Denver. The study area for the remedial action encompasses approximately 15 square miles, and includes California Gulch and the City of Leadville. California Gulch is a tributary of the Arkansas River. Mining for lead, zinc, and gold has occurred in the area since the late 1800's. This site was added to the NPL in 1983 (U.S. EPA, 1991).

A Remedial Investigation conducted by EPA in 1984 indicated that the area is contaminated with metals (including cadmium, copper, lead, and zinc migrating from numerous abandoned and active mining

operations). A primary source of the metals contamination in the Arkansas River is acid-mine drainage from the Yak Tunnel into California Gulch. The Yak Tunnel was built to drain the mine workings in the area of California Gulch. The acid dissolves and mobilizes cadmium, copper, iron, lead, manganese, zinc, and other metals. The tunnel and its laterals and drifts collect this metal-laden acidic water, and drain it to the tunnel portal. The tunnel drains into California Gulch and then to the Arkansas River. The Yak Tunnel's discharge contributes to the contamination of California Gulch, the Arkansas River, and the associated shallow alluvial ground-water and sediment systems. From previous investigations and sampling data, it was concluded that, as of the early 1980's, the Yak Tunnel discharged a combined total of 210 tons per year of cadmium, lead, copper, manganese, iron, and zinc into California Gulch, which is biologically sterile (U.S. EPA 1991). Results of acid generation predictive tests of tailings and waste rock samples were not available for this report.

3.5 Clear Creek/Central City

The Clear Creek/Central City NPL site is located approximately 30 miles west of Denver, Colorado, and includes the Clear Creek mainstem and the North and West Forks of Clear Creek. Active operations, which began in 1859, include gold, silver, copper, lead, molybdenum, and zinc mining. Initial investigations at the site focused on the discharges of Acid Mine Drainage (AMD) and milling and mining wastes from five mines/tunnels in the Clear Creek and North Clear Creek Drainages. The five mines/tunnels of interest are: (1) the Argo Tunnel; (2) the Big Five; (3) the National Tunnel; (4) the Gregory Incline; and (5) the Quartz Hill Tunnel. The first two are portals along Clear Creek and the last three are in the North Clear Creek Drainage. They are close to the Cities of Idaho Springs, Black Hawk, and Central City. Associated with the AMD is contamination of surface drainages by metals in solution such as cadmium, chromium (VI), lead, manganese, nickel, and silver (U.S. EPA 1991).

Acid/base potentials, similar to acid/base accounting, of waste materials were tested as part of the Remedial Investigation. The acid/base potentials (NNP) were calculated as the neutralization potential (NP) minus the potential acidity (AP). Results indicated that waste materials at the Gregory Incline, the Quartz Hill Tunnel, and the Argo Tunnel have the capacity to generate large quantities of acid leachate. The mill tailings at the Gregory Incline are especially capable of producing acid through the oxidation of large quantities of pyrite. For example, the average acid potential for the Gregory Incline mill tailings was -21.5, the waste rock was 1.7, and the alluvium was 11.6 (a negative acid/base potential indicates acid forming potential). In the waste rock and alluvium, 11 of 18 and 2 of 13 samples showed acid forming potential. Information on the types of sampling and analytical methods used was not available.

The City of Blackhawk, with guidance from EPA, is requiring, through a city ordinance, acid generation potential testing of onsite materials prior to any development activities. Central City is in the process of doing the same. The ordinance requires that, for any excavation or site development, a sample collection plan that includes chemical analysis of acid-base potential must be prepared. The ordinance requires that the tests conform to the methods outlined in EPA-670/2-74-070, *Mine Spoil Potential for Soil and Water Quality or an equivalent method*, and that sampling must be representative of the conditions at the property. If the

acid/base potential is negative, the applicant must have a mitigation plan approved by the city (Fliniau, 1993).

3.6 Iron Mountain Mine

The Iron Mountain Mine is a 4,400-acre NPL site in Shasta County, California, approximately nine miles northwest of the City of Redding. Between 1865 and 1963, the area was used for the mining and processing of copper, silver, gold, zinc, and pyrite. In 1983, Iron Mountain Mine was added to the NPL. Acid mine drainage, leaching from both the underground mine workings and from the tailings piles located at the site, is causing zinc, cadmium, and copper contamination of the Spring Creek Watershed and the Sacramento River. Environmental damage is primarily in the Sacramento River and tributaries in the Spring Creek and Flat Creek watersheds, where fishery productivity loss and periodic fish kills have been observed. Drinking water drawn from the Sacramento River for the City of Redding (population 50,000) is also threatened (U.S. EPA 1991).

In general, acid mine drainage generation is seasonal and is accelerated during periods of heavy rainfall. According to EPA, the annual average rate of acid mine drainage at the site is 100 gallons per minute (gpm) with peak flows of 300 to 600 gpm. The average loading per day to the Spring Creek Watershed from Iron Mountain Mine is 423 lbs of copper, 1,466 lbs of zinc, and 10.4 lbs of cadmium (U.S. EPA 1991, Biggs 1991).

According to the Remedial Project Manager acid generation potential tests were conducted while the tunnels were being mucked out. The procedures used are those required by California State law. Information on test results and sampling and analytical methods used was not available (Hyman 1993 and Sugarek 1993).

3.7 Silver Bow Creek/Butte Area Site

The Silver Bow Creek/Butte Area NPL site is one of four separate but contiguous Superfund Sites located along the course of the Clark Fork River in southwestern Montana. The Silver Bow Creek/Butte Area Superfund Site is the largest (450 acres) and most complex of the four sites. The site was listed on the NPL in 1983. The Silver Bow Creek/Butte Area site includes the Cities of Butte and Walkerville (population 38,000), the Berkeley Pit (a nonoperating open-pit copper mine); numerous underground mine workings; the Continental Pit (operated by Montana Resources); Silver Bow Creek; Warm Springs Ponds (mine tailings); and Rocker Timber Framing and Treating Plant.

In the early 1980s the Berkeley Pit open pit mine was closed and dewatering pumps were shut down. As a result, the interconnected underground workings and the open pit began filling with water. EPA is concerned with the waters filling Berkeley Pit because they are highly acidic (the RI shows pH values ranging between 2.5 and 3.3, depending upon at what depth the samples were taken) and contain high concentrations of copper, iron, manganese, lead, arsenic, cadmium, zinc, and sulfates. If the water continues to rise in the Berkeley Pit, contaminated water may eventually flow into shallow ground water (alluvial aquifer) and into

Silver Bow Creek, creating the potential for significant environmental impacts and human health problems (U.S. EPA 1991). There have been no tests performed to predict pH changes either in Berkely Pit or the drainages that feed the Berkely Pit (Forba 1993). Total acidity has been tested for some samples collected at the Silver Bow Creek site. Information on the materials sampled, analytical methods, and results were not available.

4. REFERENCES

- Biggs, F., 1991, Remediation Progress at the Iron Mountain Mine Superfund Site, California, Bureau of Mines Information Circular, IC 9289.
- Bradham, W.S., and F.T. Caruccio, 1990. A Comparative Study of Tailings Analysis using Acid/Base Accounting, Cells, Columns and Soxhelets. Proceeding of the 1990 Mining and Reclamation Conference and Exhibition, Charleston, WV, April 23-26, 1990. p.19-25.
- British Columbia AMD Task Force, December 1989. Acid Rock Drainage Draft Technical Guide, Volumes I and II. Report 66002/2. Prepared for the British Columbia AMD Task Force by SRK, Inc.
- British Columbia AMD Task Force, 1990 (August). Monitoring Acid Mine Drainage. Prepared by E. Robertson in association with Steffen Robertson and Kirsten (B.C.) Inc. Bitech Publishing, Richmond, B.C.
- Brodie, M.J., L.M. Broughton, and Dr. A. MacG. Robertson, 1991. A Conceptual Rock Classification System for Waste Management and a Laboratory Method for ARD Prediction From Rock Piles. In Second International Conference on the Abatement of Acidic Drainage. Conference Proceedings, Volumes 1 - 4, September 16, 17, and 18, 1991, Montreal, Canada.
- Broughton, L.M. and Dr. A. MacG. Robertson, 1991. Modeling of Leachate Quality From Acid Generation Waste Dumps. In Second International Conference on the Abatement of Acidic Drainage. Conference Proceedings, Volumes 1 - 4, September 16, 17, and 18, 1991, Montreal, Canada.
- Broughton, L.M. and Dr. A. MacG. Robertson, 1992. Acid Rock Drainage From Mines - Where Are We Now. Steffen, Robertson and Kirsten, Vancouver, B.C. Internal Draft Paper.
- Bruynesteyn, A. and R. Hackl, 1982. Evaluation of Acid Production Potential of Mining Waste Materials. Minerals and the Environment 4(1).
- California Mining Association, 1991. Mine Waste Management. Edited and Authored by Ian Hutchison and Richard D. Ellison. Sponsored by the California Mining Association, Sacramento, CA.
- Coastech Research Inc. 1989. Investigation of Prediction techniques for Acid Mine Drainage. MEND Project 1.16.1a. Canada Center for Mineral and Energy Technology, Energy, Mines, and Resources Canada. 61 pages
- diPretoro, Richard S., 1986. Premining Prediction of Acid Drainage Potential for Surface Coal Mines in Northern West Virginia. Master of Science thesis submitted to West Virginia University.
- Doepker, Richard D., 1993. Laboratory Determination of Parameters Influencing Metal Dissolution From Sulfidic Waste Rock. Preprint from American Society of Surface Mining and Reclamation (Spokane, Washington, May 16 to 19, 1993).
- Duncan, D. and A. Bruynesteyn, 1979. Determination of Acid Production Potential of Waste Materials. Metalurgy Society, AIME, paper A-79-29. Published by AIME, Littleton, CO.
- Duncan, D. and C. Walden, 1975. Prediction of Acid Generation Potential. Report to Water Pollution Control Directorate, Environmental Protection Service, Environment Canada, November 1975.

- Edgar, A., and K. Lapakko, 1985. Heavy Metal Study Progress Report on the Field Leaching and Reclamation Program: 1977-1983. MN Dept. Nat. Res., Division of Minerals, St. Paul, MN.
- Ferguson, K.D. and P.M. Erickson, 1988. Pre-Mine Prediction of Acid Mine Drainage. In: Dredged Material and Mine Tailings. Edited by Dr. Willem Salomons and Professor Dr. Ulrich Forstner. Copyright by Springer-Verlag Berlin Heidelberg 1988.
- Ferguson, K. D., and K. A. Morin, 1991. The Prediction of Acid Rock Drainage - Lessons From the Database. In Second International Conference on the Abatement of Acidic Drainage. Conference Proceedings, Volumes 1 - 4, September 16, 17, and 18, 1991, Montreal, Canada.
- Fliniau, H., 1993, Personal communication between Holly Fliniau, Remedial Project Manager for Clear Creek, EPA Region 8, and Chris Lewicki, Science Applications International, on April 5 and May 5, 1993.
- Forba, R., 1993, Personal communication between Russ Forba, Remedial Project Manager for Silver Bow Creek/Butte Area Site, EPA Region 8, and Chris Lewicki, Science Applications International, April 5 and April 30, 1993.
- Gaskin, D., 1994. Supervisor of Mining Regulation, Nevada Department of Environmental Protection, Nevada, Personal Communication with Laurie Lamb, SAIC, August 23, 1994.
- Halbert, B., J. Scharer, R. Knapp, and D. Gorber, 1983. Determination of Acid Generation Rates in Pyritic Mine Tailings. Presented at the 56th Annual Conference of Water Pollution Control Federation, October 2-7, 1983.
- Hood, W. and A. Oertel, 1984. A Leaching Column Method for Predicting Effluent Quality From Surface Mines. In Proc. Symp. on Surface Mining Hydrology, Sedimentology and Reclamation. University of Kentucky.
- Humphries, R., 1994. Water Quality, State Water Resources Control Board, California, Personal Communication with Laurie Lamb, SAIC, August 23, 1994.
- Hyman, D., 1993, Personal communication between Dennis Hyman, California State Water Quality Control Board contact for Iron Mountain Mine, Redding Office, and Chris Lewicki, Science Applications International, May 5, 1993.
- Kim, A.G., B. Heisey, R. Kleinmann, and M. Duel, 1982. Acid Mine Drainage: Control and Abatement Research. U.S. DOI, Bureau of Mines IC 8905, p.22.
- Lapakko, K. 1988. Prediction of Acid Mine Drainage From Duluth Complex Mining Wastes In Northeastern Minnesota. In: Mine Drainage and Surface Mine Reclamation. Volume I: Mine Water and Mine Waste. U.S. Department of Interior, Bureau of Mines Information Circular 9183. p.180-191.
- Lapakko, K. 1990a. Regulatory Mine Waste Characterization: A Parallel to Economic Resource Evaluation. In: Mining and Mineral Processing Wastes. Proceedings of the Western Regional Symposium on Mining and Mineral Processing Wastes, May 30 - June 1, 1990, Berkley, California p.31-39. Edited by Fiona Doyle, Published by the Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO.

- Lapakko, K. 1990b. Solid Phase Characterization in Conjunction with Dissolution Experiments for Prediction of Drainage Quality. *In*: Mining and Mineral Processing Wastes. Proceedings of the Western Regional Symposium on Mining and Mineral Processing Wastes, May 30 - June 1, 1990, Berkley, California p.31-39. Edited by Fiona Doyle, Published by the Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO.
- Lapakko, K. 1992. Evaluation of Tests for Predicting Mine Waste Drainage pH. Draft Report to the Western Governors' Association, May 1992.
- Lapakko, K. 1993a. Predictive Testing for Mine Waste Drainage Quality. *In* Mine Operation and Closure Short Course. Sponsored by EPA and others April 27 - 29, 1993. Helena, MT.
- Lapakko, K. 1993b. Mine Waste Drainage Quality Prediction: A Literature Review. Draft Paper. Minnesota Department of Natural Resources, Division of Minerals, St. Paul, MN.
- Lapakko, K., 1994. Department of Natural Resources, Minnesota, Personal Communication with Laurie Lamb, SAIC, August 23, 1994.
- Lawrence, R., 1990. Prediction of the Behavior of Mining and Processing Wastes in the Environment. *In* Proc. Western Regional Symposium on Mining and Mineral Processing Wastes. Edited by Fiona Doyle, Published by the Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO.
- Lawrence, R., S. Jaffe, and L. Broughton, 1988. In-house Development of the Net Acid Production Test Method. Coastech Research.
- Lu, Ning, and Yiqiang Zhang, undated. Thermally Induced Gas Convection in Mine Wastes. Disposal Safety Inc., Washington, DC.
- Lutwick, G.D., 1986. Mineral Composition and Acid Consuming Potential of Nova Scotia Shales. Nova Scotia Research Foundation Corporation, Halifax, Nova Scotia.
- Manahan, Stanley E. 1991. Environmental Chemistry. Fifth edition. Lewis Publishers, Inc. Chelsa, MI.
- Miller, R., 1994. Hardrock Bureau, Montana Department of State Lands, Montana, Personal Communication with Laurie Lamb, SAIC, August 23, 1994.
- Nicholson, Ronald V., 1992. A Review of Models to Predict Acid Generation Rates in Sulphide Waste Rock at Mine Sites. Presented to the International Workshop on Waste Rock Modelling, sponsored by the Mine Environment Neutral Drainage Program, September 29 - October 1, 1992 in Toronto, Canada.
- Overbay, M., 1993. Personal communication between Mike Overbay, Remedial Project Manager for Tar Creek, EPA Region 6, and Chris Lewicki, Science Applications International, April 7 and April 13, 1993.
- Plumlee, G.S., Smith, K.S., Ficklin, W.H., Briggs, P.H., and McHugh, J.B., 1993. Empirical Studies of Diverse Mine Drainages in Colorado: Implications for the Prediction of Mine-Drainage Chemistry. Planning, Rehabilitation and Treatment of Disturbed Lands Billings Symposium, 1993.
- Robertson, Dr. A. MacG. and L.M. Broughton, undated. Reliability of Acid Rock Drainage Testing. Steffen, Robertson and Kirsten, Vancouver, B.C.
-

- Schafer, Dr. William M. 1993. Design of Geochemical Sampling Programs. In Mine Operation and Closure Short Course. Sponsored by EPA and others April 27 - 29, 1993. Helena, MT.
- Schuld B., 1993. Letter from Bruce A. Schuld, Idaho Division of Environmental Quality, to Joe Rissing, SAIC, regarding Idaho protocol and requirements for prediction, prevention and remediation of acid mine drainage, dated April 13, 1993.
- Schuld, B., 1994. Idaho Division of Environmental Quality, Idaho, Personal Communication with Laurie Lamb, SAIC, August 23, 1994.
- Singleton, G.A. and L.M. Lavkulich, 1978. Adaption of the Soxhlet Extractor for Pedologic Studies. Soil Science Society of America Journal, Vol. 42, p. 984-986.
- Smith, A. and J.B. Barton Bridges, 1991. Some Considerations in the Prediction and Control of Acid Mine Drainage Impact on Groundwater From Mining in North America. In: Proceeding of the EPPIC Water Symposium, Johannesburg, May 16-17.
- Sobek, A.A., Schuller, W.A., Freeman, J.R. Smith, R.M. 1978. Field and Laboratory Methods Applicable to Overburden and Minesoils. EPA 600/2-78-054.
- Steffen, Robertson and Kirsten, Inc. (B.C.), in association with Norecol Environment Consultants and Gormely Process Engineering, 1989. Draft Acid Rock Drainage Technical Guide. Volumes I and II. Prepared for British Columbia Acid Mine Drainage Task Force.
- Steffen, Robertson and Kirsten, Inc. (B.C.), 1992. Mine Rock Guidelines: Design and Control of Drainage Water Quality. Saskatchewan Environment and Public Safety. Mines Pollution Control Branch Report #93301.
- Sugarek, R., 1993, Personal communication between Rick Sugarek, Remedial Project Manager for Iron Mountain Mine, EPA Region 9, and Chris Lewicki, Science Applications International, April 5, 1993.
- Sullivan, P.J. and A. Sobek, 1982. Laboratory Weathering Studies of Coal Refuse. Minerals and the Environment 4(1).
- Taylor, G., 1993, Personal communication between Gene Taylor, Remedial Project Manager for Eagle Mine, EPA Region 8, and Chris Lewicki, Science Applications International, April 5 and May 6, 1993.
- Univ. of California, Berkley 1988. Mining Waste Study: Final Report. Prepared for the California State Legislature.
- USDA Forest Service 1992. A Conceptual Waste Rock Sampling Program for Mines Operating in Metallic Sulfide Ores With a Potential for Acid Rock Drainage. Written by Gene Farmer with the Department of Agriculture, Forest Service, Ogden, Utah.
- USDA Forest Service 1993. Acid Mine Drainage From Mines on the National Forests, A Management Challenge. Program Aid 1505, p.12.

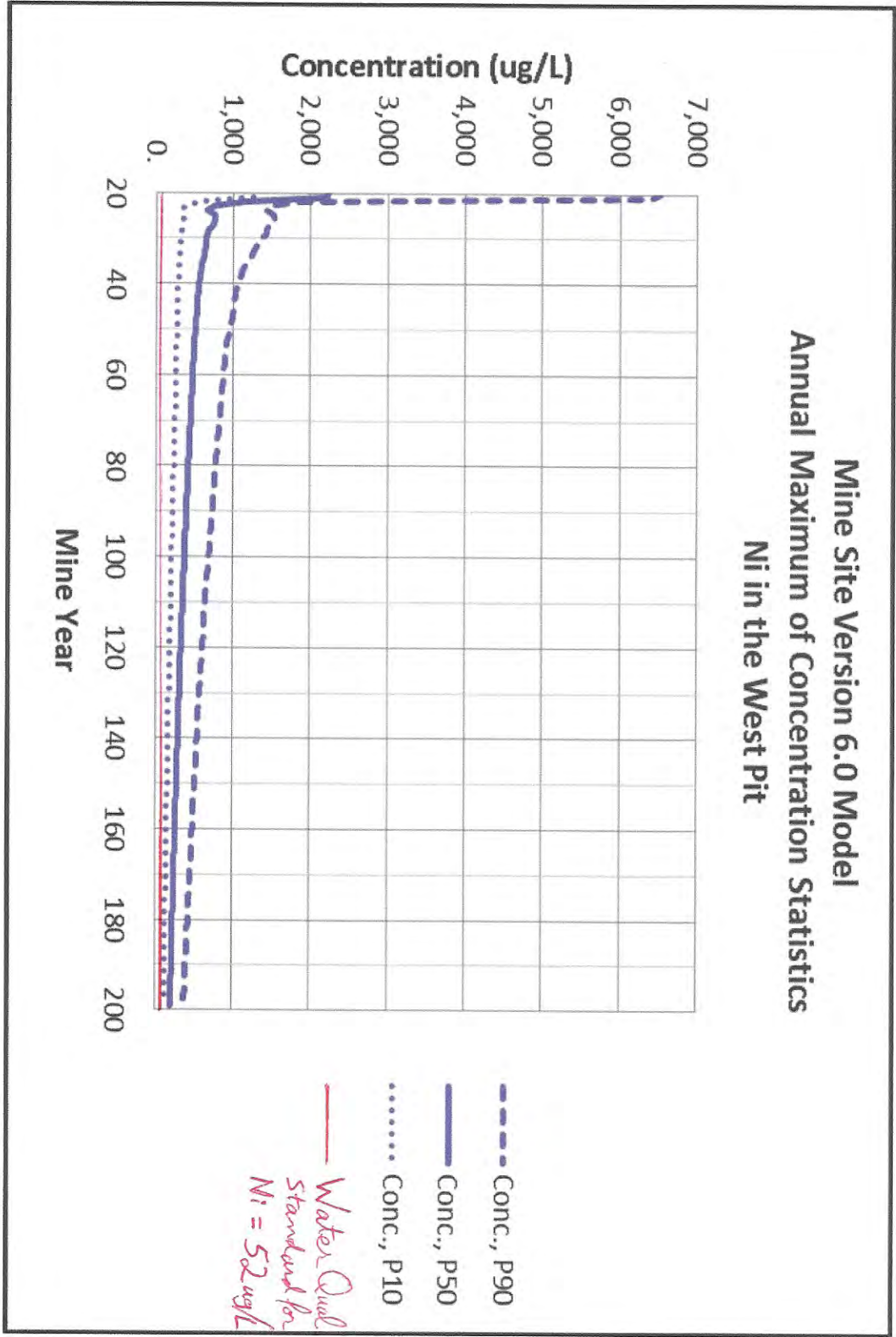
- U.S. Environmental Protection Agency, Office of Research and Development, 1992a. Draft. Predicting Acid Generation From Non-Coal Mining Waste: Notes of July 1992 Workshop. Prepared for the Environmental Monitoring Systems Laboratory, Las Vegas, NV 89193-3478 by SAIC, Falls Church, VA.
- U.S. Environmental Protection Agency, Office of Solid Waste, July 1992b. Mine Site Visit: Newmont Gold Company, Rain Facility. Draft of July 1992 prepared by the Office of Solid Waste, Washington, D.C.
- U.S. Environmental Protection Agency, Office of Solid Waste, June 1992c. Mine Site Visit: Cyprus Minerals Corporation Thompson Creek Mine. Draft of June 1992 prepared by the Office of Solid Waste, Washington, D.C.
- U.S. Environmental Protection Agency, Office of Solid Waste, June 1992d. Mine Site Visit: LTV Steel Mining Company (LTV SMC Co.) Hoyt Lakes, Dunka, and Taconite Harbor Facilities. Draft of June 1992 prepared by the Office of Solid Waste, Washington, D.C.
- U.S. Environmental Protection Agency, Office of Solid Waste, 1991 (June 21). Mining Sites on the National Priorities List. Final Draft. NPL Site Summary Reports Volumes I-V. NTIS - PB 92-124767, PB 92-124775, PB 92-124783, PB 92-124791, PB 92-124809.
- U.S. Environmental Protection Agency, 1992. Mine Site Visit: Cyprus Minerals Corporation Thompson Creek Mine. Prepared for the Office of Solid Waste by Science Applications International Corporation, Falls Church, VA 22043.
- Water Resources Control Board, State of California, 1990. Report to the Legislature on Acid-Generation Potential Tests, 90-18CWP, December 1990. Written by Richard Humphreys, Division of Clean Water Programs.
- Williams, E.G., Rose, A.W., Parizek, R.R., and Waters, S.A., 1982. Factors Controlling the Generation of Acid Mine Drainage. Final Report on Research Grant No. G5105086, September 30, 1980 - December 31, 1981. Submitted to U.S. Bureau of Mines, April, 1982.

**Water Quality Modeling Results for
Nickel (Ni) and Sulfate (SO₄) at
Mine Site West Pit, Northmet
(PolyMet) Project**

**Final EIS
2015**

**A Sulfide-Ore Copper/Nickel Mine
Proposed to be Developed in the
Duluth Complex of Minnesota**

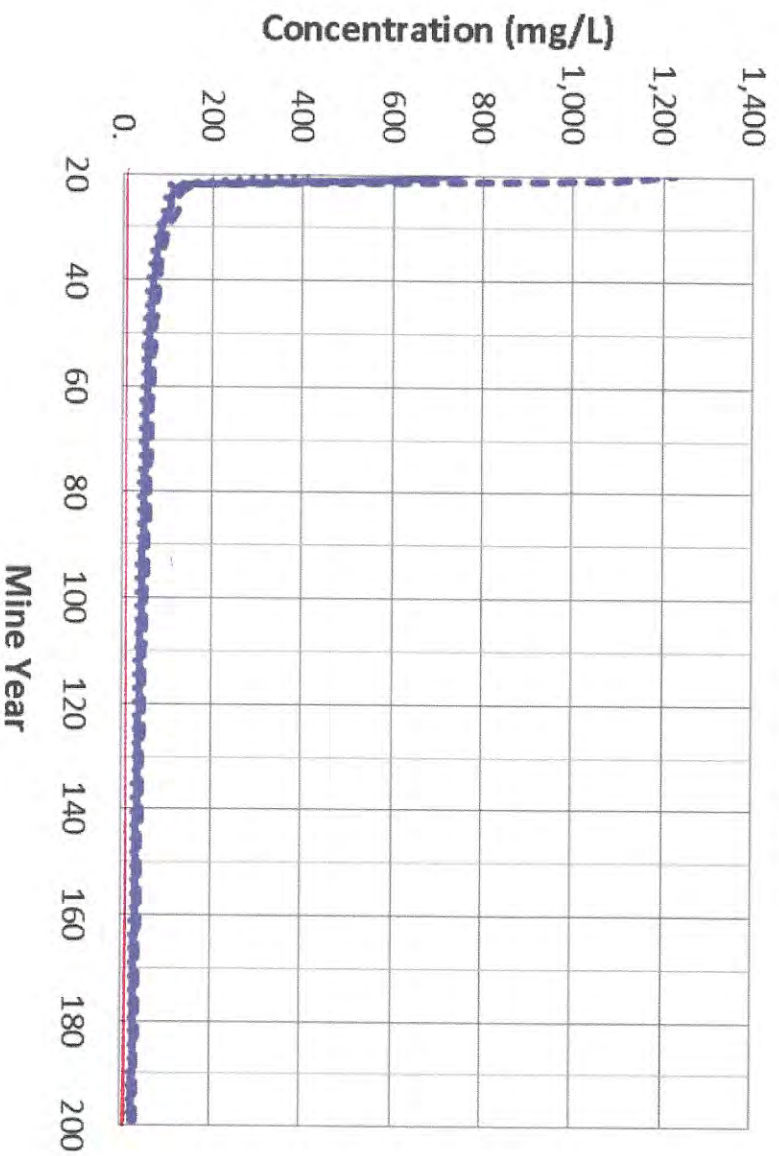
**Mitigation will be required for at
least 200 years at the Mine Site and
500 years at the Processing Site**



Source: PolyMet 2014v.

Figure 5.2.2-42 *Nickel Concentration in the West Pit during Reclamation, Closure, and Post-Closure Maintenance*

Mine Site Version 6.0 Model Annual Maximum of Concentration Statistics SO₄ in the West Pit



--- Conc., P90
 --- Conc., P50
 Conc., P10
 — Water Quality Standard for SO₄ = 10 mg/L

Source: PolyMet 2014v.

Figure 5.2.2-43 Sulfate Concentration in the West Pit during Reclamation, Closure, and Post-Closure Maintenance

Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						
Copper, Total (as Cu)	ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMax						
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg						
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Nickel, Total (as Ni)	ug/L	CalMoAvg						
Nickel, Total (as Ni)	ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Sulfate, Total (as SO4)	mg/L	CalMoAvg						
Sulfate, Total (as SO4)	mg/L	CalMoMax						
Toxicity, Final Conc	1.50 toxunt	CalMoMax						
Toxicity, Final Conc	2.00 toxunt	CalMoMax						
Toxicity, Final Conc	3.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						
Zinc, Total (as Zn)	ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2001 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				124	105.45	33.6
Copper, Total (as Cu)	ug/L	CalMoMax				124	150	38
Flow	MG	CalMoTot				0.9	0.4774	0.27
Flow	mgd	CalMoAvg				0.03	0.0154	0.009
Flow	mgd	CalMoMax				0.03	0.0321	0.0167
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg				306	580	999
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax				306	683	1110
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.05	<0.03	0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.05	<0.03	0.03
Nickel, Total (as Ni)	ug/L	CalMoAvg				2090	4525	4710
Nickel, Total (as Ni)	ug/L	CalMoMax				2090	5130	6240
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				4.4	1.2	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				4.4	1.2	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg				288	48.8	826

Sulfate, Total (as SO4)	mg/L	CalMoMax			288	48.8	826
Toxicity, Final Conc	1.50 toxunt	CalMoMax				2.53	1.48
Toxicity, Final Conc	2.00 toxunt	CalMoMax			2.26		
Toxicity, Final Conc	3.00 toxunt	CalMoMax					
Zinc, Total (as Zn)	ug/L	CalMoAvg			455	685.5	553
Zinc, Total (as Zn)	ug/L	CalMoMax			455	694	663
pH	6.5 SU	CalMoMin			7.5	7.1	7.1
pH	8.5 SU	CalMoMax			7.5	7.2	7.3

Year 2002 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				35.7	20.1	21.8
Copper, Total (as Cu)	ug/L	CalMoMax				35.7	23.8	27.5
Flow	MG	CalMoTot				0.017	0.08	0.94
Flow	mgd	CalMoAvg				0.0006	0.0027	0.0315
Flow	mgd	CalMoMax				0.0167	0.0081	0.1988
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg				260	656	850
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax				260	831	890
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.05	<0.03	<0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.05	0.03	<0.03
Nickel, Total (as Ni)	ug/L	CalMoAvg				1430	2305	2365
Nickel, Total (as Ni)	ug/L	CalMoMax				1430	2860	2710
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				1.2	<1.25	3.5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				1.2	1.5	4
Sulfate, Total (as SO4)	mg/L	CalMoAvg				160	587	768.5
Sulfate, Total (as SO4)	mg/L	CalMoMax				160	756	814
Toxicity, Final Conc	1.50 toxunt	CalMoMax					0.7647	0.7447
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.68		
Toxicity, Final Conc	3.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg				188	214	223.5
Zinc, Total (as Zn)	ug/L	CalMoMax				188	248	247
pH	6.5 SU	CalMoMin				7.7	7.3	7.5
pH	8.5 SU	CalMoMax				7.7	7.6	7.8

Year 2003 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg					22	24.15
Copper, Total (as Cu)	ug/L	CalMoMax					25.1	26.4
Flow	MG	CalMoTot					0.11	0.15
Flow	mgd	CalMoAvg					0.0035	0.0055
Flow	mgd	CalMoMax					0.0147	0.0321
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg					486.5	574

Hardness, Calcium & Magnesium, mg/L	CalMoMax			530	598
Calculated (as Iron, Dissolved (as Fe) 1.0 mg/L	CalMoAvg			<0.03	<0.03
Iron, Dissolved (as Fe) 2.0 mg/L	CalMoMax			<0.03	<0.03
Nickel, Total (as Ni) ug/L	CalMoAvg			1870	1615
Nickel, Total (as Ni) ug/L	CalMoMax			1910	1890
Solids, Total Suspended (TSS) 20 mg/L	CalMoAvg			17.25	4
Solids, Total Suspended (TSS) 30 mg/L	CalMoMax			3.2	4
Sulfate, Total (as SO4) mg/L	CalMoAvg			200	531
Sulfate, Total (as SO4) mg/L	CalMoMax			200	531
Toxicity, Final Conc 1.50 toxunt	CalMoMax			0.64	0.59
Toxicity, Final Conc 2.00 toxunt	CalMoMax				
Toxicity, Final Conc 3.00 toxunt	CalMoMax				
Zinc, Total (as Zn) ug/L	CalMoAvg			176.5	153
Zinc, Total (as Zn) ug/L	CalMoMax			184	165
pH 6.5 SU	CalMoMin			7.5	7.35
pH 8.5 SU	CalMoMax			7.7	7.5

Year 2004 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu) ug/L	CalMoAvg					28.25	13.1	11.4
Copper, Total (as Cu) ug/L	CalMoMax					34.7	13.1	12.2
Flow MG	CalMoTot					0.05	0.26	0.18
Flow mgd	CalMoAvg					0.0017	0.008	0.006
Flow mgd	CalMoMax					0.0023	0.039	0.0167
Hardness, Calcium & Magnesium, mg/L	CalMoAvg					207	434	717.5
Calculated (as Hardness, Calcium & Magnesium, mg/L	CalMoMax					236	480	861
Calculated (as Iron, Dissolved (as Fe) 1.0 mg/L	CalMoAvg					0.09	0.07	0.1
Iron, Dissolved (as Fe) 2.0 mg/L	CalMoMax					0.09	0.07	0.1
Nickel, Total (as Ni) ug/L	CalMoAvg					760.5	1130	1850
Nickel, Total (as Ni) ug/L	CalMoMax					825	1140	1960
Solids, Total Suspended (TSS) 20 mg/L	CalMoAvg					1	<1	<1
Solids, Total Suspended (TSS) 30 mg/L	CalMoMax					1	<1	<1
Sulfate, Total (as SO4) mg/L	CalMoAvg					182	367	597
Sulfate, Total (as SO4) mg/L	CalMoMax					182	367	597
Toxicity, Final Conc 1.50 toxunt	CalMoMax						0.39	0.52
Toxicity, Final Conc 2.00 toxunt	CalMoMax					0.85		
Toxicity, Final Conc 3.00 toxunt	CalMoMax							
Zinc, Total (as Zn) ug/L	CalMoAvg					120	128	171.5
Zinc, Total (as Zn) ug/L	CalMoMax					131	129	175
pH 6.5 SU	CalMoMin					7.2	7.32	7.6
pH 8.5 SU	CalMoMax					7.3	7.6	7.7

Year 2005 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				18.15	13.45	18.2
Copper, Total (as Cu)	ug/L	CalMoMax				18.4	16.4	23.3
Flow	MG	CalMoTot				0.111	0.42	0.203
Flow	mgd	CalMoAvg				0.0037	0.014	0.0068
Flow	mgd	CalMoMax				0.0081	0.035	0.0212
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg				266	450	769
& Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax				363	479	894
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.21	0.07	0.12
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.21	0.07	0.12
Nickel, Total (as Ni)	ug/L	CalMoAvg				939.5	1175	2815
Nickel, Total (as Ni)	ug/L	CalMoMax				1070	1280	3660
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				2	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				2	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg				110	380	488
Sulfate, Total (as SO4)	mg/L	CalMoMax				110	380	488
Toxicity, Final Conc	1.50 toxunt	CalMoMax					0.61	1.09
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.88		
Toxicity, Final Conc	3.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg				100.4	199	288.5
Zinc, Total (as Zn)	ug/L	CalMoMax				116	295	392
pH	6.5 SU	CalMoMin				6.9	7.5	7
pH	8.5 SU	CalMoMax				7.2	7.7	7.1

Year 2006 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				18.7	29.35	15.2
Copper, Total (as Cu)	ug/L	CalMoMax				20.3	49.3	19.6
Flow	MG	CalMoTot				0.11	0.43	0.07
Flow	mgd	CalMoAvg				0.004	0.01	0.002
Flow	mgd	CalMoMax				0.004	0.11	0.017
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg				308.5	445.5	732
& Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax				394	513	944
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.09	0.05	0.37
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.09	0.05	0.37
Nickel, Total (as Ni)	ug/L	CalMoAvg				1205	1630	3000
Nickel, Total (as Ni)	ug/L	CalMoMax				1370	1650	3380
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				<1	2	3.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				<1	2	3.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg				180	457	919
Sulfate, Total (as SO4)	mg/L	CalMoMax				180	457	919

Toxicity, Final Conc	1.50 toxunt	CalMoMax			0.84	0.86
Toxicity, Final Conc	2.00 toxunt	CalMoMax		0.7		
Toxicity, Final Conc	3.00 toxunt	CalMoMax				
Zinc, Total (as Zn)	ug/L	CalMoAvg		114.5	156	192
Zinc, Total (as Zn)	ug/L	CalMoMax		128	185	227
pH	6.5 SU	CalMoMin		7.6	7.2	7.3
pH	8.5 SU	CalMoMax		7.6	7.7	7.4

Year 2007 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			13.8	12.565	8.99	37.25
Copper, Total (as Cu)	ug/L	CalMoMax			13.8	15.5	10.7	46.9
Flow	MG	CalMoTot			0.009	0.15	0.26	0.47
Flow	mgd	CalMoAvg			0.0003	0.005	0.009	0.02
Flow	mgd	CalMoMax			0.0008	0.007	0.017	0.08
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg			106	297	394.5	736
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax			106	320	446	1030
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.175	0.098	0.173	0.0775
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.175	0.098	0.173	0.0775
Nickel, Total (as Ni)	ug/L	CalMoAvg			490	1199	1135	3170
Nickel, Total (as Ni)	ug/L	CalMoMax			490	1410	1170	3860
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg			4.8	1.5	<1	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax			4.8	1.5	<1	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg			67.3	196	2500	375
Sulfate, Total (as SO4)	mg/L	CalMoMax			67.3	196	2500	375
Toxicity, Final Conc	1.50 toxunt	CalMoMax					0.34	1.01
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.42		
Toxicity, Final Conc	3.00 toxunt	CalMoMax			0.68			
Zinc, Total (as Zn)	ug/L	CalMoAvg			35.8	84	61.15	278
Zinc, Total (as Zn)	ug/L	CalMoMax			35.8	97.8	64.2	290
pH	6.5 SU	CalMoMin			7.1	6.9	7.5	7
pH	8.5 SU	CalMoMax			7.1	6.9	7.6	7.5

Year 2008 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				28.2	29.45	48.85
Copper, Total (as Cu)	ug/L	CalMoMax				28.2	34.7	70.8
Flow	MG	CalMoTot				0.097	0.37	0.82
Flow	mgd	CalMoAvg				0.003	0.012	0.03
Flow	mgd	CalMoMax				0.006	0.024	0.09
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg				161	329	579

Hardness, Calcium & Magnesium, mg/L	CalMoMax		161	409	761
Calculated (as Iron, Dissolved (as Fe) 1.0 mg/L	CalMoAvg		0.0598	<0.05	0.107
Iron, Dissolved (as Fe) 2.0 mg/L	CalMoMax		0.0598	<0.05	0.107
Nickel, Total (as Ni) ug/L	CalMoAvg		710	1540	3615
Nickel, Total (as Ni) ug/L	CalMoMax		710	1900	4710
Solids, Total Suspended (TSS) 20 mg/L	CalMoAvg		2	1.2	3
Solids, Total Suspended (TSS) 30 mg/L	CalMoMax		2	1.2	3
Sulfate, Total (as SO4) mg/L	CalMoAvg		98.5	197	380
Sulfate, Total (as SO4) mg/L	CalMoMax		98.5	197	380
Toxicity, Final Conc 1.50 toxunt	CalMoMax			0.85	1.38
Toxicity, Final Conc 2.00 toxunt	CalMoMax		0.95		
Toxicity, Final Conc 3.00 toxunt	CalMoMax				
Zinc, Total (as Zn) ug/L	CalMoAvg		95.5	161	391.5
Zinc, Total (as Zn) ug/L	CalMoMax		95.5	196	501
pH 6.5 SU	CalMoMin		6.7	6.9	7.1
pH 8.5 SU	CalMoMax		6.7	7.2	7.2

Year 2009 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu) ug/L	CalMoAvg					25	21.4	16.5
Copper, Total (as Cu) ug/L	CalMoMax					26	25.7	17
Flow MG	CalMoTot					0.47	0.44	0.12
Flow mgd	CalMoAvg					0.016	0.015	0.0041
Flow mgd	CalMoMax					0.021	0.024	0.019
Hardness, Calcium & Magnesium, mg/L	CalMoAvg					252.5	332	563.5
Calculated (as Hardness, Calcium & Magnesium, mg/L	CalMoMax					328	420	599
Calculated (as Iron, Dissolved (as Fe) 1.0 mg/L	CalMoAvg					0.138	<0.050	<0.050
Iron, Dissolved (as Fe) 2.0 mg/L	CalMoMax					0.138	<0.050	<0.050
Nickel, Total (as Ni) ug/L	CalMoAvg					764.5	837	1260
Nickel, Total (as Ni) ug/L	CalMoMax					920	1020	1280
Solids, Total Suspended (TSS) 20 mg/L	CalMoAvg					3.2	<1	<1
Solids, Total Suspended (TSS) 30 mg/L	CalMoMax					3.2	<1	<1
Sulfate, Total (as SO4) mg/L	CalMoAvg					213	156	391
Sulfate, Total (as SO4) mg/L	CalMoMax					213	156	391
Toxicity, Final Conc 1.50 toxunt	CalMoMax						0.53	0.41
Toxicity, Final Conc 2.00 toxunt	CalMoMax					0.72		
Toxicity, Final Conc 3.00 toxunt	CalMoMax							
Zinc, Total (as Zn) ug/L	CalMoAvg					92.25	71.8	103.5
Zinc, Total (as Zn) ug/L	CalMoMax					124	87.6	106
pH 6.5 SU	CalMoMin					7.16	7.29	7.1
pH 8.5 SU	CalMoMax					7.16	7.38	7.2

Year 2010 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			56.9	35.2		32
Copper, Total (as Cu)	ug/L	CalMoMax			56.9	35.2		37
Flow	MG	CalMoTot			0.04	0.0007	0.003	0.16
Flow	mgd	CalMoAvg			0.001	0.00003	0.0001	0.01
Flow	mgd	CalMoMax			0.002	0.0001	0.002	0.02
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoAvg			356	426		763
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoMax			356	426		797
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.1	0.1		1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.1	0.1		1.4
Nickel, Total (as Ni)	ug/L	CalMoAvg			1440	1290		573
Nickel, Total (as Ni)	ug/L	CalMoMax			1440	1290		670
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg			<1	3.5		5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax			<1	3.5		5
Sulfate, Total (as SO4)	mg/L	CalMoAvg			257	289		541
Sulfate, Total (as SO4)	mg/L	CalMoMax			257	289		541
Toxicity, Final Conc	1.50 toxunt	CalMoMax						0.41
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.53		
Toxicity, Final Conc	3.00 toxunt	CalMoMax			0.91			
Zinc, Total (as Zn)	ug/L	CalMoAvg			174	88.7		38
Zinc, Total (as Zn)	ug/L	CalMoMax			174	88.7		43
pH	6.5 SU	CalMoMin			6.9	7.4		6.5
pH	8.5 SU	CalMoMax			6.9	7.4		6.7

Year 2011 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				27	15	6.1
Copper, Total (as Cu)	ug/L	CalMoMax				27	17	8
Flow	MG	CalMoTot	0	0	0	0.26	0.25	0.25
Flow	mgd	CalMoAvg	0	0	0	0.0088	0.01	0.009
Flow	mgd	CalMoMax	0	0	0	0.026	0.03	0.03
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoAvg				410	555	908
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoMax				410	641	982
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.06	0.1	0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.06	0.1	0.2
Nickel, Total (as Ni)	ug/L	CalMoAvg				711	791	499
Nickel, Total (as Ni)	ug/L	CalMoMax				711	795	547
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				<1	<1	8
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				<1	<1	8
Sulfate, Total (as SO4)	mg/L	CalMoAvg				287	331	613
Sulfate, Total (as SO4)	mg/L	CalMoMax				287	331	613

Toxicity, Final Conc	1.50 toxunt	CalMoMax			0.3	0.17
Toxicity, Final Conc	2.00 toxunt	CalMoMax		0.39		
Toxicity, Final Conc	3.00 toxunt	CalMoMax				
Zinc, Total (as Zn)	ug/L	CalMoAvg		76	68	31.4
Zinc, Total (as Zn)	ug/L	CalMoMax		76	69	38
pH	6.5 SU	CalMoMin		7.2	7	7
pH	8.5 SU	CalMoMax		7.2	7.1	7

Year 2012 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			21.2	16.3	14.8	14.5
Copper, Total (as Cu)	ug/L	CalMoMax			22.2	17.9	17.2	17.9
Flow	MG	CalMoTot			0.03	0.1	0.515	0.7
Flow	mgd	CalMoAvg			0.0009	0.0034	0.017	0.02
Flow	mgd	CalMoMax			0.0047	0.011	0.1	0.25
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg			570	645	759	946
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax			662	744	810	1110
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.1	<.05	<.1	<.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.1	<.05	<.1	<.1
Nickel, Total (as Ni)	ug/L	CalMoAvg			1148	1073	1200	1975
Nickel, Total (as Ni)	ug/L	CalMoMax			1470	1550	1230	2370
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg			2	1.2	3.6	1.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax			2	1.2	3.6	1.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg			370	607	523	661
Sulfate, Total (as SO4)	mg/L	CalMoMax			370	607	523	661
Toxicity, Final Conc	1.50 toxunt	CalMoMax					0.43	0.59
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.51		
Toxicity, Final Conc	3.00 toxunt	CalMoMax			0.52			
Zinc, Total (as Zn)	ug/L	CalMoAvg			106	113	109	112
Zinc, Total (as Zn)	ug/L	CalMoMax			146	158	128	148
pH	6.5 SU	CalMoMin			7.5	7.4	7.5	7.3
pH	8.5 SU	CalMoMax			7.6	7.7	7.6	7.6

Year 2013 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						11.1
Copper, Total (as Cu)	ug/L	CalMoMax						11.4
Flow	MG	CalMoTot						0.242
Flow	mgd	CalMoAvg						0.0081
Flow	mgd	CalMoMax						0.0422
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg						766

Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax				870
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.1
Nickel, Total (as Ni)	ug/L	CalMoAvg				1250
Nickel, Total (as Ni)	ug/L	CalMoMax				1290
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				2
Sulfate, Total (as SO4)	mg/L	CalMoAvg				564
Sulfate, Total (as SO4)	mg/L	CalMoMax				564
Toxicity, Final Conc	1.50 toxunt	CalMoMax				0.33
Toxicity, Final Conc	2.00 toxunt	CalMoMax				
Toxicity, Final Conc	3.00 toxunt	CalMoMax				
Zinc, Total (as Zn)	ug/L	CalMoAvg				77.3
Zinc, Total (as Zn)	ug/L	CalMoMax				78.1
pH	6.5 SU	CalMoMin				6.5
pH	8.5 SU	CalMoMax				7.2

Year 2014 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						8.4
Copper, Total (as Cu)	ug/L	CalMoMax						9.7
Flow	MG	CalMoTot						0.14
Flow	mgd	CalMoAvg						0.0077
Flow	mgd	CalMoMax						0.024
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg						756
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoMax						764
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoAvg						0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						0.1
Nickel, Total (as Ni)	ug/L	CalMoAvg						1480
Nickel, Total (as Ni)	ug/L	CalMoMax						1530
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg						607
Sulfate, Total (as SO4)	mg/L	CalMoMax						607
Toxicity, Final Conc	1.50 toxunt	CalMoMax						0.33
Toxicity, Final Conc	2.00 toxunt	CalMoMax						
Toxicity, Final Conc	3.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						66.3
Zinc, Total (as Zn)	ug/L	CalMoMax						69.6
pH	6.5 SU	CalMoMin						7.6
pH	8.5 SU	CalMoMax						7.8

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						5.5
Copper, Total (as Cu)	ug/L	CalMoMax						5.5
Flow	MG	CalMoTot						5.5
Flow	mgd	CalMoAvg						0.18
Flow	mgd	CalMoMax						0.34
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoAvg						692
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoMax						739
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						<.05
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						<.05
Nickel, Total (as Ni)	ug/L	CalMoAvg						1555
Nickel, Total (as Ni)	ug/L	CalMoMax						1630
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						2.4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						2.4
Sulfate, Total (as SO4)	mg/L	CalMoAvg						451
Sulfate, Total (as SO4)	mg/L	CalMoMax						451
Toxicity, Final Conc	1.50 toxunt	CalMoMax						0.67
Toxicity, Final Conc	2.00 toxunt	CalMoMax						
Toxicity, Final Conc	3.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						192
Zinc, Total (as Zn)	ug/L	CalMoMax						343
pH	6.5 SU	CalMoMin						7.2
pH	8.5 SU	CalMoMax						7.8

Jul	Aug	Sep	Oct	Nov	Dec
	20.8	16.1	9.9	16.3	
	21.3	17.8	14.6	16.4	
	0.08	0.12	0.08	0.09	
	0.003	0.004	0.003	0.003	
	0.011	0.013	0.015	0.006	
	1250	1135	1270	1090	
	1300	1170	1350	1180	
	<0.03	<0.03	<0.02	0.06	
	<0.03	<0.03	<0.03	0.06	
	2350	3650	3800	3755	
	2940	4100	4010	4190	
	9	9	4	2.4	
	9	9	4	2.4	
	1165	1185	1310	788	
	1190	1270	1310	788	
	0.82	1.19			
			1.05		
				1.21	
	171	383	385	432	
	253	486	392	476	
	7.2	7.1	7.3	7.2	
	7.3	7.3	7.3	7.2	

Jul	Aug	Sep	Oct	Nov	Dec
32.7	31.1	27.1	32.65	15	19.9
41.6	33	32.7	46.5	15.6	19.9
0.13	0.28	0.05	0.08	0.07	0.02
0.004	0.009	0.00015	0.0025	0.0024	0.0007
0.011	0.0291	0.0057	0.0095	0.0047	0.0012
1095	700	1133	1130	1165.5	1030
1290	727	1186	1210	1181	1030
<0.03	0.05	<0.03	<0.03	<0.03	<0.03
<0.03	0.05	<0.03	<0.03	<0.03	<0.03
4035	4640	4320	4380	3955	4340
44.2	6020	4590	4850	4080	4340
4.8	2.8	8.4	4.7	1.6	2.4
4.8	2.8	8.4	4.7	1.6	2.4
1310	668	1080	1150	1030	972

1310	668	1080	1150	1030	972
1.181	1.8141	1.307			
			1.4992		
				1.2031	1.4332
347	494.5	403	409	475.5	612
392	686	422	466	484	612
7.4	7.4	7.1	7.1	7.3	7.1
7.6	7.4	7.6	7.4	7.4	7.1

Jul	Aug	Sep	Oct	Nov	Dec
23.1	18.85	18.95	17.05	22	
25.7	21	21.1	20.9	22	
0.12	0.27	0.18	0.16	0.03	
0.0038	0.0087	0.0059	0.0052	0.0011	
0.0128	0.054	0.0188	0.0147	0.0023	
1330	1100	1145	1080	1180	
1400	1150	1160	1140	1180	
<0.03	<0.03	<0.03	<0.03	<0.03	
<0.03	<0.03	<0.03	<0.03	<0.03	
2585	4145	4940	4820	5800	
2670	4250	5250	4830	5800	
5	4	2	2	3.5	
5.3	4	2	2	3.5	
1260	1160	1080	952	920	
1290	1160	1080	952	920	
0.7793	1.0942	1.4969			
			1.53		
				1.98	
200	362.5	506.5	627.5	894	
221	381	578	636	894	
7.2	7.4	7.2	7.4	7.8	
7.3	7.5	7.4	7.4	7.8	

Jul	Aug	Sep	Oct	Nov	Dec
24.6	20.4	29.6	27.35	14.35	7
26	25.7	44.2	32.4	15.7	7
0.26	0.1	0.19	0.09	0.04	0.0033
0.0085	0.0034	0.0064	0.0028	0.0014	0.0001
0.0353	0.0237	0.0886	0.0029	0.0017	0.0003
1320	1101.5	1022	982.5	1125	1150

1860	1240	1250	1050	1200	1150
<0.03	<0.03	0.07	<0.03	0.05	0.35
<0.03	<0.03	0.07	<0.03	0.05	0.35
2890	3825	3520	4990	3290	3030
3340	4220	4130	5220	3370	3030
<1	3.6	4.5	2	<1	<1
<1	3.6	4.5	2	<1	<1
715	998	1170	869	1080	1080
715	998	1170	869	1080	1080
0.95	1.18	1.47			
			1.81		
				1.19	0.91
270	325.5	363	679.5	538.5	397
307	396	519	756	547	397
7.1	7.52	7.4	7.4	7.1	7.3
7.1	7.67	7.7	7.6	7.4	7.3

Jul	Aug	Sep	Oct	Nov	Dec
11.1	10.2	15.45	10.25	9.45	
11.7	11.3	21.7	14.1	9.6	
0.0539	0.03	0.24	0.0643	0.0741	
0.0017	0.001	0.008	0.0021	0.0025	
0.0321	0.019	0.046	0.0037	0.0047	
1125	1250	1235	1029	1004.5	
1230	1400	1370	1090	1050	
0.16	0.55	0.05	0.41	0.09	
0.16	0.55	0.05	0.41	0.09	
1335	582	1625	1510	2215	
1610	608	2480	1760	2570	
8	5.5	3	4	<1	
8	5.5	3	4	<1	
1080	1185	1180	973	895	
1080	1185	1180	973	895	
0.37	0.2	0.61			
			0.45		
				0.73	
73.85	39.65	93.75	108.5	255.5	
83	39.8	131	114	288	
7.2	7.3	7.2	7.2	7.7	
7.3	7.3	7.2	7.21	7.83	

Jul	Aug	Sep	Oct	Nov	Dec
8.1			16.7	17.6	37.1
8.1			18.2	25.9	37.1
0.041			1.86	0.124	1
0.0013			0.06	0.0041	0.03
0.0095			0.26	0.0057	0.07
1070			1090	989	989
1070			1130	1080	989
0.23			0.26	0.09	<0.05
0.23			0.26	0.09	<0.05
1520			2770	3855	5140
1520			3020	4430	5140
4.5			4.4	2.8	2
4.5			4.4	2.8	2
1000			17.3	992	964
1000			17.3	992	964
0.4					
			0.82		
				1.47	1.89
132			272	453.5	796
132			286	600	796
6.9			7.2	7.5	7.4
6.9			7.5	7.6	7.4

Jul	Aug	Sep	Oct	Nov	Dec
	16.7		8.24		
	19.6		8.78		
0.148	0.258	0.019	0.1117		
0.005	0.008	0.0006	0.0036		
0.127	0.173	0.0047	0.0047		
	1052.5		1092.5		
	1110		1220		
	0.213		0.192		
	0.213		0.192		
	2835		2580		
	2870		2590		
	3.2		3.2		
	3.2		3.2		
	880		1010		
	880		1010		

	0.7		0.61	
	173		192	
	182		202	
	7.3		7.2	
	7.4		7.3	

Jul	Aug	Sep	Oct	Nov	Dec
10.9		231.5		42.1	38.4
10.9		338		46.8	38.4
0.006		1.03		0.27	0.008
0.0003		0.03		0.01	0.0003
0.005		0.13		0.024	0.0005
1160		717.5		708.5	1210
1160		912		727	1210
0.251		0.098		0.112	0.342
0.251		0.098		0.112	0.342
1820		6210		3495	8420
1820		7190		3910	8420
3.2		7.6		8	3.6
3.2		7.6		8	3.6
966		486		676	1100
966		486		676	1100
0.42		4.25			
				1.47	2.69
102		1034.5		521	1120
102		1240		572	1120
7.1		6.6		7.1	7
7.1		6.7		7.1	7

Jul	Aug	Sep	Oct	Nov	Dec
24.3		18.2	12	13	
24.6		18.2	13.9	13.7	
0.045		0.07	0.16	0.085	
0.002		0.0023	0.0053	0.0028	
0.007		0.017	0.019	0.0068	
1045		990	954	1100	

1120	990	1010	1170
0.0612	<0.050	<0.050	<0.050
0.0612	<0.050	<0.050	<0.050
4190	4290	4450	5615
4360	4290	4460	6130
<1	1.6	<1	<1
<1	1.6	<1	<1
879	834	928	874
879	834	928	874
1.16	1.17		
		1.16	
			1.75
330	424	406.5	669.5
378	424	432	745
7.1	6.76	7.13	7.11
7.3	7.2	7.26	7.39

Jul	Aug	Sep	Oct	Nov	Dec
13.6	9.69			30.65	33.7
15.2	10.3			50.5	33.7
0.045	0.04			0.057	0.0007
0.0014	0.0013			0.0019	0.00005
0.011	0.015			0.0029	0.0001
891.5	1110			935	1210
932	1120			953	1210
0.0682	<0.050			<0.050	2
0.0682	<0.050			<0.050	2
941.5	944			2240	2720
1130	1150			2580	2720
1.2	2.8			<1	7.6
1.2	2.8			<1	7.6
700	976			807	1010
700	976			807	1010
0.35	0.28				
				0.96	0.84
67.35	50.8			171.5	217
81.6	56.3			219	217
7	7			6.5	6.8
7.2	7			6.8	6.8

Jul	Aug	Sep	Oct	Nov	Dec
14	10	3.9	2.7	3.1	
16	17	3.9	3.7	3.3	
0.12	0.12	2.8	2.4	0.024	0
0.004	0.004	0.093	0.077	0.0008	0
0.03	0.03	0.17	0.14	0.0047	0
923	935	1080	1160	1120	
968	1030	1080	1230	1170	
0.9	0.5	0.2	0.2	0.2	
0.9	0.5	0.2	0.2	0.2	
235	184	185	105	168	
269	263	185	130	169	
5	2	2	2	2	
5	2	2	2	2	
692	735	863	886	814	
692	735	863	886	814	
0.2	0.21	0.09			
			0.07		
				0.09	
34	27	27	17	34	
34	42	27	21	36	
7.1	6.9	7.2	6.8	6.7	
7.1	7.2	7.2	6.9	7.1	

Jul	Aug	Sep	Oct	Nov	Dec
3.18	4.84				
3.85	5.56				
0.1	0.129			0	
0.003	0.004			0	
0.013	0.01			0	
907	1070				
1000	1080				
0.9	0.2				
0.9	0.2				
285	111				
347	116				
2	2				
2	2				
645	838				
645	838				

0.1	0.08		
21.7	13		
30.4	<20		
7	7.3		
7.3	7.4		

Jul	Aug	Sep	Oct	Nov	Dec
14.3	5.6			16.5	
20.3	6.2			17.6	
0.16	0.0072			0.0042	
0.0057	0.0003			0.0001	
0.058	0.0023			0.0005	
1120	1240			1200	
1160	1280			1210	
0.52	0.3			<.1	
0.52	0.3			<.1	
1000	201			2490	
1590	225			2690	
4.4	3			1	
4.4	3			1	
951	928			979	
951	928			979	
0.43	0.08				
				0.8	
50.4	12.5			252	
78.6	14.5			283	
7.2	6.9			7	
7.3	7.3			7	

Jul	Aug	Sep	Oct	Nov	Dec
10.4	7.2	6.4	6.2	5.3	
11.3	9.2	6.8	6.7	5.4	
0.329	0.032	0.021	0.062	0.071	
0.0106	0.001	0.0007	0.002	0.0024	
0.0676	0.0081	0.0029	0.0057	0.0037	
752	1050	1220	1080	980	

782	1110	1230	1170	1040
0.1	0.6	0.1	<.1	0.4
0.1	0.6	0.1	<.1	0.4
920	563	281	352	594
1020	715	313	433	636
10	2.4	5	4	2
10	2.4	5	4	2
622	790	975	922	856
622	790	975	922	856
0.25	0.42	0.11		
			0.15	
				0.18
46.1	110	18.2	28.4	55.5
51.7	204	21.8	37.8	55.9
7	6.9	7.5	7.1	7.5
7.1	7.3	7.6	7.7	7.5

Jul	Aug	Sep	Oct	Nov	Dec
6.2	6.2	5.3	4.5		
6.5	6.6	5.5	4.8		
0.12	0.032	0.045	0.0036		
0.0039	0.001	0.0015	0.00011		
0.024	0.0057	0.0081	0.00052		
868	1050	1010	1020		
898	1080	1040	1030		
0.2	0.1	0.2	<.1		
0.2	0.1	0.2	<.1		
843	319	288	354		
1120	337	322	396		
2	3	7	<1		
2	3	7	<1		
727	779	789	856		
727	779	789	856		
0.22	0.11	0.1			
			0.1		
31	17.6	15.1	17.2		
38.8	19.4	16.4	18.6		
7.7	7.5	7.6	8.1		
7.7	7.7	7.6	8.1		

Jul	Aug	Sep	Oct	Nov	Dec
5.5	4.5				
7.3	4.9				
0.19	0.16				
0.01	0.01				
0.04	0.02				
949	990				
964	1030				
0.16	0.1				
0.16	0.1				
721	247				
1270	315				
1.6	1.2				
1.6	1.2				
769	682				
802	682				
0.24	0.09				
17	<12				
36	<12				
7.4	7.9				
7.8	8				

Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						
Copper, Total (as Cu)	ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMax						
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg						
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Nickel, Total (as Ni)	ug/L	CalMoAvg						
Nickel, Total (as Ni)	ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Sulfate, Total (as SO4)	mg/L	CalMoAvg						
Sulfate, Total (as SO4)	mg/L	CalMoMax						
Toxicity, Final Conc	1.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						
Zinc, Total (as Zn)	ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2001 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2.0	<2.0	<2.0	<2	<2	<2
Copper, Total (as Cu)	ug/L	CalMoMax	<2.0	<2.0	<2.0	<2	<2	<2
Flow	MG	CalMoTot	2.263	2.8	0.217	5.73	6.62	3.96
Flow	mgd	CalMoAvg	0.073	0.1	0.007	0.191	0.2134	0.132
Flow	mgd	CalMoMax	0.073	0.1	0.007	0.191	0.5011	0.2189
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1760	1800	1860	1620	442	812
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax	1760	1800	1860	1620	442	812
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.14	0.25	0.21	0.03	0.19	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.14	0.25	0.21	0.03	0.19	0.1
Nickel, Total (as Ni)	ug/L	CalMoAvg	5.7	6.7	4.7	7.3	59.6	28.4
Nickel, Total (as Ni)	ug/L	CalMoMax	5.7	6.7	4.7	7.3	59.6	28.4
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	6.8	4.4	41.2	1.2	3.2	3.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	6.8	4.4	41.2	1.2	3.2	3.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1700	1770	1630	1500	398	898
Sulfate, Total (as SO4)	mg/L	CalMoMax	1700	1770	1630	1500	398	898
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.0006	0.0007	0.0001	0.03	0.03496	0.03427

Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	<10	<10	<10	<10	12.4
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	<10	<10	<10	<10	12.4
pH	6.5 SU	CalMoMin	7.4	7.4	7.5	7.6	7.6	7.6
pH	8.5 SU	CalMoMax	7.4	7.4	7.5	7.6	7.6	7.6

Year 2002 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2	<1	<2	<2	<2	<2
Copper, Total (as Cu)	ug/L	CalMoMax	<2	<1	<2	<2	<2	<2
Flow	MG	CalMoTot	0.3829	0.902	1.6771	0.261	2.48	1.88
Flow	mgd	CalMoAvg	0.0213	0.0322	0.0541	0.009	0.08	0.0625
Flow	mgd	CalMoMax	0.0237	0.0353	0.0353	0.2494	0.271	0.2092
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg	1700	2460	2070	2110	748	916
& Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoMax	1700	2460	2070	2110	748	916
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.19	0.28	0.26	0.29	0.07	0.18
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.19	0.28	0.26	0.29	0.07	0.18
Nickel, Total (as Ni)	ug/L	CalMoAvg	12	10.6	8.9	38.7	42.1	31.7
Nickel, Total (as Ni)	ug/L	CalMoMax	12	10.6	8.9	38.7	42.1	31.7
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5.6	<1	9.6	2.8	<1	3.6
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	5.6	<1	9.6	2.8	<1	3.6
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1820	2090	2370	2220	650	874
Sulfate, Total (as SO4)	mg/L	CalMoMax	1820	2090	2370	2220	650	874
Toxicity, Final Conc	1.00 toxunt	CalMoMax	<0.0296	<0.0218	<0.0292	0.05	<0.0331	<0.0319
Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	<10	<10	25	<10	<10
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	<10	<10	25	<10	<10
pH	6.5 SU	CalMoMin	7	7.3	7.3	7	7.6	7.2
pH	8.5 SU	CalMoMax	7	7.3	7.3	7	7.6	7.2

Year 2003 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2		8.8	<2	14.3	2.2
Copper, Total (as Cu)	ug/L	CalMoMax	<2		8.8	<2	14.3	2.2
Flow	MG	CalMoTot	0.54			6.23	7.32	2.48
Flow	mgd	CalMoAvg	0.0174			0.2007	0.236	0.0826
Flow	mgd	CalMoMax	0.0353			0.3056	0.3961	0.2189
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg	2180		679	1500	728	896
& Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoMax	2180		679	1500	728	896
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.14		0.24	0.42	0.26	0.14
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.14		0.24	0.42	0.26	0.14
Nickel, Total (as Ni)	ug/L	CalMoAvg	6.6		111	32.3	22.9	23.3
Nickel, Total (as Ni)	ug/L	CalMoMax	6.6		111	32.3	22.9	23.3

Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	4	3.6	20.5	1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	4	3.6	20.5	1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1880	505	1340	476	962
Sulfate, Total (as SO4)	mg/L	CalMoMax	1880	505	1340	476	962
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.03	0.1	0.03	0.12	0.03
Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	15.7	<10	<10	<10
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	15.7	<10	<10	<10
pH	6.5 SU	CalMoMin	7.6	7.2	7.4	7.3	7.6
pH	8.5 SU	CalMoMax	7.6	7.2	7.4	7.3	7.6

Year 2004 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	4.7	<2	<2	5.5	7.3	<2
Copper, Total (as Cu)	ug/L	CalMoMax	4.7	<2	<2	5.5	7.3	<2
Flow	MG	CalMoTot	3.48	1.64	2.46	7.61	13.6	2.6
Flow	mgd	CalMoAvg	0.11	0.057	0.0798	0.2507	0.434	0.09
Flow	mgd	CalMoMax	0.15	0.1489	0.083	0.2938	0.678	0.1567
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	1810	2270	2210	807	622	915
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1810	2270	2210	807	622	915
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.19	0.08	0.13	0.21	0.13	0.08
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.19	0.08	0.13	0.21	0.13	0.08
Nickel, Total (as Ni)	ug/L	CalMoAvg	80.7	19.2	15.6	317	92.8	98
Nickel, Total (as Ni)	ug/L	CalMoMax	80.7	19.2	15.6	317	92.8	98
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2	2	4	1	7.2	3
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2	2	4	1	7.2	3
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2090	2300	2140	800	569	1010
Sulfate, Total (as SO4)	mg/L	CalMoMax	2090	2300	2140	800	569	1010
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.06	0.03	0.03	0.09	0.08	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	<10	<10	<10	<10	<10
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	<10	<10	<10	<10	<10
pH	6.5 SU	CalMoMin	7.4	7.4	7.4	7.3	7.23	7.6
pH	8.5 SU	CalMoMax	7.4	7.4	7.4	7.3	7.23	7.6

Year 2005 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	12.7	<2	2.5	10.5	6.5	2.5
Copper, Total (as Cu)	ug/L	CalMoMax	12.7	<2	2.5	10.5	6.5	2.5
Flow	MG	CalMoTot	3.85	2.019	0.25	5.97	5.5	9.93
Flow	mgd	CalMoAvg	0.1226	0.0777	0.0081	0.226	0.18	0.333
Flow	mgd	CalMoMax	0.1489	0.0777	0.0081	0.356	0.32	0.603
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1960	2020	1840	253	887	746

Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1960	2020	1840	253	887	746
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.26	0.3	0.23	0.32	0.03	0.11
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.26	0.3	0.23	0.32	0.03	0.11
Nickel, Total (as Ni)	ug/L	CalMoAvg	36.4	45.5	49.7	101	82.1	92.5
Nickel, Total (as Ni)	ug/L	CalMoMax	3.64	45.5	49.7	101	82.1	92.5
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	6.4	5.2	1.6	<1	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	6.4	5.2	1.6	<1	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2060	2060	1790	131	782	704
Sulfate, Total (as SO4)	mg/L	CalMoMax	2060	2060	1790	131	782	704
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.11	0.03	0.04	0.16	0.09	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	<10	<10	<10	<25	<10
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	<10	<10	<10	<25	<10
pH	6.5 SU	CalMoMin	7.6	7.5	6.62	7.3	7.6	6.6
pH	8.5 SU	CalMoMax	7.6	7.5	6.62	7.3	7.6	6.6

Year 2006 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	4.9	<2		9.6	<2	<2
Copper, Total (as Cu)	ug/L	CalMoMax	4.9	<2		9.6	<2	<2
Flow	MG	CalMoTot	9.47	10.2		8.47	6.76	1.64
Flow	mgd	CalMoAvg	0.31	0.36		0.28	0.22	0.05
Flow	mgd	CalMoMax	0.31	0.38		0.28	0.93	0.13
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium)	mg/L	CalMoAvg	1810	1980		438	802	947
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1810	1980		438	802	947
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.12	0.29		0.36	0.05	0.33
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.12	0.29		0.36	0.05	0.33
Nickel, Total (as Ni)	ug/L	CalMoAvg	241	72.6		198	83	74.7
Nickel, Total (as Ni)	ug/L	CalMoMax	241	72.6		198	83	74.7
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	4.4	3.6		<1	1.6	5.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	4.4	3.6		<1	1.6	5.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1900	1950		417	775	1020
Sulfate, Total (as SO4)	mg/L	CalMoMax	1900	1950		417	775	1020
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.1	0.04		0.13	0.06	0.06
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25	<10		<25	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25	<10		<25	<25	<25
pH	6.5 SU	CalMoMin	7.3	7.4		7.6	6.9	7
pH	8.5 SU	CalMoMax	7.3	7.4		7.6	6.9	7

Year 2007 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			<2	7.74	<2	4.2

Copper, Total (as Cu)	ug/L	CalMoMax		<2	7.74	<2	4.2
Flow	MG	CalMoTot		0.794	13.76	4.7	5.3
Flow	mgd	CalMoAvg		0.026	0.46	0.17	0.18
Flow	mgd	CalMoMax		0.054	0.72	0.62	0.36
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg		1740	343	566	515
Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax		1740	343	566	515
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg		0.207	0.423	0.18	0.194
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax		0.207	0.423	0.18	0.194
Nickel, Total (as Ni)	ug/L	CalMoAvg		85.4	56	58.3	51.5
Nickel, Total (as Ni)	ug/L	CalMoMax		85.4	56	58.3	51.5
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg		5.6	14	2	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax		5.6	14	2	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg		1810	306	454	453
Sulfate, Total (as SO4)	mg/L	CalMoMax		1810	306	454	453
Toxicity, Final Conc	1.00 toxunt	CalMoMax		0.06	0.11	0.05	0.07
Zinc, Total (as Zn)	ug/L	CalMoAvg		<25	<25	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax		<25	<25	<25	<25
pH	6.5 SU	CalMoMin		7.2	7	7.2	7.4
pH	8.5 SU	CalMoMax		7.7	7	7.2	7.4

Year 2008 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	2.4	2.2		<2	6.9	2.67
Copper, Total (as Cu)	ug/L	CalMoMax	2.4	2.2		<2	6.9	2.67
Flow	MG	CalMoTot	2.06	0.64		14.57	13.3	19.6
Flow	mgd	CalMoAvg	0.07	0.02		0.49	0.46	0.69
Flow	mgd	CalMoMax	0.11	0.07		0.82	0.81	1.2
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1880	2110		1440	327	753
Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1880	2110		1440	327	753
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.718	0.885		1.05	0.169	0.346
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.718	0.885		1.05	0.169	0.346
Nickel, Total (as Ni)	ug/L	CalMoAvg	216	63		142	203	145
Nickel, Total (as Ni)	ug/L	CalMoMax	216	63		142	203	145
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.2	4		1	<1	2.5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.2	4		1	<1	2.5
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1910	2050		1400	297	737
Sulfate, Total (as SO4)	mg/L	CalMoMax	1910	2050		1400	297	737
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.07	0.06		0.06	0.13	0.07
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25	<25		<25	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25	<25		<25	<25	<25
pH	6.5 SU	CalMoMin	7.3	7.2		6.6	6.5	6.8
pH	8.5 SU	CalMoMax	7.3	7.2		6.6	6.5	6.8

Year 2009 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2	<2		4.73	8.3	12.2
Copper, Total (as Cu)	ug/L	CalMoMax	<2	<2		4.73	8.3	12.2
Flow	MG	CalMoTot	3.8	2.27		5.3	22	18
Flow	mgd	CalMoAvg	0.12	0.081		0.18	0.72	0.58
Flow	mgd	CalMoMax	0.16	0.094		0.27	1	1.2
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	2120	2310		940	362	699
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2120	2310		940	362	699
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.193	0.112		0.357	0.185	0.144
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.193	0.112		0.357	0.185	0.144
Nickel, Total (as Ni)	ug/L	CalMoAvg	176	80		249	106	92.4
Nickel, Total (as Ni)	ug/L	CalMoMax	176	80		249	106	92.4
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	2		1.2	<1	7
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	2		1.2	<1	7
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1880	2080		840	316	658
Sulfate, Total (as SO4)	mg/L	CalMoMax	1880	2080		840	316	658
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.07	0.06		0.1	0.12	0.14
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25	<25		<25	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25	<25		<25	<25	<25
pH	6.5 SU	CalMoMin	6.56	6.52		6.68	6.85	6.6
pH	8.5 SU	CalMoMax	6.56	6.52		6.68	6.85	6.6

Year 2010 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	2.6	1.5	4.6	1.4	1.82	1.3
Copper, Total (as Cu)	ug/L	CalMoMax	2.6	1.5	4.6	1.4	1.82	1.3
Flow	MG	CalMoTot	0.73	0.53	7.27	1.43	0.74	0.75
Flow	mgd	CalMoAvg	0.024	0.02	0.23	0.05	0.02	1.3
Flow	mgd	CalMoMax	0.024	0.02	0.45	0.06	0.03	1.3
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1980	2190	681	734	1110	892
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1980	2190	681	734	1110	892
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.23	0.2	0.2	0.2	0.08	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.23	0.2	0.2	0.2	0.08	0.1
Nickel, Total (as Ni)	ug/L	CalMoAvg	27.9	8	74.4	75.2	60.8	36
Nickel, Total (as Ni)	ug/L	CalMoMax	27.9	8	74.4	75.2	60.8	36
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	13.6	5.2	1.6	<1	2.5	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	13.6	5.2	1.6	<1	2.5	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1950	2060	556	651	971	805
Sulfate, Total (as SO4)	mg/L	CalMoMax	1950	2060	556	651	971	805
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.03	0.03	0.05	0.03	0.03	0.02

Zinc, Total (as Zn)	ug/L	CalMoAvg	6.9	11.2	<6	<6.0	8.22	<6
Zinc, Total (as Zn)	ug/L	CalMoMax	6.9	11.2	<6	<6.0	8.22	<6
pH	6.5 SU	CalMoMin	6.5	6.5	6.7	6.5	7	6.7
pH	8.5 SU	CalMoMax	6.5	6.5	6.7	6.5	7	6.7

Year 2011 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	1.3			8.2	4.1	1.2
Copper, Total (as Cu)	ug/L	CalMoMax	1.3			8.2	4.1	1.2
Flow	MG	CalMoTot	0.23	0	0	4.1	3.3	3.23
Flow	mgd	CalMoAvg	0.0074	0	0	0.14	0.11	0.11
Flow	mgd	CalMoMax	0.012	0	0	0.21	0.16	0.16
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg	1950			636	619	1340
& Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoMax	1950			636	619	1340
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.1			0.2	0.1	0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.1			0.2	0.1	0.2
Nickel, Total (as Ni)	ug/L	CalMoAvg	13			139	117	39
Nickel, Total (as Ni)	ug/L	CalMoMax	13			139	117	39
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2			2	2	3
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2			2	2	3
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1660			557	534	1210
Sulfate, Total (as SO4)	mg/L	CalMoMax	1660			557	534	1210
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.02			0.09	0.05	0.02
Zinc, Total (as Zn)	ug/L	CalMoAvg	6.5			6.4	<6	<6
Zinc, Total (as Zn)	ug/L	CalMoMax	6.5			6.4	<6	<6
pH	6.5 SU	CalMoMin	6.7			7	7.1	6.9
pH	8.5 SU	CalMoMax	6.7			7	7.1	6.9

Year 2012 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			7.7	3.4	4.3	6.1
Copper, Total (as Cu)	ug/L	CalMoMax			7.7	3.4	4.3	6.1
Flow	MG	CalMoTot			1.97	2.23	5.16	6.09
Flow	mgd	CalMoAvg			0.06	0.074	0.167	0.2
Flow	mgd	CalMoMax			0.13	0.26	0.551	0.56
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg			2090	1010	905	440
& Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoMax			2090	1010	905	440
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.3	0.08	<.1	0.14
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.3	0.08	<.1	0.14
Nickel, Total (as Ni)	ug/L	CalMoAvg			55.3	39.7	55.4	74.1
Nickel, Total (as Ni)	ug/L	CalMoMax			55.3	39.7	55.4	74.1

Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg		2	2.4	2.4	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax		2	2.4	2.4	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg		1860	928	786	408
Sulfate, Total (as SO4)	mg/L	CalMoMax		1860	928	786	408
Toxicity, Final Conc	1.00 toxunt	CalMoMax		0.09	0.04	0.05	0.06
Zinc, Total (as Zn)	ug/L	CalMoAvg		16.7	7	<6	<6
Zinc, Total (as Zn)	ug/L	CalMoMax		16.7	7	<6	<6
pH	6.5 SU	CalMoMin		6.7	7	7	7.2
pH	8.5 SU	CalMoMax		6.7	7	7	7.2

Year 2013 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	7.8			4.2	3.9	3.8
Copper, Total (as Cu)	ug/L	CalMoMax	7.8			4.2	3.9	3.8
Flow	MG	CalMoTot	0.115			2.55	5.95	3.04
Flow	mgd	CalMoAvg	0.0037			0.091	0.192	0.101
Flow	mgd	CalMoMax	0.0081			0.12	0.382	0.282
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	2750			1880	465	624
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2750			1880	465	624
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.116			0.2	0.2	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.116			0.2	0.2	0.1
Nickel, Total (as Ni)	ug/L	CalMoAvg	16.4			9.3	63.3	87.8
Nickel, Total (as Ni)	ug/L	CalMoMax	16.4			9.3	63.3	87.8
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	6			4	5	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	6			4	5	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2710			1700	437	610
Sulfate, Total (as SO4)	mg/L	CalMoMax	2710			1700	437	610
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.07			0.04	0.04	0.05
Zinc, Total (as Zn)	ug/L	CalMoAvg	8.4			<6	<6	<6
Zinc, Total (as Zn)	ug/L	CalMoMax	8.4			<6	<6	<6
pH	6.5 SU	CalMoMin	6.8			6.5	6.7	6.5
pH	8.5 SU	CalMoMax	6.8			6.5	6.7	6.5

Year 2014 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	7.8	8.5	4.3	5.8	8	4
Copper, Total (as Cu)	ug/L	CalMoMax	7.8	8.5	4.3	5.8	8	4
Flow	MG	CalMoTot	0.66	0.035	0.079	3.9	9	4.6
Flow	mgd	CalMoAvg	0.021	0.0013	0.0028	0.14	0.29	0.15
Flow	mgd	CalMoMax	0.032	0.0029	0.0081	0.29	0.47	0.32
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1960	2190	2310	1950	412	779
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax	1960	2190	2310	1950	412	779

Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.2	0.1	0.1	0.1	0.2	0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.2	0.1	0.1	0.1	0.2	0.2
Nickel, Total (as Ni)	ug/L	CalMoAvg	10.1	4	12.3	7.4	146	113
Nickel, Total (as Ni)	ug/L	CalMoMax	10.1	4	12.3	7.4	146	113
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	14	<1	7	2	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	14	<1	7	2	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1990	1870	2100	1760	365	734
Sulfate, Total (as SO4)	mg/L	CalMoMax	1990	1870	2100	1760	365	734
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.08	0.08	0.04	0.05	0.09	0.06
Zinc, Total (as Zn)	ug/L	CalMoAvg	<12	<12	<6	<12	<12	<12
Zinc, Total (as Zn)	ug/L	CalMoMax	<12	<12	<6	<12	<12	<12
pH	6.5 SU	CalMoMin	6.5	7	6.9	6.9	6.6	6.8
pH	8.5 SU	CalMoMax	6.9	7	7.1	7.2	7.7	7.7

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			9	3.3	2.5	2.3
Copper, Total (as Cu)	ug/L	CalMoMax			9	3.3	2.5	2.3
Flow	MG	CalMoTot			0.37	3.7	3.4	3.7
Flow	mgd	CalMoAvg			0.012	0.12	0.11	0.12
Flow	mgd	CalMoMax			0.047	0.18	0.24	0.32
Hardness, Calcium & Magnesium, Calculated (as CaCO3)	mg/L	CalMoAvg			508	933	771	666
Hardness, Calcium & Magnesium, Calculated (as CaCO3)	mg/L	CalMoMax			508	933	771	666
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.2	0.3	0.07	<05
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.2	0.3	0.07	<05
Nickel, Total (as Ni)	ug/L	CalMoAvg			102	50.8	52	54
Nickel, Total (as Ni)	ug/L	CalMoMax			102	50.8	52	54
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg			<1	<1	1.2	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax			<1	<1	1.2	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg			465	894	661	564
Sulfate, Total (as SO4)	mg/L	CalMoMax			465	894	661	564
Toxicity, Final Conc	1.00 toxunt	CalMoMax			0.1	0.05	0.04	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg			<12	<12	<12	<12
Zinc, Total (as Zn)	ug/L	CalMoMax			<12	<12	<12	<12
pH	6.5 SU	CalMoMin			7	6.5	7.2	7.2
pH	8.5 SU	CalMoMax			7	7.2	7.2	7.2

Jul	Aug	Sep	Oct	Nov	Dec
	<2.0	<2.0	<2.0	<2.0	<2.0
	<2.0	<2.0	<2.0	<2.0	<2.0
	7.07	15.15	5.58	5.22	0.899
	0.228	0.505	0.18	0.174	0.029
	0.697	1.502	0.454	0.282	0.029
	895	506	863	925	1130
	980	631	863	925	1130
	0.23	0.24	0.2	0.18	0.33
	0.29	0.28	0.2	0.18	0.33
	7	14.5	12.3	7.6	20.4
	8.5	16.7	12.3	7.6	20.4
	4.4	5.6	<1.0	2.8	3.5
	6	6.7	<1.0	2.8	3.6
	793	708	929	822	1150
	858	724	929	822	1150
	0.03	0.002	0.001	0.001	0.002
	10.2	<10	<1.0	<10	<10
	20.4	<10	<1.0	<10	<10
	7.4	7.6	7.5	7.5	7.5
	7.5	7.6	7.5	7.5	7.5

Jul	Aug	Sep	Oct	Nov	Dec
<2	3.6	<2	<2	<2	<2
<2	3.6	<2	<2	<2	<2
2.49	4.2	3.94	11.74	7.7	1.23
0.08	0.1356	0.1313	0.3787	0.2567	0.0396
0.382	0.4696	0.1818	0.5853	0.5011	0.0676
1030	845	1350	1420	1340	1350
1030	845	1350	1420	1340	1350
0.4	0.24	0.26	0.07	0.05	0.07
0.4	0.24	0.26	0.07	0.05	0.07
9.3	17.6	12.7	5.8	43.7	55.3
9.3	17.6	12.7	5.8	43.7	55.3
5.2	8.8	5.2	4	1.6	1.6
5.2	8.8	5.2	4	1.6	1.6
1290	930	1350	1510	1360	1290
1290	930	1350	1510	1360	1290
<0.029	<0.0424	<0.0299	<0.0289	<0.0330	<0.0343

<10	<10	10.2	<10	<10	<10
<10	<10	10.2	<10	<10	<10
7.3	7.3	7.4	7.6	7.2	7.4
7.3	7.3	7.4	7.6	7.2	7.4

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	<2	<2	21.7
<2	<2	<2	<2	<2	21.7
0.58	1.8	1.26	4.76	3.39	1.43
0.0187	0.058	0.0421	0.1535	0.1131	0.046
0.0777	0.1907	0.083	0.2189	0.1131	0.046
1140	1210	1280	1200	1330	1620
1140	1210	1280	1200	1330	1620
0.41	0.11	0.11	<0.03	0.5	0.26
0.41	0.11	0.11	<0.03	0.5	0.26
18.6	12.9	14.8	21	27.9	13.8
18.6	12.9	14.8	21	27.9	13.8
4.7	1.3	<1	2	4.5	3.2
4.7	1.3	<1	2	4.5	3.2
850	1050	1090	3310	1210	1520
850	1050	1090	3310	1210	1520
<0.0316	<0.0299	<0.0372	0.05	0.03	0.19
10.8	<10	15.4	<10	<10	13.5
10.8	<10	15.4	<10	<10	13.5
7.2	7.2	7.3	7.2	7.8	7.3
7.2	7.2	7.3	7.2	7.8	7.3

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	<2	<2	<2
<2	<2	<2	<2	<2	<2
1.35	2.99	5.09	7.35	8.68	3.31
0.0435	0.0966	0.1696	0.2372	0.2893	0.107
0.0944	0.1267	0.4392	0.3177	0.4102	0.107
791	861	1500	991	1190	1420
791	861	1500	991	1190	1420
0.22	0.19	0.1	0.05	0.11	0.23
0.22	0.19	0.1	0.05	0.11	0.23
19.1	11.2	7.8	78.3	121	184
19.1	11.2	7.8	78.3	121	184

1.6	30	2	<1	1.2	<1
1.6	30	2	<1	1.2	<1
877	805	1480	1020	1220	1340
877	805	1480	1020	1220	1340
0.03	0.03	0.03	0.04	0.04	0.05
11	<10	<10	<10	<10	<10
11	<10	<10	<10	<10	<10
7.3	7.34	7.8	7.5	7.2	7.4
7.3	7.34	7.8	7.5	7.2	7.4

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	<2	<2	<2
<2	<2	<2	<2	<2	<2
0.85	0.49	2.49	2.34	1.932	0.99
0.0284	0.016	0.09	0.082	0.0741	0.035
0.0676	0.046	0.26	0.107	0.1412	0.035
1370	1920	1880	1420	1320	1800
1370	1920	1880	1420	1320	1800
0.24	0.17	0.09	0.05	0.04	0.41
0.24	0.17	0.09	0.05	0.04	0.41
49.3	21.8	26.7	17.7	53.6	63.8
49.3	21.8	26.7	17.7	53.6	63.8
3.5	2.5	6	3	<1	4.5
3.5	2.5	6	3	<1	4.5
1350	1670	1910	1680	1320	1820
1350	1670	1910	1680	1320	1820
0.07	0.03	0.03	0.03	0.03	0.04
39.1	<10	<10	<10	<10	<10
39.1	<10	<10	<10	<10	<10
7.5	6.7	6.8	7.5	8.09	7.5
7.5	6.7	6.8	7.5	8.09	7.5

Jul	Aug	Sep	Oct	Nov	Dec
3.5	<2	2	<2	<2	<2
3.5	<2	2	<2	<2	<2
1.09	2.35	5.78	11.3	15	16.55
0.035	0.082	0.21	0.369	0.5	0.534
0.094	0.149	0.356	0.98	0.5	0.534
1290	1680	1830	1820	1610	1180

1290	1680	1830	1820	1610	1180
0.12	0.2	0.23	0.08	0.08	0.25
0.12	0.2	0.23	0.08	0.08	0.25
2	31.8	25	39.8	49.9	201
2	31.8	25	39.8	49.9	201
2	8	<1	4.4	4	2
2	8	<1	4.4	4	2
1350	1600	1680	1700	1640	1130
1350	1600	1680	1700	1640	1130
0.04	0.05	0.05	0.07	0.05	0.05
<10	<25	<25	37.9	<25	<10
<10	<25	<25	37.9	<25	<10
6.5	6.8	6.5	7.1	7	7.4
6.5	6.8	6.5	7.1	7	7.4

Jul	Aug	Sep	Oct	Nov	Dec
3.9	<2	9.5	5.1	<2	<2
3.9	<2	9.5	5.1	<2	<2
0.556	4.47	0.42	3.98	0.759	0.62
0.018	0.144	0.014	0.1284	0.0253	0.02
0.078	0.2	0.026	0.2092	0.0291	0.021
1616	1400	1560	1710	1710	2090
1616	1400	1560	1710	1710	2090
0.2	0.349	0.234	0.146	0.203	0.924
0.2	0.349	0.234	0.146	0.203	0.924
35	38.3	15.3	23.1	70.1	58.6
35	38.3	15.3	23.1	70.1	58.6
1.6	4	12	6	2.8	<1
1.6	4	12	6	2.8	<1
1250	1300	1400	1560	1570	2150
1250	1300	1400	1560	1570	2150
0.07	0.05	0.11	0.07	0.06	0.05
<25	<25	<25	<25	<25	<25
<25	<25	<25	<25	<25	<25
7.1	7.2	7.1	7.2	7.1	7.2
7.1	7.2	7.1	7.2	7.1	7.2

Jul	Aug	Sep	Oct	Nov	Dec
5.7	<2	27.4	16	5.04	<2

5.7	<2	27.4	16	5.04	<2
5.82	0.21	2.06	4.64	1.8	3.28
0.196	0.009	0.07	0.16	0.063	0.11
0.282	0.06	0.07	0.19	0.078	0.13
1530	1860	521	504	1100	1810
1530	1860	521	504	1100	1810
0.275	0.25	0.226	0.58	0.443	1.44
0.275	0.25	0.226	0.58	0.443	1.44
26.6	10.7	142	161	284	124
26.6	10.7	142	161	284	124
4.4	6.4	2	4	10	3.6
4.4	6.4	2	4	10	3.6
1380	2210	502	39.4	986	1720
1380	2210	502	39.4	986	1720
0.08	0.05	0.26	0.18	0.1	0.06
<25	<25	<25	27.6	<25	<25
<25	<25	<25	27.6	<25	<25
6.8	6.9	7.4	7.2	7.4	7.3
6.8	6.9	7.4	7.2	7.4	7.3

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	2.12	<2	<2	<2
<2	<2	2.12	<2	<2	<2
5.2	0.37	3	5.9	6.8	7.49
0.18	0.013	0.1	0.19	0.23	0.24
0.21	0.029	0.13	0.24	0.29	0.26
1190	1950	2130	1720	1600	1780
1190	1950	2130	1720	1600	1780
0.215	0.195	0.299	0.0742	0.0524	1
0.215	0.195	0.299	0.0742	0.0524	1
87.8	57.6	44.5	87.3	144	189
87.8	57.6	44.5	87.3	144	189
1.2	2	4.7	2	2	2.8
1.2	2	4.7	2	2	2.8
1140	1840	2060	1680	1430	1570
1140	1840	2060	1680	1430	1570
0.06	0.05	0.05	0.06	0.07	0.07
<25	<25	<25	<25	27.3	<25
<25	<25	<25	<25	27.3	<25
6.6	6.6	6.62	7.02	6.95	6.6
6.6	6.6	6.62	7.02	6.95	6.6

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	2.61	<2	1.7
<2	<2	<2	2.61	<2	1.7
1.3	0.98	0.6	1.99	5.18	0.59
0.043	0.032	0.019	0.064	0.17	0.021
0.05	0.05	0.026	0.068	0.22	0.032
1030	1290	1580	1650	1260	1630
1030	1290	1580	1650	1260	1630
0.122	0.104	0.13	0.064	0.0608	0.336
0.122	0.104	0.13	0.064	0.0608	0.336
62.1	49.7	29.8	30.4	61.9	89.1
62.1	49.7	29.8	30.4	61.9	89.1
2	4	2	2.8	3.5	1.6
2	4	2	2.8	3.5	1.6
1010	1270	1540	1590	1290	1550
1010	1270	1540	1590	1290	1550
0.06	0.05	0.05	0.06	0.06	0.03
<25	<25	27.2	<25	<25	6
<25	<25	27.2	<25	<25	6
6.6	6.6	6.7	6.5	7.1	6.5
6.6	6.6	6.7	6.5	7.1	6.6

Jul	Aug	Sep	Oct	Nov	Dec
1.1	1.1	1.3	2.5	1.3	1.2
1.1	1.1	1.3	2.5	1.3	1.2
1.4	2.2	0.79	2.3	0.95	0.73
0.05	0.07	0.026	0.073	0.032	0.024
0.06	0.13	0.063	0.094	0.045	0.024
1050	1000	1740	1300	1210	1700
1050	1000	1740	1300	1210	1700
0.1	0.1	0.2	0.06	0.1	0.3
0.1	0.1	0.2	0.06	0.1	0.3
29	24	18	28	47	36
29	24	18	28	47	36
1	<1	4	2	4	1
1	<1	4	2	4	1
939	988	1560	1150	1050	1420
939	988	1560	1150	1050	1420
0.02	0.02	0.02	0.03	0.02	0.03

<6	<6	<6	<6	<6	12
<6	<6	<6	<6	<6	12
7	7	7.1	6.6	6.5	6.7
7	7	7.1	6.6	6.5	6.7

Jul	Aug	Sep	Oct	Nov	Dec
0.7	3.8	5.35	4.6	8.1	6.08
0.7	3.8	5.35	4.6	8.1	6.08
1.4	0.33	0.03	0.56	0.5	0.192
0.05	0.01	0.001	0.02	0.02	0.006
0.06	0.02	0.007	0.04	0.03	0.007
1160	1280	1660	1700	1920	2600
1160	1540	1660	1700	1920	2600
0.4	0.2	0.1	<0.1	0.06	0.2
0.4	0.2	0.1	<0.1	0.06	0.2
39.6	10.6	19.7	21	33	11.1
39.6	10.6	19.7	21	33	11.1
4	3.2	4.4	4	4	10
4	3.2	4.4	4	4	10
1100	1340	1570	1650	1720	2450
1100	1340	1570	1650	1720	2450
0.02	0.06	0.05	0.05	0.09	0.06
<6	<20	7.2	6.8	16	9.61
<6	<20	7.2	6.8	16	9.61
7.3	7.3	7.1	7	6.9	6.7
7.3	7.3	7.1	7	6.9	6.7

Jul	Aug	Sep	Oct	Nov	Dec
3.6	6.6	7.6	7.1	7.5	5.6
3.6	6.6	7.6	7.1	7.5	5.6
4.22	0.83	0.23	1.13	0.87	0.565
0.14	0.03	0.0076	0.0376	0.029	0.018
0.27	0.13	0.017	0.12	0.035	0.042
1160	1630	1960	2160	1760	1670
1160	1630	1960	2160	1760	1670
0.87	0.2	0.1	0.121	<.1	0.117
0.87	0.2	0.1	0.121	<.1	0.117
53.9	19.4	7.4	17.4	117	120
53.9	19.4	7.4	17.4	117	120

3.6	1	6	5	4	4
3.6	1	6	5	4	4
1040	1450	1880	2060	1760	1720
1040	1450	1880	2060	1760	1720
0.04	0.06	0.07	0.07	0.08	0.06
<6	7.7	11.5	10.1	10.6	6.5
<6	7.7	11.5	10.1	10.6	6.5
7.1	6.9	7.4	7.2	6.8	7
7.1	6.9	7.4	7.2	6.8	7

Jul	Aug	Sep	Oct	Nov	Dec
3.4	3.2	3.4	5.4	5.1	8.3
3.4	3.2	3.4	5.4	5.1	8.3
4.78	1.2	0.71	1.3	0.74	0.51
0.154	0.04	0.024	0.041	0.025	0.017
0.534	0.16	0.058	0.13	0.029	0.021
670	763	1400	1720	1540	1820
670	763	1400	1720	1540	1820
0.1	0.1	0.2	0.1	0.1	0.3
0.1	0.1	0.2	0.1	0.1	0.3
52.2	31	10.7	9	52.1	78.2
52.2	31	10.7	9	52.1	78.2
1	2.8	7	3	4	<1
1	2.8	7	3	4	<1
565	695	1230	1580	1440	1760
565	695	1230	1580	1440	1760
0.04	0.04	0.04	0.05	0.05	0.08
6.9	<6	<6	<6	6.2	<12
6.9	<6	<6	<6	6.2	<12
6.9	6.8	6.7	6.9	6.7	6.5
6.9	6.8	6.8	7.5	7.6	7

Jul	Aug	Sep	Oct	Nov	Dec
3.6	4.5	5.8	4.7	4.6	3.8
3.6	4.5	5.8	4.7	4.6	3.8
1.8	0.42	0.95	0.89	0.54	3.2
0.058	0.014	0.032	0.029	0.018	0.1
0.13	0.032	0.1	0.047	0.026	0.15
979	1400	1590	1610	1670	2010
979	1400	1590	1610	1670	2010

0.1	0.5	0.4	0.1	<.1	0.4
0.1	0.5	0.4	0.1	<.1	0.4
82.5	37.9	27.8	15.7	50.6	44.2
82.5	37.9	27.8	15.7	50.6	44.2
<1	5	<3	3	5	5
<1	5	<3	3	5	5
908	1320	1390	1570	1620	1700
908	1320	1390	1570	1620	1700
0.05	0.05	0.06	0.05	0.09	0.05
<12	<12	<12	<12	34.1	<12
<12	<12	<12	<12	34.1	<12
6.7	6.8	6.5	7	6.7	6.6
7.3	7.4	7.1	7.6	7.4	6.6

Jul	Aug	Sep	Oct	Nov	Dec
2.9	4.2				
3.9	4.2				
3.9	1.5				
0.13	0.05				
0.61	0.17				
1144	1580				
1600	1580				
0.14	0.4				
0.14	0.4				
49	29				
56	29				
<1	1.6				
<1	1.6				
1007	1370				
1440	1370				
0.03	0.05				
<21	<12				
<30	<12				
6.9	7				
7.1	7				

Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						
Copper, Total (as Cu)	ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMax						
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg						
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Mercury, Total (as Hg)	ng/L	SingleVal						
Nickel, Total (as Ni)	ug/L	CalMoAvg						
Nickel, Total (as Ni)	ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Sulfate, Total (as SO4)	mg/L	CalMoAvg						
Sulfate, Total (as SO4)	mg/L	CalMoMax						
Toxicity, Final Conc	1.00 toxunt	CalMoMax						
Toxicity, Final Conc	2.00 toxunt	CalMoMax						
Toxicity, Final Conc	5.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						
Zinc, Total (as Zn)	ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2001 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	364	329	307	147	66.6	46.7
Copper, Total (as Cu)	ug/L	CalMoMax	383	352	458	253	76.1	58.6
Flow	MG	CalMoTot	1.659	0.672	0.341	0.75	2.7	2.33
Flow	mgd	CalMoAvg	0.054	0.024	0.011	0.025	0.0866	0.077
Flow	mgd	CalMoMax	0.068	0.026	0.021	0.03	0.1267	0.1004
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	2455	2375	2450	1720	1955	1730
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2530	2530	2510	2360	1970	1900
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<0.03	0.03	0.05	0.04	0.05	<0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<0.03	0.03	0.05	0.04	0.05	<0.03
Mercury, Total (as Hg)	ng/L	SingleVal					1.32	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1585	1620	1520	1305	799.5	907.5
Nickel, Total (as Ni)	ug/L	CalMoMax	1620	1770	1550	1440	881	1010
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	8.8	6	10.4	6.4	6.4	7.6

Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	8.8	6	10.4	6.4	6.4	7.6
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2270	3000	2380	2280	2200	2190
Sulfate, Total (as SO4)	mg/L	CalMoMax	2270	3000	2380	2280	2200	2190
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.9761	1.113
Toxicity, Final Conc	2.00 toxunt	CalMoMax				2.73		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	3.88	3.54	4.42			
Zinc, Total (as Zn)	ug/L	CalMoAvg	598	52.9	493	328	273	366
Zinc, Total (as Zn)	ug/L	CalMoMax	598	52.9	573	487	337	421
pH	6.5 SU	CalMoMin	7.3	7.1	7.2	7.1	7.2	7.3
pH	8.5 SU	CalMoMax	7.5	7.1	7.3	7.6	7.3	7.4

Year 2002 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	239	235	335	200.3	28.45	21
Copper, Total (as Cu)	ug/L	CalMoMax	261	243	338	309	34	26.4
Flow	MG	CalMoTot	1.097	0.839	0.657	0.075	0.62	1
Flow	mgd	CalMoAvg	0.0354	0.03	0.0212	0.0026	0.0208	0.0334
Flow	mgd	CalMoMax	0.0387	0.0387	0.0212	0.0725	0.0422	0.1267
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	2370	2215	2095	1454.5	2065	2190
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2530	2300	2120	2010	2150	2400
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<0.03	<0.03	<0.03	0.03	0.05	<0.045
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<0.03	<0.03	<0.03	0.03	0.05	0.06
Mercury, Total (as Hq)	ng/L	SingleVal					1.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1670	1585	1540	1335	585.5	365
Nickel, Total (as Ni)	ug/L	CalMoMax	1760	1600	1540	1450	651	370
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5.2	2	2.8	1.2	<2.5	7.9
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	5.2	2	2.8	1.2	4	13
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2350	2240	2490	2320	1705	2175
Sulfate, Total (as SO4)	mg/L	CalMoMax	2350	2240	2490	2320	2270	2460
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.592	0.394
Toxicity, Final Conc	2.00 toxunt	CalMoMax				3.18		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.9757	2.8082	3.5157			
Zinc, Total (as Zn)	ug/L	CalMoAvg	657	596.5	580	400	184.5	124
Zinc, Total (as Zn)	ug/L	CalMoMax	700	601	581	499	198	132
pH	6.5 SU	CalMoMin	7.2	7	7.2	7.1	7.2	7.4
pH	8.5 SU	CalMoMax	7.4	7.2	7.2	7.5	7.6	7.5

Year 2003 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	183.5	384.5	132.75	56.4	26.1	29.8
Copper, Total (as Cu)	ug/L	CalMoMax	191	432	194	62.6	27.3	34.2
Flow	MG	CalMoTot	0.7	0.78	0.3581	0.64	0.54	0.6248

Flow	mgd	CalMoAvg	0.0225	0.0277	0.0116	0.0213	0.0174	0.0208
Flow	mgd	CalMoMax	0.0263	0.0353	0.0188	0.0321	0.0499	0.0629
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg	2340	2335	1395	1471.5	2295	2235
& Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2420	2440	1760	2030	2330	2610
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.05	0.03	0.1	<0.03	<0.03	<0.03
Mercury, Total (as Hg)	2.0 mg/L	CalMoMax	0.05	0.03	0.1	<0.03	<0.03	<0.03
Nickel, Total (as Ni)	ng/L	SingleVal					1	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1415	1580	1080	1013.5	341.5	299.5
Nickel, Total (as Ni)	ug/L	CalMoMax	1440	1620	1130	1400	364	302
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2	3	3.5	2	2.35	4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2	3	3.5	2	3.2	4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2270	2230	857	1960	2180	2390
Sulfate, Total (as SO4)	mg/L	CalMoMax	2270	2230	857	1960	2270	2390
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.36	0.45
Toxicity, Final Conc	2.00 toxunt	CalMoMax				1.01		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.37	4.14	2.08			
Zinc, Total (as Zn)	ug/L	CalMoAvg	529.5	525.5	300.5	207.5	85.1	98.95
Zinc, Total (as Zn)	ug/L	CalMoMax	569	541	360	287	87.4	115
pH	6.5 SU	CalMoMin	7.2	7.2	7.3	7.2	7.3	7.4
pH	8.5 SU	CalMoMax	7.4	7.5	7.7	7.4	7.5	7.42

Year 2004 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	125.55	147.5	91.1	70.05	25.6	10.05
Copper, Total (as Cu)	ug/L	CalMoMax	170	162	112	87.6	30.5	22.3
Flow	MG	CalMoTot	0.78	0.53	0.688	1.02	1.26	1.91
Flow	mgd	CalMoAvg	0.025	0.0184	0.0222	0.034	0.041	0.0638
Flow	mgd	CalMoMax	0.026	0.0212	0.0263	0.0387	0.089	0.0777
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium	mg/L	CalMoAvg	2370	2225	2020	1355	2025	1875
& Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2460	2230	2100	1440	2120	2020
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.06	<0.03	0.08	0.03	0.03	<0.03
Mercury, Total (as Hg)	2.0 mg/L	CalMoMax	0.06	<0.03	0.08	0.03	0.03	<0.03
Nickel, Total (as Ni)	ng/L	SingleVal					<4	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1410	1355	1088.5	841	497.5	548
Nickel, Total (as Ni)	ug/L	CalMoMax	1470	1400	1240	869	500	558
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.2	<1	<1	<1.0	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.2	<1	<1	<1.0	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2410	2390	2280	1370	2240	1940
Sulfate, Total (as SO4)	mg/L	CalMoMax	2410	2390	2280	1370	2240	1940
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.46	0.44
Toxicity, Final Conc	2.00 toxunt	CalMoMax				1.17		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.22	2.11	1.57			
Zinc, Total (as Zn)	ug/L	CalMoAvg	588	518	384	251	132	159.5

Zinc, Total (as Zn)	ug/L	CalMoMax	596	545	441	307	133	162
pH	6.5 SU	CalMoMin	7.3	7.3	7.1	7.2	7.5	7.6
pH	8.5 SU	CalMoMax	7.3	7.4	7.2	7.4	7.6	7.7

Year 2005 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	117.5	101.4	81.7	40.5	22.75	32.85
Copper, Total (as Cu)	ug/L	CalMoMax	134	104	82.3	41.3	25.2	33.1
Flow	MG	CalMoTot	6.486	0.7183	0.8397	0.58	1.25	2.53
Flow	mgd	CalMoAvg	0.2092	0.0257	0.0271	0.019	0.04	0.084
Flow	mgd	CalMoMax	0.2092	0.0263	0.0291	0.035	0.07	0.127
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2195	2190	2255	1251.5	2095	2105
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2260	2220	2270	1640	2200	2310
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.05	0.05	0.03	0.16	<0.03	0.04
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.05	0.05	0.03	0.16	<0.03	0.04
Mercury, Total (as Hg)	ng/L	SingleVal					1	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1320	1340	1350	465	459.5	651
Nickel, Total (as Ni)	ug/L	CalMoMax	1340	1440	1390	555	472	755
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.6	2.8	4	1.5	3.25	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.6	2.8	4	1.5	4	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2180	2360	22.6	731	1945	2020
Sulfate, Total (as SO4)	mg/L	CalMoMax	2180	2360	22.6	731	2100	2020
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.43	0.63
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.59		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	1.91	1.51	1.39			
Zinc, Total (as Zn)	ug/L	CalMoAvg	547	475	445.5	142.5	147.5	212
Zinc, Total (as Zn)	ug/L	CalMoMax	558	478	459	174	154	226
pH	6.5 SU	CalMoMin	7.4	7.4	6.9	7.1	7.4	7.1
pH	8.5 SU	CalMoMax	7.5	7.6	7.3	7.4	7.6	7.1

Year 2006 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	168	154	195	46	27.8	34.35
Copper, Total (as Cu)	ug/L	CalMoMax	170	161	204	55	31.7	39.4
Flow	MG	CalMoTot	1.07	0.84	0.517	0.71	1.7	1.89
Flow	mgd	CalMoAvg	0.035	0.03	0.017	0.024	0.06	0.06
Flow	mgd	CalMoMax	0.035	0.032	0.017	0.032	0.17	0.09
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2280	2250	2230	1400	1720	1101.5
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2330	2280	2250	1800	2040	1880
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.05	<0.05	0.05	0.07	0.05	0.16
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.05	<0.05	0.05	0.07	0.05	0.16

Mercury, Total (as Hg)	ng/L	SingleVal					1.4	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1645	1545	1525	697	424.5	536
Nickel, Total (as Ni)	ug/L	CalMoMax	1670	1560	1540	885	458	557
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.6	2.8	3.6	3.6	3	2.4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.6	2.8	3.6	3.6	3	2.4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2210	2120	2220	898	2020	1980
Sulfate, Total (as SO4)	mg/L	CalMoMax	2210	2120	2220	898	2020	1980
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.41	0.61
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.62		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.26	2.14	2.4			
Zinc, Total (as Zn)	ug/L	CalMoAvg	579.5	553	517	140	220	164.5
Zinc, Total (as Zn)	ug/L	CalMoMax	594	564	512	184	124	168
pH	6.5 SU	CalMoMin	7.4	7.4	7.4	7.5	7.1	7.3
pH	8.5 SU	CalMoMax	7.4	7.4	7.4	7.5	7.6	7.5

Year 2007 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	182	179	73.25	36.7	26.7	15.7
Copper, Total (as Cu)	ug/L	CalMoMax	188	179	99.1	41.6	33	16.4
Flow	MG	CalMoTot	0.56	0.037	0.542	0.41	0.65	1.73
Flow	mgd	CalMoAvg	0.018	0.001	0.018	0.014	0.022	0.06
Flow	mgd	CalMoMax	0.027	0.005	0.026	0.015	0.039	0.13
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	2300	2480	1815	1231.5	1860	1560
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2380	2480	2540	1780	1950	1840
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<0.050	0.085	0.437	0.0753	0.161	0.0624
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<0.050	0.085	0.437	0.0753	0.161	0.0624
Mercury, Total (as Hg)	ng/L	SingleVal					<2	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1495	1730	982	941	281.5	238
Nickel, Total (as Ni)	ug/L	CalMoMax	1540	1730	1200	1300	351	275
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	3.2	4.4	2.8	3.5	8	1.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	3.2	4.4	2.8	3.5	8	1.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1860	2400	2240	1610	1630	1220
Sulfate, Total (as SO4)	mg/L	CalMoMax	1860	2400	2240	1610	1630	1220
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.36	0.26
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.9		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.31	2.28	1.32			
Zinc, Total (as Zn)	ug/L	CalMoAvg	532	546	264	160.5	58.1	69.1
Zinc, Total (as Zn)	ug/L	CalMoMax	536	546	330	208	62.4	78.4
pH	6.5 SU	CalMoMin	7.4	7.3	7.1	6.9	7.3	7.2
pH	8.5 SU	CalMoMax	7.4	7.3	7.5	7.2	7.4	7.4

Year 2008 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	139.5	162.5	208.5	59.95	34.55	30.7
Copper, Total (as Cu)	ug/L	CalMoMax	154	191	211	68.3	37.6	35.8
Flow	MG	CalMoTot	0.81	0.3	0.31	1.84	3.69	5.14
Flow	mgd	CalMoAvg	0.027	0.01	0.01	0.06	0.12	0.18
Flow	mgd	CalMoMax	0.029	0.01	0.011	0.08	0.16	0.28
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2025	2240	2345	1306.5	1860	1585
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	2050	2270	2350	1960	1870	2090
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<0.05	0.127	<0.05	<0.05	<0.05	0.102
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<0.05	0.127	<0.05	<0.05	<0.05	0.102
Mercury, Total (as Hq)	ng/L	SingleVal					0.6	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1665	1805	1865	875	847.5	1035
Nickel, Total (as Ni)	ug/L	CalMoMax	1680	1860	1870	1350	963	1510
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	1.6	<1	1.6	<1	2.5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	1.6	<1	1.6	<1	2.5
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2020	2120	2170	1860	1600	1140
Sulfate, Total (as SO4)	mg/L	CalMoMax	2020	2120	2170	1860	1600	1140
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.88	1.08
Toxicity, Final Conc	2.00 toxunt	CalMoMax				1.09		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.36	2.69	2.68			
Zinc, Total (as Zn)	ug/L	CalMoAvg	730.5	735	627	222.5	270.5	339.5
Zinc, Total (as Zn)	ug/L	CalMoMax	757	780	684	317	370	489
pH	6.5 SU	CalMoMin	7.3	7.3	7.3	6.8	7	7.1
pH	8.5 SU	CalMoMax	7.4	7.4	7.4	7.1	7.1	7.1

Year 2009 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	169	208	139.5	80.95	38.45	30.4
Copper, Total (as Cu)	ug/L	CalMoMax	191	215	166	124	47.2	33.1
Flow	MG	CalMoTot	0.77	1.14	1.3	1	0.99	1.6
Flow	mgd	CalMoAvg	0.025	0.041	0.041	0.034	0.032	0.053
Flow	mgd	CalMoMax	0.026	0.046	0.046	0.039	0.035	0.12
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2165	2215	1880	1356.5	1720	1920
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	2270	2240	2100	2120	1820	1940
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Mercury, Total (as Hq)	ng/L	SingleVal					1.4	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1655	1670	1231	585.5	626.5	641
Nickel, Total (as Ni)	ug/L	CalMoMax	1810	1720	1480	691	734	658
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	3.6	3.5	2	1.6	4.4	1.6
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	3.6	3.5	2	1.6	4.4	1.6
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2000	2130	2140	1900	1460	1820
Sulfate, Total (as SO4)	mg/L	CalMoMax	2000	2130	2140	1900	1460	1820

Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.62	0.59
Toxicity, Final Conc	2.00 toxunt	CalMoMax				1.72		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	2.62	2.75	2.17			
Zinc, Total (as Zn)	ug/L	CalMoAvg	659	658.5	483.5	303.5	137.5	214.5
Zinc, Total (as Zn)	ug/L	CalMoMax	731	694	563	480	139	227
pH	6.5 SU	CalMoMin	6.98	6.86	7.01	6.93	7.23	7.1
pH	8.5 SU	CalMoMax	7.01	7	7.02	7.09	7.59	7.4

Year 2010 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	64.85	55.9	68.5	71.4	20.5	8.6
Copper, Total (as Cu)	ug/L	CalMoMax	68	58.3	68.5	86.9	23.5	9
Flow	MG	CalMoTot	0.69	0.57	0.47	0.31	0.6	0.91
Flow	mgd	CalMoAvg	0.024	0.02	0.02	0.01	0.02	0.03
Flow	mgd	CalMoMax	0.032	0.02	0.03	0.01	0.11	0.09
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2140	2135	1470	1780	2100	1825
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	2240	2150	1470	1880	2180	1840
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.246	0.3	0.8	0.4	1.5	1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.246	0.3	0.8	0.4	2.8	1
Mercury, Total (as Hg)	ng/L	SingleVal					1.6	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1175	1095	726	694	285	191
Nickel, Total (as Ni)	ug/L	CalMoMax	1190	1140	726	912	363	198
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.6	6.4	6.5	3.6	3.5	11
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.6	6.4	6.5	3.6	3.5	11
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2190	2120	1340	1410	1890	1600
Sulfate, Total (as SO4)	mg/L	CalMoMax	2190	2120	1340	1410	1890	1600
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.3	0.14
Toxicity, Final Conc	2.00 toxunt	CalMoMax				1.04		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	1.11	1.01	0.91			
Zinc, Total (as Zn)	ug/L	CalMoAvg	360.5	344	233	150	50.95	33
Zinc, Total (as Zn)	ug/L	CalMoMax	370	365	233	213	61.7	38
pH	6.5 SU	CalMoMin	6.5	6.6	6.6	6.6	6.7	6.5
pH	8.5 SU	CalMoMax	6.7	6.7	6.6	6.6	6.8	6.6

Year 2011 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	40	42	38	22	7	4.1
Copper, Total (as Cu)	ug/L	CalMoMax	45	44	40	32	8	4.5
Flow	MG	CalMoTot	0.61	0.48	0.48	0.48	0.73	1.04
Flow	mgd	CalMoAvg	0.02	0.017	0.016	0.016	0.02	0.03
Flow	mgd	CalMoMax	0.024	0.02	0.021	0.017	0.05	0.07
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	2065	2140	2175	1390	1830	2105

Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	2090	2180	2210	1690	2010	2140
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.2	0.1	0.2	0.2	0.2	0.4
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.2	0.1	0.2	0.2	0.2	0.4
Mercury, Total (as Hg)	ng/L	SingleVal					0.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1029	871	664	284	112	73.8
Nickel, Total (as Ni)	ug/L	CalMoMax	1100	896	665	436	114	83.3
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2	2	3	2	5	8
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2	2	3	2	5	8
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1870	1870	1840	1470	1450	1830
Sulfate, Total (as SO4)	mg/L	CalMoMax	1870	1870	1840	1470	1450	1830
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.14	0.1
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.49		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	0.91	0.84	0.69			
Zinc, Total (as Zn)	ug/L	CalMoAvg	298	299	233	96	38	36.3
Zinc, Total (as Zn)	ug/L	CalMoMax	336	314	237	152	44	40.9
pH	6.5 SU	CalMoMin	7.1	7	7	7.1	6.8	6.9
pH	8.5 SU	CalMoMax	7.2	7	7.1	7.2	7	7

Year 2012 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	21	11.5	19.9	17.8	10.1	12
Copper, Total (as Cu)	ug/L	CalMoMax	21	15.9	25.5	20.3	11.3	14.1
Flow	MG	CalMoTot	0.55	0.54	0.49	0.42	1.18	2.73
Flow	mgd	CalMoAvg	0.018	0.02	0.02	0.014	0.038	0.09
Flow	mgd	CalMoMax	0.024	0.02	0.02	0.034	0.107	0.32
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	2160	2155	1563	1600	1890	1615
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.3	0.6	0.5	0.11	0.1	<.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.3	0.6	0.5	0.11	0.1	<.1
Mercury, Total (as Hg)	ng/L	SingleVal					<.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1120	444	369	260	106	166
Nickel, Total (as Ni)	ug/L	CalMoMax	1140	504	456	304	138	213
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	7	10	2	5.6	3.2	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	7	10	2	5.6	3.2	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1980	1980	1890	1470	1610	1410
Sulfate, Total (as SO4)	mg/L	CalMoMax	1980	1980	1890	1470	1610	1410
Toxicity, Final Conc	1.00 toxunt	CalMoMax					0.17	0.21
Toxicity, Final Conc	2.00 toxunt	CalMoMax				0.33		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	0.8	0.36	0.35			
Zinc, Total (as Zn)	ug/L	CalMoAvg	386	137	113	82	41.1	51.1
Zinc, Total (as Zn)	ug/L	CalMoMax	387	140	131	109	49.2	61.5
pH	6.5 SU	CalMoMin	7	6.8	6.8	7.4	7.4	7.3
pH	8.5 SU	CalMoMax	7	7.2	7.5	7.7	7.4	7.7

Year 2013 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	20.2	11.6	14.4	80		9.9
Copper, Total (as Cu)	ug/L	CalMoMax	21.4	14.9	15.8	118		12
Flow	MG	CalMoTot	0.21	0.061	0.7	0.5		0.755
Flow	mgd	CalMoAvg	0.0068	0.0022	0.025	0.018		0.0252
Flow	mgd	CalMoMax	0.0167	0.0047	0.026	0.021		0.0886
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2280	2260	2340	1990		1690
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	2310	2400	2470	2020		1730
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.265	0.3	0.4	0.1		0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.265	0.3	0.4	0.1		0.2
Mercury, Total (as Hg)	ng/L	SingleVal						
Nickel, Total (as Ni)	ug/L	CalMoAvg	1540	355	399	882		198
Nickel, Total (as Ni)	ug/L	CalMoMax	1540	413	441	1050		315
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	3	8	5	4		4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	3	8	5	4		4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2450	2050	2300	1870		1470
Sulfate, Total (as SO4)	mg/L	CalMoMax	2450	2050	2300	1870		1470
Toxicity, Final Conc	1.00 toxunt	CalMoMax						0.21
Toxicity, Final Conc	2.00 toxunt	CalMoMax				1.44		
Toxicity, Final Conc	5.00 toxunt	CalMoMax	0.85	0.27	0.26			
Zinc, Total (as Zn)	ug/L	CalMoAvg	288	68.4	70	253		45.7
Zinc, Total (as Zn)	ug/L	CalMoMax	391	83.5	74.7	325		64.6
pH	6.5 SU	CalMoMin	7.3	6.7	6.6	6.8		6.7
pH	8.5 SU	CalMoMax	7.4	6.9	7	6.9		7.2

Year 2014 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			74.4	87		18.7
Copper, Total (as Cu)	ug/L	CalMoMax			77.6	87		18.7
Flow	MG	CalMoTot			0.39	0.016		1.4
Flow	mgd	CalMoAvg			0.014	0.00058		0.093
Flow	mgd	CalMoMax			0.083	0.0081		0.12
Hardness, Calcium & Magnesium, Calculated (as CaCO3)	mg/L	CalMoAvg			2080	1830		1740
Hardness, Calcium & Magnesium, Calculated (as CaCO3)	mg/L	CalMoMax			2140	1830		1740
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.1	0.3		<1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.1	0.3		<1
Mercury, Total (as Hg)	ng/L	SingleVal						
Nickel, Total (as Ni)	ug/L	CalMoAvg			944	822		512
Nickel, Total (as Ni)	ug/L	CalMoMax			953	822		512

Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg		2	3	5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax		3	3	5
Sulfate, Total (as SO4)	mg/L	CalMoAvg		1930	1710	1520
Sulfate, Total (as SO4)	mg/L	CalMoMax		1930	1710	1520
Toxicity, Final Conc	1.00 toxunt	CalMoMax				0.45
Toxicity, Final Conc	2.00 toxunt	CalMoMax			1.17	
Toxicity, Final Conc	5.00 toxunt	CalMoMax		1.15		
Zinc, Total (as Zn)	ug/L	CalMoAvg		340	313	194
Zinc, Total (as Zn)	ug/L	CalMoMax		343	313	194
pH	6.5 SU	CalMoMin		6.9	7.5	7.7
pH	8.5 SU	CalMoMax		7.4	7.5	7.7

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	68.5					12
Copper, Total (as Cu)	ug/L	CalMoMax	68.5					13
Flow	MG	CalMoTot	0.059					11
Flow	mgd	CalMoAvg	0.0019					0.36
Flow	mgd	CalMoMax	0.015					0.67
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	2490					1750
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	2490					1820
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.1					<.05
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.1					<.05
Mercury, Total (as Hg)	ng/L	SingleVal						
Nickel, Total (as Ni)	ug/L	CalMoAvg	1070					254
Nickel, Total (as Ni)	ug/L	CalMoMax	1070					293
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	3					4.8
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	3					4.8
Sulfate, Total (as SO4)	mg/L	CalMoAvg	2300					1470
Sulfate, Total (as SO4)	mg/L	CalMoMax	2300					1470
Toxicity, Final Conc	1.00 toxunt	CalMoMax						0.23
Toxicity, Final Conc	2.00 toxunt	CalMoMax						
Toxicity, Final Conc	5.00 toxunt	CalMoMax	1.21					
Zinc, Total (as Zn)	ug/L	CalMoAvg	434					78
Zinc, Total (as Zn)	ug/L	CalMoMax	434					83
pH	6.5 SU	CalMoMin	7.1					7.1
pH	8.5 SU	CalMoMax	7.1					7.4

Jul	Aug	Sep	Oct	Nov	Dec
	36.6	39.9	50	57.6	213
	40.7	40.3	56.2	57.8	293
	2.14	2.23	1.48	1.545	1.736
	0.07	0.074	0.048	0.052	0.056
	0.127	0.104	0.094	0.063	0.073
	2205	2155	2090	2400	2650
	2400	2180	2150	2520	2690
	<0.03	<0.03	<0.03	0.48	<0.03
	<0.03	<0.03	<0.03	0.48	<0.03
		0.42			
	424	797	1050	1029	1590
	502	904	1060	1110	1780
	12	16	4.4	6	8
	12	16	4.4	6	8
	2210	2340	2490	1840	2310
	2310	2460	2490	1840	2310
	0.59	0.7			
			0.93		
				1.1	3.33
	115.1	106	315	367	614
	168	224	336	413	678
	7.6	7.5	7.2	7.2	7.3
	7.7	7.5	7.5	7.3	7.4

Jul	Aug	Sep	Oct	Nov	Dec
33.1	27.25	49.95	80.2	36.05	88.6
43.3	27.9	55.4	113	36.6	123
2.31	3.2	1.97	1.72	1.49	1.1
0.075	0.1033	0.0656	0.0554	0.0495	0.0355
0.106	0.2389	0.0866	0.1004	0.0725	0.046
1876	1593	2173	1955	2135	2680
1990	1630	2426	2210	2180	3150
0.09	0.07	0.03	<0.03	0.05	0.04
0.09	0.07	0.03	<0.03	0.05	0.04
		0.49			
688	1216.5	1295	987	1044.5	1660
703	1630	1500	1620	1090	2060
4.4	5.2	7.6	5.2	1.6	<1

4.4	5.2	7.6	5.2	1.6	<1
2520	1690	2190	2230	2160	2100
2520	1690	2190	2230	2160	2100
0.734	0.8752	1.084			
			1.7443		
				0.9013	2.328
235	303.5	339.5	476	404	704
248	367	440	534	413	882
7.3	7.4	7.5	7.3	7	7.2
7.5	7.5	7.5	7.4	7.2	7.2

Jul	Aug	Sep	Oct	Nov	Dec
11.2	19.2	25.15	23.1	31.2	160.5
12.6	19.3	26	24.1	38.6	180
1.38	2.05	1.84	1.69	0.98	0.9
0.0444	0.066	0.0614	0.0544	0.0327	0.0289
0.1267	0.1066	0.1267	0.1198	0.046	0.0353
2140	1915	1730	2120	2145	2670
2290	1920	1910	2210	2160	2770
<0.03	<0.03	<0.03	<0.03	0.04	0.04
<0.03	<0.03	<0.03	<0.03	0.04	0.04
		<50			
192.5	249	394.5	545	1355	1605
247	305	409	792	1480	1700
3.85	<1	<1	2.7	4	2
6.7	<1	<1	2.7	4	2
2075	1920	1890	1980	2290	2370
2220	1920	1890	1980	2290	2370
0.2043	0.2871	0.361			
			0.59		
				1.11	2.23
67.7	73.15	95.3	242	429	532
70.5	81.8	98.9	282	493	557
7.2	7	7.1	7.2	7.6	7.2
7.3	7	7.3	7.3	7.7	7.3

Jul	Aug	Sep	Oct	Nov	Dec
15.55	16.9	16.55	24.5	40.35	53.75
16.8	18.9	16.7	26.9	42.8	59.9
1.67	1.64	2.21	1.88	1.34	1.11

0.0539	0.053	0.0736	0.0607	0.0448	0.036
0.0944	0.0886	0.1412	0.0676	0.0499	0.042
1555	2185.5	18.55	2090	1990	2355
1850	2430	2470	2160	2000	2370
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
		<10			
197.5	466	461.5	1072.5	1425	1480
212	555	498	1180	1430	1480
2	8	3	2.8	<1	<1
2	8	3	2.8	<1	<1
1850	1930	2140	1910	1680	2380
1850	1930	2140	1910	1680	2380
0.25	0.35	0.32			
			0.64		
				1.28	1.4
67.25	103.35	109.5	241.5	587.5	580
72.5	113	112	247	633	595
7.3	7.57	7.5	7.3	7.4	7.1
7.4	7.57	7.7	7.4	7.5	7.1

Jul	Aug	Sep	Oct	Nov	Dec
25.1	25.6	23.35	25.65	27.45	81.6
25.5	25.6	26.7	32.5	27.8	94.3
1.7739	1.42	2.046	1.86	1.161	1.022
0.0572	0.046	0.068	0.06	0.0387	0.033
0.0886	0.083	0.141	0.078	0.0387	0.035
2070	2295	2050	1835	1925	2180
2160	2310	2260	1890	2100	2180
0.04	0.04	0.03	0.04	0.03	0.08
0.04	0.04	0.03	0.04	0.03	0.08
		<4			
727	664.5	770	768	1056.5	1330
767	767	774	956	1120	1350
4	1	2	2	<1	<1
4	1	2	2	<1	<1
2620	2140	2300	1960	1950	1.4
2620	2140	2300	1960	1950	1.4
0.58	0.6	0.57			
			0.73		
				0.83	1.62
214	220.5	224.5	248	378	590.5

232	244	250	288	380	610
7.4	6.9	7.2	7.1	7.6	7.3
7.5	7.2	7.3	7.4	7.7	7.3

Jul	Aug	Sep	Oct	Nov	Dec
33.7	36.85	43.85	38.5	30.9	104.15
35.2	38	52.2	46.1	36.1	160
2.073	1.77	1.46	3.27	1.283	0.995
0.067	0.057	0.049	0.106	0.0428	0.032
0.073	0.1	0.083	0.318	0.046	0.032
2285	2335	2380	2050	2000	2165
2560	2460	2430	2060	2110	2270
<0.05	<0.05	0.05	<0.05	0.08	0.07
<0.05	<0.05	0.05	<0.05	0.08	0.07
		0.7			
850.5	921	971.5	1080	1150	1625
856	950	1190	1110	1190	1800
1.5	9	9.1	3.6	4.4	2.8
1.5	9	17	3.6	4.4	2.8
2020	2280	2040	1860	2100	2030
2020	2280	2140	1860	2100	2030
0.71	0.79	0.97			
			0.95		
				0.92	2.26
270	266.5	278.5	356	386	549.5
282	311	334	386	386	637
6.5	7	7	7	7.4	7.4
7	7.3	7.1	7.1	7.5	7.5

Jul	Aug	Sep	Oct	Nov	Dec
29	25.35	27.5	29.55	32.95	124.8
29	28.1	27.9	34	37.2	162
1.76	2.18	1.69	1.9991	1.144	0.79
0.057	0.071	0.056	0.0645	0.0381	0.026
0.2	0.173	0.094	0.1131	0.0629	0.026
2420	1855	2035	1945	2220	2560
2490	1890	2090	2100	2280	2720
0.07	0.124	<0.050	0.0522	0.123	0.216
0.07	0.124	<0.050	0.0522	0.123	0.216

		0.7			
482.5	638	829.5	1020	1325	1675
484	638	890	1030	1380	1690
3.2	4.4	4.4	4.4	2.8	4.4
3.2	4.4	4.4	4.4	2.8	4.4
1900	1760	1850	1950	2110	2490
1900	1760	1850	1950	2110	2490
0.52	0.5	0.57			
			0.71		
				0.97	2.18
174.5	156.5	190.5	284.5	404.5	558
184	159	199	311	407	575
7.3	7.4	7.2	7.3	7.3	7.3
7.4	7.4	7.3	7.4	7.9	7.4

Jul	Aug	Sep	Oct	Nov	Dec
24.05	22.65	29.8	65.6	117.5	189
25.3	30.8	35.5	66.6	123	194
1.43	1.16	3.95	5.86	3.65	1.33
0.048	0.04	0.13	0.19	0.13	0.045
0.083	0.06	0.53	0.31	0.15	0.05
2035	2225	1440	1750	1935	2170
2040	2280	1640	1830	1950	2180
0.106	0.0806	0.0865	0.0858	0.0625	0.0671
0.106	0.0806	0.0865	0.0858	0.0625	0.0671
		0.9			
526	341	1130	2135	2085	1995
572	438	1340	2160	2180	2070
3.6	6.8	1.6	3.2	12	<1
3.6	6.8	1.6	3.2	12	<1
1850	2690	1200	147	1890	2120
1850	2690	1200	147	1890	2120
0.42	0.45	0.67			
			1.59		
				2.36	2.84
125.5	106.6	198	589.5	857	886
130	130	260	640	894	904
7.4	7.3	7.2	7.2	7.3	7.1
7.4	7.3	7.3	7.4	7.3	7.2

Jul	Aug	Sep	Oct	Nov	Dec
40.8		24.35	22.65	32.8	114.55
40.8		27	25.1	43.1	174
3.75		1.6	1.7	1.9	1.27
0.13		0.053	0.055	0.065	0.041
0.16		0.17	0.083	0.068	0.063
2330		1960	1825	2210	2265
2330		2040	1910	2400	2290
<0.050		<0.050	<0.050	<0.050	<0.050
<0.050		<0.050	<0.050	<0.050	<0.050
		<1			
1550		845.5	886.5	1485	1970
1550		870	967	1660	2020
2.4		2.8	<1	1.2	2.7
2.4		2.8	<1	1.2	2.7
1920		1950	1730	1880	1990
1920		1950	1730	1880	1990
1.2		0.67			
			0.72		
				1.33	2.57
543		293	291	540	762
543		299	320	621	780
7		7.09	7.41	7.18	6.98
7		7.25	7.47	7.44	7.21

Jul	Aug	Sep	Oct	Nov	Dec
19.85	25.15	23.85	19.9	78.45	101.6
20	29.4	27.2	20.3	142	119
1.6	1.6	1.36	1.31	1.12	0.64
0.051	0.052	0.045	0.042	0.037	0.022
0.089	0.14	0.068	0.054	0.042	0.029
1940	1930	2120	2015	1850	2095
1990	2020	2240	2050	1920	2160
<0.050	<0.050	<0.050	<0.050	<0.050	0.155
<0.050	<0.050	<0.050	<0.050	<0.050	0.155
		0.5			
786	629	570	915.5	1027	1470
799	843	615	929	1460	1490
1.2	4	1.6	1.2	1.6	2
1.2	4	1.6	1.2	1.6	2
1780	1780	1960	1920	1800	1900
1780	1780	1960	1920	1800	1900

0.59	0.73	0.58			
			0.66		
				2.37	1.71
259	228	206	290	537.5	579
270	313	230	306	856	685
7	6.9	7.1	7.3	6.5	6.6
7.1	7.2	7.1	7.3	6.9	6.7

Jul	Aug	Sep	Oct	Nov	Dec
6.6	3.3	1.9	3.8	9.2	18
7	6.6	2	4.1	9.5	21
1.6	1.4	2.9	0.78	0.76	0.73
0.05	0.05	0.098	0.025	0.025	0.024
0.19	0.12	0.76	0.032	0.032	0.024
1795	1575	1835	1890	1885	2090
1830	1780	1860	2050	1960	2100
0.9	0.4	0.6	0.2	0.2	0.3
1.6	0.4	0.6	0.2	0.2	0.3
		1.1			
142	97	51	90	629	586
149	113	55	95	635	624
8	2	5	1	1	4
8	2	5	1	1	4
1540	1260	1640	1550	1580	1800
1540	1260	1640	1550	1580	1800
0.1	0.1	0.05			
			0.09		
				0.35	0.51
24	14	13	36	151	207
25	28	19	38	157	223
6.8	6.8	7.1	6.6	6.7	6.9
6.9	6.8	7.2	6.7	7	7

Jul	Aug	Sep	Oct	Nov	Dec
2.6	5.53	6.11	7.4	14.6	12
3.6	6.03	6.47	8.9	14.9	14.2
1.57	0.91	1	1.02	0.82	0.62
0.05	0.03	0.03	0.03	0.03	0.02
0.11	0.28	0.07	0.06	0.03	0.02
1820	1955	1945	1915	2100	2145

1870	1960	1980	1920	2190	2190
0.3	0.6	0.2	0.1	0.1	0.25
0.3	0.6	0.2	0.1	0.1	0.25
		<0.5			
124	60.2	100	97	421	416
140	61.6	119	128	471	464
6	3.6	5	8	5	6.8
6	3.6	5	8	5	6.8
1600	1720	1790	1790	1800	2070
1600	1720	1790	1790	1800	2070
0.09	0.07	0.1			
			0.13		
				0.36	0.33
34	13	25.8	31	126	124
38.1	<20	27.6	39	144	130
7.2	7.1	7.2	6.9	6.9	6.9
7.2	7.1	7.3	7.1	6.9	7

Jul	Aug	Sep	Oct	Nov	Dec
14.6	12.6	12	15.4	19.1	27.5
16.6	13.7	12.6	15.8	19.7	32.5
2.87	2.49	0.69	0.685	0.86	0.233
0.096	0.08	0.023	0.0228	0.029	0.008
0.17	0.16	0.035	0.054	0.035	0.021
1720	2010	2000	1990	1910	2140
1900	2070	2020	2000	1940	2200
0.12	0.2	0.1	<.1	0.1	0.057
0.12	0.2	0.1	<.1	0.1	0.057
		<.5			
375	270	224	600	609	1060
429	280	245	661	684	1080
1.6	3	3	2	2	4
1.6	3	3	2	2	4
1430	1730	1860	1880	1790	1880
1430	1730	1860	1880	1790	1880
0.32	0.22	0.22			
			0.46		
				0.54	0.84
92	72.7	69.2	184	413	371
111	79.4	76.7	209	246	383
7.3	7.2	7.2	7.1	6.9	7.3
7.5	7.4	7.5	7.5	7	7.3

Jul	Aug	Sep	Oct	Nov	Dec
14	13.4	10.7	11.7	14.4	
15.3	13.7	11.1	16.9	15.6	
2.05	1.4	1.1	1.3	0.98	
0.0662	0.046	0.036	0.043	0.033	
0.141	0.073	0.078	0.078	0.042	
1450	1760	1880	1760	1760	
1630	1850	1940	1860	1780	
0.1	<.1	0.1	<.1	0.1	
0.1	<.1	0.1	<.1	0.1	
		<.5			
210	502	273	349	760	
277	652	281	509	817	
3	3.6	4	3	6	
3	3.6	4	3	6	
1450	1530	1750	1770	1720	
1450	1530	1750	1770	1720	
0.24	0.37	0.25			
			0.4		
				0.53	
62.9	125	92	110	229	
72.6	148	101	161	241	
7.2	7.1	7	7.2	7.4	
7.3	7.2	7.1	7.2	7.5	

Jul	Aug	Sep	Oct	Nov	Dec
18.5	14.1	14.3	12.4	21.8	
20.3	15.8	15.5	12.8	26.2	
2.6	1.8	1.8	1.4	0.96	
0.084	0.057	0.059	0.047	0.032	
0.16	0.11	0.13	0.063	0.046	
1760	2000	1830	1880	2070	
1800	2050	1900	1930	2180	
<1	0.2	0.1	0.1	<1	
<1	0.2	0.1	0.1	<1	
		0.584			
526	367	333	428	753	
530	440	370	493	775	

2	6	<3	2	7
2	6	<3	2	7
1660	1820	1660	1740	1850
1660	1820	1660	1740	1850
0.47	0.37	0.37		
			0.45	
				0.75
197	127	131	193	337
198	150	157	227	356
7.5	7.2	7.2	7.6	7.2
7.6	7.8	7.6	7.8	7.4

Jul	Aug	Sep	Oct	Nov	Dec
9.2	7.4				
12	8.5				
1.7	1.7				
0.05	0.06				
0.11	0.12				
1777	1905				
1930	1960				
0.1	0.1				
0.1	0.1				
159	124				
188	146				
3.6	1.6				
3.6	1.6				
1575	1570				
1700	1570				
0.2	0.12				
50	32				
68	32				
7.1	7.2				
7.5	7.2				

Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						
Copper, Total (as Cu)	ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMax						
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg						
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Mercury, Total (as Hg)	ng/L	SingleVal						
Nickel, Total (as Ni)	ug/L	CalMoAvg						
Nickel, Total (as Ni)	ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Sulfate, Total (as SO4)	mg/L	CalMoAvg						
Sulfate, Total (as SO4)	mg/L	CalMoMax						
Toxicity, Final Conc	1.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						
Zinc, Total (as Zn)	ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2001 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2.0	1.6	1.3	5.2	<2.05	3.5
Copper, Total (as Cu)	ug/L	CalMoMax	<2.0	3.1	2.5	8.4	2.1	5
Flow	MG	CalMoTot	8.742	0.14	0.093	1.77	3.11	2.27
Flow	mgd	CalMoAvg	0.282	0.005	0.003	0.059	0.1004	0.0757
Flow	mgd	CalMoMax	0.545	0.006	0.005	0.11	0.2938	0.1131
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1430	1325	1335	800	713.5	820.5
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1500	1330	1370	1220	832	864
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.27	0.78	0.43	0.46	0.08	<0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.27	0.78	0.43	0.46	0.08	<0.03
Mercury, Total (as Hg)	ng/L	SingleVal					0.59	
Nickel, Total (as Ni)	ug/L	CalMoAvg	71.7	35.5	29.6	143	124	119
Nickel, Total (as Ni)	ug/L	CalMoMax	83.9	37.6	38	248	136	131
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	4.8	6.8	10	3.2	2.4	3.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	4.8	6.8	10	3.2	2.4	3.2

Sulfate, Total (as SO4)	mg/L	CalMoAvg	1130	1350	1100	919	514	815
Sulfate, Total (as SO4)	mg/L	CalMoMax	1130	1350	1100	919	514	815
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.009	0.03	0.05	0.11	0.0439	0.0739
Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	<10	17.7	13.3	<10	<13.15
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	<10	23.5	16.6	<10	16.3
pH	6.5 SU	CalMoMin	7.4	7.3	7.4	7.1	7	7.4
pH	8.5 SU	CalMoMax	7.5	7.6	7.4	7.1	7.5	7.5

Year 2002 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2	<1.5	<2	2.55	<2	<2.3
Copper, Total (as Cu)	ug/L	CalMoMax	<2	<2	<2	3.1	<2	2.6
Flow	MG	CalMoTot	0.22	0.136	0.058	0.1479	1.38	6.13
Flow	mgd	CalMoAvg	0.0071	0.0047	0.0019	0.0051	0.0445	0.204
Flow	mgd	CalMoMax	0.0095	0.0059	0.0037	0.1489	0.0725	0.5339
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	1670	1590	1640	1004	1106.5	1330
& Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1780	1630	1640	1520	1205	1330
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.07	0.25		0.21	0.04	0.06
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.07	0.25		0.21	0.04	0.06
Mercury, Total (as Hg)	ng/L	SingleVal					1	
Nickel, Total (as Ni)	ug/L	CalMoAvg	304	102.95	48.6	112.5	119	108.2
Nickel, Total (as Ni)	ug/L	CalMoMax	333	135	48.6	194	123	92.4
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5.6	2.8		<1	<1	2.4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	5.6	2.8		<1	<1	2.4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1450	1400		1170	878	1200
Sulfate, Total (as SO4)	mg/L	CalMoMax	1450	1400		1170	878	1200
Toxicity, Final Conc	1.00 toxunt	CalMoMax	<0.0687	<0.0360	<0.0336	0.07	<0.0419	<0.0466
Zinc, Total (as Zn)	ug/L	CalMoAvg	12	<10	<10	15.95	<10	12.95
Zinc, Total (as Zn)	ug/L	CalMoMax	13.1	<10	<10	16.1	<10	15.9
pH	6.5 SU	CalMoMin	7.2	7.2	7.3	7.4	7.3	7.3
pH	8.5 SU	CalMoMax	7.4	7.2	7.3	7.6	7.5	7.4

Year 2003 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			2.45	<2	<2	<2
Copper, Total (as Cu)	ug/L	CalMoMax			2.9	<2	<2	<2
Flow	MG	CalMoTot			1.14	0.83	0.67	0.64
Flow	mgd	CalMoAvg			0.0368	0.0276	0.0215	0.0212
Flow	mgd	CalMoMax			0.0944	0.046	0.0353	0.054
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg			916	448	1024	1069
& Magnesium, Calculated (as	mg/L	CalMoMax			1190	564	1050	1180

Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg		0.51	0.15	0.03	<0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax		0.51	0.15	0.03	<0.03
Mercury, Total (as Hg)	ng/L	SingleVal				0.7	
Nickel, Total (as Ni)	ug/L	CalMoAvg		91.2	119	78.8	65.25
Nickel, Total (as Ni)	ug/L	CalMoMax		136	121	90	66.1
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg		3.6	1.6	2.3	4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax		3.6	1.6	3.6	4
Sulfate, Total (as SO4)	mg/L	CalMoAvg		409	369	756.5	1040
Sulfate, Total (as SO4)	mg/L	CalMoMax		409	369	807	1040
Toxicity, Final Conc	1.00 toxunt	CalMoMax		0.05	0.04	0.04	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg		10.5	<10	<10	<10
Zinc, Total (as Zn)	ug/L	CalMoMax		11	<10	<10	<10
pH	6.5 SU	CalMoMin		7.5	7.3	7.4	7.3
pH	8.5 SU	CalMoMax		7.9	7.5	7.6	7.4

Year 2004 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg				2.8	<2	<2
Copper, Total (as Cu)	ug/L	CalMoMax				3.6	<2	<2
Flow	MG	CalMoTot				1.43	1.55	1.09
Flow	mgd	CalMoAvg				0.0477	0.05	0.0364
Flow	mgd	CalMoMax				0.0629	0.165	0.1131
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg				517.5	842	882
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax				634	870	935
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.14	0.04	0.04
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.14	0.04	0.04
Mercury, Total (as Hg)	ng/L	SingleVal					<4	
Nickel, Total (as Ni)	ug/L	CalMoAvg				130.75	69.35	76.8
Nickel, Total (as Ni)	ug/L	CalMoMax				190	71	88.7
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				<1.0	<1	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				<1.0	<1	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg				538	737	833
Sulfate, Total (as SO4)	mg/L	CalMoMax				538	737	833
Toxicity, Final Conc	1.00 toxunt	CalMoMax				0.06	0.04	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg				<10	<10	<10
Zinc, Total (as Zn)	ug/L	CalMoMax				<10	<10	<10
pH	6.5 SU	CalMoMin				7.1	7.62	7.7
pH	8.5 SU	CalMoMax				7.2	7.7	7.7

Year 2005 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2		<2	<3.2	<2	2.45

Copper, Total (as Cu)	ug/L	CalMoMax	<2	<2	4.4	<2	2.6
Flow	MG	CalMoTot	0.2282	0.02	2.27	2.78	1.89
Flow	mgd	CalMoAvg	0.0074	0.0007	0.076	0.09	0.063
Flow	mgd	CalMoMax	0.0111	0.0023	0.149	0.22	0.191
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1375	1450	599	850	892.5
Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1410	1450	791	865	934
Calculated (as Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.08	0.56	0.11	0.04	0.09
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.08	0.56	0.11	0.04	0.09
Mercury, Total (as Hg)	ng/L	SingleVal				0.7	
Nickel, Total (as Ni)	ug/L	CalMoAvg	149.5	66.3	96.35	68.75	88.05
Nickel, Total (as Ni)	ug/L	CalMoMax	155	66.3	119	77	90.3
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	12.4	3.6	1	1.5	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	12.4	3.6	1	2	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1150	1150	285	648	680
Sulfate, Total (as SO4)	mg/L	CalMoMax	1150	1150	285	660	680
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.05	0.04	0.06	0.05	0.06
Zinc, Total (as Zn)	ug/L	CalMoAvg	<10	<10	<17.05	<17.5	16.75
Zinc, Total (as Zn)	ug/L	CalMoMax	<10	<10	24.1	<17.5	20
pH	6.5 SU	CalMoMin	7.4	7.5	7.1	7.6	7.1
pH	8.5 SU	CalMoMax	7.5	7.5	7.4	7.6	7.2

Year 2006 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<3.7	<2.25	<2	3.55	1.2	<2.0
Copper, Total (as Cu)	ug/L	CalMoMax	5.4	2.5	<2	4.9	2.4	<2.0
Flow	MG	CalMoTot	1.24	1.15	0.15	2.62	3.32	0.67
Flow	mgd	CalMoAvg	0.04	0.041	0.005	0.087	0.11	0.02
Flow	mgd	CalMoMax	0.042	0.042	0.006	0.165	0.57	0.07
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1425	1550	1720	613.5	799.5	598
Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1450	1580	1730	677	928	946
Calculated (as Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.12	0.39	1	0.16	0.09	0.25
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.12	0.39	1	0.16	0.09	0.25
Mercury, Total (as Hg)	ng/L	SingleVal					0.6	
Nickel, Total (as Ni)	ug/L	CalMoAvg	183.5	95.65	46.9	142	89.25	62.2
Nickel, Total (as Ni)	ug/L	CalMoMax	197	110	49	167	107	73.3
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	4.4	7.2	<1	2.4	1.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	4.4	7.2	<1	2.4	1.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	155	1310	1460	446	726	838
Sulfate, Total (as SO4)	mg/L	CalMoMax	155	1310	1460	446	726	838
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.1	0.04	0.03	0.09	0.07	0.08
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25	<10	<10	<25	15.25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25	<10	<10	<25	30.5	<25
pH	6.5 SU	CalMoMin	7.4	7.3	7.3	7.6	7.1	7.3

pH	8.5 SU	CalMoMax	7.4	7.4	7.4	7.6	7.5	7.4
----	--------	----------	-----	-----	-----	-----	-----	-----

Year 2007 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2		3	1.75	5.4	1.55
Copper, Total (as Cu)	ug/L	CalMoMax	<2		6	3.5	10.8	3.1
Flow	MG	CalMoTot	0.096		1.22	1.3	1.37	2.92
Flow	mgd	CalMoAvg	0.003		0.039	0.043	0.045	0.1
Flow	mgd	CalMoMax	0.009		0.127	0.046	0.1	0.45
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1850		907	440	937	799.5
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1850		1550	502	1050	890
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.97		1.24	0.266	0.157	0.086
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.97		1.24	0.266	0.157	0.086
Mercury, Total (as Hg)	ng/L	SingleVal					<2	
Nickel, Total (as Ni)	ug/L	CalMoAvg	162		145.5	128	82.1	74.85
Nickel, Total (as Ni)	ug/L	CalMoMax	162		176	148	91.8	81.6
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5.6		5.6	1	<1	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	5.6		5.6	1	<1	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1200		868	381	6280	544
Sulfate, Total (as SO4)	mg/L	CalMoMax	1200		868	381	6280	544
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.07		0.13	0.08	0.27	0.07
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25		<25	<25	69	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25		<25	<25	138	<25
pH	6.5 SU	CalMoMin	7.5		7.4	7.1	7.4	7.2
pH	8.5 SU	CalMoMax	7.5		7.7	7.2	7.4	7.5

Year 2008 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	1			2.25	2.9	2.145
Copper, Total (as Cu)	ug/L	CalMoMax	2			4.5	3.2	2.2
Flow	MG	CalMoTot	0.33			5.29	2.89	4.3
Flow	mgd	CalMoAvg	0.011			0.18	0.097	0.16
Flow	mgd	CalMoMax	0.015			0.31	0.18	0.45
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1625			751.5	790	876
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1680			892	926	969
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.352			0.223	0.061	0.144
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.352			0.223	0.061	0.144
Mercury, Total (as Hg)	ng/L	SingleVal					0.8	
Nickel, Total (as Ni)	ug/L	CalMoAvg	257.5			189	176	162
Nickel, Total (as Ni)	ug/L	CalMoMax	289			208	185	168
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1			<1	<1	<1

Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1		<1	<1	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1500		730	546	734
Sulfate, Total (as SO4)	mg/L	CalMoMax	1500		730	546	734
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.08		0.09	0.08	0.07
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25		<25	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25		<25	<25	<25
pH	6.5 SU	CalMoMin	7.2		6.9	7.2	7.2
pH	8.5 SU	CalMoMax	7.3		7.1	7.2	7.3

Year 2009 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	<2	<2	<2	5.365	1.88	<2
Copper, Total (as Cu)	ug/L	CalMoMax	<2	<2	<2	6.54	3.76	<2
Flow	MG	CalMoTot	0.19	0.088	0.28	2.3	2.8	1
Flow	mgd	CalMoAvg	0.0062	0.0032	0.0091	0.076	0.09	0.033
Flow	mgd	CalMoMax	0.0068	0.0047	0.013	0.094	0.13	0.1
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1670	1710	1830	755.5	764	969.5
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1680	1710	1830	944	880	1010
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.156	0.74	1.82	0.154	0.0744	<0.050
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.156	0.74	1.82	0.154	0.0744	<0.050
Mercury, Total (as Hg)	ng/L	SingleVal					1.3	
Nickel, Total (as Ni)	ug/L	CalMoAvg	216	126	88.9	237.5	141.5	100.6
Nickel, Total (as Ni)	ug/L	CalMoMax	236	126	88.9	245	166	104
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.6	3.2	<1	<1	<1	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.6	3.2	<1	<1	<1	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1320	1450	1450	799	516	790
Sulfate, Total (as SO4)	mg/L	CalMoMax	1320	1450	1450	799	516	790
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.07	0.06	0.06	0.11	0.08	0.06
Zinc, Total (as Zn)	ug/L	CalMoAvg	<25	<25	<25	<25	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	<25	<25	<25	<25	<25	<25
pH	6.5 SU	CalMoMin	7.05	7.02	7.02	7.06	7.31	7
pH	8.5 SU	CalMoMax	7.09	7.02	7.02	7.23	7.33	7.2

Year 2010 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	0.92	1.4	1.7	1.64	1.04	1.2
Copper, Total (as Cu)	ug/L	CalMoMax	1.1	1.4	1.7	2.3	1.06	1.2
Flow	MG	CalMoTot	0.76	0.22	0.86	1.95	0.59	1.7
Flow	mgd	CalMoAvg	0.02	0.008	0.03	0.06	0.02	0.06
Flow	mgd	CalMoMax	0.032	0.013	0.05	0.11	0.05	0.27
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1730	1710	612	773	1075	942

Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1760	1710	612	824	1100	966
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.95	0.8	0.5	0.1	<0.05	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.95	1.1	0.5	0.1	<0.05	0.1
Mercury, Total (as Hg)	ng/L	SingleVal					<0.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	45.5	26.1	81.3	1006	96.2	73
Nickel, Total (as Ni)	ug/L	CalMoMax	46	26.1	81.3	1130	108	74
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5.6	4.4	1.2	2	<1	1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	5.6	4.4	1.2	2	<1	1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1340	1410	476	532	816	784
Sulfate, Total (as SO4)	mg/L	CalMoMax	1340	1410	476	532	816	784
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.03	0.03	0.03	0.04	0.03	0.03
Zinc, Total (as Zn)	ug/L	CalMoAvg	5.05	9.6	<6	<6	7.2	<6
Zinc, Total (as Zn)	ug/L	CalMoMax	10.1	9.6	<6	<6	8.5	<6
pH	6.5 SU	CalMoMin	6.9	6.8	6.9	7.2	7.5	7
pH	8.5 SU	CalMoMax	7	6.8	6.9	7.4	7.6	7.3

Year 2011 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	1			1.1	0.6	1.2
Copper, Total (as Cu)	ug/L	CalMoMax	1			2.2	1.2	<1.4
Flow	MG	CalMoTot	0.12	0	0	1.3	3.6	3.31
Flow	mgd	CalMoAvg	0.0038	0	0	0.044	0.12	0.11
Flow	mgd	CalMoMax	0.019	0	0	0.1	0.28	0.26
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	1300			751	738	926
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1300			1030	828	986
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.2			0.4	0.1	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.2			0.4	0.1	0.1
Mercury, Total (as Hg)	ng/L	SingleVal					0.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	137			68	69	48
Nickel, Total (as Ni)	ug/L	CalMoMax	137			96	77	48
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1			<1	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1			<1	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	998			738	462	667
Sulfate, Total (as SO4)	mg/L	CalMoMax	998			738	462	667
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.04			0.04	0.03	0.02
Zinc, Total (as Zn)	ug/L	CalMoAvg	14			<6	<6	<6
Zinc, Total (as Zn)	ug/L	CalMoMax	14			<6	<6	<6
pH	6.5 SU	CalMoMin	7.3			7.2	7.2	7.1
pH	8.5 SU	CalMoMax	7.3			7.3	7.2	7.2

Year 2012 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	6.45	7.8	3.6	2.9	4	3.2
Copper, Total (as Cu)	ug/L	CalMoMax	6.45	9.8	4.8	3.1	4.3	3.8
Flow	MG	CalMoTot	0.02	0.06	1.2	0.42	3.95	5.41
Flow	mgd	CalMoAvg	0.0006	0.002	0.04	0.014	0.128	0.18
Flow	mgd	CalMoMax	0.003	0.003	0.06	0.034	0.534	0.62
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1840	2010	1028	823	1035	804
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1840	2060	1620	851	1070	917
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.5	0.9	0.6	0.08	0.1	<.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.5	1.4	0.6	0.08	0.1	<.1
Mercury, Total (as Hq)	ng/L	SingleVal					<.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	130	95.2	44.8	74.2	61.2	60.8
Nickel, Total (as Ni)	ug/L	CalMoMax	130	96.7	60.9	85.6	66.8	61.4
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	6	9	4	1.6	<1	<1.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	6	9	4	1.6	<1	<1.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1460	1500	1160	633	765	562
Sulfate, Total (as SO4)	mg/L	CalMoMax	1460	1500	1160	633	765	562
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.08	0.1	0.05	0.04	0.05	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg	8.93	10.7	6.32	6	6.1	<6
Zinc, Total (as Zn)	ug/L	CalMoMax	8.93	10.7	6.64	6	6.1	<6
pH	6.5 SU	CalMoMin	6.6	6.8	6.9	7.6	7.5	7.5
pH	8.5 SU	CalMoMax	6.6	7.3	7.5	7.8	7.5	7.8

Year 2013 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	5.9			2.7	7.3	3.2
Copper, Total (as Cu)	ug/L	CalMoMax	6.9			2.7	12	3.4
Flow	MG	CalMoTot	2.93			0.089	3.96	5.07
Flow	mgd	CalMoAvg	0.0944			0.0032	0.128	0.169
Flow	mgd	CalMoMax	0.107			0.0081	0.343	0.26
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1980			1250	575	810
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1980			1310	735	820
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<.1			0.5	0.1	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<.1			0.5	0.1	0.1
Mercury, Total (as Hq)	ng/L	SingleVal					1.9	
Nickel, Total (as Ni)	ug/L	CalMoAvg	170			26.3	117	67.9
Nickel, Total (as Ni)	ug/L	CalMoMax	170			30.3	156	72.5
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2			4	1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2			4	1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1730			1070	337	673
Sulfate, Total (as SO4)	mg/L	CalMoMax	1730			1070	337	673
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.09			0.03	0.12	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg	10.9			<6	<6	7.3

Zinc, Total (as Zn)	ug/L	CalMoMax	13.1		<6	<6	7.3
pH	6.5 SU	CalMoMin	6.7		6.6	7	6.9
pH	8.5 SU	CalMoMax	7.4		6.7	7.1	7.2

Year 2014 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	6.2			4.5	3.9	3
Copper, Total (as Cu)	ug/L	CalMoMax	6.9			5.4	5.3	3.1
Flow	MG	CalMoTot	1.1			0.87	5	3
Flow	mgd	CalMoAvg	0.036			0.031	0.16	0.1
Flow	mgd	CalMoMax	0.36			0.058	0.31	0.23
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1630			496	567	778
Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1660			525	656	853
Calculated (as Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	1			0.6	0.1	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	1			0.6	0.1	0.1
Mercury, Total (as Hg)	ng/L	SingleVal					1.6	
Nickel, Total (as Ni)	ug/L	CalMoAvg	144			142	109	92.4
Nickel, Total (as Ni)	ug/L	CalMoMax	210			169	120	97.2
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	15			2	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	23			2	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1450			363	367	620
Sulfate, Total (as SO4)	mg/L	CalMoMax	1450			363	367	620
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.09			0.08	0.07	0.05
Zinc, Total (as Zn)	ug/L	CalMoAvg	12.3			<6	<12	<12
Zinc, Total (as Zn)	ug/L	CalMoMax	12.6			<6	<12	<12
pH	6.5 SU	CalMoMin	6.6			7.5	6.6	7.1
pH	8.5 SU	CalMoMax	7.8			7.7	7.8	7.8

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg			3.2	2.1	2.6	2.1
Copper, Total (as Cu)	ug/L	CalMoMax			3.8	2.4	3	2.1
Flow	MG	CalMoTot			0.34	2	2	11
Flow	mgd	CalMoAvg			0.011	0.067	0.07	0.37
Flow	mgd	CalMoMax			0.083	0.18	0.13	0.67
Hardness, Calcium & Magnesium, Calculated (as CaCO3)	mg/L	CalMoAvg			1200	565	799	774
Hardness, Calcium & Magnesium, Calculated (as CaCO3)	mg/L	CalMoMax			1240	583	823	866
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg			0.2	0.5	0.12	0.07
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax			0.2	0.5	0.12	0.07
Mercury, Total (as Hg)	ng/L	SingleVal					0.51	
Nickel, Total (as Ni)	ug/L	CalMoAvg			41	104	83	64

Nickel, Total (as Ni)	ug/L	CalMoMax		42.7	126	84	73
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg		6	<1	<1	2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax		6	<1	<1	2
Sulfate, Total (as SO4)	mg/L	CalMoAvg		984	505	584	640
Sulfate, Total (as SO4)	mg/L	CalMoMax		984	505	584	640
Toxicity, Final Conc	1.00 toxunt	CalMoMax		0.05	0.04	0.05	0.04
Zinc, Total (as Zn)	ug/L	CalMoAvg		<12	<12	<12	<12
Zinc, Total (as Zn)	ug/L	CalMoMax		<12	<12	<12	<12
pH	6.5 SU	CalMoMin		6.6	7.1	7.4	7.1
pH	8.5 SU	CalMoMax		6.8	7.5	7.7	7.7

Jul	Aug	Sep	Oct	Nov	Dec
	<2.0	<2.0	<2.0	1.6	1
	<2.0	<2.0	<2.0	3.2	2
	1.44	1.85	2.05	1.38	1.147
	0.047	0.062	0.066	0.046	0.037
	0.239	0.209	0.219	0.077	0.039
	1045	920	1005	1078	1330
	1100	947	1010	1160	1400
	0.04	0.02	<0.03	0.28	0.04
	0.05	0.03	<0.03	0.28	0.04
		0.4			
	37.1	44.9	45.9	79.6	171
	37.8	49.2	55.5	87	182
	7.8	3.2	<1.0	2.8	2.8
	12	4	<1.0	2.8	2.8
	825	924	959	792	1070
	829	950	959	792	1070
	0.04	0.005	0.006	0.03	0.03
	12.1	<10	<10	<10	<10
	24.2	<10	<10	<10	<10
	7.4	7.5	7	7.1	7.4
	7.6	7.5	7.1	7.1	7.4

Jul	Aug	Sep	Oct	Nov	Dec
<2	<7.05	<7.4	<3.15	<2	<2
<2	12.1	12.8	4.3	<2	<2
1.57	2.61	1.02	1.58	1.32	0.6
0.05	0.0842	0.0341	0.0511	0.0439	0.0194
0.31	0.5011	0.0725	0.0944	0.0583	0.0387
1070	520	1033.5	2277	1455	1435
1080	900	1140	1227	1530	1440
0.04	0.08	0.07	<0.03	0.06	<0.03
0.04	0.08	0.07	<0.03	0.06	<0.03
		0.64			
115	79.55	43.25	102.9	195.5	292.5
148	98.1	46.6	155	206	355
<1	3.2	2	2.8	2	3.6
<1	3.2	2	2.8	2	3.6

1130	907	1020	1050	1200	1160
1130	907	1020	1050	1200	1160
<0.044	0.1153	<0.2346	<0.0514	<0.0507	<0.0670
<10	11.75	<10	<10	<10	<10
<10	12.5	<10	<10	<10	<10
7.3	7.5	7.2	7.3	7.3	7.1
7.5	7.5	7.4	7.4	7.4	7.2

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	<2	<2	<2
<2	<2	<2	<2	<2	<2
1	1.69	1.04	1.19	0.47	0.2
0.0321	0.054	0.0347	0.0383	0.0156	0.0064
0.1198	0.41	0.0886	0.0629	0.0188	0.0081
1252	1050	1041.5	1110	1245	1585
1305	1070	1080	1150	1370	1590
0.04	<0.03	<0.03	<0.03	0.06	0.06
0.04	<0.03	<0.03	<0.03	0.06	0.06
		<50			
73.35	40.85	38.15	121	164.5	225
91.5	41	43.6	138	193	244
4	2	<1	<1	2.5	1.6
4	2	<1	<1	2.5	1.6
1050	915	860	873	940	1240
1050	915	860	873	940	1240
<0.0465	<0.0361	<0.0332	0.04	0.05	0.06
15.65	<11.2	<10	<10		<10
16.1	12.4	<10	<10	<10	<10
7.3	7.1	7.4	7.1	7.4	7.2
7.3	7.4	7.6	7.5	7.9	7.3

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	<2	<2	<2
<2	<2	<2	<2	<2	<2
1.07	0.6	1.37	1.02	0.71	0.31
0.0346	0.0195	0.0456	0.033	0.0237	0.01
0.0886	0.0499	0.2823	0.0353	0.0237	0.011
901	937.5	884	931.5	891	1207.5
909	982	1060	1010	942	1310

0.05	0.04	0.04	<0.03	<0.03	0.06
0.05	0.04	0.04	<0.03	<0.03	0.06
		<10			
50.05	32.7	57.8	68.7	116.5	118.4
57.5	35.6	88.3	69.5	129	138
<1	2.5	1.2	<1	<1	<1
<1	2.5	1.2	<1	<1	<1
743	778	813	745	853	991
743	778	813	745	853	991
0.04	0.04	0.06	0.04	0.04	0.04
10.85	13.35	23.35	<10	<10	<10
11.7	16.7	27.1	<10	<10	<10
7.5	7.61	7.3	7.1	7	7.2
7.5	7.7	7.5	7.2	7.4	7.3

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	7.6	<2	<2
<2	<2	<2	13.2	<2	<2
0.4974	0.64	1.44	1.71	0.8669	0.446
0.016	0.021	0.048	0.055	0.0289	0.014
0.0725	0.05	0.094	0.127	0.0422	0.019
1095	1255	1300	1170	1021.5	1305
1150	1260	1330	1200	1170	1310
0.07	0.05	0.03	0.04	0.04	0.04
0.07	0.05	0.03	0.04	0.04	0.04
		<4			
54.1	25.3	44.6	71.6	125	201
58.6	38.1	53.9	90.1	134	237
4.5	2	2.5	1.5	1.6	5.5
4.5	2	2.5	1.5	1.6	5.5
1020	1090	1150	1090	1020	1140
1020	1090	1150	1090	1020	1140
0.03	0.03	0.03	0.12	0.06	0.05
<10	<10	<10	<10	<15.8	<10
<10	<10	<10	<10	<20	<10
7.4	7.4	7.3	7.2	7.6	7.2
7.4	7.4	7.4	7.33	8.04	7.6

Jul	Aug	Sep	Oct	Nov	Dec
<2	<3.95	<2	<2.2	<2.65	<2.05

2	5.9	<2	2.4	3.3	2.1
0.6	0.31	0.607	2.09	2.24	1.25
0.019	0.01	0.02	0.067	0.075	0.04
0.058	0.07	0.042	0.282	0.094	0.046
1150	1325	1385	1280	1205	1340
1270	1340	1400	1300	1310	1520
0.16	<0.05	0.1	0.06	0.05	<0.05
0.16	<0.05	0.1	0.06	0.05	<0.05
		<0.5			
51.35	35.6	37	113.5	167	250.5
57.1	41	37.1	116	212	280
1	7	<3.5	4.4	3.6	1.6
1	7	6	4.4	3.6	1.6
934	1080	1110	812	1160	1070
934	1080	1130	812	1160	1070
0.05	0.08	0.05	0.13	0.08	0.07
<17.5	<25	<25	<48.85	<25	<17.5
<25	<25	<25	72.7	<25	<25
7.2	7.3	7.15	7.3	7.4	7.4
7.3	7.4	7.2	7.5	7.5	7.4

Jul	Aug	Sep	Oct	Nov	Dec
<2.0	<2	1.3	<2	<2	1.3
<2.0	<2	2.6	<2	<2	2.6
0.423	1.58	0.665	1.272	0.456	0.31
0.014	0.051	0.022	0.041	0.0152	0.01
0.113	0.165	0.073	0.0583	0.0167	0.011
1365	1065	1320	1210	1425	1780
1420	1080	1340	1300	1480	1890
0.13	0.141	0.0605	<0.05	0.0921	<0.05
0.13	0.141	0.0605	<0.05	0.0921	<0.05
		<0.5			
38.5	57.35	37.05	102.05	163	204
41.2	66.7	40.4	150	171	225
<1	3.2	2.8	2.8	1.2	2.4
<1	3.2	2.8	2.8	1.2	2.4
978	890	1020	1030	1080	1270
978	890	1020	1030	1080	1270
0.05	0.06	0.06	0.06	0.07	0.08
<25	<25	<25	<25	<25	<25
<25	<25	<25	<25	<25	<25
7.3	7.3	7.3	7.4	7.3	7.2

7.3	7.4	7.3	7.4	7.4	7.4
-----	-----	-----	-----	-----	-----

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	11.35	6.3175	3.75	2.35
<2	<2	19.3	8	3.8	2.5
0.43	0.01	6.1	5.76	2.7	0.67
0.014	0.0005	0.2	0.19	0.093	0.023
0.035	0.007	0.66	0.28	0.094	0.024
1075	1270	841	1045	1250	1735
1120	1270	1060	1250	1280	1750
0.176	0.155	0.203	0.157	0.0706	0.307
0.176	0.155	0.203	0.157	0.0706	0.307
		1.9			
44.05	54.5	237	511.75	474.5	433
46.8	54.5	293	615	489	458
<1	3.2	3	<1	10	<1
<1	3.2	3	<1	10	<1
797	930	2520	63.6	1070	1500
797	930	2520	63.6	1070	1500
0.05	0.05	0.2	0.18	0.13	0.1
<25	<25	<25	34.05	30.2	<25
<25	<25	<25	50.3	33.3	<25
7.3	7.2	7.3	7	7.3	7.2
7.3	7.2	7.4	7.3	7.3	7.3

Jul	Aug	Sep	Oct	Nov	Dec
<2	1.115	3.27	1.11	1.02	<2
<2	2.23	6.54	2.22	2.04	<2
0.77	0.31	1.6	2.8	1	0.3
0.027	0.011	0.052	0.089	0.034	0.0097
0.054	0.024	0.24	0.2	0.042	0.017
1285	1595	1485	1355	1440	1790
1390	1630	1530	1400	1500	1800
0.0942	0.182	0.436	<0.050	<0.050	<0.050
0.0942	0.182	0.436	<0.050	<0.050	<0.050
		<0.5			
120.5	82.45	104.55	175.5	261.5	328
132	105	165	224	271	346
<1	2	2.8	<1	<1	2

<1	2	2.8	<1	<1	2
1030	1320	1380	1600	1070	1450
1030	1320	1380	1600	1070	1450
0.06	0.06	0.09	0.07	0.08	0.09
<25	<25	<25	<25	<25	<25
<25	<25	<25	<25	<25	<25
7.1	7.1	7.23	7.19	7.23	6.97
7.4	7.2	7.36	7.61	7.7	7.34

Jul	Aug	Sep	Oct	Nov	Dec
<2	<2	<2	2.17	<2	1.65
<2	<2	<2	2.34	<2	1.7
0.61	0.82	0.46	1.47	1.46	1.05
0.02	0.027	0.02	0.047	0.049	0.039
0.05	0.058	0.04	0.083	0.058	0.068
1140	1170	1180	1330	1115	1340
1170	1210	1210	1410	1130	1390
0.0529	<0.050	0.132	<0.050	<0.050	<0.050
0.0529	<0.050	0.132	<0.050	<0.050	<0.050
		0.5			
75.55	61.85	42.9	65.15	161.5	182
79.2	64.3	44.4	74.8	162	189
1.6	<1	1.2	1.2	<1	<1
1.6	<1	1.2	1.2	<1	<1
919	961	1020	1070	1010	1070
919	961	1020	1070	1010	1070
0.06	0.06	0.05	0.06	0.07	0.05
<25	<25	<25	<25	<25	9.625
<25	<25	<25	<25	<25	12.5
7.1	7.1	7.1	7.4	6.7	6.9
7.2	7.4	7.3	7.4	7.2	7.2

Jul	Aug	Sep	Oct	Nov	Dec
0.47	0.78	<0.7	1	1.1	1.1
0.94	0.82	<0.7	1.3	1.1	1.2
0.95	2.2	0.24	0.051	0.22	0.38
0.03	0.07	0.008	0.0016	0.0073	0.012
0.23	0.23	0.035	0.0047	0.017	0.017
952	937	1040	978	973	1235

976	995	1070	1060	1060	1240
0.1	<0.05	0.1	<0.05	<0.05	<0.05
0.1	<0.05	0.1	<0.05	<0.05	<0.05
		0.7			
56	44	40	54	72	139
62	45	41	61	76	156
2	2	4	<1	2	<1
2	2	4	<1	2	<1
721	746	835	750	721	919
721	746	835	750	721	919
0.02	0.02	0.02	0.02	0.02	0.04
<6	<6	<6	3.3	<6	7.2
<6	<6	<6	6.6	<6	8.3
7.1	7.2	7.3	6.9	7.1	7.3
7.2	7.4	7.4	7.3	7.6	7.4

Jul	Aug	Sep	Oct	Nov	Dec
0.8	2.6	2.5	3	4.9	3.6
0.9	2.6	2.59	3.6	5	3.7
0.85	0.28	0.12	0.47	0.58	0.143
0.03	0.009	0.004	0.015	0.02	0.005
0.06	0.05	0.01	0.026	0.03	0.006
871	1006	1140	1145	1210	1540
914	1020	1140	1180	1280	1660
0.2	0.2	0.1	<0.05	<0.05	<0.05
0.2	0.2	0.1	<0.05	<0.05	<0.05
		<0.5			
41	16.1	22.4	41	74	85.7
43	17.3	25.5	51	80	86.6
1	2.8	1	5	3	3.2
1	2.8	1	5	3	3.2
640	762	854	902	950	1390
640	762	854	902	950	1390
0.03	0.05	0.03	0.04	0.06	0.05
11	13	<6	<6	7.7	8.13
15	<20	<6	<6	8.2	8.38
7.4	7.4	7.4	7.1	7.2	7.2
7.5	7.4	7.6	7.4	7.4	7.3

Jul	Aug	Sep	Oct	Nov	Dec
4	4.2	4.9	4.3	5.5	5.2
5.3	5.1	5	4.6	5.5	5.3
2.59	3.2	0.61	0.39	0.63	0.5
0.086	0.11	0.021	0.013	0.021	0.016
0.28	0.55	0.078	0.083	0.026	0.029
978	1250	1330	1420	1370	1580
1070	1280	1340	1440	1410	1650
0.14	<.1	<.1	<.1	<.1	<.05
0.14	<.1	<.1	<.1	<.1	<.05
		<.5			
60.1	33.5	21.5	51.1	119	144
76.6	37.7	22.9	61	133	154
2.8	2	3	2	2	2
2.8	2	3	2	2	2
720	963	1150	1180	1120	1350
720	963	1150	1180	1120	1350
0.05	0.05	0.05	0.05	0.07	0.07
6.8	6.5	<6	7.6	7.2	8.2
6.8	6.8	<6	9.1	8	8.3
7.4	7.3	7.4	7.4	7.2	7.4
7.4	7.5	7.6	7.8	7.3	7.5

Jul	Aug	Sep	Oct	Nov	Dec
2.5	3	2.9	3.8	3.5	6.3
2.9	3	3.3	3.9	3.7	7.1
3.31	0.89	1.6	2.1	0.8	0.25
0.107	0.029	0.053	0.069	0.027	0.008
0.425	0.068	0.15	0.16	0.035	0.011
753	848	1070	1140	1150	1540
791	927	1090	1190	1150	1540
0.1	0.1	0.1	<.1	0.1	<.1
0.1	0.1	0.1	<.1	0.1	<.1
		<.5			
49.9	49	32.6	53.2	119	205
50.4	49.4	34.7	75.8	144	243
1	1.2	3	2	2	5
1	1.2	3	2	2	5
586	656	876	967	1050	1310
586	656	876	967	1050	1310
0.04	0.04	0.04	0.05	0.06	0.08
7.7	<6	<6	<6	<9	12.1

9.3	<6	<6	<6	<12	12.1
7.2	7.2	7.2	7.3	6.7	6.6
7.3	7.3	7.5	7.8	7.6	7.4

Jul	Aug	Sep	Oct	Nov	Dec
3.4	3.6	3.8	3.1	3.7	3.8
3.4	3.8	4	3.4	4.1	3.8
1.5	0.86	1.2	0.83	0.63	0.26
0.047	0.029	0.041	0.027	0.021	0.0085
0.15	0.073	0.13	0.054	0.032	0.011
905	1130	1170	1200	1310	1500
907	1150	1220	1210	1390	1540
<.1	0.1	0.1	0.1	0.1	<.1
<.1	0.1	0.1	0.1	0.1	<.1
		0.826			
73.7	43	49.8	55.1	88.9	195
81.2	49	51.6	57.3	100	220
1	4	<3	2	4	7
1	4	<3	2	4	7
762	896	928	1020	1080	1190
762	896	928	1020	1080	1190
0.05	0.05	0.05	0.05	0.08	0.07
<12	<12	<12	<12	23.1	6.2
<12	<12	<12	<12	34.1	12.4
7.2	7.2	7.3	7.6	7.2	7
7.6	7.4	7.7	7.9	7.6	7.3

Jul	Aug	Sep	Oct	Nov	Dec
2.1	2.2				
2.2	2.3				
1.2	0.62				
0.04	0.02				
0.19	0.07				
842	950				
869	982				
0.14	0.1				
0.14	0.1				
30	18				

34	19		
1.6	1.2		
1.6	1.2		
654	630		
667	630		
0.04	0.04		
<12	<12		
<12	<12		
7.3	7.5		
7.4	7.5		

Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	23 ug/L	CalMoAvg						
Copper, Total (as Cu)	65 ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMin						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Nickel, Total (as Ni)	213 ug/L	CalMoAvg						
Nickel, Total (as Ni)	4582 ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Zinc, Total (as Zn)	343 ug/L	CalMoAvg						
Zinc, Total (as Zn)	378 ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2001 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	23 ug/L	CalMoAvg						
Copper, Total (as Cu)	65 ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMin						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Nickel, Total (as Ni)	213 ug/L	CalMoAvg						
Nickel, Total (as Ni)	4582 ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Zinc, Total (as Zn)	343 ug/L	CalMoAvg						
Zinc, Total (as Zn)	378 ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	23 ug/L	CalMoAvg						
Copper, Total (as Cu)	65 ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						

Flow	mgd	CalMoMin				
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				
Nickel, Total (as Ni)	213 ug/L	CalMoAvg				
Nickel, Total (as Ni)	4582 ug/L	CalMoMax				
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				
Zinc, Total (as Zn)	343 ug/L	CalMoAvg				
Zinc, Total (as Zn)	378 ug/L	CalMoMax				
pH	6.5 SU	CalMoMin				
pH	8.5 SU	CalMoMax				

Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg						
Copper, Total (as Cu)	ug/L	CalMoMax						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMax						
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg						
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Mercury, Total (as Hg)	ng/L	SingleVal						
Nickel, Total (as Ni)	ug/L	CalMoAvg						
Nickel, Total (as Ni)	ug/L	CalMoMax						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
Sulfate, Total (as SO4)	mg/L	CalMoAvg						
Sulfate, Total (as SO4)	mg/L	CalMoMax						
Toxicity, Final Conc	1.00 toxunt	CalMoMax						
Zinc, Total (as Zn)	ug/L	CalMoAvg						
Zinc, Total (as Zn)	ug/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2001 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	8.5	18.6	20.7	25	14.35	10.7
Copper, Total (as Cu)	ug/L	CalMoMax	10.8	21	22.3	29.2	17.3	12.9
Flow	MG	CalMoTot	3.689	2.548	3.1	10.35	4.67	6.4
Flow	mgd	CalMoAvg	0.119	0.091	0.1	0.345	0.266	0.27
Flow	mgd	CalMoMax	0.169	2.548	0.121	0.44	0.405	0.509
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1565	1580	1640	1270	954	1075
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax	1630	1720	1670	1430	1060	1110
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.6	0.12	0.04	0.16	0.18	<0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.6	0.12	0.04	0.16	0.18	<0.03
Mercury, Total (as Hg)	ng/L	SingleVal					0.67	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1850	2000	1865	1520	1180	1335
Nickel, Total (as Ni)	ug/L	CalMoMax	2230	2150	1900	1540	1210	1470
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	8.8	4.4	8	4.8	4	11
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	8.8	4.4	8	4.8	4	11
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1650	1610	1790	1480	904	1210

Sulfate, Total (as SO4)	mg/L	CalMoMax	1650	1610	1790	1480	904	1210
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.4	0.47	0.47	0.46	0.3121	0.2755
Zinc, Total (as Zn)	ug/L	CalMoAvg	41	41.8	80	48.6	25.75	31.45
Zinc, Total (as Zn)	ug/L	CalMoMax	59	57.8	80	50.4	31.7	35
pH	6.5 SU	CalMoMin	7.2	7	7	7.1	7.2	7.2
pH	8.5 SU	CalMoMax	7.2	7.3	7	7.3	7.5	7.4

Year 2002 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	9.95	8.5	12.1	9.5	6.3	4.95
Copper, Total (as Cu)	ug/L	CalMoMax	12.3	12.3	16.8	10.1	6.7	6.2
Flow	MG	CalMoTot	2.47	3.45	1.16	0	3.19	4.02
Flow	mgd	CalMoAvg	0.1115	0.134	0.06	0.01	0.13	0.17
Flow	mgd	CalMoMax	0.1442	0.1688	0.121	0.1946	0.1688	0.5454
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1635	1410	1435	1132	1315	1230
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1700	1420	1460	1340	1330	1290
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.14	0.41	0.21	0.05	0.1	0.06
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.14	0.41	0.21	0.05	0.1	0.06
Mercury, Total (as Hg)	ng/L	SingleVal					0.9	
Nickel, Total (as Ni)	ug/L	CalMoAvg	2310	1490	1590	1730	1615	779
Nickel, Total (as Ni)	ug/L	CalMoMax	2750	1790	1890	1980	1790	923
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5.2	2	4.8	2	1.6	4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	5.2	2	4.8	2	1.6	4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1730	1540	1750	3480	1310	1410
Sulfate, Total (as SO4)	mg/L	CalMoMax	1730	1540	1750	3480	1310	1410
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.4389	0.3497	0.4026	0.34	0.2845	0.164
Zinc, Total (as Zn)	ug/L	CalMoAvg	53.6	35.85	42.2	48.4	27.75	11.9
Zinc, Total (as Zn)	ug/L	CalMoMax	61.3	45.9	51.7	50.6	28.8	12.1
pH	6.5 SU	CalMoMin	7	7.2	7.3	7.2	7.1	7.1
pH	8.5 SU	CalMoMax	7.1	7.4	7.4	7.6	7.6	7.4

Year 2003 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	8.2	5.25	7.8	5.15	3.8	7.15
Copper, Total (as Cu)	ug/L	CalMoMax	8.6	6.3	7.9	5.9	3.9	11
Flow	MG	CalMoTot	4.4	10.67	1.93	3.46	2.3	2.33
Flow	mgd	CalMoAvg	0.18	0.22	0.078	0.1442	0.093	0.0971
Flow	mgd	CalMoMax	0.405	0.3399	0.121	0.1442	0.1442	0.3399
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1605	1645	1530	986	1190	1250
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1700	1740	1780	1400	1240	1340
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.14	2.39	0.78	0.14	0.06	0.09

Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.14	2.39	0.78	0.14	0.06	0.09
Mercury, Total (as Hg)	ng/L	SingleVal					1.1	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1745	758.5	1205	1051	758.5	641
Nickel, Total (as Ni)	ug/L	CalMoMax	1930	931	1270	1430	868	728
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	6.5	1.6	1.6	2.8	3.5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	6.5	1.6	1.6	3.6	3.5
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1540	1530	1600	1430	1125	1440
Sulfate, Total (as SO4)	mg/L	CalMoMax	1540	1530	1600	1430	1160	1440
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.34	0.19	0.25	0.23	0.14	0.19
Zinc, Total (as Zn)	ug/L	CalMoAvg	50.1	24.75	31.85	26.5	15.7	23.9
Zinc, Total (as Zn)	ug/L	CalMoMax	51	27	37.7	33	18.5	37.8
pH	6.5 SU	CalMoMin	7.1	7.3	7.5	7.3	7.4	7.07
pH	8.5 SU	CalMoMax	7.4	7.6	7.6	7.4	7.5	7.5

Year 2004 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	10.7	9.7	11	13.15	7.1	7.6
Copper, Total (as Cu)	ug/L	CalMoMax	13.3	10.2	11.5	13.5	7.4	9
Flow	MG	CalMoTot	2.59	2.19	2.27	5.39	5.39	4.73
Flow	mgd	CalMoAvg	0.0015	0.0012	0.0011	0.0049	0.004	0.004
Flow	mgd	CalMoMax	0.0017	0.0017	0.0012	0.0081	0.017	0.0081
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1580	1570	1505	1260	1160	1140
Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoMax	1580	1590	1520	1260	1160	1250
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.25	0.31	0.32	0.18	0.05	0.06
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.25	0.31	0.32	0.18	0.05	0.06
Mercury, Total (as Hg)	ng/L	SingleVal					<4	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1865	1690	1740	1925	1580	1370
Nickel, Total (as Ni)	ug/L	CalMoMax	2050	1700	1770	1980	1630	1480
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	1.6	<1	2	2	<1	1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	1.6	<1	2	2	<1	1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1670	1760	1570	1290	1340	1210
Sulfate, Total (as SO4)	mg/L	CalMoMax	1670	1760	1570	1290	1340	1210
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.36	0.32	0.32	0.36	0.26	0.26
Zinc, Total (as Zn)	ug/L	CalMoAvg	48.55	38.85	34.7	21.5	20.8	18
Zinc, Total (as Zn)	ug/L	CalMoMax	54.7	40.7	34.8	33	21.8	19.6
pH	6.5 SU	CalMoMin	7.2	7.1	7.1	7.1	7.39	7.6
pH	8.5 SU	CalMoMax	7.3	7.1	7.2	7.3	7.5	7.7

Year 2005 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	65.9	<6.3	9.9	8.55	7.05	9.7
Copper, Total (as Cu)	ug/L	CalMoMax	12.3	10.6	10.5	10.9	7.1	10.6

Flow	MG	CalMoTot	1.87	3.06	2.18	5.39	5.87	6.14
Flow	mgd	CalMoAvg	0.0009	0.0021	0.0011	0.0057	0.005	0.0061
Flow	mgd	CalMoMax	0.0017	0.0023	0.0029	0.0111	0.011	0.0167
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	1430	1410	1505	1155	1215	1100
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1480	1470	1540	1270	1300	1100
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.09	0.05	0.07	0.3	0.05	0.18
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.09	0.05	0.07	0.3	0.05	0.18
Mercury, Total (as Hq)	ng/L	SingleVal					<0.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	2360	2290	2035	1670	1570	1285
Nickel, Total (as Ni)	ug/L	CalMoMax	2360	2430	2080	1840	1710	1330
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	2	6	2.5	1.5	5.5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	2	6	2.5	2.5	5.5
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1520	1860	1580	920	1167	1130
Sulfate, Total (as SO4)	mg/L	CalMoMax	1520	1860	1580	920	1370	1130
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.43	0.43	0.37	0.35	0.29	0.26
Zinc, Total (as Zn)	ug/L	CalMoAvg	58.4	60	50.9	46.75	34.3	27.75
Zinc, Total (as Zn)	ug/L	CalMoMax	60.5	66.4	51	49.9	38	35.5
pH	6.5 SU	CalMoMin	7.4	7.3	6.8	7	7.1	6.7
pH	8.5 SU	CalMoMax	7.5	7.4	7.4	7.5	7.3	7

Year 2006 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	10.9	9.65	10.45	9.6	7	2.7
Copper, Total (as Cu)	ug/L	CalMoMax	10.9	10.9	11.3	13.1	9.2	2.8
Flow	MG	CalMoTot	6.02	6.62	3.19	4.5	7.66	4.01
Flow	mgd	CalMoAvg	0.006	0.008	0.002	0.004	0.01	0.003
Flow	mgd	CalMoMax	0.006	0.01	0.003	0.005	0.04	0.013
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoAvg	1475	1505	1475	1070	1105.5	949
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1490	1480	1520	1100	1330	1310
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.15	<0.05	0.14	0.29	0.15	0.65
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.15	<0.05	0.14	0.29	0.15	0.65
Mercury, Total (as Hq)	ng/L	SingleVal					0.6	
Nickel, Total (as Ni)	ug/L	CalMoAvg	2850	2525	2495	1680	1410	878.5
Nickel, Total (as Ni)	ug/L	CalMoMax	3030	2590	2610	1930	1550	950
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2	2.4	2.8	1.6	3.2	4.4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2	2.4	2.8	1.6	3.2	4.4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1560	1470	1600	1090	1310	1240
Sulfate, Total (as SO4)	mg/L	CalMoMax	1560	1470	1600	1090	1310	1240
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.49	0.44	0.43	0.38	0.24	0.16
Zinc, Total (as Zn)	ug/L	CalMoAvg	67.25	59.9	56.95	38.25	25.8	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	67.7	61.2	60.4	50.7	26	<25
pH	6.5 SU	CalMoMin	7.4	7.3	7.3	7.4	7.2	6.9
pH	8.5 SU	CalMoMax	7.4	7.4	7.4	7.6	7.6	7.1

Year 2007 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	7.895	3.1	10.15	6.54	3.83	4.25
Copper, Total (as Cu)	ug/L	CalMoMax	9.15	3.1	10.5	7.38	5.45	4.7
Flow	MG	CalMoTot	0.58	0.1	1.54	1.33	2.95	5.15
Flow	mgd	CalMoAvg	0.0001	0.00002	0.001	0.0005	0.002	0.005
Flow	mgd	CalMoMax	0.0003	0.00005	0.003	0.0008	0.01	0.03
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1655	1670	1246.5	1020	1034	1086
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1760	1670	1570	1370	1140	1290
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.247	0.519	0.384	0.268	0.484	0.182
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.247	0.519	0.384	0.268	0.484	0.182
Mercury, Total (as Hg)	ng/L	SingleVal					<2	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1985	382	1165	1322	366.5	626.5
Nickel, Total (as Ni)	ug/L	CalMoMax	2050	382	1180	1690	417	667
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2.8	4.8	4.4	3.5	2.4	1.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2.8	4.8	4.4	3.5	2.4	1.2
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1330	1600	1620	1330	836	776
Sulfate, Total (as SO4)	mg/L	CalMoMax	1330	1600	1620	1330	836	776
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.35	0.1	0.24	0.3	0.08	0.14
Zinc, Total (as Zn)	ug/L	CalMoAvg	36.9	<25	12.75	37.35	<25	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	40.5	<25	25.5	45	<25	<25
pH	6.5 SU	CalMoMin	7.5	7.4	7.2	7	7.5	7.3
pH	8.5 SU	CalMoMax	7.5	7.4	7.5	7	7.6	7.4

Year 2008 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	15	13.05	10.24	12.85	7.275	3.975
Copper, Total (as Cu)	ug/L	CalMoMax	15.9	15.6	10.7	14.1	8.85	4.25
Flow	MG	CalMoTot	3.77	4.33	2.63	4.64	4.98	6.95
Flow	mgd	CalMoAvg	0.002	0.004	0.001	0.004	0.005	0.008
Flow	mgd	CalMoMax	0.003	0.005	0.002	0.006	0.017	0.017
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1400	1615	1775	1035	1150	802
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1420	1690	1840	1370	1230	910
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.0669	0.12	0.666	0.625	0.0549	0.231
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.0669	0.12	0.666	0.625	0.0549	0.231
Mercury, Total (as Hg)	ng/L	SingleVal					0.8	
Nickel, Total (as Ni)	ug/L	CalMoAvg	3055	2475	2270	1720	1730	409
Nickel, Total (as Ni)	ug/L	CalMoMax	3110	2740	2320	2030	2040	530
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	<1	1	2	2	1.2
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	<1	1	2	2	1.2

Sulfate, Total (as SO4)	mg/L	CalMoAvg	1540	1620	1630	1280	1100	755
Sulfate, Total (as SO4)	mg/L	CalMoMax	1540	1620	1630	1280	1100	755
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.59	0.52	0.41	0.38	0.35	0.12
Zinc, Total (as Zn)	ug/L	CalMoAvg	90.9	62.7	63.5	44.45	21.7	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	95.5	74.5	73.1	52.8	43.4	<25
pH	6.5 SU	CalMoMin	7.3	7.3	7.3	6.9	6.9	7.3
pH	8.5 SU	CalMoMax	7.3	7.3	7.4	7.1	7.3	7.4

Year 2009 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	18.5	18.25	14.8	22.15	8	5.03
Copper, Total (as Cu)	ug/L	CalMoMax	18.6	20.9	16.1	24	10.3	6.02
Flow	MG	CalMoTot	4.18	3.06	4.81	6.31	4.11	5.7
Flow	mgd	CalMoAvg	0.0029	0.0021	0.0037	0.0063	0.0031	0.0082
Flow	mgd	CalMoMax	0.0029	0.0023	0.0037	0.0068	0.0047	0.058
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1405	1425	1320	1181	895.5	972
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1460	1440	1440	1430	921	998
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	<0.050	<0.050	<0.050	0.121	0.0744	0.0843
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	<0.050	<0.050	<0.050	0.121	0.0744	0.0843
Mercury, Total (as Hg)	ng/L	SingleVal					1.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	2840	2685	2250	2155	1100	681
Nickel, Total (as Ni)	ug/L	CalMoMax	3040	2720	2520	2660	1320	809
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2.8	3	<1	<1	1.2	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2.8	3	<1	<1	1.2	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1360	1480	1460	1370	828	947
Sulfate, Total (as SO4)	mg/L	CalMoMax	1360	1480	1460	1370	828	947
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.59	0.56	0.5	0.58	0.26	0.17
Zinc, Total (as Zn)	ug/L	CalMoAvg	84.85	78.45	65.45	64.85	13.2	<25
Zinc, Total (as Zn)	ug/L	CalMoMax	90.2	84.8	74.5	83.2	26.4	<25
pH	6.5 SU	CalMoMin	6.87	6.91	6.9	6.91	7.06	6.9
pH	8.5 SU	CalMoMax	6.91	6.94	6.95	6.97	7.27	7

Year 2010 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	6.24	6.3	5.8	4.9	3.8	2.7
Copper, Total (as Cu)	ug/L	CalMoMax	8.9	8.3	7.8	5.7	4.3	2.8
Flow	MG	CalMoTot	2.8	0.38	0.87	1.46	0.006	0.06
Flow	mgd	CalMoAvg	0.09	0.01	0.03	0.05	0.0002	0.002
Flow	mgd	CalMoMax	0.1	0.01	0.03	0.06	0.0008	0.01
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1475	1410	1285	891	1285	1135
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1550	1420	1540	1040	1300	1150

Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.9	0.3	0.4	0.1	0.08	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	1.6	0.3	0.4	0.1	0.08	0.1
Mercury, Total (as Hg)	ng/L	SingleVal					<0.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	886	705	425	906	589	282
Nickel, Total (as Ni)	ug/L	CalMoMax	1270	1140	708	1060	592	290
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	4.8	1.6	3.6	2	1.6	6
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	4.8	1.6	3.6	2	1.6	6
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1540	1480	1360	671	1180	1040
Sulfate, Total (as SO4)	mg/L	CalMoMax	1540	1480	1360	671	1180	1040
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.25	0.23	0.17	0.19	0.12	0.06
Zinc, Total (as Zn)	ug/L	CalMoAvg	14.75	24.4	19.4	20	12.6	6.7
Zinc, Total (as Zn)	ug/L	CalMoMax	29.5	29.8	24.5	<25	15.1	6.7
pH	6.5 SU	CalMoMin	6.6	6.6	6.7	6.9	7.2	6.7
pH	8.5 SU	CalMoMax	7	6.7	6.7	6.9	7.2	6.8

Year 2011 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	3.6	4	3.9	6.5	6.2	3.6
Copper, Total (as Cu)	ug/L	CalMoMax	4.1	4.1	4	9	7.7	3.7
Flow	MG	CalMoTot	1.9	2.6	1.2	2.4	3.4	3.93
Flow	mgd	CalMoAvg	0.062	0.09	0.04	0.078	0.11	0.13
Flow	mgd	CalMoMax	0.097	0.14	0.12	0.12	0.18	0.23
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium, Calculated (as	mg/L	CalMoAvg	1350	1405	1460	1087	1150	1370
Hardness, Calcium & Magnesium, Calculated (as Iron, Dissolved (as Fe)	mg/L	CalMoMax	1360	1420	1490	1240	1220	1440
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.8	0.5	0.4	0.5	0.1	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.8	0.5	0.4	0.5	0.1	0.1
Mercury, Total (as Hg)	ng/L	SingleVal					1.2	
Nickel, Total (as Ni)	ug/L	CalMoAvg	125	67	40	511	743	481
Nickel, Total (as Ni)	ug/L	CalMoMax	142	69	40	935	915	632
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	<1	2	2	2	3
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	<1	2	2	2	3
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1280	1290	1280	1140	983	1210
Sulfate, Total (as SO4)	mg/L	CalMoMax	1280	1290	1280	1140	983	1210
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.06	0.06	0.05	0.21	0.19	0.11
Zinc, Total (as Zn)	ug/L	CalMoAvg	14	15	12	23	21	14
Zinc, Total (as Zn)	ug/L	CalMoMax	14	16	13	33	24	14
pH	6.5 SU	CalMoMin	6.7	6.6	6.8	6.8	6.5	6.9
pH	8.5 SU	CalMoMax	6.9	6.7	6.9	6.9	6.9	6.9

Year 2012 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	9.2	9.8	6.05	4.6	5.1	11.8

Copper, Total (as Cu)	ug/L	CalMoMax	9.7	11.6	7.86	5.2	5.6	14
Flow	MG	CalMoTot	0.5	0.27	1.03	1.23	5.11	10.27
Flow	mgd	CalMoAvg	0.016	0.01	0.03	0.041	0.165	0.34
Flow	mgd	CalMoMax	0.022	0.01	0.03	0.17	0.538	0.93
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1545	1520	915	902	1110	1145
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1550	1540	1350	973	1140	1150
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.2	0.1	0.1	0.13	0.1	<.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.2	0.1	0.1	0.13	0.1	<.1
Mercury, Total (as Hg)	ng/L	SingleVal					0.62	
Nickel, Total (as Ni)	ug/L	CalMoAvg	236	179	297	309	405	1130
Nickel, Total (as Ni)	ug/L	CalMoMax	246	246	342	441	618	1500
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	7	4	<1	3.2	4	2.4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	7	4	<1	3.2	4	2.4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1460	1450	1260	761	956	1080
Sulfate, Total (as SO4)	mg/L	CalMoMax	1460	1450	1260	761	956	1080
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.13	0.14	0.12	0.1	0.13	0.31
Zinc, Total (as Zn)	ug/L	CalMoAvg	21	18.7	14.3	11	10.6	24.4
Zinc, Total (as Zn)	ug/L	CalMoMax	23	19.4	18.2	11	13	31.3
pH	6.5 SU	CalMoMin	6.7	6.8	6.9	7.3	7.6	7.2
pH	8.5 SU	CalMoMax	6.7	7.2	7.6	7.5	7.6	7.6

Year 2013 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	10.1	9		9.6	27.4	8.1
Copper, Total (as Cu)	ug/L	CalMoMax	10.5	9.7		9.8	45.4	8.2
Flow	MG	CalMoTot	2.51	1.1		2.35	6.69	3.25
Flow	mgd	CalMoAvg	0.0809	0.0391		0.084	0.22	0.108
Flow	mgd	CalMoMax	0.0974	0.0481		0.097	0.414	0.506
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1740	1160		1290	1012	794
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1810	1760		1310	1150	856
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.436	0.2		0.3	0.1	0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.436	0.2		0.3	0.1	0.2
Mercury, Total (as Hg)	ng/L	SingleVal					0.89	
Nickel, Total (as Ni)	ug/L	CalMoAvg	492	407		808	1283	453
Nickel, Total (as Ni)	ug/L	CalMoMax	678	559		1000	1868	547
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	6	5		<1	3	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	6	5		<1	3	<1
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1850	1600		1180	1110	835
Sulfate, Total (as SO4)	mg/L	CalMoMax	1850	1600		1180	1110	835
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.18	0.15		0.23	0.61	0.14
Zinc, Total (as Zn)	ug/L	CalMoAvg	49.7	23.8		33.5	34.1	12.7
Zinc, Total (as Zn)	ug/L	CalMoMax	49.7	26.8		33.5	48.7	12.8
pH	6.5 SU	CalMoMin	7.2	6.5		6.5	6.7	6.8

pH	8.5 SU	CalMoMax	7.4	6.8	6.6	6.9	7.2
----	--------	----------	-----	-----	-----	-----	-----

Year 2014 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	20.9	19.8	19	19.4	18.6	15.7
Copper, Total (as Cu)	ug/L	CalMoMax	26.7	24.2	23.7	23.7	18.6	17.7
Flow	MG	CalMoTot	6.8	8.8	1.8	1.9	13	9.7
Flow	mgd	CalMoAvg	0.22	0.32	0.064	0.067	0.42	0.32
Flow	mgd	CalMoMax	0.25	0.33	0.12	0.18	0.78	0.64
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1560	1490	1480	1220	981	1140
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1590	1580	1500	1360	1030	1230
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.1	0.1	0.1	0.1	0.1	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.1	0.1	0.1	0.1	0.1	0.1
Mercury, Total (as Hg)	ng/L	SingleVal					0.96	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1930	1810	1740	1670	1290	1240
Nickel, Total (as Ni)	ug/L	CalMoMax	2550	1980	1920	1990	1300	1250
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	4	<1	2	1	2	4
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	4	<1	2	1	2	4
Sulfate, Total (as SO4)	mg/L	CalMoAvg	1670	1560	1530	1330	871	1030
Sulfate, Total (as SO4)	mg/L	CalMoMax	1670	1560	1530	1330	871	1030
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.65	0.53	0.51	0.49	0.34	0.33
Zinc, Total (as Zn)	ug/L	CalMoAvg	98	76.3	69.7	59.1	38.8	39.6
Zinc, Total (as Zn)	ug/L	CalMoMax	125	97.6	91.9	68.8	40	41.7
pH	6.5 SU	CalMoMin	7.2	6.8	7.1	7	7.2	7
pH	8.5 SU	CalMoMax	7.6	7.5	7.4	7.4	7.6	8

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	ug/L	CalMoAvg	15.4	15.8	19.8	10.4	9	7.8
Copper, Total (as Cu)	ug/L	CalMoMax	20.7	18.2	23.2	13.5	11	8.6
Flow	MG	CalMoTot	3.3	2.6	2.3	3.8	3	4.2
Flow	mgd	CalMoAvg	0.11	0.095	0.075	0.13	0.1	0.14
Flow	mgd	CalMoMax	0.12	0.13	0.16	0.19	0.3	0.25
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoAvg	1650	1710	1340	836	1045	1065
Hardness, Calcium & Magnesium, Calculated (as Hardness, Calcium & Magnesium,	mg/L	CalMoMax	1730	1750	1600	847	1070	1080
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	1	<.1	<.1	0.1	0.08	0.13
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	1	<.1	<.1	0.1	0.08	0.13
Mercury, Total (as Hg)	ng/L	SingleVal					<.5	
Nickel, Total (as Ni)	ug/L	CalMoAvg	1440	1600	1820	890	792	587
Nickel, Total (as Ni)	ug/L	CalMoMax	1690	1660	1940	1020	825	670
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	7	1	1	<1	1.6	2.4

Solids, Total	30 mg/L	CalMoMax	7	1	1	<1	1.6	2.4
Suspended (TSS)								
Sulfate, Total (as								
SO4)	mg/L	CalMoAvg	1610	1620	1630	823	872	899
Sulfate, Total (as								
SO4)	mg/L	CalMoMax	1610	1620	1630	823	872	899
Toxicity, Final Conc	1.00 toxunt	CalMoMax	0.37	0.45	0.54	0.27	0.19	0.16
Zinc, Total (as Zn)	ug/L	CalMoAvg	66.7	72	86	32	17	6.9
Zinc, Total (as Zn)	ug/L	CalMoMax	78.9	96	116	45	19	14
pH	6.5 SU	CalMoMin	6.9	7.2	7.3	7	7.3	6.8
pH	8.5 SU	CalMoMax	7	7.2	7.4	7.6	7.7	7.2

Jul	Aug	Sep	Oct	Nov	Dec
	1.7	4.3	7.9	8.2	10.1
	3.3	4.7	10.7	10.9	11.3
	4.25	1.75	3.18	5.07	3.596
	0.137	0.058	0.103	0.169	0.116
	0.346	0.103	0.505	0.194	0.144
	1245	1135	1190	1245	1650
	1300	1240	1250	1290	1710
	<0.03	<0.03	<0.03	0.05	0.03
	<0.03	<0.03	<0.03	0.05	0.03
		0.42			
	505	1163	1495	1485	2085
	644	1348	1650	1670	2160
	12	17	4.4	3.6	4.8
	12	17	4.4	3.6	4.8
	1270	1350	1510	1080	1530
	1340	1510	1510	1080	1530
	0.1	0.22	0.27	0.32	0.39
	0.6	22.6	37.1	31	38.6
	1.1	25	40	40	48.2
	7.3	7.2	7.3	7.3	7.1
	7.5	7.9	7.4	7.4	7.4

Jul	Aug	Sep	Oct	Nov	Dec
6.5	12.65	17.6	21.85	<4.45	9.2
8.7	20.5	20.5	35	7.9	13.6
4.95	5.74	6.15	4.49	4.16	3.57
0.2	0.23	0.26	0.18	0.17	0.1442
0.405	0.6205	0.405	0.2496	0.2496	0.1442
1044	937	1055	1165.5	1335	1450
1090	1122	1090	1190	1370	1470
0.1	0.1	0.07	0.04	<0.03	0.07
0.1	0.1	0.07	0.04	<0.03	0.07
		0.47			
1315	1570	1925	2370	2025	2285
1390	1770	2040	2560	2050	2440
<1	1.6	6.8	3.6	<1	6.8
<1	1.6	6.8	3.6	<1	6.8
1380	857	1330	1400	1340	1390

1380	857	1330	1400	1340	1390
0.234	0.3935	0.4209	0.605	0.3515	0.451
22.95	29.75	37.7	42.35	47.95	53.05
24.5	33.3	43.7	43.6	48.7	61.4
7.2	7.3	7.2	7.1	7.2	7.3
7.3	7.5	7.4	7.5	7.4	7.3

Jul	Aug	Sep	Oct	Nov	Dec
6.4	<2	3.4	4.75	6.25	7.1
10.1	<2	3.5	6.4	7.1	7.5
4.44	7.59	4.99	4.34	3.73	6.93
0.18	0.31	0.21	0.18	0.16	0.29
0.5826	0.4735	0.3399	0.2787	0.1688	0.3088
1290	1085	1025	1135	1295	1480
1310	1120	1100	1200	1340	1530
0.12	<0.03	0.03	<0.03	0.38	0.26
0.12	<0.03	0.03	<0.03	0.38	0.26
		<50			
305.5	684.5	660.5	1615	1960	1985
374	691	756	1800	2070	2010
2	2	2	2	4.5	4.4
2	2	2	2	4.5	4.4
1070	1010	1010	970	1340	1540
1070	1010	1010	970	1340	1540
0.124	<0.1047	0.1249	0.31	0.35	0.34
14.15	10.55	12.6	37.25	49.95	49.8
15.8	10.6	13	46.5	51.6	50.2
7.4	7.2	7.3	7.3	7.3	7.4
7.4	7.2	7.4	7.5	7.4	7.5

Jul	Aug	Sep	Oct	Nov	Dec
3.55	3.45	5	5.1	7.65	6.8
4.1	4.2	7.2	5.8	7.8	7.9
4.29	2.89	2.89	4.02	2.72	1.32
0.1734	0.1167	0.1615	0.1624	0.1137	0.0005
0.3088	0.1688	0.4388	0.1688	0.121	0.0012
1032	1295	1150.5	1295	1210	1435
1070	1400	1410	1420	1260	1510
0.11	0.1	0.08	0.04	0.05	0.81

0.11	0.1	0.08	0.04	0.05	0.81
		<10			
513	568	758.5	1690	1910	1895
527	594	808	1900	2070	1910
1.6	6	1.5	2.4	<1	1.5
1.6	6	1.5	2.4	<1	1.5
1060	1330	1310	1170	1380	1450
1060	1330	1310	1170	1380	1450
0.11	0.11	0.16	0.3	0.34	0.32
12.75	14.9	18.1	33.2	41.85	40.75
15.5	19.7	19.5	37.6	42.7	42.8
7.1	7.4	7.1	7.3	7.1	7.2
7.3	7.5	7.6	7.4	7.1	7.2

Jul	Aug	Sep	Oct	Nov	Dec
3.15	<2.5	5.25	3.5	7	9.25
4.3	3	5.3	4.5	8.3	9.5
3.82	4.12	4.66	2.95	7.78	2.59
0.0048	0.003	0.004	0.0017	0.0012	0.001
0.0944	0.011	0.011	0.0029	0.0012	0.002
1265	1320	1200	1160	1330	1390
1360	1330	1340	1190	1450	1440
0.18	0.11	0.05	0.07	0.04	0.34
0.18	0.11	0.05	0.07	0.04	0.34
		5.8			
1050.5	951	1320	760.2	2000	2240
1220	1140	1510	1430	2170	2340
2.5	1	1	1.5	<1	2.5
2.5	1	1	1.5	<1	2.5
1700	1380	1370	1290	1250	1580
1700	1380	1370	1290	1250	1580
0.18	0.16	0.22	0.2	0.38	0.4
<10	<10	14.5	<13.25	60.8	57.7
<10	<10	14.6	16.5	63.5	58.3
7.2	6.9	6.9	7.22	7.5	7.2
7.3	7.2	7.3	7.3	7.8	7.3

Jul	Aug	Sep	Oct	Nov	Dec
5.4	6.1	2.6	6.45	6.25	4.95
6.1	6.7	2.9	7.2	7.1	6.7

3.64	3.07	3.41	1.96	2.37	7.31
0.003	0.0018	0.002	0.0009	0.0012	0.0076
0.005	0.0037	0.01	0.0012	0.0012	0.008
1390	1495	1480	1145	1215	1405
1570	1560	1550	1150	1340	1450
0.26	0.16	0.27	0.11	0.08	0.1
0.26	0.16	0.27	0.11	0.08	0.1
		0.7			
985	1305	798.5	2070	2250	2060
1110	1450	940	2550	2350	2370
3	6	<5	2	7.2	2.4
3	6	9	2	7.2	2.4
1260	1410	1355	940	1370	1320
1260	1410	1410	940	1370	1320
0.19	0.24	0.16	0.39	0.36	0.37
<21.3	<29.1	<35.75	65.6	48.8	40.65
<25	33.2	46.5	86.2	49.2	47.3
6.7	6.8	6.74	7	7.2	7.3
6.8	6.8	6.8	7.1	7.2	7.3

Jul	Aug	Sep	Oct	Nov	Dec
2.65	1.25	1.2	3.1	6.14	8.905
3	2.5	2.4	3.5	6.6	10.2
3.32	4.46	7.32	2.72	1.26	1.06
0.002	0.004	0.015	0.0014	0.0004	0.0003
0.007	0.007	0.054	0.0017	0.0008	0.0003
1425	1068.5	1315	1225	1400	1705
1440	1170	1330	1320	1410	1720
0.77	0.82	0.118	0.128	0.136	0.388
0.77	0.82	0.118	0.128	0.136	0.388
		0.6			
260.5	360	829.5	2035	2840	2455
369	534	1030	2480	3070	2570
5.6	5.2	2.8	2.8	1.6	4
5.6	5.2	2.8	2.8	1.6	4
1180	796	1280	1230	1430	1690
1180	796	1280	1230	1430	1690
0.1	0.11	0.16	0.37	0.47	0.4
<25	<25	<25	42.95	63.45	45.95
<25	<25	<25	56	71.6	48.7
7.2	7.3	6.9	7.1	7.2	7.3
7.3	7.3	7	7.2	7.4	7.4

Jul	Aug	Sep	Oct	Nov	Dec
6.25	<2	9.7	23.25	14.1	16.65
8.4	<2	16.2	31.9	15.6	16.8
5.98	4.21	3.57	11.31	8.9	4.51
0.008	0.01	0.006	0.02	0.011	0.003
0.089	0.42	0.11	0.04	0.011	0.004
1245	1460	790	1036.5	1285	1520
1260	1490	1000	1130	1290	1560
0.175	0.557	0.344	0.563	0.105	0.141
0.175	0.557	0.344	0.563	0.105	0.141
		2.2			
782	113.95	634	1955	3830	3755
810	137	713	2800	3920	3860
2	6	1.2	2.4	8	<1
2	6	1.2	2.4	8	<1
1170	1500	518	814	1280	1570
1170	1500	518	814	1280	1570
0.18	0.06	0.22	0.52	0.69	0.7
<25	<25	<25	54.75	104.3	109.5
<25	<25	<25	74.4	110	113
6.8	7.1	7.2	7.2	7.3	7.2
7.2	7.2	7.3	7.3	7.3	7.3

Jul	Aug	Sep	Oct	Nov	Dec
10.37	6.2125	2.925	3.055	6.855	14.45
21.6	6.92	3.09	3.74	9.71	16.1
5.74	4.01	1.16	0.67	2.08	3.1
0.006	0.003	0.00048	0.00014	0.0011	0.0018
0.009	0.007	0.0047	0.0003	0.0017	0.0023
1240	1570	1365	1069.5	1270	1525
1510	1610	1460	1150	1510	1560
0.302	0.242	0.0774	0.0582	<0.050	0.211
0.302	0.242	0.0774	0.0582	<0.050	0.211
		<0.5			
580	887.75	507.5	251.5	917	2860
864	1190	568	252	1520	2910
4	3.2	2.8	1.2	<1	2
4	3.2	2.8	1.2	<1	2

911	1570	1480	1060	870	1460
911	1570	1480	1060	870	1460
0.29	0.23	0.12	0.09	0.31	0.55
8.6	35.075	<25	<25	27.05	77
25.8	40.5	<25	<25	54.1	80.2
6.9	6.6	6.6	7.15	6.95	6.86
7.4	6.7	6.93	7.31	7.18	7

Jul	Aug	Sep	Oct	Nov	Dec
3.695	4.995	3.83	3.385	10.185	9.2
4.72	5.27	3.94	3.61	11.4	9.79
5.58	3.1	1.87	0.66	3.47	3.33
0.0049	0.1	0.06	0.021	0.12	0.11
0.0095	0.2	0.16	0.079	0.13	0.12
1120	1165	1245	1195	1085	1410
1180	1250	1250	1210	1110	1490
0.162	<0.050	0.0503	<0.050	0.09	0.0743
0.162	<0.050	0.0503	<0.050	0.09	0.0743
		<0.5			
544	663	559	637	1805	1455
690	698	636	719	1930	1690
<1	3.6	2.4	<1	1.6	<1
<1	3.6	2.4	<1	1.6	<1
525	1080	1210	1220	1190	1270
525	1080	1210	1220	1190	1270
0.14	0.15	0.13	0.14	0.37	0.32
<25	<25	<25	<25	47.95	40.3
<25	<25	<25	<25	53.3	48.1
6.5	6.8	6.7	6.8	6.8	6.7
6.7	6.8	6.8	7.1	6.9	6.7

Jul	Aug	Sep	Oct	Nov	Dec
1.7	1.6	2.7	3.8	3.8	3.7
1.7	2.1	3	4.2	4.3	4.2
0.04	3.8	5.8	3.9	1.8	1.9
0.001	0.12	0.19	0.13	0.061	0.061
0.01	0.44	0.3	0.16	0.073	0.08
1175	978	1115	1185	1008	1310
1180	1100	1170	1280	1100	1380

0.1	0.1	0.2	<0.05	0.2	0.9
0.1	0.1	0.2	<0.05	0.2	1.9
		0.6			
143	86	487	946	596	231
152	101	802	1300	600	344
3	2	<1	<1	1	2
3	2	<1	<1	1	2
1030	786	1060	1020	1000	1140
1030	786	1060	1020	1000	1140
0.04	0.03	0.12	0.2	0.12	0.1
<6	<6	5.3	19	15	7.8
<6	<6	10.6	21	17	16
6.8	6.8	7	6.6	6.2	6.6
6.8	7	7.2	6.8	6.7	6.7

Jul	Aug	Sep	Oct	Nov	Dec
3.3	5.14	4.42	5.8	8.4	6.7
3.4	5.16	4.49	6.4	8.6	6.9
4.25	2.08	2.2	2.67	1.44	1.56
0.14	0.07	0.07	0.09	0.05	0.05
0.23	0.08	0.14	0.14	0.05	0.06
1120	1215	1310	1255	1340	1525
1180	1220	1320	1270	1380	1610
0.9	0.3	0.2	<0.1	0.05	0.8
1.4	0.3	0.2	<0.1	0.05	0.8
		<0.5			
248	149	87.4	391	845	264
305	149	92.7	491	922	429
6	3.6	6	5	4	5
6	3.6	6	5	4	5
1000	1150	1240	1250	1190	1400
1000	1150	1240	1250	1190	1400
0.09	0.08	0.05	0.11	0.2	0.12
19.5	15	7	15	29	18.6
<30	<20	8	16	29	19.9
7	7.1	7	6.8	6.7	6.8
7.2	7.1	7.3	6.9	6.7	6.8

Jul	Aug	Sep	Oct	Nov	Dec
12.1	7.5	6.1	7.9	12.3	12.4

13	9.2	7.1	8.4	13.6	14.8
7.56	3.96	3	2.66	1.9	2.54
0.25	0.13	0.099	0.0866	0.063	0.082
0.57	0.23	0.14	0.226	0.063	0.116
1150	1350	1290	1320	1290	1530
1200	1370	1320	1350	1310	1570
0.13	0.2	0.2	<.1	<.1	0.233
0.13	0.3	0.2	<.1	<.1	0.233
		<.5			
1050	417	108	1400	1750	930
1370	553	194	1630	2030	1250
2.8	2	4	2	2	4
2.8	2	4	2	2	4
1070	1210	1330	1330	1260	1370
1070	1210	1330	1330	1260	1370
0.3	0.15	0.09	0.29	0.39	0.29
30.9	13.7	8.1	29.4	41.1	30.3
42	15.1	13.2	35.2	46.8	34.2
7.1	7	7.3	7.1	6.8	7.1
7.2	7.3	7.3	7.5	6.8	7.1

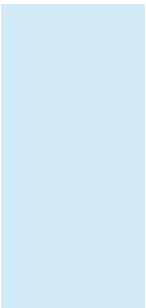
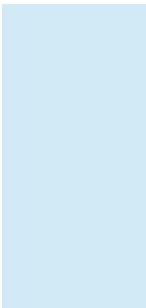
Jul	Aug	Sep	Oct	Nov	Dec
8.9	9.5	5.7	8.1	11.3	16.5
9.5	11.3	5.8	9.2	13	19.5
6.85	5.3	3	3.1	2.8	3.6
0.221	0.17	0.1	0.1	0.093	0.12
0.538	0.36	0.14	0.16	0.12	0.2
837	980	1170	1100	1090	1430
839	1040	1190	1180	1140	1440
0.1	0.1	0.9	<.1	0.1	0.1
0.1	0.1	0.9	<.1	0.1	0.1
		0.58			
516	780	310	930	1610	1420
696	925	409	1260	1790	1650
2	2	5	3	3	2
2	2	5	3	3	2
761	901	1130	1160	1120	1390
761	901	1130	1160	1120	1390
0.17	0.21	0.11	0.24	0.35	0.32
14.7	16.7	10.2	19.9	39.2	59.1
16.1	18.6	12.5	25.2	40.8	63.6
6.8	6.9	6.9	7.1	7.3	7.3

7	7.2	7.1	7.2	7.6	7.5
---	-----	-----	-----	-----	-----

Jul	Aug	Sep	Oct	Nov	Dec
12.7	7.3	8.2	7.5	12.9	16.4
13.6	7.5	8.6	8.3	14.8	18.7
6.4	7.5	3.4	2.2	2.4	3.5
0.21	0.24	0.11	0.07	0.081	0.11
0.33	0.57	0.2	0.15	0.098	0.18
1110	1250	1140	1210	1330	1530
1160	1280	1140	1210	1450	1550
0.1	0.1	0.1	0.1	<.1	0.1
0.1	0.1	0.1	0.1	<.1	0.1
		0.553			
1230	593	862	1130	1810	1420
1390	609	909	1580	1870	1550
2	5	5	2	5	2
2	5	5	2	5	2
1130	1220	1090	1200	1230	1370
1130	1220	1090	1200	1230	1370
0.29	0.14	0.19	0.28	0.39	0.42
27.2	13	21	28.1	60.4	92.9
29.9	13.3	25.1	36.6	66.8	122
7.5	7	7.3	7.7	7.1	7.3
7.5	7.8	7.6	7.7	7.3	7.4

Jul	Aug	Sep	Oct	Nov	Dec
7	5.4				
8	6.1				
2.8	3.5				
0.09	0.11				
0.29	0.26				
1117	1210				
1190	1220				
0.12	0.1				
0.12	0.1				
528	266				
619	301				
2	2				

2	2
1095	1070
1110	1070
0.14	0.09
<18	8.2
<30	16
7.1	7.1
7.4	7.1



Year 2000 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax						
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg						
Flow	MG	CalMoTot						
Flow	mgd	CalMoAvg						
Flow	mgd	CalMoMin						
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg						
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax						
Nickel, Total (as Ni)	1137 ug/L	CalMoMax						
Nickel, Total (as Ni)	126 ug/L	CalMoAvg						
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg						
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax						
pH	6.5 SU	CalMoMin						
pH	8.5 SU	CalMoMax						

Year 2008 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax					5.7	6.78
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg					5.7	5.265
Flow	MG	CalMoTot					45.59	119
Flow	mgd	CalMoAvg					5.1	3.98
Flow	mgd	CalMoMin					5.1	2.96
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg					0.0691	0.156
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax					0.0691	0.203
Nickel, Total (as Ni)	1137 ug/L	CalMoMax					16.8	16.3
Nickel, Total (as Ni)	126 ug/L	CalMoAvg					16.8	16.05
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg					<1	0.5
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax					<1	1
pH	6.5 SU	CalMoMin					7.98	7.9
pH	8.5 SU	CalMoMax					7.98	8

Year 2009 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax				6.26	6.59	5.77
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg				6.26	5.875	5.43
Flow	MG	CalMoTot				14	161.8	159
Flow	mgd	CalMoAvg				6.8	5.2	5.3
Flow	mgd	CalMoMin				6.8	5	5.1
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.138	0.12505	0.0757
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.138	0.153	0.078
Nickel, Total (as Ni)	1137 ug/L	CalMoMax				14.8	17	16

Nickel, Total (as Ni)	126 ug/L	CalMoAvg			14.8	15.8	15.65
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg			2	<1	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax			2	<1	<1
pH	6.5 SU	CalMoMin			7.77	7.85	7.8
pH	8.5 SU	CalMoMax			7.77	8.01	8

Year 2010 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax				4.3	4.6	3.7
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg				4.3	4.3	3.7
Flow	MG	CalMoTot				157	160	154
Flow	mgd	CalMoAvg				5.2	5.2	5.1
Flow	mgd	CalMoMin				5.2	5.1	5
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.168	0.06	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.21	0.07	0.2
Nickel, Total (as Ni)	1137 ug/L	CalMoMax				13.5	14.6	14
Nickel, Total (as Ni)	126 ug/L	CalMoAvg				13.2	14.2	13
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				2	<1	0.8
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				2.8	<1	1.6
pH	6.5 SU	CalMoMin				7.8	8.1	7.5
pH	8.5 SU	CalMoMax				8	8.1	8.1

Year 2011 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax				4.4	4.7	4.7
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg				4.4	4.7	4.4
Flow	MG	CalMoTot				154	158	93
Flow	mgd	CalMoAvg				5.1	5.1	3.1
Flow	mgd	CalMoMin				5.1	3.2	0
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg				0.3	0.3	0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax				0.3	0.3	0.3
Nickel, Total (as Ni)	1137 ug/L	CalMoMax				11	12	12
Nickel, Total (as Ni)	126 ug/L	CalMoAvg				11	12	12
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg				1	1	1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax				1	2	1
pH	6.5 SU	CalMoMin				7.7	7.7	7.9
pH	8.5 SU	CalMoMax				7.7	8	8.5

Year 2012 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax	4.9	4.9	4.6	4.4	4.4	

Copper, Total (as Cu)	8.4 ug/L	CalMoAvg	4.6	4.5	4.4	4.4	4.1
Flow	MG	CalMoTot	148	138.9	144.1	137.9	108.9
Flow	mgd	CalMoAvg	4.8	4.8	4.7	4.6	3.5
Flow	mgd	CalMoMin	4.6	4.7	4.4	4.37	2.43
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.2	0.3	0.3	0.2	0.1
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.2	0.3	0.3	0.2	0.1
Nickel, Total (as Ni)	1137 ug/L	CalMoMax	11.2	10	12	12	11
Nickel, Total (as Ni)	126 ug/L	CalMoAvg	10.9	10	11	12	11
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	2	2	1	1	1.6
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	2	2	1	1	2
pH	6.5 SU	CalMoMin	7.7	7.8	7.7	7.8	8.2
pH	8.5 SU	CalMoMax	8	7.8	7.9	8.1	8.3

Year 2013 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax	3.8	3.7	3.4	3.6	3.7	
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg	3.7	3.7	3.3	3.5	3.7	
Flow	MG	CalMoTot	171.8	154	169.3	104.4	32.8	
Flow	mgd	CalMoAvg	5.54	5.5	5.46	3.48	1.06	
Flow	mgd	CalMoMin	5.47	5.47	5.34	5.47	5.47	
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.125	0.1	0.1	<.1	0.1	
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.13	0.1	0.1	<.1	0.1	
Nickel, Total (as Ni)	1137 ug/L	CalMoMax	9.8	9.3	9	10.5	11	
Nickel, Total (as Ni)	126 ug/L	CalMoAvg	9.6	9.2	8.8	9.9	11	
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	2	<1	<1	<1	
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	2	<1	<1	<1	
pH	6.5 SU	CalMoMin	7.9	7.6	7.3	7.5	7.5	
pH	8.5 SU	CalMoMax	8	7.7	7.6	7.7	7.5	

Year 2014 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax	4.1	3.7	4.1	5.5	3.8	3.9
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg	4.1	3.6	4.1	4.7	3.8	3.8
Flow	MG	CalMoTot	123.16	110	63.96	93	118	102
Flow	mgd	CalMoAvg	3.97	3.93	2.28	3.3	3.8	3.4
Flow	mgd	CalMoMin	3.42	3.87	0	2.6	3.7	2.7
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.1	0.1	0.1	0.1	0.1	0.2
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.1	0.1	0.1	0.1	0.1	0.2
Nickel, Total (as Ni)	1137 ug/L	CalMoMax	9.2	8.7	9.9	11.1	9.6	9.5
Nickel, Total (as Ni)	126 ug/L	CalMoAvg	9	8.3	9.7	10.2	9.3	9.3
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	5	<1	<1	1	1	1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	9	<1	<1	2	2	1
pH	6.5 SU	CalMoMin	7.5	7.8	7.3	7.7	7.8	7.2

pH	8.5 SU	CalMoMax	8	8	7.9	8.1	8	8
----	--------	----------	---	---	-----	-----	---	---

Year 2015 Data

Pollutant	Limit	Type	Jan	Feb	Mar	Apr	May	Jun
Copper, Total (as Cu)	14 ug/L	CalMoMax	6.4	4.2	3.6	3.3	3.6	3.5
Copper, Total (as Cu)	8.4 ug/L	CalMoAvg	4.9	4.1	3.6	3.3	3.5	3.4
Flow	MG	CalMoTot	110	94	105.6	98.17	99	16
Flow	mgd	CalMoAvg	3.5	3.3	3.4	3.27	3.2	3.2
Flow	mgd	CalMoMin	3.5	3	3	3.23	3.2	3.1
Iron, Dissolved (as Fe)	1.0 mg/L	CalMoAvg	0.2	0.3	0.4	0.2	0.08	0.03
Iron, Dissolved (as Fe)	2.0 mg/L	CalMoMax	0.3	0.3	0.4	0.3	0.1	0.07
Nickel, Total (as Ni)	1137 ug/L	CalMoMax	53.5	13.5	7.7	8.4	8.5	8.5
Nickel, Total (as Ni)	126 ug/L	CalMoAvg	31.5	10.8	7.6	7.8	8.2	8
Solids, Total Suspended (TSS)	20 mg/L	CalMoAvg	<1	1	1	<1	1	<1
Solids, Total Suspended (TSS)	30 mg/L	CalMoMax	<1	2	1	<1	2	<1
pH	6.5 SU	CalMoMin	7.6	7.5	7.5	7.5	7.4	8
pH	8.5 SU	CalMoMax	7.9	8	8	8	8.1	8.1

Jul	Aug	Sep	Oct	Nov	Dec

Jul	Aug	Sep	Oct	Nov	Dec
5.44	5.54	4.61	4.57	5.23	4.67
5.08	5.3	4.195	4.06	4.91	4.67
143.9	170.24	152.546	147.71	140.5	84.48
4.64	5.49	5.08488	4.76482	4.68	5.28
4.25	5.85	4.84767	3.73133	2.66	5.26
0.1114	0.2125	0.0515	<0.050	<0.050	<0.050
0.152	0.227	0.103	<0.050	<0.050	<0.050
16.6	18.1	18.2	17.4	15.9	13.9
16.25	17.65	18.2	17.1	15.75	13.9
<1	<1	<1	<1	<1	1.2
<1	<1	<1	<1	<1	1.2
7.9	7.9	7.97	8.18	7.88	7.98
8.1	7.9	8.1	8.31	8.12	7.98

Jul	Aug	Sep	Oct	Nov	Dec
4.61	4.43	5.3	5.63		
4.565	4.355	4.63	5.155		
160	135	156	156		
5.2	4.4	5.2	5		
4.9	2.9	5.2	4.9		
0.0304	0.08	0.08515	<0.050		
0.0608	0.16	0.12	<0.050		
14.2	14.6	13.9	13.9		

14.1	14.4
<1	0.6
<1	1.2
7.7	7.8
7.8	7.8

13.75	13.8
<1	<1
<1	<1
7.8	8
7.9	8.1

Jul	Aug
4.4	4.1
4.3	4.1
149	157
4.8	5.1
4.2	5
0.3	0.1
0.3	0.1
13	13
12	12
1	1
2	1
8	8.1
8.2	8.3

Sep	Oct
3.9	4
3.9	3.9
149	138
5	4.6
5	3.7
0.2	0.06
0.3	0.06
12	13
12	13
<1	2
<1	3
8.1	7.9
8.3	8

Nov	Dec

Jul	Aug
4.9	4.88
4.6	4.65
83.7	135.5
2.7	4.37
0	0.01
0.2	0.2
0.2	0.2
12	10.6
12	10.4
1	2.2
1	2.4
8	8
8.2	8.5

Sep	Oct
4.3	4.5
4.1	4.4
105	150
2.75	4.9
0	0
0.2	0.1
0.2	0.1
9	11
9	10
1	<1
2	<1
8	7.8
8.4	7.8

Nov	Dec
4.7	4
4.7	4
132	149
4.4	4.8
0	4.8
0.13	0.1
0.13	0.16
11	10
11	10
<1	<1
<1	<1
7.5	7.9
7.8	8

Jul	Aug
	4.6

Sep	Oct
4	4.2

Nov	Dec
4.3	3.9

	4.6	3.9	4	4.1	3.8
	138	140	134.9	78.2	164
	4.76	4.66	4.35	2.6	5.3
	4.67	4.57	3.59	3.27	5.21
	0.2	0.1	<.1	0.1	0.097
	0.2	0.1	<.1	0.1	0.106
	10.6	8.7	10	10.2	9.9
	10.4	8.7	9	9.7	9.7
	1	<1	<1	<1	2
	2	<1	<1	<1	2
	8.2	8.4	8	7.7	7.4
	8.3	8.5	8.3	7.8	8.3

Jul	Aug	Sep	Oct	Nov	Dec
				3.8	4
				3.8	3.9
				113.95	120.64
				3.8	3.89
				3.86	3.86
				0.2	0.1
				0.3	0.1
				8.9	9.4
				8.6	9
				<1	<1
				<2	<1
				7.9	8
				8.3	8.3

Jul	Aug	Sep	Oct	Nov	Dec
4	3.9	4.1	4.4	3.6	4.4
4	3.8	3.9	4	3.5	4
92	115.41	110	93	100	110
3	3.72	3.5	3	3.5	3.6
2	3.69	3.5	1.6	3.4	3.5
0.1	0.2	0.2	0.1	0.1	0.1
0.2	0.3	0.3	0.1	0.1	0.2
10	9.8	9	8.1	8.6	10.4
10	9.1	8.5	7.9	8.4	9.6
<1	2	2	1	<1	2
<1	2	2	1	<1	3
7.7	7.7	7.8	8.2	7.9	7.7

8.1 8

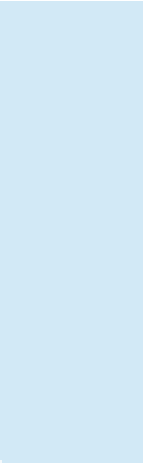
8.2 8.3

8.3 8

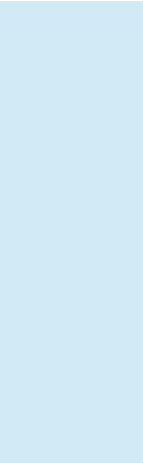
Jul Aug



Sep Oct



Nov Dec



CASE STUDY

Dunka Mine Minnesota

August 2010

**Prepared by
The Interstate Technology & Regulatory Council
Mining Waste Team**

Permission is granted to refer to or quote from this publication with the customary acknowledgment of the source. The suggested citation for this document is as follows:

ITRC (Interstate Technology & Regulatory Council). 2010. *Dunka Mine, Minnesota*. Mining Waste Treatment Technology Selection Web. Washington, D.C.: Interstate Technology & Regulatory Council, Mining Waste Team. www.itrcweb.org.

Acknowledgements

The ITRC Mining Waste Team would like to acknowledge Paul Eger from the Minnesota Department of Natural Resources for preparing this case study.

TABLE OF CONTENTS

1. SITE INFORMATION	1
1.1 Contacts.....	1
1.2 Name, Location, and Description.....	1
2. REMEDIAL ACTION AND TECHNOLOGIES.....	2
3. PERFORMANCE	4
4. COSTS	7
5. REGULATORY CHALLENGES	8
6. STAKEHOLDER CHALLENGES	9
7. OTHER CHALLENGES AND LESSONS LEARNED	9
8. REFERENCES	11

LIST OF TABLES

Table 2-1. Stockpile capping summary, LTV Dunka Mine.....	3
Table 2-2. Wetland treatment summary.....	5
Table 5-1. Minnesota water quality standards	9
Table 7-1. Wetland sizing	10

LIST OF FIGURES

Figure 1-1. Dunka Mine waste location schematic.....	1
Figure 3-1. Nickel concentrations in the outflow from Seep X.....	7

DUNKA MINE, MINNESOTA

1. SITE INFORMATION

1.1 Contacts

Paul Eger
Minnesota Department of Natural Resources
Telephone: 651-259-5384
E-mail: a.paul.eger@state.mn.us

1.2 Name, Location, and Description

The Dunka Mine is a large, open-pit taconite mine located in northern Minnesota at the eastern end of the Biwabik Iron Formation. The mine covers approximately 160 hectares and has a depth of around 100 m. It sits along the western edge of a small watershed (920 hectares), which is drained by a small stream (Unnamed Creek, Figure 1-1). The watershed is typical for this area of Minnesota and is characterized by a series of upland ridges and low areas containing wetlands. Sulfide-containing waste material from the mine was stockpiled along the eastern edge of the mine and adjacent to these wetlands.

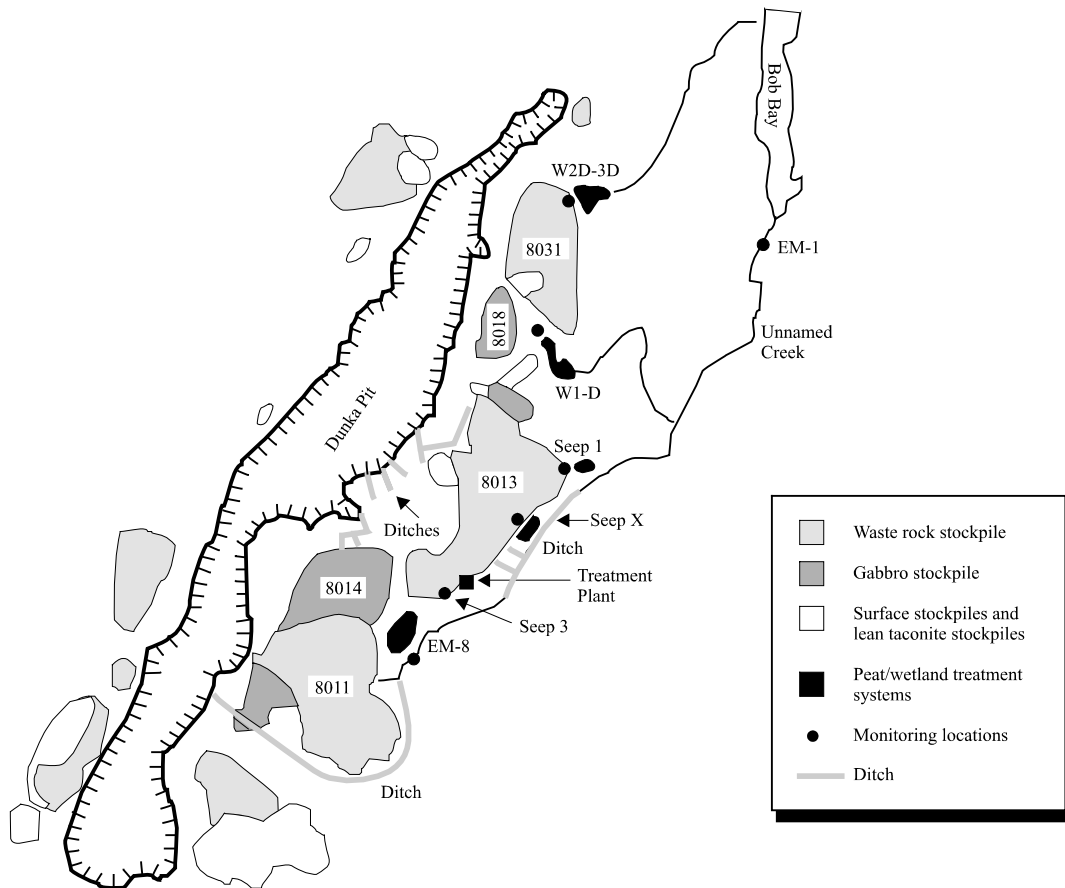


Figure 1-1. Dunka Mine waste location schematic.

The sulfide material came from an igneous intrusive rock formation known as the Duluth Complex. This formation is a gabbro which contained disseminated copper and nickel sulfides and overlies some of the iron ore at this site. During 30 years of operation, over 50 million metric tons of sulfide-containing waste was removed and stockpiled on 120 hectares of land adjacent to the mine. As water infiltrated this material, drainage with elevated copper, nickel, cobalt, and zinc was produced. Due to shallow water tables, precipitation that infiltrates the stockpiles appears as seepage in many places along the toes of the stockpiles. Although some of this seepage is diffuse, the majority of the flow occurs as discrete flow, which generally flows continuously from spring melt in April till freeze-up in late November. Average flows from the various seepages prior to closure have ranged from 3 L/min to 840 L/min, but flows exceeding 6000 L/min had been observed after periods of heavy precipitation. Annual median concentrations in the drainage from the stockpiles of Duluth Complex have ranged 1.5–50 mg/L for nickel, <0.1–1 mg/L for copper, <0.1–3 mg/L for cobalt, and <0.1–4 mg/L for zinc. Most of the drainage had pH greater than 6.5, but two sites produced acidic drainage.

2. REMEDIAL ACTION AND TECHNOLOGIES

In 1986, LTV conducted a preliminary feasibility study to determine the best method to mitigate the drainage problem at the Dunka Mine, examining both active treatment systems (lime treatment, reverse osmosis) and passive alternatives (limiting infiltration into stockpiles, wetland treatment) (Barr Engineering 1986). An active treatment plant which would treat all the stockpile drainage was projected to have a capital cost of \$8.5 million and an annual operating cost of \$1.2 million. The passive alternative was projected to cost \$4 million to construct but only \$40,000 in annual maintenance. Since mine drainage problems can persist for over 100 years, LTV decided to pursue passive alternatives.

However, acidic drainage developed in 1989 at a site (Seep 3) which had previously been neutral (Figure 1-1). As a result, the company was forced to construct a lined equalization pond and an active treatment plant to treat seeps emanating from some of the stockpiles on the eastern side of the mine. LTV's goal was still to have a completely passive system, and when the decision to close the mine was made in 1991, LTV began to develop and implement a final closure plan. This plan included reducing infiltration into the stockpile and treating all residual drainage with wetland treatment systems. Since there was a limited area available for construction and wetland systems function best under low-flow conditions, it was important that the flow rates be reduced as much as practical. This was accomplished by reducing the upstream watershed which may contribute to the drainages and by capping the stockpiles to limit infiltration of precipitation.

Watershed Reduction, Diversion

LTV conducted an extensive investigation of the surface and groundwater in the area and identified several areas where surface water was believed to flow through Duluth Complex stockpiles. Drainage ditches were constructed to route water away from the piles (Figure 1-1). Although most of these were relatively shallow ditches (~2 m), the ditch at the southern end of the mine, around the 8011 stockpile, was much larger. To isolate a relatively large upstream watershed (83 hectares), a 670 m long ditch, up to 18 m deep, was excavated through bedrock into the mine. The original plan was to drill and blast to fracture the bedrock and create a drain.

The drain did not have sufficient permeability to drain the area, and as a result, the bedrock had to be excavated. This ditch cost over \$600,000 and accounted for the majority of the total ditching budget.

Based on the hydrological study, LTV also concluded that by channelizing flow in Unnamed Creek it could lower the water level in the surrounding wetlands and, as a result, reduce the amount of water in contact with the stockpile in these wetlands. The channelization project included straightening and deepening portions of the stream and required cutting through bedrock at several locations (Figure 1-1).

Limiting Infiltration into Stockpiles, Capping

Once the amount of surface and groundwater entering the piles had been minimized, the next step was to limit the volume of precipitation entering the stockpiles. Minnesota's mineland reclamation rules require that the tops and benches of rock stockpiles that do not produce water quality problems be covered with 2 ft of soil and vegetated. When water quality problems exist, additional steps to limit infiltration must be taken. Traditionally, infiltration is decreased by covering the waste with several feet of clay. For this mine, the nearest clay source is over 40 miles away, and the high transportation cost to the site made this approach too expensive. As a result, a pilot test was conducted to investigate the effectiveness of various cover systems (Eger, Antonson, and Udoh 1990). These results, in addition to computer model runs using the EPA HELP model (Schroeder et al. 1984), were used to design an approach to selecting covers for each of the stockpiles based on the chemical composition of the pile and the observed water quality in the drainage.

Stockpiles that contained Duluth Complex material with less than 0.2% CuO and less than 0.05% NiO and that produced neutral drainage were covered with 2 ft of native soil, with at least 10% silt (-200 mesh), screened to minus 15 cm. Stockpiles containing more mineralized material and/or with acid drainage were covered with a barrier layer of compacted soil or a 30-mil low-density polyethylene liner (Table 2-1). Since these stockpiles were constructed prior to the realization that a water quality problem would develop, the piles were constructed to place the maximum amount of material in the minimum area. Stockpiles were generally built in 10–15 m lifts with 45° side slopes. Only the flat top portions of the stockpiles could be economically covered.

Table 2-1. Stockpile capping summary, LTV Dunka Mine

Stockpile	Area Capped (hectares)	Stockpile Classification	Cap	Costs	
				Total	\$/hectare
8011	14	Waste rock	Screened soil, no barrier	445,000	32,000
8031	22	Waste rock	Screened soil, no barrier	835,700	38,000
8013	21	Waste rock	Compacted soil barrier	1,180,000	56,000
8014	18	Gabbro	Screened soil. A flexible membrane liner was placed over a mineralized portion of the pile.	963,000	54,000
8018	3.7	Gabbro	Flexible membrane liner	455,000	123,000

Constructed Treatment Wetlands

In 1988, four pilot wetland cells were built to determine the feasibility of using wetland treatment to remove metals from stockpile drainage at the Dunka Mine. Nickel removal was on the order of 90%, and the cells were capable of producing water that met water quality standards (Eger et al. 1994, 1993). Based on these results, LTV designed and constructed two wetland systems in 1992 (Eger and Melchert 1992, Frostman 1992). These systems were 4200 m² (W2D/3D) and 7000 m² (W1D) and were designed to treat water with 1–5 mg/L nickel and flows on the order of 75 L/min.

These systems were constructed with a series of pools and soil berms to reduce the hydraulic gradient and contained a substrate which was a mixture of peat and peat screenings (a waste product from the production of horticultural peat) between the berms. In 1995, one of the original wetlands (W1D) was increased by 10,000 m², and two new systems (Seep 1, Seep X) were built (Eger, Wagner, and Melchert 1996). These new systems also contained a series of soil berms, but every other berm in the cell had a limestone cobble base to permit underflow through the berm.

In 1997, another wetland (EM8) was designed and constructed to maintain water level at a uniform depth of 10–15 cm, better distribute flow, and maximize treatment area. Input flow is controlled by three adjustable stainless steel weirs, and adjustable stop log style weirs were built on all of the berms in the system. A summary of the size, water quality, and cost for each of the wetlands is presented in Table 2-2.

3. PERFORMANCE

Flow Reductions Related to Ditching and Infiltration Control

Since reducing the upstream watershed and limiting infiltration into the stockpile will decrease the total flow from the stockpile, the effectiveness of these steps must be considered together. Diverting upstream flow reduced the watershed contributing to flow at Seep X and EM8 by 13% and 54%, respectively. Most of the other ditching did not affect the watersheds which contributed to the major discrete seepages but reduced the overall watershed through the stockpiles. The largest watershed affected was upstream of the 8011 stockpile, in which 83 hectares were removed from the watershed.

Stockpile capping began in 1991 when 21 hectares of stockpile 8013 was covered with a cap consisting of 27 cm of compacted soil and 60 cm of soil cover (Gale 1992). The top of the stockpile was extensively contoured with a complex of ridges and ditches and four 76 cm culverts were installed to carry water off the pile. Observations and periodic measurements indicate that a substantial quantity of water is routed off the piles, particularly during spring melt (G. Halberg, LTV Steel Mining Co., Hoyt Lakes, Minn., personal communication, 1997). Flow monitoring instrumentation was installed in 1998 so that quantitative data can be collected. Since 1989, LTV has capped about 76 hectares of stockpiles containing Duluth Complex material, with capping material ranging from uncompacted soil to 30 mil polyethylene membranes.

Table 2-2. Wetland treatment summary, LTV Dunka Mine

Site	Time	Size m ²	Flow	Design Factors - Input					Performance Factors - Output					Cost (\$)
				Metal Concentrations (mg/L)					Metal Concentrations (mg/L)					
			L/min	pH	Ni	Cu	Co	Zn	pH	Ni	Cu	Co	Zn	
W2D/3D	1992-97	4200	75	7.0	1.9	0.05	0.02	0.05	7.0	.08	.004	.002	.008	75,000
W1D	1992-97	7000	150	7.07	3.98	.068	.036	.052	7.18	.70	.010	.008	.013	125,000
Expanded	1995-97	17,000	130	7.14	1.20	.059	.023	.017	7.38	.18	.005	.001	.011	244,000
Seep I	1995-97	2500	20	6.94	5.39	.15	.13	.65	7.23	1.85	.05	.04	.29	192,000
Seep X	1995-97	10,000	100	7.03	1.50	.33	.08	.48	7.13	.61	.08	.02	.21	282,000
EM8	1998 (Jan-Sept)	16,000	310	7.20	1.6	.029	.015	.059	7.01	.902	.011	.006	.033	290,000
Water Quality Standard									6.5- 8.5	.213	.023	.05	.343	
Total Cost														\$1,200,000
Note: The flow and metal concentration values presented are the average values for the periods of record.														

Flow measurements for most of the seeps were made from water level measurements. All seeps were instrumented with a Stevens level recorder and a 60° v-notch weir. Continuous flow measurements are generally available from May 1 to October 31. Freezing temperatures before and after these dates often makes collection of continuous data difficult. As a result, flow during spring melt is generally not recorded. Although this flow can be substantial, 74% of the annual precipitation in northeast Minnesota occurs during the months of May through October. In the past, estimates of spring and fall flow have been made (Eger, Lapakko, and Weir 1981), but for purposes of comparing the effectiveness of the stockpile capping program, only the data representing actual flow measurements have been used.

The sites with the best long-term record and the largest changes to the watershed contributing to the drainage were EM8 and W1D. In the early 1990s the watershed that contributes to EM8 was reduced by 54% by an extensive and expensive ditching program, and in 1996 and 1997 the flat portions of the stockpile were covered with native soil and vegetated. Since 2006, average volume for May through October was around 100 million L. Prior to any activity which might have dramatically altered the flow at EM8 (1977–1979), the flow for this same period was 240 million L, more than twice the post-reclamation flow.

At W1D, around 60% of the total area of the stockpile was covered with 30 mil polyethylene. Since the stockpile contributes 40% of the total area to the monitoring weir, an overall flow reduction of around 25% was expected. Data from the first two years after capping indicate that flow from May through October decreased 36%, from an average of 36 million to 23 million L.

Reductions in infiltration for the covered portions were predicted to range from 40% for native soil to over 90% for flexible membrane liners. Since the side slopes were not covered, the total reduction in flow would be a function of the ratio of the area of the top to the total area of the stockpile.

Wetland Treatment

All the wetlands at the Dunka Mine have been effective at removing metals, but some are not always effective at achieving compliance with permit limits. Annual average metal removal has ranged around 60%–90% for nickel, 70%–90% for copper, 70%–90% for cobalt, and 50%–75% for zinc (Table 2-2). The ability to achieve compliance is largely a function of the wetland's size and the hydraulic and metal loading rate. The Dunka wetlands range in size 2500–17,000 m², and the average nickel loading rate ranges 15–70 mg/m²/day. Pilot-scale tests indicated that adequate nickel removal could be achieved with a residence time as low as two days, and that nickel removal rates were on the order of 40–80 mg/m²/day (Eger et al. 1994). With the exception of the system constructed in the fall of 1997 (EM8), the wetland systems were constructed with a series of berms and pools that ranged in depth 0.3–0.6 m. This design increases the overall residence time in the systems but decreases the area where the drainage is in direct contact with the substrate. Flow channels have developed at the low spots in the berms, further reducing contact with the substrate. The newly constructed system at EM8 was built to control the distribution of flow and to maximize contact with the substrate. This system is expected to have much less flow channelization and provide better metal removal than the older wetlands.

Although the wetland systems are generally effective at removing metals, efficiency tends to decrease as temperatures decrease in the fall. In general, stockpile flow ceases during the winter as precipitation accumulates as snow and seep flow freezes. Most of the stockpile drainage ceases in the winter, but some winter flow has been observed at site Seep X and EM8. Limited data from the outflow of the Seep X system suggest that treatment decreases substantially during winter, with outflow concentrations approaching inlet concentrations in December (Figure 3-1).

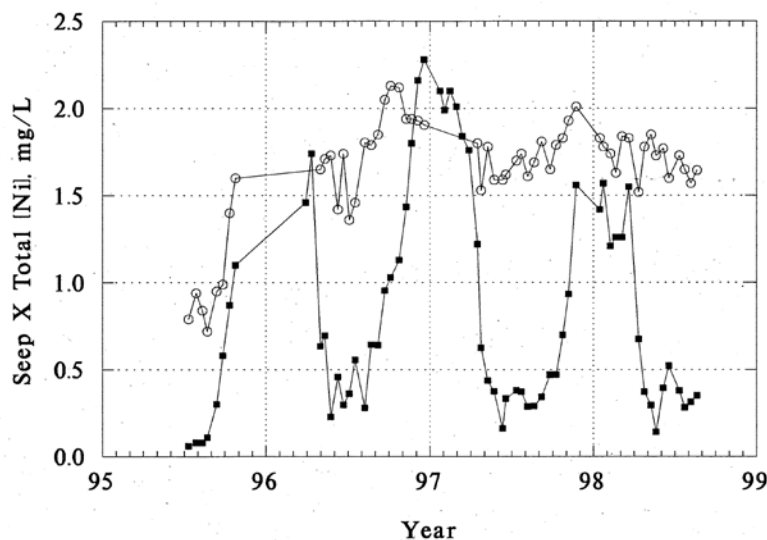


Figure 3-1. Nickel concentrations in the outflow from Seep X. Dark squares are output concentrations, and open circles are input concentrations. Concentrations increase in the fall and approach inlet concentrations in December.

Nickel removal in the test cells and the WID system also decrease in the fall (Eger et al. 1994; Eger, Wagner, and Melchert 1996). Winter operation data for other wetland systems are limited, but year-round copper removal has been reported in British Columbia (Sobolewski, Gormely, and Kistritz 1995), and metal removal was also observed throughout the winter in the Big 5 Tunnel pilot cells in Colorado (Wildeman et al. 1991). Recent work in Montana also found that metal removal occurred during winter operation (J. Pantano, Arco Mining, Anaconda, Mont., personal communication, 1997). Additional data is needed on the LTV systems to determine whether these systems can meet water quality standards throughout the year.

4. COSTS

Mine closure is an expensive undertaking. LTV has spent over \$6.5 million to close the Dunka Mine. Capping the stockpiles containing Duluth Complex material was the most expensive cost at around \$3.9 million. Costs ranged from \$32,000/hectare for a soil cover to \$123,000/hectare for flexible membrane liners. These costs generally included some reshaping of the stockpiles. Covering the stockpiles with 2 ft of native soil, as required by mineland reclamation laws, generally costs about \$20,000–25,000/hectare.

A total of \$1.2 million was spent to construct the wetland systems. The design of these systems has changed over time; costs have ranged from \$18/m² for the systems built in 1992 and 1997, to \$24-28/m² for the systems with underdrains built in 1995.

Active treatment for the southern portion of the mine (which began in 1992), cost around \$1.3 million to construct and has an annual operating cost of \$200,000. Maintenance costs for the passive systems generally decrease as vegetation becomes established on the stockpiles and in the wetlands, and by the fourth season, the only maintenance required was the annual inspections in the spring and fall. LTV has projected an annual maintenance cost of less than \$2,000, or less than 1% of the cost of the actual plant. With an annual savings of \$198,000, LTV will recover the cost of the wetland treatment systems in about six to seven years.

5. REGULATORY CHALLENGES

Although all the wetland treatment systems removed metals, removal varied substantially between systems and among metals and only two systems were able to meet the original water quality-based standard. As a result, regulatory flexibility was needed to allow passive treatment to continue.

Standards were raised to include the hardness of the discharges, and then variances were granted for two of the sites. The basic requirement was that the discharge could not be acutely toxic. In order to ensure that the variance was not causing impacts to the receiving stream, the company was required to increase its biological monitoring of the receiving stream.

Water Quality Standards

In Minnesota, all effluents must be nontoxic. Therefore at a minimum, metals concentrations must be below the Final Acute Values (FAV, Minnesota Rules, Chap. 7050). Since metal toxicity decreases as hardness increases, permissible metal concentrations generally increase with hardness up to a maximum allowable hardness of 400 mg/L as CaCO₃. For the metals at Dunka, the final acute values range from 126 µg/L for copper to 9136 µg/L for nickel (Table 5-1). Due to limited toxicity data on cobalt, no provision for hardness is included in the rules. LTV conducted a site-specific bioassay study, which demonstrated that cobalt toxicity decreased as hardness increased.

Originally, permit standards for the mine were based on chronic toxicity values, which were up to an order of magnitude lower than acute values (Table 5-1). When the company went bankrupt several years after the mine had closed, it sought a variance for several of the discharges. The new permit based standards on FAV include biological monitoring in the receiving stream to insure that the higher concentrations were not producing any adverse impacts on the aquatic system. Since the seeps at Dunka contain a mixture of metals, the current permit assumed that the toxicity of the effluent would be equal to the sum of the toxicities from the individual metals. Therefore, to ensure that the effluent was nontoxic, the permit requires the following:

$$\sum \frac{\text{Concentration of metal}}{\text{Final acute value}} \leq c1$$

Table 5-1. Minnesota water quality standardsConcentration in µg/L; hardness in mg/L CaCO₃.

Trace metal	Standard	Hardness, 50	Hardness, 100	Hardness, 200	Hardness, 400
Copper	CS	6.4	9.8	15	23
	MS	9.2	18	34	63
	FAV	18	35	68	126
Nickel	CS	88	158	283	508
	MS	789	1418	2549	4568
	FAV	1578	2836	5098	9136
Zinc	CS	59	106	191	343
	MS	65	117	211	3784
	FAV	130	234	421	7567
Cobalt*	CS	2.8	2.8	2.8	2.8
	MS	436	436	436	436
	FAV	872	872	872	872

Standards: CS = chronic standard, MS = maximum standard; FAV = final acute value.

CS is defined as “the highest water concentration of a toxicant to which organisms can be exposed indefinitely without causing chronic toxicity.” This is considered the ambient in stream water quality standard, which must be met on an average basis.

MS is defined as “the highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality. The MS equals the FAV divided by 2.” This is considered the ambient in stream concentration that cannot be exceeded on any given day.

FAV is defined as “an estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant.” By rule, any wastewater discharge must not exceed these standards at end-of-pipe at any time.

*LTV conducted site-specific testing and demonstrated that cobalt toxicity was a function of hardness. The cobalt chronic value for the Dunka Mine was increased to 50 µg/L.

Additional variances were granted for the Seep 1 and Seep X systems for spring flow and the company instituted a contingency plan to avoid water quality violations. If the concentrations in the outfall exceed the variance levels, water is collected and pumped to the beginning of the W1D system. Although this procedure has been effective, it is costly and cumbersome.

6. STAKEHOLDER CHALLENGES

None reported.

7. OTHER CHALLENGES AND LESSONS LEARNED

Part of the explanation for the difference in performance of the wetland treatment systems at the Dunka Mine appears to be the size of the treatment systems. Before the systems were built, pilot tests were conducted to determine the ability of wetlands to treat the stockpile drainage and to develop criteria to design full scale systems (Eger and Lapakko 1989; Eger et al. 1991, 1993, 1994; Eger, Wagner, and Melchert. 1996). Based on these tests, the average areal removal rate for nickel was about 40 mg nickel/m²/day. Using this value and the estimated nickel loading to

the wetland, the area required to treat each seep was calculated. Area ranged from about 0.4 hectare (4100 m²) for Seep 1 to about 3.2 hectares (32,200 m²) for EM8 (Table 7-1).

Table 7-1. Wetland sizing

Seep	Input			Area (m ²)		
	Average flow (L/min)	Average concentration (mg/L)	Daily load (mg/d × 10 ³)	Calculated*	As built	Expanded
W2D/3D						
• Original	75	2	216	5,000	4200 ^a	
• After reclamation	45 est ^b	2	130	3,000		
W1D						
• Original	150	4	864	23,000	7000	17,000 ^c
• After reclamation	40	0.8		1,200		
Seep 1	20	5.4	156	4100	2500	
Seep X	100	1.5	216	5000	10,000	
EM8 ^d	400	2.1	1210	32,200	16,000	

* Area required. Based on an areal removal rate for nickel of 40 mg/m² day, which is average from test cells.

^a This is the size of the constructed portion. There is about an additional 2,000 m² of natural wetland before the discharge monitoring point (SD-006).

^b The 8031 was covered with 2 ft of local soil and revegetated. After successful reclamation, flow is reduced by about 40% (based on field data from test stockpiles and HELP model).

^c Wetland was expanded in 1995.

^d Flow data from 1997. Data 2001–2003: average flow 1140, which is higher than prereclamation flow data being checked.

For Seep 1, Seep X, the systems were built after the stockpile was capped in the fall of 1991, so there were no changes due to reclamation activity.

Note: Average flow is based on May–October records when continuous flow records are available.

In general, adequate treatment was achieved when the size of the wetland exceeded the calculated area. Originally the W1D system was not effective in meeting the original permit requirements, but performance improved after the system was expanded (Eger, Wagner, Melchert 1996). After the stockpile was reclaimed, the original part of the system met the criteria and currently meets the original water quality standard.

One of the most common reasons for the failure of wetland treatment systems is that the systems were too small (ITRC 2003). Wetlands can be effective, but in general, sufficient land must be available. Insufficient area was available at both Seep 1 and EM8, and the current systems are only about half of the calculated size.

Although the size of the Seep X wetland appears to be adequate for nickel removal, the effective treatment size is substantially smaller than the total size of the system. This system contains a series of soil berms that reduces the effective treatment area by about 20%. Field observations revealed that the flow is not equally divided between the two cells and that the northern portion of the wetland receives about three times as much water as the southern section.

Water is routed through the overflow berms by a series of pipes, which further tends to concentrate flow and lessen contact with the substrate. In addition, the limestone drains were not effective in transmitting flow through underflow berms. The hydraulic gradient in the system is only about 1%, and the permeability of the peat mixture is at best on the order of 10^{-3} cm/sec. Under these conditions, the drains could only transmit a few percent of the flow. Visual observation confirmed that a large volume of water was moving over the top of the underflow berms. Seep X also flows during most of the winter, and channelization increases dramatically as areas with little water movement freeze. Metal removal decreases too less than 10% during the winter, and the FAV of outfall is essentially the same as the input. Channelization has also been observed in the Seep 1 system, and despite the inclusion of level maintenance structures in EM8, flow has not been evenly distributed partially due to a lack of maintenance and adjustment of the level control structures.

In 2004 substantial renovation was performed on the Seep 1 and Seep X systems. The goal was to provide better flow distribution and increase the contact of the drainage with the peat substrate. Berms, which had subsided, were raised by adding limestone to the surface, and additional peat was added to some of the open water areas to increase the amount of reactive surface area. Maintenance work on the EM8 system was scheduled to occur during the summer of 2005.

In contrast, maintenance requirements for the W2D/3D and the W1D expanded system have been minimal. The systems were built with sufficient area to treat the original flow, and water quality and reclamation activities have further reduced the input load so that both systems are estimated to have lifetimes well in excess of 100 years. Based on a model that calculates the addition of new removal sites, it appears that for the W1D system, there are enough new removal sites generated each year to remove the annual nickel load from the stockpile (Eger and Wagner 2002). As a result, the wetland can theoretically remove nickel in perpetuity.

8. REFERENCES

- Barr Engineering. 1986. *Feasibility Assessment of Mitigation Measures for Gabbro and Waste Rock Stockpiles—Dunka Pit Area*. Prepared for Erie Mining Company, Hoyt Lakes, Minn.
- Eger, P., D. Antonson, and F. Udoh. 1990. “The Use of Low-Permeability Covers to Reduce Infiltration into Missing Stockpiles,” presented at Western Regional Symposium on Mining and Mineral Processing Wastes, May 30–June 1, Berkeley, Calif.
- Eger, P., and K. A. Lapakko. 1989. “The Use of Wetlands to Remove Nickel and Copper from Mine Drainage,” in *Constructed Wetlands for Wastewater Treatment*, D. Hammer, ed. Chelsea, Mich.: Lewis.
- Eger, P., K. A. Lapakko, and A. Weir. 1981. *The Environmental Leaching of Stockpiles Containing Copper-Nickel Sulfide Minerals: A Study of Chemical Release, Chemical Transport, and Mitigation Conducted at Erie Mining Company’s Dunka Mine, Babbitt, MN, 1976–1980*. St. Paul: Minnesota Department of Natural Resources, Division of Minerals.
- Eger, P., and G. Melchert. 1992. “The Design of a Wetland Treatment System to Remove Trace Metals from Drainage,” pp. 98–107 in *Achieving Land Use Potential through Reclamation*,

- Proceedings, 9th National American Society for Surface Mining and Reclamation Conference*, June 14–18, Duluth, Minn.
- Eger, P., G. Melchert, D. Antonson, and J. Wagner. 1991. *The Use of Wetland Treatment to Remove Trace Metals from Mine Drainage at LTV's Dunka Mine*. St. Paul: Minnesota Department of Natural Resources, Division of Minerals.
- Eger, P., G. Melchert, D. Antonson, and J. Wagner. 1993. "The Use of Wetland Treatment to Remove Trace Metals from Mine Drainage," in *Constructed Wetlands for Water Quality Improvement*, G. Moshiri, ed. Boca Raton, Fla.: Lewis.
- Eger, P., and J. Wagner. 2002. "The Use of Wetlands to Remove Nickel from Mine Drainage: Is Perpetual Treatment Really Possible?" in *Proceedings, American Society of Mining and Reclamation Meeting*, June 9–13, Lexington, Ky.
- Eger, P., J. Wagner, Z. Kassa, and G. Melchert. 1994. "Metal Removal in Wetland Treatment Systems," *Proceedings, International Land Reclamation and Mine Drainage Conference/3rd International Conference on the Abatement of Acidic Drainage*, April 25–29, Pittsburgh.
- Eger, P., J. Wagner, and G. Melchert. 1996. "The Use of Overland Flow Wetland Treatment Systems to Remove Nickel from Neutral Mine Drainage," pp. 580–89 in *Success and Failures: Applying Research Results to Insure Reclamation Success, Proceedings, 13th National American Society for Surface Mining and Reclamation Conference*, May 18–23, Knoxville, Tenn.
- Frostman, T. 1992. "Constructed Peat/Wetland Treatment System for Heavy Metal Removal," pp. 255–59 in *Achieving Land Use Potential through Reclamation, Proceedings, 9th National American Society for Surface Mining and Reclamation Conference*, June 14–18, Duluth, Minn.
- Gale, L. 1992. "Reclamation of Minerock Stockpiles," p. 232 in *Achieving Land Use Potential through Reclamation, Proceedings, 9th National American Society for Surface Mining and Reclamation Conference*, June 14–18, Duluth, Minn.
- ITRC (Interstate Technology & Regulatory Council) 2003. *Technical and Regulatory Guidance for Constructed Treatment Wetlands*. WTLND-1. Washington, D.C.: Interstate Technology & Regulatory Council, Mining Waste Team. www.itrcweb.org.
- Schroeder, P., J. Morgan, T. Walskiand, and A. Gibson. 1984. *The Hydrologic Evaluation of Landfill Performance (HELP) Model*, vol. 1, Users Guide for Version 1. EPA/530/2-87/050. U.S. Environmental Protection Agency Technical Resource Document.
- Sobolewski, A., L. Gormely, and R. U. Kistritz. 1995. "Copper Removal from Mine Drainage by an Experimental Wetland at Bell Copper Mine," pp. 683–92 in *Proceedings, Sudbury '95, Mining and the Environment*, B. C Smithers, ed., May 28–June 1, Sudbury, Ontario.
- Wildeman, T., L. Dugan, J. Bolis, and J. Gusek. 1991. "Constructed Wetlands that Emphasize Sulfate Reduction: A Staged Design Process and Operation in Cold Climates," paper #32 in *Proceedings, 24th Annual Canadian Mineral Processors Meeting*, Ottawa, Ontario.

PRELIMINARY REPORT
SPRUCE ROAD BULK SAMPLE SITE
MONITORING RESULTS

May 26, 1977

Introduction

International Nickel Company was granted permission from the U.S. Forest Service to remove a 10,000 ton sample of ore from the Spruce Road area for testing. The sample was taken and the area was reclaimed as requested.

During the summer of 1975 a surface discharge was noticed originating from the foot of the bulk sample site. The discharge was monitored during the fall of 1975 in an effort to determine the nature and amount of discharge emanating from the site. Upon analysis of the data, it was felt that the discharge did not constitute a pollution hazard and could serve a useful purpose in determining the nature of leachates from ore and lean ore piles. However, MPCA requested that the site be corrected, as soon as possible. Also, at about this time, INCO decided to withdraw its application to mine. Therefore, the site was reclaimed as per the attached memo. (See appendix for details).

In April 1976, the bulk sample site on the Spruce Road was inspected to determine the condition of the reclamation work and to ascertain whether any seepage continued flowing from the site after spring thaw. The site was filled and contoured as requested. The seep began to flow during snow melt. The point of discharge had moved approximately 30' west of last summer's (1975) point of discharge. A specific conductivity check demonstrated little change from past values indicating that the source of water is unchanged. It was, therefore, proposed to continue the monitoring work initiated by INCO last fall.

The objectives for the sampling are:

1. To determine a change in water quantity, if any, emanating from the site as a result of the reclamation work.
2. To determine a change in water quality, if any, emanating from the site as a result of the reclamation work.
3. To determine if any pollution hazard exists to Filson Creek from the seep emanating from the bulk sample site.

Monitoring Plan

A. Stations (See maps I, II, III)

1. INCO Site A; seep originating from bulk sample site; station number - 4749570914030-03.
2. INCO Site B; Filson Creek Tributary at mouth near Ely (above culvert crossing of Spruce Road); Station number - 05124993.

3. New Site; Filson Creek Tributary above mouth near Ely (above seep discharge into tributary); station number - 05124992.
4. Existing Site - FS #13; Upper Filson Creek, Sec. 30 near Ely. Station number - 05124980.
5. Existing Site - FS #14; Filson Creek at mouth near Ely. Station number - 05124994.

B. Sampling Frequency

<u>Station</u>	<u>Samples/Month</u>
4749570914030-03	2
05124993	2
05124992	2
05124980	1
05124994	2

C. Parameters

<u>Station</u>	<u>Analytical Schedule</u>
4749570914030-03	271
05124993	271 (Totals only)
05124992	271 (Totals only)
05124980	Existing secondary station
05124994	Existing primary station

D. Water Quantity

1. Precipitation will be obtained from a standard 8" shielded gage located approximately 500 yds. west of the bulk sample site which is associated with the pan evaporation station.
2. Flow is continuously recorded immediately above station 05124994 via a bubble gage.
3. A staff and a provisional rating curve has been established at station 05124980.

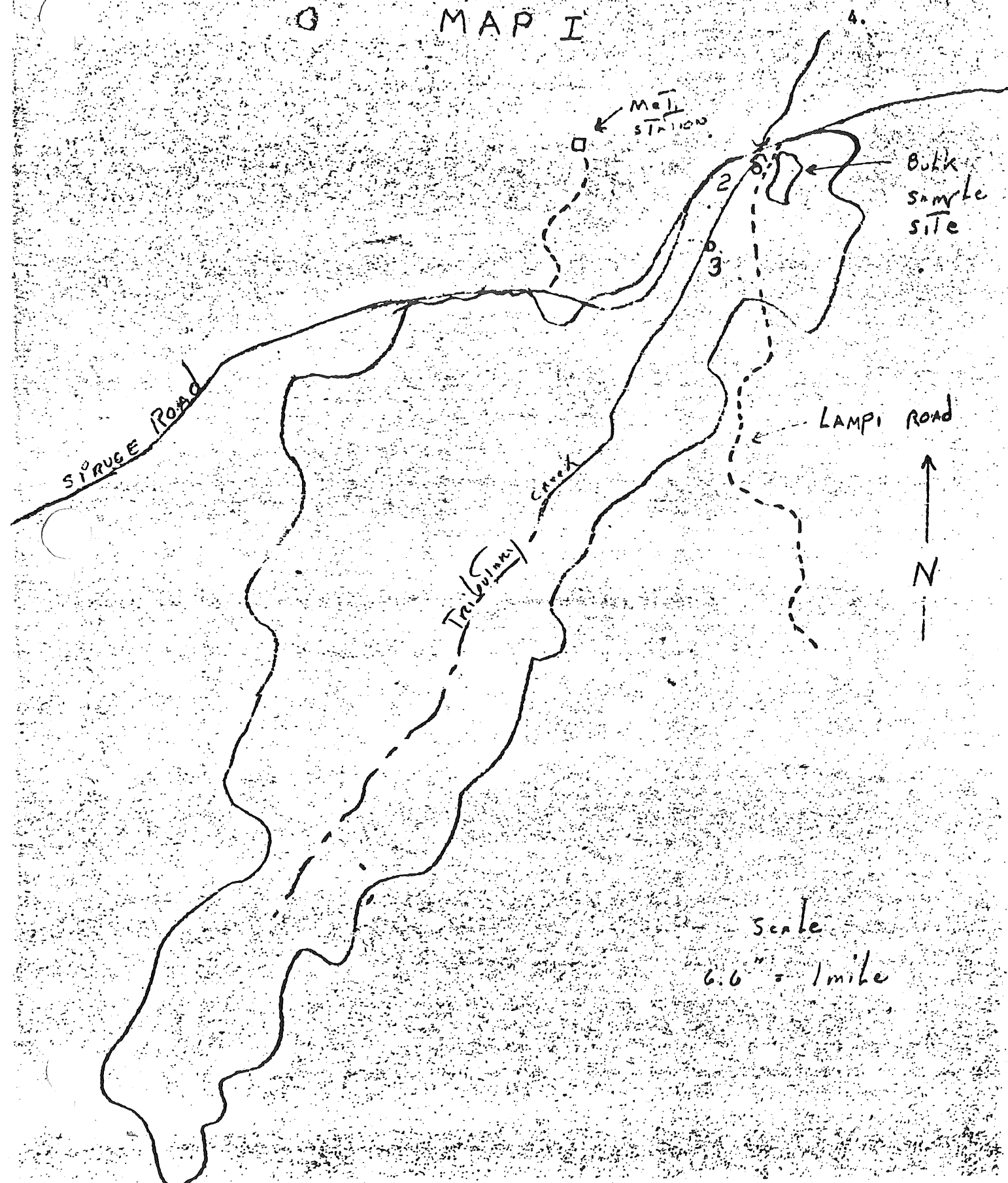
3.

4. Flows for station 05124993 will be determined at the time of sample collection. Flows at above mentioned station will also be used for station 05124992.
5. Flows obtained by INCO last fall will be used unless significant changes are apparent for station 4749570914030-03.

The duration of the monitoring will be six (6) months (May - Sept.) or until the seep ceases, whichever occurs first.

Tributary watershed

MAP I



SEC. 23

SEC. 24

CLEARED

AREA

WEATHER
STATION
SITE

SEC. 26

LAMPY ROAD

SPRUCE ROAD

BULK SAMPLE
SITE

SEC. 30
SITE

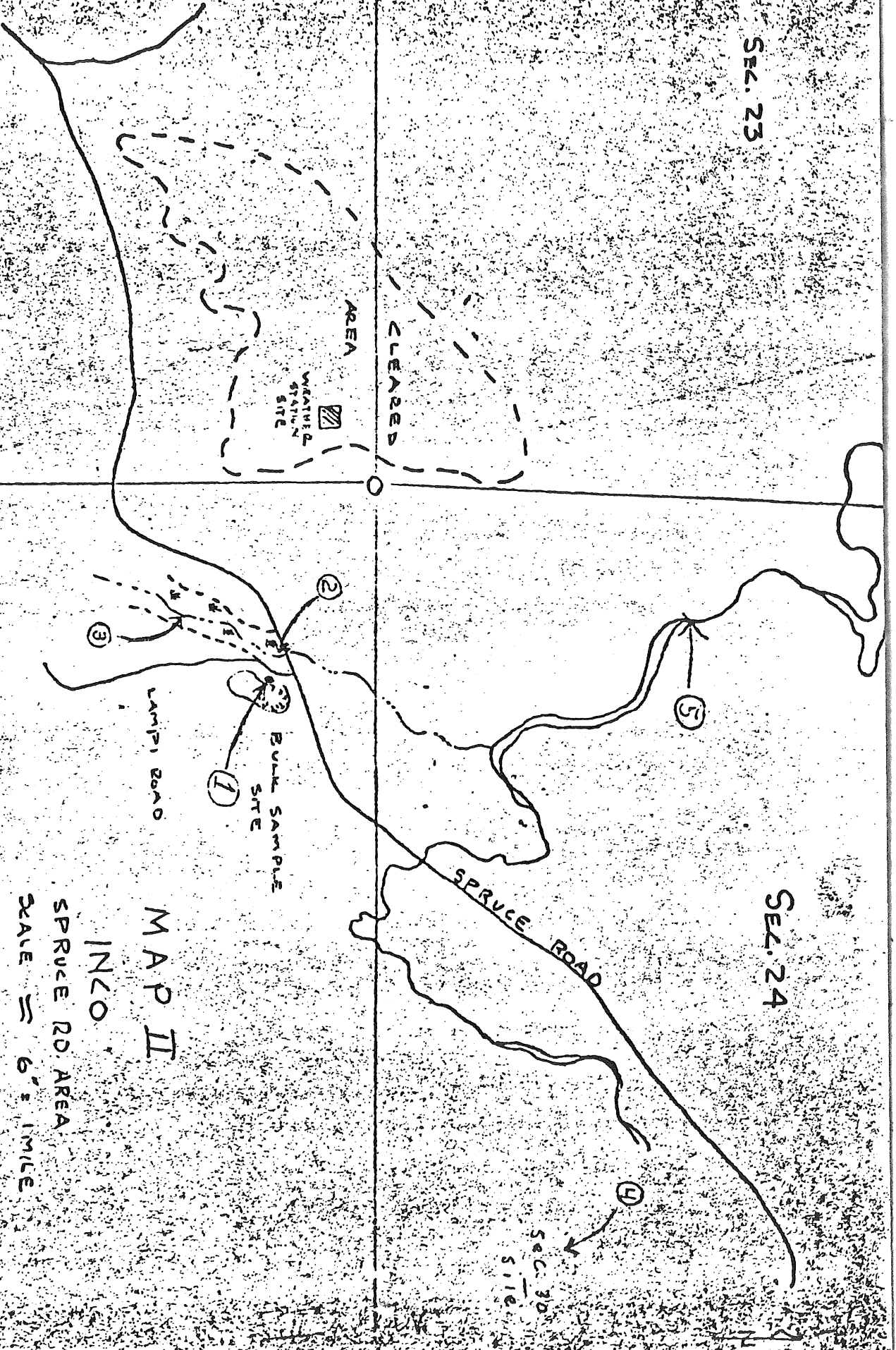
MAP II

INCO

SPRUCE RD. AREA

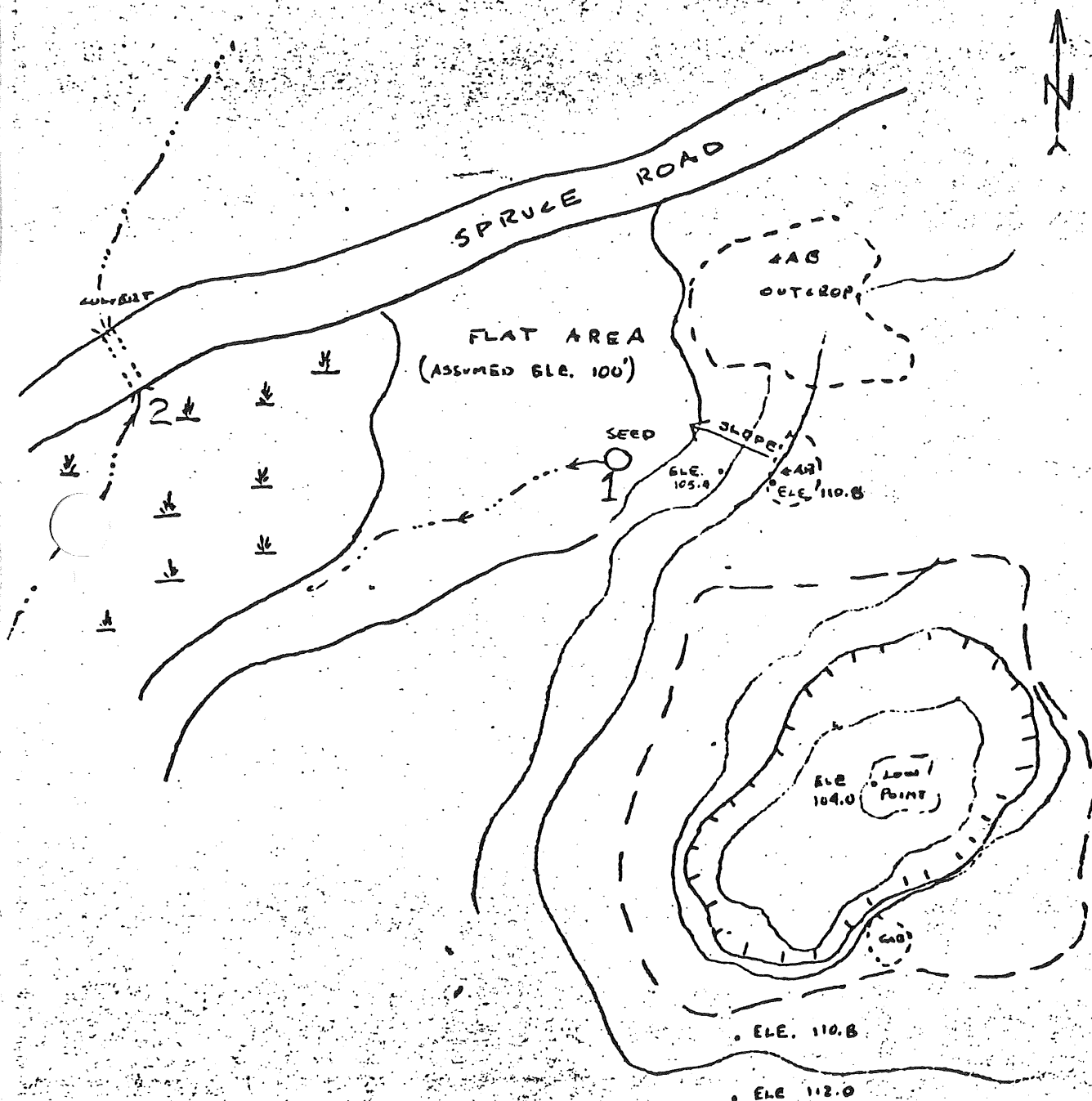
SCALE = 6" = 1 MILE

SEC. 25



Map III

6.



BULK SAMPLE SITE

HAND LEVEL SKETCH

SCALE 1" = 50'

SECT. 35, T62, R11

Results

1. Flow

The tributary flow data is presented on Table I. All of the flow information is on the tributary next to the bulk sample site. It was not possible to obtain flow values for the seep. Flow was measured during sample collection immediately below the culvert on the Spruce Road with a pygmy meter.

The flow ratios between Filson and its tributary are demonstrated on Table II. The ratio is approximately 40-50 to 1. Watershed ratio is about 35 to 1.

Total rainfall for the period was about 9 inches, most of which occurred in June. Only 1.4 inches fell between April 1 and May 3 and none fell between May 3 and June 6. The water equivalent in the snowpack was about 4 inches.

2. Bulk sample site chemistry

Surface flow from the bulk sample site lasted for only a very short time. The chemical levels are demonstrated on Table III. The values are little different from those reported by INCO with the exception of heavy metals, particularly nickel and copper. This could be due to differences in sampling methods. INCO built a small catchment basin to collect the seepage for the purposes of sampling and measuring flow. No doubt, considerable amounts of suspended particulates settled in this pool and are not reflected in the analyses. No attempt was made to build a pool for the Forest Service sampling and much higher levels are found. It is also possible that the higher levels found are the result of the reclamation work done the previous fall, (i.e., exposure of fresh soil to weathering and erosion).

3. Tributary; chemistry

The results of the chemical analysis are shown on Table IV. All samples are surface grab samples. The upstream site is about 100 yards south of the culvert on the Spruce Road and is located in a dense alder swamp. This sampling point is above any discharge originating from the bulk sample site. The sampling site located at the culvert on the Spruce Road is immediately below the bulk sample site. Because of the surrounding topography and the elevated, compacted Spruce Road, most, if not all, of the discharge from the bulk sample site will pass through the culvert.

TABLE I

Flow data from tirbutary next to bulk sample site

<u>Date</u>	<u>CFS</u>	<u>Liters/Sec</u>
4/13/76 ^{1/}	1.76	49.84
5/5/76	.34	9.63
5/20/76	.09	2.55
6/22/76 ^{2/}	.35	9.91
7/7/76	.03	.85
7/20/76	.02	.57
8/5/76 ^{3/}	0.00	0.00

1/ Estimated flow from bulk sample site was .008 CFS.

2/ Surface discharge from the bulk sample site ceased.

3/ Surface flow in tributary ceased.

TABLE II

Flow Ratios: Filson/Tributary

<u>Date</u>	<u>Filson CFS</u>	<u>Tributary CFS</u>	<u>Ratio</u>
4/13/76	74	1.76	42
5/5/76	17	.34	50
5/20/76	3.3	.09	37
6/22/76	14	.35	40
7/7/76	2.8	.03	93
7/20/76	.94	.02	47
8/5/76	.18	--	--

TABLE III

Seep: Bulk Sample Site

Date	pH	Sp. Cond.	Temp. °C	Alk mg/l	SO ₄ mg/l	Fe ug/l
4/13/76	6.8	628	6.0	118	--	4600
5/5/76	7.0	711	6.0	107	250	4200
5/20/76	7.0	655	13.0	110	270	1500

Date	Ca mg/l	Mg mg/l	K mg/l	Na mg/l	Turb. JTU	Color PT/co
4/13/76	84	48	7.3	2.6	26	60
5/5/76	72	43	7.0	10	30	25
5/20/76	70	45	6.8	9.3	6	22

Date	Ni ug/l	Cu ug/l	Cd ug/l	Pb ug/l	Zn ug/l	Si mg/l
4/13/76	13000	360	2.4	1.0	190	--
5/5/76	10000	970	2.0	.3	210	24
5/20/76	11000	1000	2.4	1.2	5300	24

TABLE IV

Tributary Upstream of Bulk Sample Site

Date	pH	Sp. Cond.	Temp. °C	Alk mg/l	Fe ug/l	Ni ug/l	Cu ug/l	Cd ug/l	Pb ug/l	Zn ug/l
4/13/76	5.6	30	1.0	11	450	9	11	.04	.5	4.2
5/5/76	5.4	29	5.5	16	470	9	16	.02	<.2	3.9
5/20/76	5.8	19	10.0	10	440	12	19	.02	.5	6.9
6/22/76	6.0	26	16.5	35	--	19	35	<.01	.4	3.6
7/7/76	6.4	30	14.0	18	--	21	18	.01	.2	2.9
7/20/76	5.5	31	18.0	11	1600	26	19	<.01	.5	6.4
$\bar{X}$ =	5.8	27.5				16	20	.02	.4	4.7

Tributary Downstream of Bulk Sample Site

	pH	Sp. Cond.	Temp. °C	Alk mg/l	Fe ug/l	Ni ug/l	Cu ug/l	Cd ug/l	Pb ug/l	Zn ug/l
4/13/76	5.7	36	1.0	10	510	25	19	.08	1.1	3.0
5/5/76	5.7	34	5.0	8	460	15	22	.02	<.2	3.1
5/20/76	5.7	36	10.0	7	490	19	28	.02	.7	6.2
6/22/76	5.7	29	17.0	--	--	33	34	<.01	.2	3.1
7/7/76	6.1	36	16.0	--	--	24	22	<.01	.3	2.4
7/20/76	5.5	37	19.0	16	3100	27	25	<.01	.4	2.2
$\bar{X}$ =	5.7	34.8				24.0	25	.03	.5	3.3

An increase in copper and nickel concentrations as the tributary flows past the bulk sample site is apparent. A paired t test performed on the data demonstrated that the difference in the data sets (upstream vs. downstream) was significant at the .05 probability level for both copper and nickel. The average increase in nickel and copper concentrations is about 9 ug/l and 5 ug/l, respectively.

Instantaneous loadings from the bulk sample site to the tributary are shown on Table V. Instantaneous loading and load ratios for Filson Creek are shown on Table VI.

Using the Filson Creek hydrograph and the measured values obtained on the tributary, a hydrograph was developed for the sampling period which is demonstrated on Graph I. Using this hydrograph and changes in copper and nickel concentrations between the upstream and downstream site, a loading of .5 Kg of copper and 1.0 Kg of nickel occurred over the sampling period (April - July) from the bulk sample site.

Paired t Test

Upstream vs. Downstream Sampling Stations

Pair	Copper ug/l						Sum	$\bar{X}$
	1	2	3	4	5	6		
Downstream (D)	19	22	28	34	22	25	150	25.00
Upstream (U)	11	16	19	35	18	19	118	19.67
$d_i = D_i - U_i$	8	6	9	-1	4	6	32	5.33

$$S_d^2 = \frac{\sum d_i^2 - \frac{(\sum d_i)^2}{n}}{n-1} = 12.66$$

$$t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{S_d^2}{n}}} = 3.68$$

The difference is significant at the .02 probability level

Paired t Test

Upstream vs. Downstream Sampling Stations

Pair	Nickel ug/l						Sum	$\bar{X}$
	1	2	3	4	5	6		
Downstream (D)	25	15	19	33	24	27	143	23.8
Upstream (U)	9	9	12	19	21	26	96	16.0
$d_i = D_i - U_i$	16	6	7	14	3	1	47	7.8

$$S_d^2 = \frac{\sum d_i^2 - \frac{(\sum d_i)^2}{n}}{n-1} = 35.77$$

$$t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{S_d^2}{n}}} = 3.20$$

The difference is significant at the .05 probability level

TABLE V

a

Copper Loading From Bulk Sample

Site on Tributary System

Date	Cu ug/s Upstream	Cu ug/s Downstream	Difference Cu ug/s
4/13/76	548	947	399
5/5/76	154	212	58
5/20/76	48	71	23
6/22/76	347	337	0
7/7/76	15	19	4
7/20/76	11	14	3

b

Nickel Loading From Bulk Sample

Site on Tributary Stream

Date	Ni ug/s Upstream	Ni ug/s Downstream	Difference Ni ug/s
4/13/76	449	1246	797
5/5/76	87	144	57
5/20/76	31	48	17
6/22/76	188	327	139
7/7/76	18	20	2
7/20/76	15	15	0

TABLE VI

Bulk Sample Site Loading
on Filson Creek at Mouth

Date	Filson Cu & Ni Conc. ug/l		ug/sec Filson	ug/sec Seepage	Ratio Seep/Filson
4/13/76	Cu	5.5	11526	399	.035
	Ni	6.0	12570	797	.063
5/5/76	Cu	8.7	4184	58	.014
	Ni	5.0	2405	57	.024
5/20/76	Cu	12.0	1121	23	.021
	Ni	7.0	654	17	.026
6/22/76	Cu	10	3960	0	0
	Ni	7	2775	139	.050
7/7/76	Cu	9.5	753	4	.005
	Ni	7.0	555	2	.004
7/20/76	Cu	7.4	197	3	.015
	Ni	5	133	0	0

Discussion

1. It is impossible to determine if the additional reclamation work done during the fall of 1975 had any effect on reducing the amount of water emanating from the bulk sample site. Although the seep ceased after a short period of time, it could be due to the extremely dry conditions that occurred last spring and summer.
2. The chemical composition of the seep water has changed little from INCO's initial tests. The seep has a neutral pH, high conductivity, high alkalinity, high sulfate, and high iron concentrations. All of the major cations (Cs, Mg, Na, K) are elevated. With the exception of lead, all of the heavy metals that were measured are 2-3 orders of magnitude higher than the surrounding surface water. Although far less nickel occurs in the ore ($\sim 3:1$), nickel concentrations are ten times higher than the copper levels.
3. The influence of the seep on Filson Creek would not be measurable. The loading ratios are too small and concentration changes would be less than .5 ug/l.
4. The chemical composition of the tributary upstream of the bulk sample site demonstrates an acid pH and low conductivity, alkalinity. Cadmium, lead, and zinc levels are not much different from other surface waters in the area. Copper and nickel levels are twice as high as those found in Filson Creek and almost 10 times higher than those found in the South Kawishiwi River. There is slightly more copper than nickel in this runoff water and in this respect is similar to Filson Creek. A plot of concentration vs. time is presented on Graph II for the upstream sampling station. It is interesting to note the increase in nickel concentration over time. Copper concentrations also appear to rise early in the spring. A large flush of copper seems to occur with the June rains; however, the steady climb of nickel concentration seems to be unaffected by the rain and subsequent increase in runoff.
5. The tributary immediately below the bulk sample site exhibits increases in specific conductivity, nickel, copper, and probably iron. Cadmium, lead and zinc levels are not measurably changed. The increase is roughly 10 ug/l for nickel and about 5 ug/l for copper. It appeared that the changes in nickel concentration at the downstream site were very dependent on water movement from the bulk sample site. As flow from the bulk sample site could not be measured, tributary flow was used as an indicator of water movement. Therefore, tributary flow was regressed against the change in concentration between the upstream and downstream site and the results are shown on Graph III. Increased copper concentration is not related to water movement from the bulk sample site while nickel increases appear to be very dependent on water movement.

GRAPH I

FLOW L/SEC

10.0

1.0

● MEASURED FLOWS

--- HYDROGRAPH BASED ON
FILSON CREEK RECORD

A

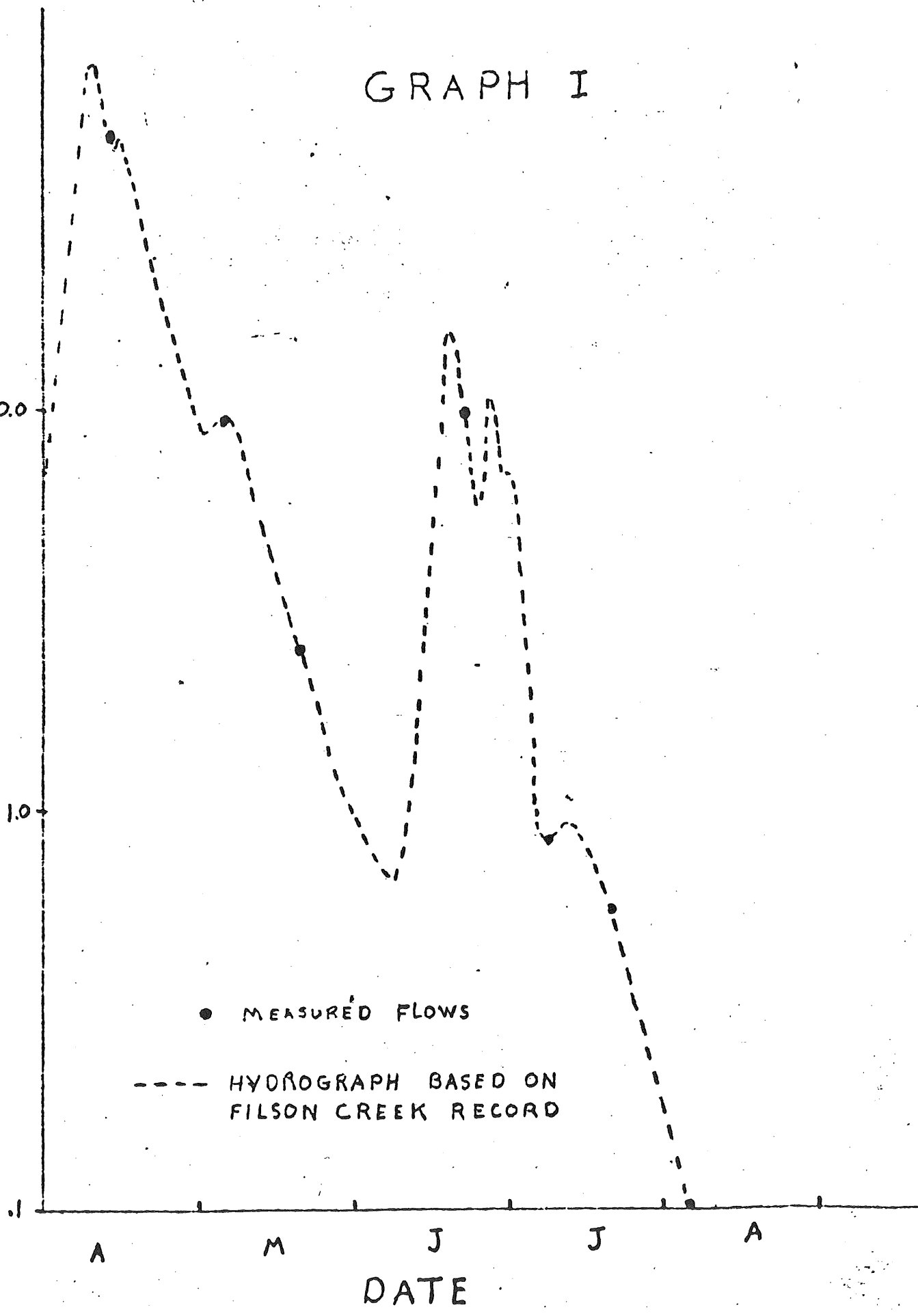
M

J

J

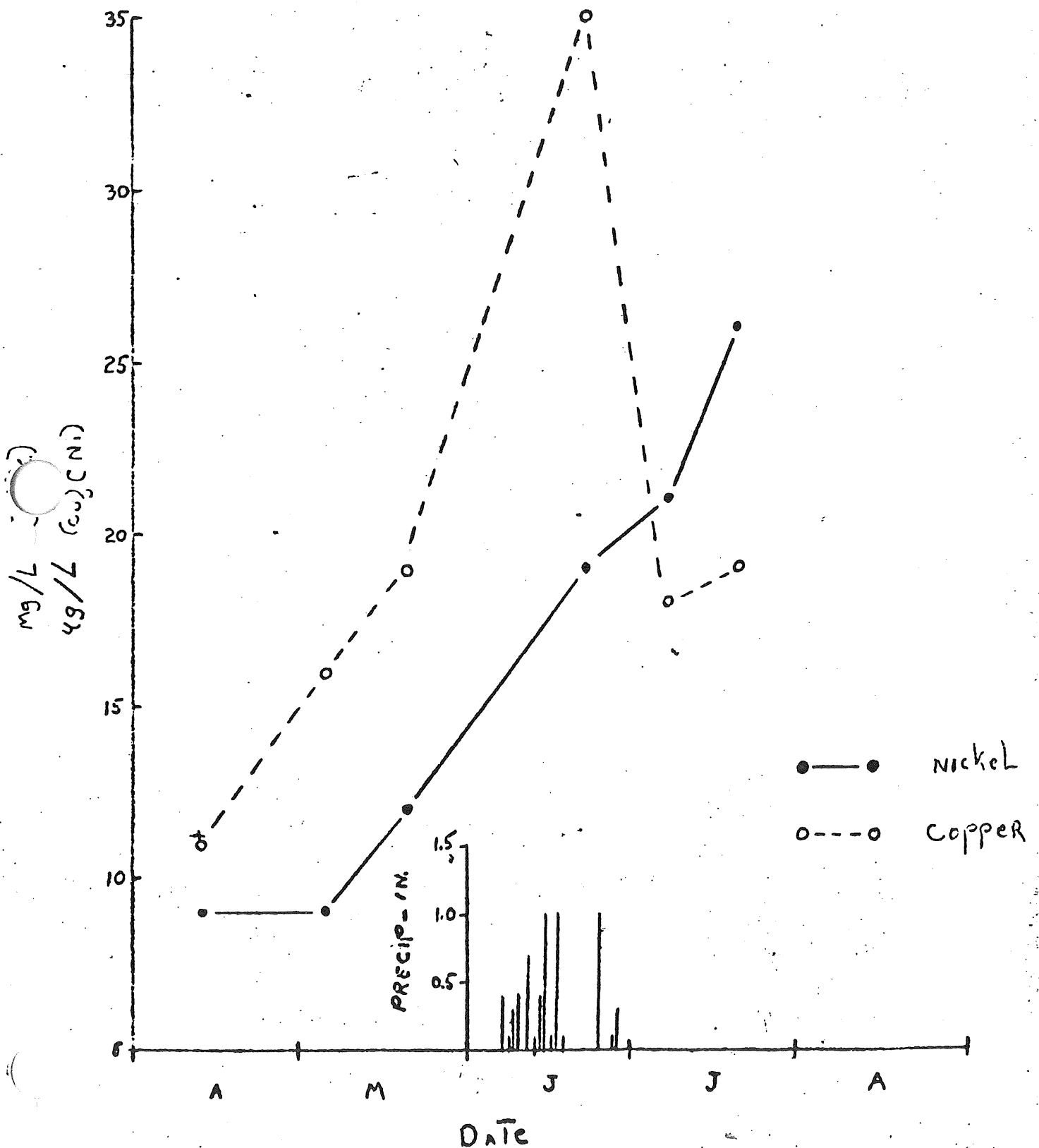
A

DATE



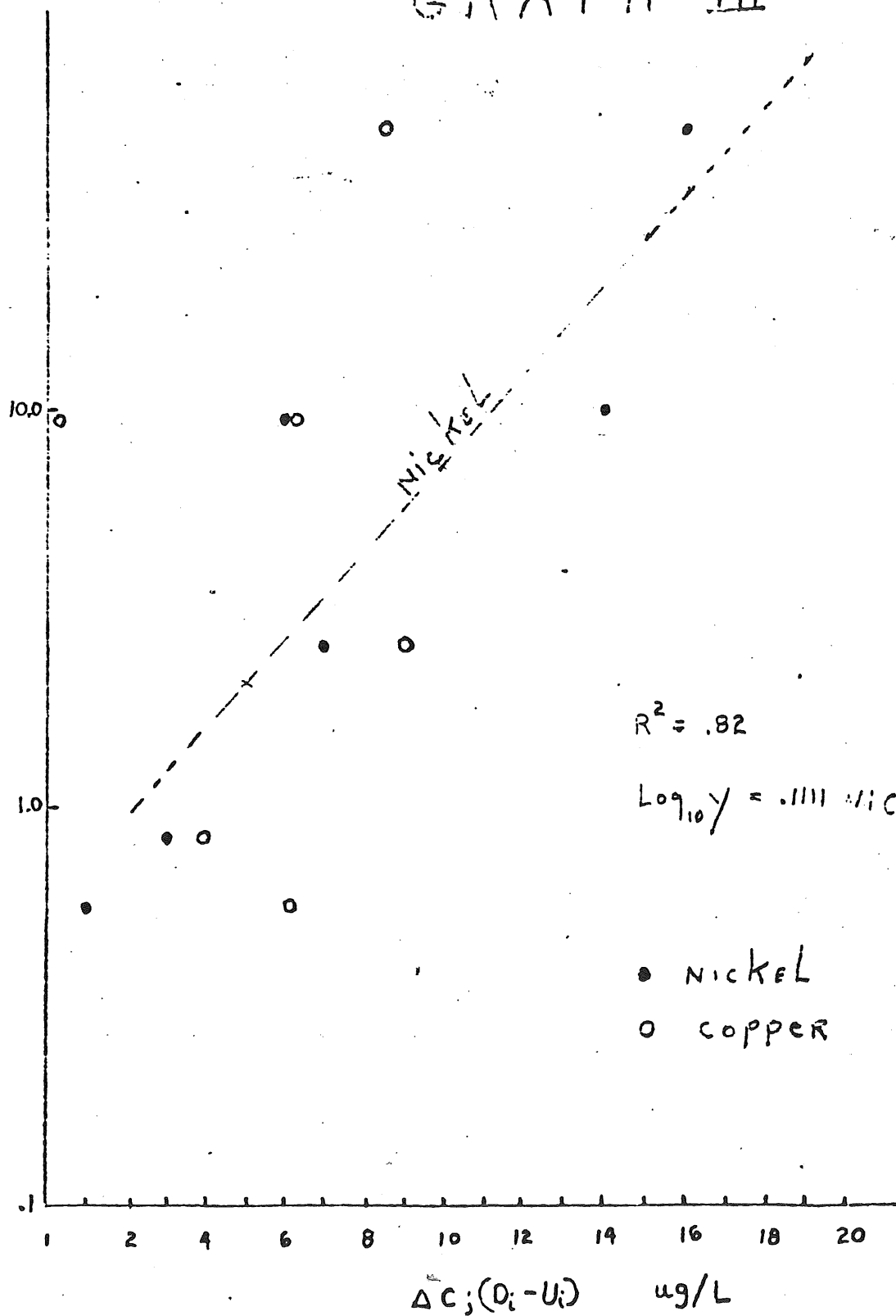
GRAPH II

UPSTREAM CU, Ni CONCENTRATIONS



GRAPH III

Flow cc



Update on Spruce and Bulk Sample Site

The summer and fall of 1976 and the winter of 1977 were very dry. Filson Creek ceased to flow in late December and did not resume flowing until March of 1976. The total water content of the snowpack over the winter was less than two inches and the peak flow for Filson Creek at snowmelt was only 4 cfs. It is, therefore, not surprising that the seep ceased to flow during the summer of 1976 and did not resume flow during the spring of 1977. However, the seep did begin to flow in early June and has continued to flow to date. Samples have been taken of the discharge. Although chemical data is not available at this time for the summer of 1977, field measurements of specific conductivity and pH indicate little if any change from previous measurements and it is unlikely that any changes in the chemistry of the discharge has occurred.

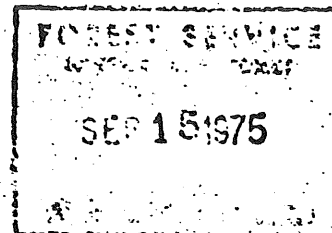
Information is very limited at this time, but it appears that the surface reclamation procedures accomplished little relative to the quantity and quality of the water being discharged from the bulk sample site.

APPENDIX



Minnesota Pollution Control Agency

September 10, 1975



Mr. William Mounce
Resident Manager
International Nickel Company, Inc.
7600 Parklawn Ave.
Minneapolis, MN 55435

Dear Mr. Mounce:

On January 7, 1974, International Nickel Company requested from the Supervisor of the Superior National Forest permission to remove a 10,000 ton sample for milling and metallurgical tests. The sample was taken and the site was covered and seeded.

It has come to the attention of the Minnesota Pollution Control Agency that subsidence of the site has occurred and that waters from the site, which have come into contact with mineralized Duluth Gabbro, are draining to waters of the State. We believe there exists a potential for leached heavy metals entering and polluting waters of the State.

At this time, we request that you begin sampling runoff from the bulk sample site and supply the Agency with a report discussing any adverse effects resulting from the runoff.

The report should include a site description; source, quantity and quality of waters leaving the site; the analytical results of the sampling; a description of the drainage course; and possible mitigative procedures to eliminate contaminated runoff.

As you know, Minn. Statutes 115 and 116 defines the Agency's duty to enforce all laws relating to pollution of any waters of the State. The Agency under its power and duties must take action on this potential violation of laws and regulations under its charge.

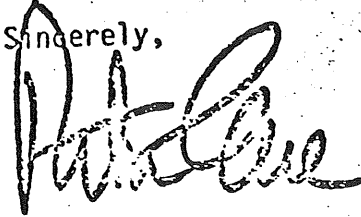
CU-NI PROJECT		
SEP 11 '75		
Superior Natl. Forest		
Info		
In Pcc.		
Don Surui		
Ann. Syst.		

Handwritten: Copy for S/N

We ask that you respond to this request by September 19, 1975.

If you have any questions, please contact me or Mr. Curtis Sparks of my staff at (612) 296-7229.

Sincerely,

A handwritten signature in dark ink, appearing to read "Peter L. Gove". The signature is fluid and cursive, with a large initial "P" and a long, sweeping underline.

Peter L. Gove
Executive Director

cc: U.S. FS, Attn: Ed Vandermilen
John Pegors
Robert Poppe, EQC

D R A F T

September 11, 1975

Mr. Peter Gove
Executive Director
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, MN 55113

Dear Mr. Gove:

This is to reply to your letter of September 10 concerning a small amount of seepage occurring at the site on our Federal lease 01353 from which a 10,000-ton bulk sample of copper-nickel ore was removed during January, 1974.

As indicated in your letter, after removal of the sample the site was reclaimed by back-filling and restoring the excavated area to approximately the original contours using locally available materials. The area was reseeded, and upon completion the restoration was judged acceptable by the USFS District Ranger.

In the Spring of this year it was apparent that the top area of the site had experienced some subsidence to the extent of creating a saucer shaped depression approximately 20 yards in diameter by 10 feet deep. During the early summer two small seeps were noted issuing from the foot of the face slope nearest Spruce Road, these occurred, evidently, as a result of precipitation that gathered in the area of subsidence and percolated down through the backfill. It has not been determined how much water may have accumulated

in the interior of the backfilled area, nor how long nor to what degree the in-seepage may have been exposed to mineralized rock.

One estimate could be based on assuming that all of the precipitation falling on the subsided area became involved in the process. No inflow of ground water was noted during the removal of the bulk sample. Calculating the surface area and total precipitation indicates that a maximum of _____ cubic feet of water could have been available from October to August.

The volume of seepage has been too small to make any sort of rate measurements. We estimate, however, that the ^(check) total seepage does not exceed one half gallon per minute, and we have observed that the volume has not varied greatly through the past several months.

In June we started attempts to sample the seepage for chemical composition. The results can be considered as giving no more than general indications of the nature of the water because only small amounts of seepage could be accumulated in shallow puddles, and sampling necessarily risked entrainment of sediment and other local contaminants.

The analyses were performed on samples both as-gathered ^(check) and after filtering through a micropore filter. Three separate samplings between June and September gave the following results: *shown in Table I*

- 3 -

The occurrence of the seepage was discussed at various times during the summer with representatives of the USFS and the Minnesota Department of Natural Resources. The results of our first sampling were made available to both organizations, and were confirmed, in part, by a sample gathered by DNR. It was felt that by observing the seepage for a limited period of time, very useful information could be gained on the leaching characteristics of the local geological structures in the actual environment that would exist if mining were to be established.

In mid-August it was decided, with the agreement of the USFS, that the bulk sample site should be regraded and re-vegetated to eliminate the negative contour. Plans have been drawn up as indicated in the attachments and regrading should be completed by October.

We have set up a controlled program to use various local materials and vegetating schemes on the site to determine their effectiveness in reducing infiltration of surface water and consequent accumulation in the back fill. This information should help considerably to develop methods for treating lean ore and waste rock piles should mining be initiated. The appended report provides the information on site description; source, quantity and quality of the waters leaving the site; the analytical results of sampling to date; a description of the drainage course; and the plans for regrading, sealing and revegetating the site. I hope that it will be considered a satisfactory response to your letter of September 10.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

SO

OCT 1 1975

RECEIVED

Admquist

64-101

REPLY TO: 8410 Forest Service Environmental Impact Statements

September 26, 1975

SUBJECT: Proposed Reclamation of INCO Spruce Road Bulk Sample Site

TO: File



In January, 1974, INCO removed a bulk sample of mineral bearing rock for milling and metallurgical tests adjacent to the Spruce Road, in the NW $\frac{1}{4}$ of the NW $\frac{1}{4}$ of Section 25, T62N, R11W. Removal was under terms of a Federal Lease held by INCO and the sample was the basis of INCO's request to the Supervisor, Superior National Forest, to construct an open pit mine.

The bulk sample site was regraded and seeded by INCO in the Spring of 1974 with approval by the Forest Service. Subsequent to that time a subsidence of the surface has occurred and a seepage from the base of the sample site nearest the road was noticed in the summer of 1975.

In August, 1975, I visited the bulk sample site with Bill Mounce of INCO and we discussed the seepage problem. I requested that the problem be corrected and asked that they contact the Kawishiwi District Ranger submitting a plan for restoration.

INCO complied with the request and the restoration plan was approved by the District Ranger acting on technical advice of soil scientist Don Prettyman and watershed scientist Herb Garn.

Recent evidence indicates that a seepage existed in the area before bulk sampling began and that present plans to reclaim the area may not be able to stop the seepage.

It now appears that it would be advisable to delay attempting reclamation until Spring in order to test the seepage thoroughly. On the basis of geologic observation and preliminary water quality samples a delay in reclamation does not appear to endanger the water quality of the river. It is my opinion that delaying the reclamation will allow time to gather useful information on leaching of rainwater through the mineral area. Facts gathered from these observations could be valuable in the development of EIS data collection.

2.

John Ramquist, water quality specialist, informs me that the amount of nickel released into the Kawishiwi River from the seepage is inconsequential and amounts to parts per trillion. Other metals released would be correspondingly less.

Stuart Behling's opinion is that the small amount of rock exposed by the bulk sample removal is inconsequential in comparison to other large quantities of exposed mineral in the area and that delay in reclamation in favor of further testing would be desirable.

I have informed Don Church, Kawishiwi District, of my recommendation. The District is in favor of delaying reclamation until Spring. Don Prettyman and John Ramquist are also in agreement with the recommendation.

On September 10, INCO was requested by MPCA Director, Peter Gove, to sample the seepage and report to the State.

I informed Connie Ennega of MPCA today that we were planning to delay until Spring in favor of further testing and explained reasons for doing so. She stated that MPCA did not feel that the seepage was a major problem but that their request to secure samples was a precaution measure.



E. J. VANDERMILLEN
Copper- Nickel Project Leader

Enclosure

cc: Kawishiwi District

J. Ramquist
J. Torrence
D. Prettyman
Herb Garn
S. Behling

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

S.O.

SW

REPLY TO: 8410 Forest Service Environmental Statements
(2580)

September 25, 1975

SUBJECT: Inco Project - Inco test pit

TO: E. J. Vandermillen



This is in reply to your request for geologic input regarding the question of whether Inco should do additional reclamation on the Spruce Road bulk sample site or establish a monitoring program for leaching of heavy metals. Due to the equivocal nature of the detailed information available from the site, this question will be approached in a general way.

As pointed out in numerous geologic publications, the Duluth Gabbro contains extensive zones of Cu-Ni mineralization along its basal contact. By nature, much of this mineralization has been exposed to subaerial weathering and leaching, not only in extensive outcrop areas, but also as abundant rock fragments in the glacial drift. By man, in addition to the subject site, exposures have been created in numerous borrow pits and road-cuts excavated in weathered mineralized outcrop and in glacial drift containing mineralized rock fragments, many of which are located along Spruce Road. The condition of the material in the man made excavations differ from that in the natural exposures in that it contains abundant freshly exposed mineralized surfaces from which readily available heavy metals are leached. This accelerated leaching continues until the exposed surfaces are covered with weathering products. Because of the comparably insignificant surface area involved, even though chemically more active, it is doubtful whether seepage from Inco's test pit or from the excavation related to road construction contribute significantly to the heavy metals being leached from natural exposures.

In reference to future Cu-Ni mining, it would be very useful to determine which metals are most active when freshly exposed, the duration of their accelerated activity, and their mobility in the natural environment. A well conducted monitoring program of the seepage from the bulk sample site could contribute significantly toward this insight. It would also provide control data to determine the effectiveness of the final reclamation. Therefore, I would support this alternative rather than immediate reclamation.

Stuart J. Behling
STUART J. BEHLING
Geologist

Cu-Ni Project

8410 Forest Service E.I.S.

October 3, 1975

Bulk Sample Site Leaching

Files

On September 30, 1975, flow measurements were taken in and around the spruce road bulk sample site in an attempt to determine probable levels of heavy metals in water downstream of the site.

Flow from the bulk sample site was determined volumetrically, the small tributary to Filson was metered and flows in Filson and the South Kawishiwi River were determined from rating curves. In addition, nickel concentrations from the leach at the bulk sample site were provided by INCO.

Following is a table summarizing the data and results. (Refer to attached map for site locations).

<u>Location</u>	<u>Flow</u>	<u>Ni - Concentrations</u>
Bulk Sample (Site A)	.0005 cfs	2300 ppb
Tributary (Site B)	.05 cfs	(Calc.) 25 ppb
Filson Cr. (Site D)	1.72 cfs	(Calc.) .75 ppb
South Kawishiwi	247 cfs	(Calc.) .005 ppb

The data indicates that nickel concentrations in Filson and in the South Kawishiwi will not be measurably effected by leaching from the bulk sample site and should pose no threat to aquatic life in these two streams. In addition, all other heavy metals are of far less concentration in the bulk sample site leachate.

Although there are no significant hazards associated with this leachate, it should be followed closely as long as it exists.

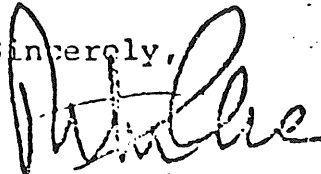
JOHN A. RAMQVIST
Water Quality Specialist

CC: Ed Vanderrillen

Mr. William Mounce
Page 2

I ask that the information previously requested be provided as soon as it becomes available. If you have any questions, please contact me or Curtis J. Sparks of my staff.

Sincerely,



Peter L. Gove
Executive Director

PLG:ss

cc: ✓ Ed Vandermillen, U.S. Forest Service
Robert Poppe, Environmental Quality Council
Robert Herbst, Department of Natural Resources
John Pegors, MPCA Regional Office

NOV 7 '75

Info		Page
------	--	------

100 F.C.C.

Suppose that

Dr. Selvi

Aug. 1901

114 C. 1. 1. 1

1. We are proceeding to develop information required to prepare the report requested in your letter of September 19. We are following the outline forwarded to MPCA on October 6, and appreciate being notified that the plan is acceptable to the Agency.
2. To date 13 water samples have been taken from the seep itself and in addition 7 sets of samples from 2 ground water observation points above the bulk sample site, and from 3 points between the site and the lower end of Filson Creek.
3. Flow has been monitored regularly and recently showed a rate less than 1 pint per minute.
4. Our plan for regrading the site was outlined to the USFS in the attached proposal on September 2. Regrading according to these procedures started on November 3 and should be completed early next week.
5. The effect of the regrading on the seep will be carefully observed.

Mr. Peter Gove
November 4, 1975
Page 2

6. We hope to have the requested report completed by
December 1.

Very truly yours,

W. S. Mounce

WSM:msh
Att.

cc: E. Vandermillen ✓

September 2, 1975

Ray Chase
District Ranger
Department of Agriculture
United States Forest Service
Postoffice Building
Ely, Minnesota 55731

Dear Ray,

It is our intention to undertake additional reclamation procedures on the Spruce Rd. bulk sample site, located in the NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 25, T62, R11.

Discussions with other Forest Service personnel has defined the following general procedure to be followed in this program.

- (1) The depression caused by settling of the original fill will be eliminated by raising to a condition of positive relief. It is estimated that this will require approximately 2,000 cubic yards of material.
- (2) The initial 8" - 10" layer will be compacted by the operating equipment and an attempt will be made to utilize largely impervious material.
- (3) Final elevation will be contoured to blend with existing topography.
- (4) Reseeding of the site will follow the attached suggested seed analysis and fertilizing schedule.
- (5) A 6" - 8" lift of gravel will be spread on the adjacent "Lampi Rd", in order to eliminate the natural boggy condition which has existed.

We hope to start the project in early September and will have it completed before the end of the month. We may wish to carry out additional experimental planting on the site and will confer with you prior to undertaking this work.

Please call if you should have any additional advice or comments on this program.

Sincerely,

R. E. Wager
Project Geologist

Suggested Seed Analysis and Fertilizing Schedule

Annual Rye) Either or both in combo
Agriculture Rye) Not more than 10% by weight

Laderno or alsac clover - either or both in combo with white clover to make up 70% by weight

Brome grass 20% by weight

Fertilizer	10/10/10	300#/acre
Best	20/15/30	200#/acre

Lime 2½ ton per Acre of Agriculture lime.

SUMMARY OF CHEMICAL ANALYSIS

SEEP

<u>Date</u> <u>1975</u>	<u>Copper</u> <u>ug/l</u>	<u>Nickel</u> <u>ug/l</u>	<u>Hardness</u> <u>mg/l</u>	<u>Sulfate</u> <u>mg/l</u>	<u>Zinc</u> <u>ug/l</u>	<u>Manganese</u> <u>ug/l</u>
5-16	380	2300	-	-	15.0	2800
7-9	78	37	-	-	14.0	3500
7-23	34	200	-	-	<10.0	4100
8-13	100	200	-	-	9.0	4500
8-25	? 1800	2900?	-	-	17.0	4800
9-15	120	1700	-	-	10.0	4600
9-29	-	3000	180	304	6.1	4500
10-4	170	3100	-	-	7.8	4300
10-7	160	3100	942	304	7.5	4200
10-10	130	2800	1217	281	6.8	4100
10-15	100	2100	1211	271	5.4	4100
10-20	78	2600	514	289	7.5	5300
10-23	190	3100	1107	286	3.0	4800
11-4	100	3100	1579	323	8.8	4500

Hickole is
checking this
one

SUMMARY OF COPPER-NICKEL ANALYSIS
ALL IN ug/l

<u>DATE</u>	<u>SEEP</u>	<u>MARSH</u>	<u>CREEK</u>	<u>FILSON</u>	<u>LOCATION II</u>
9-29	-/3000	21/13	30/30	11 /6.6	1.5/1
10-4	170/3100	40/13	40/19	30 /6	.
10-7	160/3100	40/11	40/15	40 /5	2 /2.9
10-10	130/2800	27/17	31/25	11 /6.6	
10-15	100/2100	22/16	30/28	11 /6.1	
10-20	78/2600	20/18	32/26	11.2/6	2.1/2
10-23	90/2400	25/28	36/28	10 /8	1.0/2
11-3	100/3100	25/20	---	---	---

Copper/Nickel

Generally levels have dropped in the marsh and tend to increase in creek and drop again in Filson.

CU 118.3 $\bar{x}$	27.5	34	17.7
6 35.7	8.1	4.5	12.1
Ni 2775	17.0	24.4	6.3
3770	6.3	5.4	.9

TR. 3 ABOVE SEEP

4-13-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 107003 RECORD # 8357

SAMPLE LOCATION: STATION NUMBER 3 BULK SAMPLE SITE
STATION ID: 470956091403903 LAT, LONG, SEQ.: 470956 0914039 03
DATE OF COLLECTION: BEGIN--760413 END-- TIME--1000
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY J RAMQUIST, S LUNDEEN, R BERRISFORD 200 YDS UPSTREAM OF
SAMPLE SEQUENCE NO 2 ON TRIBUTARY

MAIL TO ST PAUL MINN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 20 MCODE = 16
COST OF ANALYSIS \$ 107.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 09/04/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS REQUESTED AND THE
STATION HEADING INFORMATION IN THE WRD STATION
HEADER FILE WAS SUBSTITUTED HERE, PLEASE CHECK.

AIR TEMP (DEG C)		18.0	MAGNESIUM TOTAL USGS MG/L	2.8
ALK, TOT (AS CaCO3)	MG/L	7	NICKEL TOTAL AAGF UG/L	9
BICARBONATE	MG/L	8	PH FIELD	5.6
CADMIUM TOTAL AAGF	UG/L	0.04	POTASSIUM TOTAL USGS MG/L	0.4
CALCIUM TOTAL USGS	MG/L	2.3	RESIDUE SUSPEN 110C MG/L	1
CARBON DIOXIDE	MG/L	32	SODIUM TOTAL USGS MG/L	0.2
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	30
COLOR		110	SULFIDE TOTAL MG/L	0.8
COPPER TOTAL AAGF	UG/L	11	TURBIDITY (JTU)	1
IRON TOTAL	UG/L	450	WATER TEMP (DEG C)	1.0
LEAD TOTAL AAGF	UG/L	0.5	ZINC TOTAL AAGF UG/L	4.2

CATIONS

(MG/L) (MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L) (MEQ/L)

8 0.132
0 0.000

TOTAL 0.131

TRIB ABOVE SEEP
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 129026 RECORD # 13332

SAMPLE LOCATION: FILSON CR TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124902 LAT, LONG, SECT: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760505 END-- TIME--1000
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY J RAMQUIST, S LUNDEEN, R BERRISFORD FROM TRIBUTARY ABOVE
POINT WHERE SEEP DISCHARGES INTO TRIBUTARY

AIR TEMP (DEG C)		2.0	MAGNESIUM TOTAL USGS MG/L	2.5
ALK, TOT (AS CaCO3)	MG/L	26	NICKEL TOTAL AAGF UG/L	9
BICARBONATE	MG/L	32	PH FIELD	5.4
CADMIUM TOTAL AAGF	UG/L	0.02	POTASSIUM TOTAL USGS MG/L	0.3
CALCIUM TOTAL USGS	MG/L	2.5	RESIDUE SUSPEN 110C MG/L	6
CARBON DIOXIDE	MG/L	204	SODIUM TOTAL USGS MG/L	1.1
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	29
COLOR		150	SULFIDE TOTAL MG/L	1.8
COPPER TOTAL AAGF	UG/L	16	TURBIDITY (JTU)	1
IRON TOTAL	UG/L	470	WATER TEMP (DEG C)	5.5
LEAD TOTAL AAGF	UG/L	0.2	ZINC TOTAL AAGF UG/L	3.9

CATIONS

(MG/L) (MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L) (MEQ/L)

32 0.525
0 0.000

TOTAL 0.524

MAIL TO ST PAUL MINN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 20 MCODE = 0
COST OF ANALYSIS \$ 107.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 12/24/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-9* FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

trib. above
Julk S Site
5-2-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, ALBANY, NEW YORK

WATER QUALITY ANALYSIS
LAB ID # 143159 RECORD # 46342

JUN 23 1978

SAMPLE LOCATION: FILSON CR TRIUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT.LONG.SFO.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760520 END-- TIME--1100
COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLLECTED BY R HERRISFORD & S LUNDEEN
FROM TRIUTARY ABOVE POINT WHERE
SEEP DISCHARGES INTO TRIUTARY CS=9

AIR TEMP (DEG C)		12.0	MAGNESIUM TOTAL USGS MG/L	1.9
ALK.TOT (AS CaCO3)	MG/L	10	PH FIELD	5.9
BICARBONATE	MG/L	12	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	2.6	RESIDUE SUSPEN 110C MG/L	3
CARBON DIOXIDE	MG/L	30	SODIUM TOTAL USGS MG/L	1.1
CARBONATE	MG/L	0	SULFIDE TOTAL MG/L	1.2
COLOR		160	TURBIDITY (JTU)	1
IRON TOTAL	UG/L	440	WATER TEMP (DEG C)	10.0

MAIL TO MINN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 14 HCODE = 0
COST OF ANALYSIS \$ 37.80 DOP--740622
SUBMIT CORRECTIONS TO CENTRAL LAB WITHIN
15 DAYS FROM FLOW STAMPED DATE. INDICATE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-0# FILE STOPAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

12 0.197
0 0.000

TOTAL

0.197

TRIB ABOVE SEEP

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CENTRAL LABORATORY, DENVER, COLORADO

5-20-77

WATER QUALITY ANALYSIS

LAB ID # 168417 RECORD # 16367

SAMPLE LOCATION: FILSON CR TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT. LONG. SEC. 1 474957 0914030 00
DATE OF COLLECTION: BEGIN--760520 END-- TIME--1100
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R HERRISFORD AND S LUNDEEN FROM TRIBUTARY ABOVE POINT WHEN
SEED DISCHARGES INTO TRIBUTARY

AIR TEMP (DEG C)		18.0	NICKEL TOTAL AAGF	UG/L	12
CADMIUM TOTAL AAGF	UG/L	0.02	PH FIELD		5.8
COPPER TOTAL AAGF	UG/L	19	SP. CONDUCTANCE FLN		31
LEAD TOTAL AAGF	UG/L	0.5	WATER TEMP (DEG C)		10.0
			ZINC TOTAL AAGF	UG/L	6.9

MAIL TO ST PAUL MINN

SCHEDULES USED: 437 0 0 0

NUMBER OF DETERMINATIONS: 9 HCODE = 0

COST OF ANALYSIS \$ 70.00 BILLING CODE: 27

SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB

WITHIN 15 DAYS FROM 01/08/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.

WRO-DW FILE STORAGE WAS NOT REQUESTED FOR

THIS ANALYSIS. THE ANALYSIS WILL REMAIN

IN THE CENTRAL LAB FILE ONLY.

~~AT CONVENT~~ TRIB ABOVE SEEP

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

5-20-76

WATER QUALITY ANALYSIS
LAB ID # 148417 RECORD # 16367

SAMPLE LOCATION: FILLSON CR TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT, LONG, SEC: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760520 END-- TIME--1100
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 402704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R REPRISFORD AND S LUNDEEN FROM TRIBUTARY ABOVE POINT WHEN
SEEP DISCHARGES INTO TRIBUTARY

AIR TEMP (DEG C)		18.0	NICKEL TOTAL AAGF	UG/L	12
CADMIUM TOTAL AAGF	UG/L	0.02	PH FIELD		5.8
COPPER TOTAL AAGF	UG/L	19	SP. CONDUCTANCE FLD		31
LEAD TOTAL AAGF	UG/L	0.5	WATER TEMP (DEG C)		10.0
			ZINC TOTAL AAGF	UG/L	6.9

MAIL TO ST PAUL MINN
SCHEDULES USED: 457 0 0 0
NUMBER OF DETERMINATIONS: 9 HCODE # 0
COST OF ANALYSIS \$ 70.00 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 6/13/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
NO-CH FILE STORAGE HAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

TRIP ABOVE SEEP

FS

6-22

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, ALBANY, NEW YORK

WATER QUALITY ANALYSIS
LAB ID # 182027 RECORD # 61321

SAMPLE LOCATION: FILSON CR TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT.LONG.SEQ.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760622 END-- TIME--1040
COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:
COLL BY R BERRISFORD & S LUNDEEN FROM TRIBUTARY ABOVE POINT
WHERE SEEP DISCHARGES INTO TRIBUTARY

AIR TEMP (DEG C)		24.0	MAGNESIUM TOTAL USGS MG/L	2.5
ALK.TOT (AS CaCO3)	MG/L	13	PH FIELD	6.0
BICARBONATE	MG/L	16	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	4.0	RESIDUE SUSPEN 110C MG/L	1
CARBON DIOXIDE	MG/L	26	SODIUM TOTAL USGS MG/L	1.3
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	26
COLOR		240	SULFIDE TOTAL MG/L	1.3
IRON TOTAL	UG/L	860	TURBIDITY (JTU)	1
			WATER TEMP (DEG C)	16.5

CATIONS

(MG/L) (MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L) (MEQ/L)

16 0.263
0 0.000

TOTAL 0.262

MAIL TO MINN
SCHEDULES USED: 271 0 0 0
TOTAL PARAMETERS: 19 HCODE = 0
COST OF ANALYSIS \$ 37.80 DOP--770516
SUBMIT CORRECTIONS TO CENTRAL LAB WITHIN
15 DAYS FROM BELOW STAMPED DATE. INDICATE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

TRIP ABOVE SEEP

6-22-

6-22-

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 185406 RECORD # 20614

SAMPLE LOCATION: PILSON CR. TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124902 LAT. LONG. SEQ. 1 474957 0914030 00
DATE OF COLLECTION: BEGIN--760622 END-- TIME--1040
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R. HERRISFORD AND S. LUNDEEN FROM TRIBUTARY ABOVE POINT WHERE
SEEP DISCHARGES INTO TRIBUTARY

AIR TEMP (DEG C)		24.0	NICKEL TOTAL AAGF	UG/L	19
CADMIUM TOTAL AAGF	UG/L	0.01	PH FIELD		6.0
COPPER TOTAL AAGF	UG/L	35	SP. CONDUCTANCE FLD		26
LEAD TOTAL AAGF	UG/L	0.4	WATER TEMP (DEG C)		16.5
			ZINC TOTAL AAGF	UG/L	3.6

MAIL TO ST PAUL MN
SCHEDULES USED: 437 0 0 0
NUMBER OF DETERMINATIONS: 9 HCODE = 0
COST OF ANALYSIS \$ 76.99 BILLING CODE: 27
SURMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 01/08/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WHEN FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS, THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

*** THIS ANALYSIS HAS PREVIOUSLY BEEN APPROVED AND TRANSMITTED BUT THESE PARAMETERS HAVE BEEN UPDATED SINCE THAT TRANSMITTAL ***
LAB ID # 142027 RECORD # 61321 (ASSOCIATED CALCULATIONS HAVE ALSO BEEN UPDATED)

CODE	PARAMETER NAME	CODE	PARAMETER NAME	CODE	PARAMETER NAME
8	BICARBONATE				

TRIB ABOVE SEEP

FS

7-7-74

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, ALBANY, NEW YORK

WATER QUALITY ANALYSIS
LAR ID # 197039 RECORD # 66073

SAMPLE LOCATION: FILSON CR TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT.LONG.SEQ.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760707 END-- TIME--1025
COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R BERRISFORD & S LUNDEEN FROM TRIBUTARY ABOVE POINT
WHERE SEEP DISCHARGES INTO TRIBUTARY CS025

AIR TEMP (DEG C)		20.0	MAGNESIUM TOTAL USGS MG/L	2.5
ALK.TOT (AS CaCO3)	MG/L	13	PH FIELD	6.4
BICARBONATE	MG/L	16	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	7.3	RESIDUE SUSPEN 110C MG/L	9
CARBON DIOXIDE	MG/L	10	SODIUM TOTAL USGS MG/L	1.3
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	30
COLOR		280	SULFIDE TOTAL MG/L	3.8
IRON TOTAL	UG/L	920	TURBIDITY (JTU)	1
			WATER TEMP (DEG C)	14.0

MAIL TO MN
SCHEDULES USED: 271 0 0 0
TOTAL PARAMETERS: 19 HCODE = 0
COST OF ANALYSIS \$ 37.80 DOP--770516
SURMIT CORRECTIONS TO CENTRAL LAB WITHIN
15 DAYS FROM BELOW STAMPED DATE. INDICATE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

CATIONS

(MG/L) (MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L) (MEQ/L)

16 0.263
0 0.000

TOTAL 0.262

*** THIS ANALYSIS HAS PREVIOUSLY BEEN APPROVED AND TRANSMITTED BUT THESE PARAMETERS HAVE BEEN UPDATED SINCE THAT TRANSMITTAL ***
LAB ID # 197039 RECORD # 66073 (ASSOCIATED CALCULATIONS HAVE ALSO BEEN UPDATED)

CODE	PARAMETER NAME	CODE	PARAMETER NAME	CODE	PARAMETER NAME	CODE	PARAMETER NAME
8	BICARBONATE						

TRIB ABOVE SEEP

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

7-7-76

WATER QUALITY ANALYSIS
LAB ID # 199407 RECORD # 4562A

SAMPLE LOCATION: FILSON CR, TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT, LONG, SEQ.: 474957 N914030 W0
DATE OF COLLECTION: BEGIN--760707 END-- TIME--1025
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 402704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:

COMMENTS:

COLL BY R BERRISFORD AND S LUNDEEN FROM TRIBUTARY ABOVE POINT WHERE
SEEP DISCHARGES INTO TRIBUTARY

AIR TEMP (DEG C)		20.0	NICKEL TOTAL AAGF	UG/L	21
CADMIUM TOTAL AAGF	UG/L	0.01	PH FIELD		6.4
COPPER TOTAL AAGF	UG/L	18	SP. CONDUCTANCE FLD		30
LEAD TOTAL AAGF	UG/L	0.2	WATER TEMP (DEG C)		14.0
			ZINC TOTAL AAGF	UG/L	2.9

MAIL TO ST PAUL MINN

SCHEDULES USED: 0 0 0 0
NUMBER OF DETERMINATIONS: 9 MCODE = 0
COST OF ANALYSIS \$ 0.25 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 02/04/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
RD-Q FILE STORAGE WAS NOT REQUESTED FOR.
THIS ANALYSIS, THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

TRIB ABOVE SEEP

7-20-

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 205003 RECORD # 22707

SAMPLE LOCATION: PILSON CR, TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT, LONG, SEQ, 474957 0914030 00
DATE OF COLLECTION: BEGIN--760720 END-- TIME--1000
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R. HERRISFORD AND S. LUNDBEN FROM TRIBUTARY ABOVE POINT WHERE
SEEP DISCHARGES INTO TRIBUTARY. SHALLOW WATER MADE SAMPLING DIFFIC.

AIR TEMP (DEG C)		22.0	MAGNESIUM TOTAL USGS MG/L	28
ALK, TOT (AS CaCO3)	MG/L	11	PH FIELD	5.5
BICARBONATE	MG/L	13	POTASSIUM TOTAL USGS MG/L	0.2
CALCIUM TOTAL USGS	MG/L	4.2	RESIDUE SUSPEN 110C MG/L	1
CARBON DIOXIDE	MG/L	66	SODIUM TOTAL USGS MG/L	1.1
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	31
COLOR		360	SULFIDE TOTAL MG/L	1.1
IRON TOTAL	UG/L	1600	TURBIDITY (JTU)	1
			WATER TEMP (DEG C)	18.0

MAIL TO ST PAUL MN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 15 MCODE = 0
COST OF ANALYSIS \$ 37.80 BILLING CODE: 27
SURMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 08/25/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

13 0.214
0 0.000

TOTAL

0.213

b. above Bulk Sample
fe

7-20-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 205003 RECORD # 22707

SAMPLE LOCATION: FILSON CR, TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT, LONG, SEQ.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760720 END-- TIME--1000
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R. HERRISFORD AND S. LUNDEEN FROM TRIBUTARY ABOVE POINT WHERE
SEEP DISCHARGES INTO TRIBUTARY, SHALLOW WATER MADE SAMPLING DIFFIC.

AIR TEMP (DEG C)		22.0	MAGNESIUM TOTAL USGS MG/L	28
ALK, TOT (AS CaCO_3)	MG/L	11	PH FIELD	5.5
BICARBONATE	MG/L	13	POTASSIUM TOTAL USGS MG/L	0.2
CALCIUM TOTAL USGS	MG/L	4.2	RESIDUE SUSPEN 110C MG/L	1
CARBON DIOXIDE	MG/L	66	SODIUM TOTAL USGS MG/L	1.1
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	31
COLOR		360	SULFIDE TOTAL MG/L	1.1
IRON TOTAL	UG/L	1600	TURBIDITY (JTU)	1
			WATER TEMP (DEG C)	18.0

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

13 0.214
0 0.000

TOTAL

0.213

MAIL TO ST PAUL MN
SCHEMULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 15 HCODE = 0
COST OF ANALYSIS \$ 37.80 BILLING CODE: 27
SURMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 08/25/76, INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS, THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

COVE CULVERT
7-4 76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 213404 RECORD # 25127

SAMPLE LOCATION: FILSON CR, TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT, LONG, SEC: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760720 END-- TIME--0015
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY S. LUNDEEN AND R. BERRISFORD IMMED. ABOVE CULVERT ON SPRUCE
RD. MINIMAL FLOW. HARD TO SAMPLE WITHOUT STIRRING UP BOTTOM SEDIMENT

AIR TEMP (DEG C)		22.0	NICKEL TOTAL AAGF	UG/L	27
CADMIUM TOTAL AAGF	UG/L	0.01	PH FIELD		5.5
COPPER TOTAL AAGF	UG/L	25	SP. CONDUCTANCE FLD		37
LEAD TOTAL AAGF	UG/L	0.4	WATER TEMP (DEG C)		19.0
			ZINC TOTAL AAGF	UG/L	2.2

MAIL TO ST PAUL MN
SCHEDULES USED: 437 0 0 0
NUMBER OF DETERMINATIONS: 9 MCODE = 0
COST OF ANALYSIS \$ 76.99 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 02/26/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

No WRD
requested

rb. belo Bulk
imple Sit above
ulvert
7-20-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 205002 RECORD # 22705

SAMPLE LOCATION: FILSON CR, TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT, LONG, SEQ.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760720 END-- TIME--0915
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:

COMMENTS:
COLL BY S. LUNDEEN AND R. HERRISFORD IMMED. ABOVE CULVERT ON SPRUCE
WD. MINIMAL FLOW. HARD TO SAMPLE WITHOUT STIRRING UP BOTTOM SEDIMENT.

AIR TEMP (DEG C)		22.0	MAGNESIUM TOTAL USGS MG/L	34
ALK. TOT (AS CaCO_3)	MG/L	18	PH FIELD	5.5
BICARBONATE	MG/L	19	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	5.0	RESIDUE SUSPEN 110C MG/L	12
CARBON DIOXIDE	MG/L	96	SODIUM TOTAL USGS MG/L	1.3
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	37
COLOR		420	SULFIDE TOTAL MG/L	1.2
IRON TOTAL	UG/L	3100	TURBIDITY (JTU)	2
			WATER TEMP (DEG C)	19.0

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

19 0.312
0 0.000

TOTAL

0.311

MAIL TO ST PAUL MN
SCHEDULES USED: 271 0 0
NUMBER OF DETERMINATIONS: 15 HCODE = 0
COST OF ANALYSIS \$ 37.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 08/25/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRO-GW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

TRIB AT CULVERT

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 205002 RECORD # 22705

SAMPLE LOCATION: FILSON CR, TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT, LONG, SEQ.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760720 END-- TIME--0915
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY S. LUNDEEN AND R. BERRISFORD IMMED. ABOVE CULVERT ON SPRUCE
RD. MINIMAL FLOW. HARD TO SAMPLE WITHOUT STIRRING UP BOTTOM SEDIMENT.

MAIL TO ST PAUL MN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 15 MCODE = 0
COST OF ANALYSIS \$ 37.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 08/25/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

AIR TEMP (DEG C)		22.0	MAGNESIUM TOTAL USGS MG/L	34
ALK, TOT (AS CaCO3)	MG/L	16	PH FIELD	5.5
BICARBONATE	MG/L	19	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	5.0	RESIDUE SUSPEN 110C MG/L	12
CARBON DIOXIDE	MG/L	96	SODIUM TOTAL USGS MG/L	1.3
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	37
COLOR		420	SULFIDE TOTAL MG/L	1.2
IRON TOTAL	UG/L	3100	TURBIDITY (JTU)	2
			WATER TEMP (DEG C)	19.0

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

19 0.312
0 0.000

TOTAL

0.311

TRIB AT CULVERT

8-1-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 199408 RECORD # 45630

SAMPLE LOCATION: FILSON CR. TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT. LONG. SEC.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760707 END-- TIME--1000
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:
CUL BY R BERNISFORD AND S LUNDEEN IMMED ABOVE CULVERT ON SPRUCE RD

AIR TEMP (DEG C)		20.0	NICKEL TOTAL AAGF	UG/L	24
CADMIUM TOTAL AAGF	UG/L	0.01	PH FIELD		6.1
COPPER TOTAL AAGF	UG/L	22	SP. CONDUCTANCE FLD		36
LEAD TOTAL AAGF	UG/L	0.3	WATER TEMP (DEG C)		16.0
			ZINC TOTAL AAGF	UG/L	2.4

MAIL TO ST PAUL MINN
SCHEDULES USED: 0 0 0
NUMBER OF DETERMINATIONS: 9 HCODE = 0
COST OF ANALYSIS \$ 0.25 BILLING CODE: 27
SUMMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 02/04/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WHO-ON FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

*** THIS ANALYSIS HAS PREVIOUSLY BEEN APPROVED AND TRANSMITTED BUT THESE PARAMETERS HAVE BEEN UPDATED SINCE THAT TRANSMITTAL ***
LAB ID # 197037 RECORD # 66069 (ASSOCIATED CALCULATIONS HAVE ALSO BEEN UPDATED)

CODE	PARAMETER NAME	CODE	PARAMETER NAME	CODE	PARAMETER NAME
8	BICARBONATE				

4- TRIB. AT CULVERT

FS

7-7-

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, ALBANY, NEW YORK

WATER QUALITY ANALYSIS LAB ID # 197037 RECORD # 66069

SAMPLE LOCATION: FILSON CR TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT.LONG.SEO.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760707 END-- TIME--1000
COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:

COMMENTS:

COLL BY R BERRISFORD & S LUNDEEN IMMED.
ABOVE CULVERT ON SPRUCE RD CS#25

AIR TEMP (DEG C)		20.0	MAGNESIUM TOTAL USGS MG/L	2.9
ALK.TOT (AS CAC03)	MG/L	13	PH FIELD	6.1
BICARBONATE	MG/L	16	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	6.7	RESIDUE SUSPEN 110C MG/L	8
CARBON DIOXIDE	MG/L	20	SODIUM TOTAL USGS MG/L	1.4
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	36
COLOR		220	SULFIDE TOTAL MG/L	3.8
IRON TOTAL	UG/L	1300	TURBIDITY (JTU)	1
			WATER TEMP (DEG C)	16.0

MAIL TO MN BCODE: 27
SCHEDULES USED: 271 0 0 0
TOTAL PARAMETERS: 19 HCODE = 0
COST OF ANALYSIS \$ 37.80 DOP--770516
SUBMIT CORRECTIONS TO CENTRAL LAB WITHIN
15 DAYS FROM BELOW STAMPED DATE. INDICATE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

16 0.263
0 0.000

TOTAL

0.262

ES
Trib at Culvert
6-22-

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 145402 RECORD # 20608

SAMPLE LOCATION: PILSON CR, TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT, LONG, SEQ.: 474957 0914030 00
DATE OF COLLECTION: BEGIN==760622 END== TIME==1015
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R. HERRISFORD AND S. LUNDEEN IMMED. ABOVE CULVERT ON SPRUCE RD

AIR TEMP (DEG C)		24.0	NICKEL TOTAL AAGF	UG/L	33
CADMIUM TOTAL AAGF	UG/L	0.01	PH FIELD		5.7
COPPER TOTAL AAGF	UG/L	34	SP. CONDUCTANCE FLD		29
LEAD TOTAL AAGF	UG/L	0.2	WATER TEMP (DEG C)		17.0
			ZINC TOTAL AAGF	UG/L	3.1

MAIL TO ST PAUL MN
SCHEDULES USED: 437 0 0 0
NUMBER OF DETERMINATIONS: 4 HCODE = 0
COST OF ANALYSIS \$ 76.99 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 01/08/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRO-OW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

RIB AT CULVERT

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 14P416 RECORD # 16365

SAMPLE LOCATION: FILSON CR TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT, LONG, SECT: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760520 END-- TIME--1030
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY R BERRISFORD AND S LUNDEEN IMMED. ABOVE CULVERT ON SPRUCE RD

MAIL TO ST PAUL MINN
SCHEDULES USED: 437 0 0 0
NUMBER OF DETERMINATIONS: 9 HCODE = 0
COST OF ANALYSIS \$ 70.00 BILLING CODE: 27
SUMMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 01/08/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD=Q# FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

AIR TEMP (DEG C)		18.0	NICKEL TOTAL AAGF	UG/L	19
CADMIUM TOTAL AAGF	UG/L	0.02	PH FIELD		5.7
COPPER TOTAL AAGF	UG/L	28	SP. CONDUCTANCE FLD		36
LEAD TOTAL AAGF	UG/L	0.7	WATER TEMP (DEG C)		10.0
			ZINC TOTAL AAGF	UG/L	6.2

rib. be' u
 11K Sample Site
 above Cul
 5-20-76

UNITED STATES DEPARTMENT OF THE INTERIOR
 GEOLOGICAL SURVEY
 CENTRAL LABORATORY, ALBANY, NEW YORK

JUN 23 1976

WATER QUALITY ANALYSIS
 LAB ID # 143154 RECORD # 46320

SAMPLE LOCATION: FILSON CP TRIBUTARY AT MOUTH ABOVE CULVERT
 STATION ID: 05124993 LAT. LONG. SFO.: 474957 0914030 00
 DATE OF COLLECTION: BEGIN--760520 END-- TIME--1030
 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
 DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
 COMMENTS:
 COLLECTED BY P HERRISFORD & S LUNDEEN
 IMMEDIATE ABOVE CULVERT ON SPRUCE RD CS=9

MAIL TO MINN
 SCHEDULES USED: 271 0 0 0
 NUMBER OF DETERMINATIONS: 15 HCODE = 0
 COST OF ANALYSIS \$ 37.00 DUP--760622
 SUBMIT CORRECTIONS TO CENTRAL LAB WITHIN
 15 DAYS FROM BELOW STAMPED DATE. INDICATE
 CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
 WRD-QW FILE STORAGE WAS NOT REQUESTED FOR
 THIS ANALYSIS. THE ANALYSIS WILL REMAIN
 IN THE CENTRAL LAB FILE ONLY.

AIR TEMP (DEG C)		14.0	MAGNESIUM TOTAL USGS MG/L	2.1
ALK. TOT (AS CaCO3)	MG/L	7	PH FIELD	5.7
BICARBONATE	MG/L	2	POTASSIUM TOTAL USGS MG/L	0.1
CALCIUM TOTAL USGS	MG/L	3.0	RESIDUE SUSPEN 110C MG/L	3
CARBON DIOXIDE	MG/L	26	SODIUM TOTAL USGS MG/L	1.1
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	36
COLOR		150	SULFIDE TOTAL MG/L	2.5
IRON TOTAL	UG/L	490	TURBIDITY (JTU)	0
			WATER TEMP (DEG C)	10.0

CATIONS

(MG/L)	(MEQ/L)
	BICARBONATE
	CARBONATE
TOTAL	-----

ANIONS

(MG/L)	(MEQ/L)
0	0.132
0	0.000
TOTAL	-----
	0.131

1B AT CULVERT

5-5-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 129025 RECORD # 13330

SAMPLE LOCATION: FILSON CR TRIBUTARY AT MOUTH ABOVE CULVERT
STATION ID: 05124993 LAT, LONG, SEC: 474957 0914030 00
DATE OF COLLECTION: REGIN--760505 END-- TIME--0915
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY J RANQUIST, S LUNDEEN, R BERRISFORD IMMEDIATELY ABOVE
CULVERT ON SPRUCE RD

AIR TEMP (DEG C)		2.0	MAGNESIUM TOTAL USGS MG/L	3.0
AL ₂ CO ₃ (AS CaCO ₃)	MG/L	8	NICKEL TOTAL AAGF UG/L	15
BICARBONATE	MG/L	10	PH FIELD	5.7
CADMIUM TOTAL AAGF	UG/L	0.02	POTASSIUM TOTAL USGS MG/L	0.3
CALCIUM TOTAL USGS	MG/L	3.4	RESIDUE SUSPEN 110C MG/L	12
CARBON DIOXIDE	MG/L	32	SODIUM TOTAL USGS MG/L	1.6
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD	34
CHLOR		130	SULFIDE TOTAL MG/L	2.4
COPPER TOTAL AAGF	UG/L	22	TURBIDITY (JTU)	1
IRON TOTAL	UG/L	460	WATER TEMP (DEG C)	5.0
LEAD TOTAL AAGF	UG/L	0.2	ZINC TOTAL AAGF UG/L	3.1

CATIONS

(MG/L) (MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L) (MEQ/L)

10 0.164
0 0.000

TOTAL 0.164

MAIL TO ST PAUL MINN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 20 HCODE = 0
COST OF ANALYSIS \$ 107.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 12/16/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
HARD-ON FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

ABOVE SEEP
7-26

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 213405 RECORD # 25129

SAMPLE LOCATION: FILSON CR. TRIBUTARY ABOVE MOUTH ABOVE SEEP DISC
STATION ID: 05124992 LAT, LONG, SEC.: 474957 0914030 00
DATE OF COLLECTION: BEGIN--760720 END-- TIME--1000
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

CULL BY P. HERRISFORD AND S. LUNDEEN FROM TRIBUTARY ABOVE POINT WHERE
SEEP DISCHARGES INTO TRIBUTARY. SHALLOW WATER MADE SAMPLING DIFFIC.

WTR TEMP (DEG C)		22.0	NICKEL TOTAL AAGF	UG/L	26
CADMIUM TOTAL AAGF	UG/L	0.01	PH FIELD		5.5
COPPER TOTAL AAGF	UG/L	19	SP. CONDUCTANCE FLD		31
LEAD TOTAL AAGF	UG/L	0.5	WATER TEMP (DEG C)		18.0
			ZINC TOTAL AAGF	UG/L	6.4

No WED
request

MAIL TO ST PAUL MN
SCHEDULES USED: 437 0 0 0
NUMBER OF DETERMINATIONS: 9 HCODE = 0
COST OF ANALYSIS \$ 76.99 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 02/26/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-OW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

7 3 AT CULVERT

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
4-13-76 CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 107001 RECORD # 8353

SAMPLE LOCATION: STATION NUMBER 2 BULK SAMPLE SITE
STATION ID: 474956091403902 LAT. LONG. SEQ. 1 474956 0914039 02
DATE OF COLLECTION: BEGIN--760413 END-- TIME--0945
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY J RAMQUIST AS A SURFACE GRAB SAMPLE IMMEDIATELY ABOVE
CULVERT ON SPRUCE ROAD

AIR TEMP (DEG C)		18.0	MAGNESIUM TOTAL USGS	MG/L	2.8
ALK, TOT (AS CaCO3)	MG/L	10	NICKEL TOTAL AAGF	UG/L	25
BICARBONATE	MG/L	12	PH FIELD		5.7
CADMIUM TOTAL AAGF	UG/L	0.00	POTASSIUM TOTAL USGS	MG/L	0.5
CALCIUM TOTAL USGS	MG/L	3.5	RESIDUE SUSPEN 110C	MG/L	73
CARBON DIOXIDE	MG/L	38	SODIUM TOTAL USGS	MG/L	0.3
CARBONATE	MG/L	0	SP. CONDUCTANCE FLD		36
COLOR		100	SULFIDE TOTAL	MG/L	0.8
COPPER TOTAL AAGF	UG/L	19	TURBIDITY (JTU)		1
IRON TOTAL	UG/L	510	WATER TEMP (DEG C)		1.0
LEAD TOTAL AAGF	UG/L	1.1	ZINC TOTAL AAGF	UG/L	3.0

CATIONS

(MG/L) (MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L) (MEQ/L)

12 0.197
0 0.000

TOTAL 0.197

MAIL TO ST PAUL MINN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 20 HCODE = 16
COST OF ANALYSIS \$ 107.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 09/04/76. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS REQUESTED AND THE
STATION HEADING INFORMATION IN THE WRD STATION
HEADER FILE WAS SUBSTITUTED HERE, PLEASE CHECK.

SEEP

4-13-76

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 107002 RECORD # 8355

SAMPLE LOCATION: STATION NUMBER 1 BULK SAMPLE SITE
STATION ID: 874956091403901 LAT, LONG, SEC: 474956 0914039 01
DATE OF COLLECTION: BEGIN--760413 END-- TIME--1025
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: SURFACE WATER GEOLOGIC UNIT:
COMMENTS:

COLL BY J RAMQUIST, S LUNDEEN, AND R BERRISFORD FROM DUG SUMP HOLE
ABOUT 100 FT BELOW BOTTOM OF SLOPE AT BULK SAMPLE SITE

AIR TEMP (DEG C)		16.0	MAGNESIUM TOTAL USGS MG/L	48
ALK, TOT (AS CaCO3)	MG/L	118	NICKEL TOTAL AAGF UG/L	13000
BICARBONATE	MG/L	144	PH FIELD	6.8
CADMIUM TOTAL AAGF	UG/L	2.4	POTASSIUM TOTAL USGS MG/L	7.3
CALCIUM TOTAL USGS	MG/L	84	RESIDUE SUSPEN 110C MG/L	0
CARBON DIOXIDE	MG/L	37	SODIUM TOTAL USGS MG/L	2.6
CARBONATE	MG/L	0	SP. CONDUCTANCE FLO	628
COLOR		60	SULFIDE TOTAL MG/L	0.5
COPPER TOTAL AAGF	UG/L	360	TURBIDITY (JTU)	26
IRON TOTAL	UG/L	4600	WATER TEMP (DEG C)	6.0
LEAD TOTAL AAGF	UG/L	1.0	ZINC TOTAL AAGF UG/L	190

CATIONS

(MG/L)

(MEQ/L)

BICARBONATE
CARBONATE

TOTAL

ANIONS

(MG/L)

(MEQ/L)

144 2.361
0 0.000

TOTAL

2.360

MAIL TO ST PAUL MINN
SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 20 HCODE = 16
COST OF ANALYSIS \$ 107.80 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 09/04/76, INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD-QW FILE STORAGE WAS REQUESTED AND THE
STATION HEADING INFORMATION IN THE WRD STATION
HEADER FILE WAS SUBSTITUTED HERE, PLEASE CHECK.

SEEP

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 129027 RECORD # 13334

SAMPLE LOCATION: SEEP ORIGINATING FROM BULK SAMPLE SITE
STATION ID: 474957091403003 LAT, LONG, SEQ.: 474957 0914030 03
DATE OF COLLECTION: BEGIN--760505 END-- TIME--1030
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 442704100
DATA TYPE: 2 SOURCE: GROUND WATER GEOLOGIC UNIT:

COMMENTS:

COLL BY R HERRISFORD, J RAMQUIST, S LUNDEEN FROM DUG SUMP HOLE AT
BASE OF SLOPE, NO RUSS COLLECTED

MAIL TO ST PAUL MINN

SCHEDULES USED: 271 0 0 0
NUMBER OF DETERMINATIONS: 31 HCODE = 0
COST OF ANALYSIS \$ 121.75 BILLING CODE: 27
SURMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 12/24/76, INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WHO=QW FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS, THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

ATR TEMP (DEG C)		2.0	MAGNESIUM DISS	MG/L	42
ALK, TOT (AS CaCO3)	MG/L	107	MAGNESIUM TOTAL USGS	MG/L	43
BICARBONATE	MG/L	130	NICKEL DISS AAGF	DETR, DELETED	
CADMIUM DISS AAGF	DETR, DELETED		NICKEL TOTAL AAGF	UG/L	10000
CADMIUM TOTAL AAGF	UG/L	2.0	PH FIELD		7.0
CALCIUM DISS	MG/L	66	POTASSIUM DISS	MG/L	7.0
CALCIUM TOTAL USGS	MG/L	72	POTASSIUM TOTAL USGS	MG/L	7.0
CARBON DIOXIDE	MG/L	21	SAR		0.2
CARBONATE	MG/L	0	SILICA DISSOLVED	MG/L	24
CHLORIDE DISS	MG/L	5.5	SODIUM DISS	MG/L	9.4
COLOR		25	SODIUM TOTAL USGS	MG/L	10
COPPER DISS AAGF	DETR, DELETED		SP, CONDUCTANCE FLD		711
COPPER TOTAL AAGF	UG/L	970	SP, CONDUCTANCE LAB		711
HARDNESS NONCARB	MG/L	230	SULFATE DISS	MG/L	250
HARDNESS TOTAL	MG/L	340	SULFIDE TOTAL	MG/L	0.0
IRON TOTAL	UG/L	4200	TURBIDITY (JTU)		30
LEAD DISS AAGF	DETR, DELETED		WATER TEMP (DEG C)		6.0
LEAD TOTAL AAGF	UG/L	0.3	ZINC DISS AAGF	DETR, DELETED	
			ZINC TOTAL AAGF	UG/L	210

CATIONS

	(MG/L)	(MEQ/L)
CALCIUM DISS	66	3.294
MAGNESIUM DISS	42	3.455
POTASSIUM DISS	7.0	0.179
SODIUM DISS	9.4	0.409

TOTAL 7.336

ANIONS

	(MG/L)	(MEQ/L)
BICARBONATE	130	2.131
CARBONATE	0	0.000
CHLORIDE DISS	5.5	0.156
SULFATE DISS	250	5.205

TOTAL 7.491

PERCENT DIFFERENCE = -1.04

QUALITY CONTROL INFORMATION FOR LAB ID # 129027 RECORD # 13334

***RTH FLD
NICKEL DISS
CADMIUM DISS
COPPER DISS AAGF
LEAD DISS AAGF
ZINC DISS AAGF

CONDUCTANCES SUBMITTED - ONLY FIELD VALUE IS STORED IN QW FLD
WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT,
WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT,
WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT,
WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT,
WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT,
WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT,

UP # 711,000

SEEP

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
CENTRAL LABORATORY, DENVER, COLORADO

WATER QUALITY ANALYSIS
LAB ID # 148410 RECORD # 16353

SAMPLE LOCATION: SEEP ORIGINATING FROM RULK SAMPLE SITE
STATION ID: 474057091403003 LAT, LONG, SEU: 474057 0914030 00
DATE OF COLLECTION: BEGIN--760520 END-- TIME--1130
STATE CODE: 27 COUNTY CODE: 075 PROJECT IDENTIFICATION: 402704100
DATA TYPE: 2 SOURCE: GROUND WATER GEOLOGIC UNIT:
COMMENT:

COLL BY R HERRISFORD AND S LUNDEEN FROM DUG SUMP HOLE AT BASE OF
SLOPE

AIR TEMP (DEG C)	18.0	NICKEL DISS AAGF	DETR, DELETED
CADMIUM DISS AAGF	DETR, DELETED	NICKEL TOTAL AAGF	UG/L 11000
CADMIUM TOTAL AAGF	UG/L 2.0	PH FIELD	7.0
COPPER DISS AAGF	DETR, DELETED	SP. CONDUCTANCE FLD	655
COPPER TOTAL AAGF	UG/L 1000	WATER TEMP (DEG C)	13.0
LEAD DISS AAGF	DETR, DELETED	ZINC DISS AAGF	DETR, DELETED
LEAD TOTAL AAGF	UG/L 1.2	ZINC TOTAL AAGF	UG/L 5300

MAIL TO ST PAUL MINN
SCHEDULES USED: 437 0 0 0
NUMBER OF DETERMINATIONS: 14 MCODE = 0
COST OF ANALYSIS \$ 69.99 BILLING CODE: 27
SUBMIT CORRECTIONS TO THE DENVER CENTRAL LAB
WITHIN 15 DAYS FROM 01/08/77. INDICATE THE
CENTRAL LAB ID # AND RECORD # WITH RESPONSE.
WRD=00 FILE STORAGE WAS NOT REQUESTED FOR
THIS ANALYSIS. THE ANALYSIS WILL REMAIN
IN THE CENTRAL LAB FILE ONLY.

No WRD printout

~~at H Summit A and~~

No header file

Was WRD Storage requested? No

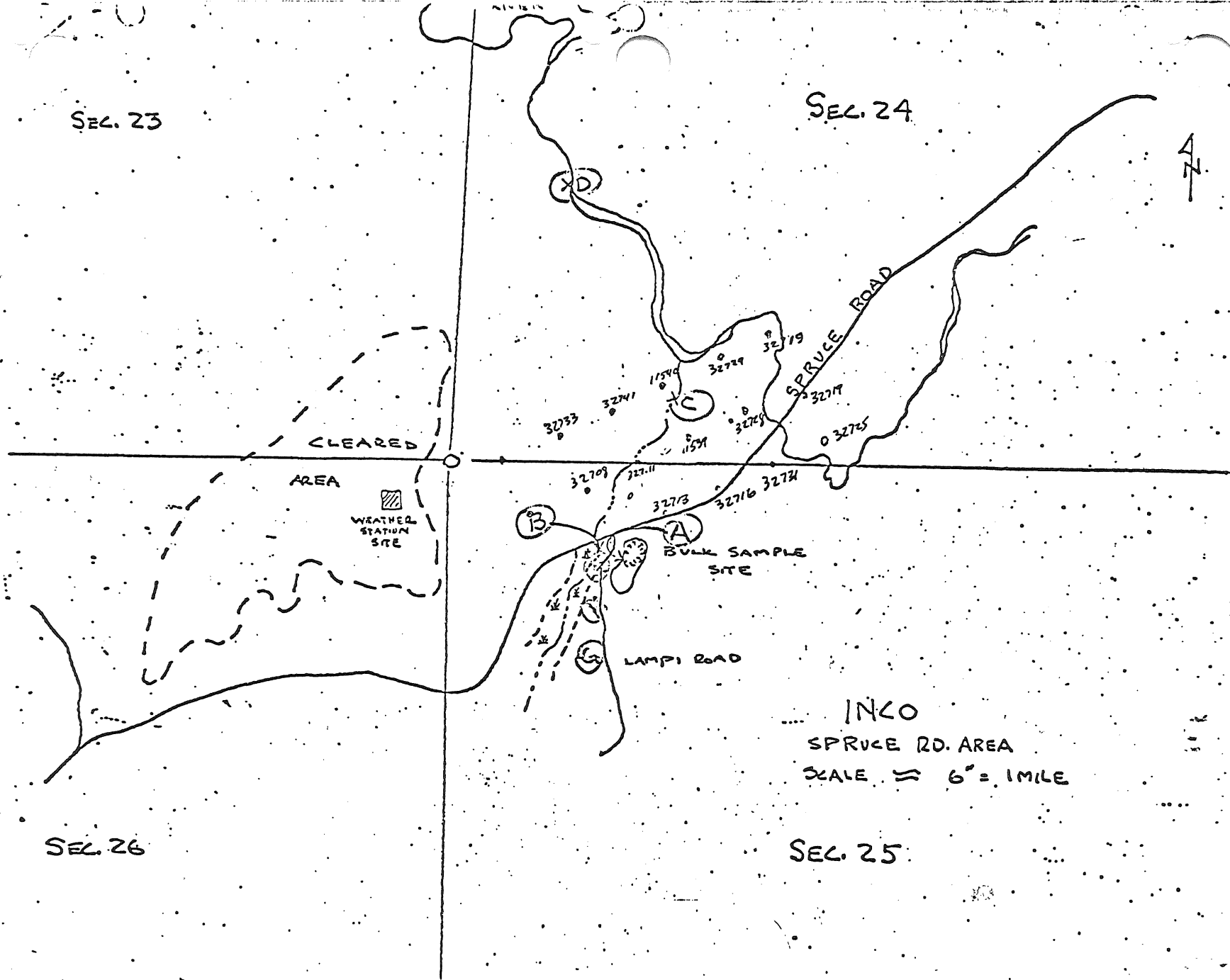
QUALITY CONTROL INFORMATION FOR LAB ID # 148410 RECORD # 16353

ICKEL DISS AA	WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT.
IODIUM DISS AAL	WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT.
OPPER DISS AAGF	WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT.
AD DISS AAGF	WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT.
AC DISS AAGF	WAS DELETED BECAUSE: DELETION REQUESTED BY DISTRICT.

SEC. 23

SEC. 24

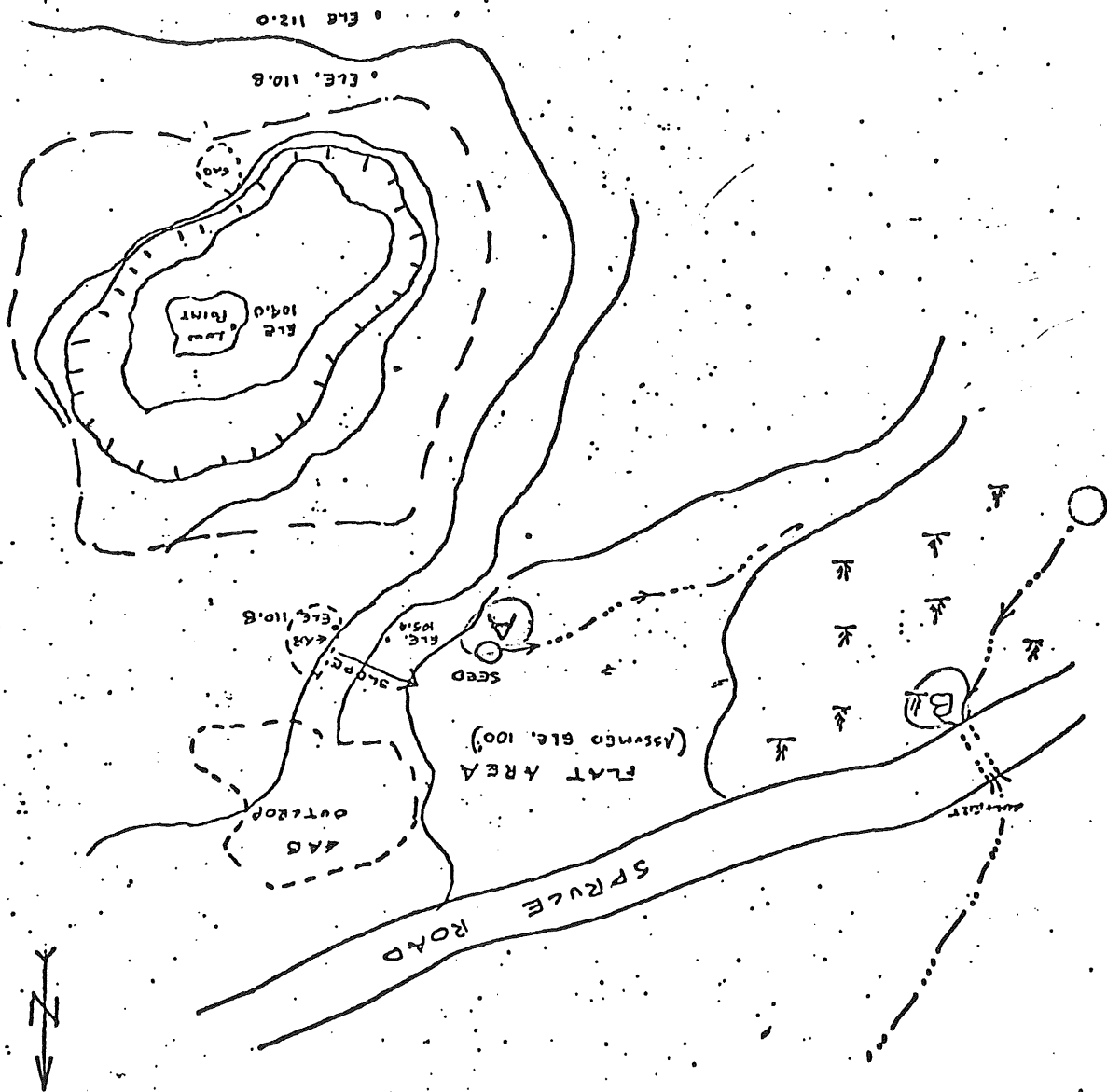
7



SEC. 26

SEC. 25

BULK SAMPLE SITE
 HAND LEVEL SKETCH
 SCALE 1" = 50'
 SEC. 35, T12, R11



Received 10-8'-75

Samples Collected

A. Hickok & Assoc.

Analyzed By E.A.Hickok&As

14

Field Number	Sampling Point and Source of Sample
1	...
2	...
3	...
4	...
5	...
6	...
7	...
8	...
9	...
10	...
11	...
12	...
13	...
14	...
15	...
16	...
17	...
18	...
19	...
20	...
21	...
22	...
23	...
24	...
25	...
26	...
27	...
28	...
29	...
30	...
31	...
32	...
33	...
34	...
35	...
36	...
37	...
38	...
39	...
40	...
41	...
42	...
43	...
44	...
45	...
46	...
47	...
48	...
49	...
50	...
51	...
52	...
53	...
54	...
55	...
56	...
57	...
58	...
59	...
60	...
61	...
62	...
63	...
64	...
65	...
66	...
67	...
68	...
69	...
70	...
71	...
72	...
73	...
74	...
75	...
76	...
77	...
78	...
79	...
80	...
81	...
82	...
83	...
84	...
85	...
86	...
87	...
88	...
89	...
90	...
91	...
92	...
93	...
94	...
95	...
96	...
97	...
98	...
99	...
100	...

Date Collected Time Collected

Field Number	Sampling Point and Source of Sample	Date Collected	Time Collected
Site A a	Seep	10-4-75	
Site B b	Culvert	10-4-75	
Site C c	Tributary	10-4-75	
Site D d	Filson	10-4-75	
e			

[illegible]

PREOPERATIONAL MONITORING

SAMPLE REPORT FORM

E. A. HICKOK & ASSOCIATES

Received 10-7-75

Samples Collected A. Hickok & Assoc. Analyzed By E.A. Hickok & Assoc. 1a

Field Number Sampling Point and Source of Sample Date Collected Time Collected

Site A	a	Seep	10-7-75	
Site B	b	Culvert	10-7-75	
Site C	c	Tributary	10-7-75	
Site D	d	Filson	10-7-75	
Sump F	e	Sump F	10-7-75	

Sample Number	Temp. °C	Dissolved Oxygen mg/l	Total Coliform col/100ml	Fecal Coliform col/100ml	Fecal Strep. col/ml	Total Solids mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Turbidity JTU
a Site A									
b Site B									
c Site C									
d Site D									
e Sump F									
Color plat. unit	Total Hardness mg/l	Total Alkalinity mg/l	pH	Ortho-phosphorus mg/l	Total Phosphorus mg/l	Nitrite Nitrogen mg/l	Nitrate Nitrogen mg/l	Ammonia Nitrogen mg/l	Organic Nitrogen mg/l
a	942	120	6.8						
b	171	12	6.7						
c	154	0	6.7						
d	121	12	6.6						
e	-	-	6.6						
COD mg/l	Chloride mg/l	Sulfate mg/l	Iron mg/l	Copper ug/l	Lead ug/l	Zinc ug/l	Manganese ug/l	Cadmium ug/l	Cobalt ug/l
a	7	304	1.24/.10	160/30	<.2/<.2	7.5/4.4	4200/4000	.18/.16	280/250
b	5	17	.35/.32	40/30	.3/<.2	3.4/3.5	17/12	<.02/<.02	.85/<.2
c	7	10	.17/.17	40/30	<.2/<.2	2.3/5.4	3/3	<.02/<.02	<.2/<.2
d	6	4	.75/.68	40/30	.2/.6	2.3/8.4	45/17	.08/<.02	1.0/.5
e	-	-	.05/.05	750/380	1.0/<.2	8.4/8.2	32/23	.35/.28	21.5/18.6
Nickel ug/l	Mercury ug/l	Sodium mg/l	Potassium mg/l	Calcium mg/l	Magnesium mg/l	Silicate mg/l	Chlorophyll ug/l	TOC mg/l	Secchi Disc feet
a 3100/2900	.12	13/13	5.2/5.0	68/71	18/18				
b 11/14	<.1	1.5/1.5	.06/.05	3.1/3.8	3.0/3.1				
c 15/14	.18	1.7/1.7	.13/1.2	3.7/4.3	3.7/3.7				
d 5/5	<.1	1.4/1.3	.25/.24	3.7/3.3	2.5/2.4				
e 500/400	<.1	3.2/3.0	1.4/1.4	6.8/5.4	6.4/6.0				

Received 10-8-75

Samples Collect

A.Hickok&Assoc.

Analyzed By E.A.Hickok&

1a

Field Number	Sampling Point and Source of Sample	Date Collected	Time Collected
Sump G a	Sump G	10-7-75	
b			
c			
d			
e			

Sample Number	Temp. °C	Dissolved Oxygen mg/l	Total Coliform col/100ml	Fecal Coliform col/100ml	Fecal Strep. col/ml	Total Solids mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Turbidity JTU
a Sump G									
b									
c									
d									
e									
Color plat. unit	Total Hardness mg/l	Total Alkalinity mg/l	pH	Ortho-phosphorus mg/l	Total Phosphorus mg/l	Nitrite Nitrogen mg/l	Nitrate Nitrogen mg/l	Ammonia Nitrogen mg/l	Organic Nitrogen mg/l
a			6.3						
b									
c									
d									
e									
COD mg/l	Chloride mg/l	Sulfate mg/l	Iron mg/l	Copper ug/l	Lead ug/l	Zinc ug/l	Manganese ug/l	Cadmium ug/l	Cobalt ug/l
a			4.4/.12	240/50	1.7/<.2	8.4/4.0	230/160	.16/.09	7.1/3.1
b									
c									
d									
e									
Nickel ug/l	Mercury ug/l	Sodium mg/l	Potassium mg/l	Calcium mg/l	Magnesium mg/l	Silicate mg/l	Chloro-phyll ug/l	TOC mg/l	Secchi Disc feet
a 150/100	.1	4/4	2.2/1.7	9.4/9	7.7/6.5				
b									
c									
d									
e									

unfiltered/filtered

PREOPERATIONAL MONITORING

SAMPLE REPORT FORM

E. A. HICKOK & ASSOCIATES

Received 10-14-75

Samples Collected By

A. Hickok & Assoc. Analyzed By E.A. Hickok & Assoc.

at

Field Number	Sampling Point and Source of Sample	Date Collected	Time Collected
Site A a	Seep	10-10-75	9:25 am
Site B b	Culvert	10-10-75	9:20 am
Site C c	Tributary	10-10-75	9:55 am
Site D d	Filson	10-10-75	10:30 am
Sump E e	Sump E	10-10-75	9:30 am

Sample Number	Temp. °C	Dissolved Oxygen mg/l	Total Coliform col/100ml	Fecal Coliform col/100ml	Fecal Strep. col/ml	Total Solids mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Turbidity JTU
a Site A									
b Site B									
c Site C									
d Site D									
e Sump E									
Color plat. unit	Total Hardness mg/l	Total Alkalinity mg/l	pH	Ortho-phosphorus mg/l	Total Phosphorus mg/l	Nitrite Nitrogen mg/l	Nitrate Nitrogen mg/l	Ammonia Nitrogen mg/l	Organic Nitrogen mg/l
a	1217	132	6.7						
b	83	16	6.2						
c	65	12	6.3						
d	52	16	6.5						
e	1435	44	6.4						
COD mg/l	Chloride mg/l	Sulfate mg/l	Iron mg/l	Copper ug/l	Lead ug/l	Zinc ug/l	Manganese ug/l	Cadmium ug/l	Cobalt ug/l
a	8	281	5.0/.2	130/30	<.2/<.2	6.8/5.9	4100/4000	.24/.15	270/270
b	6	18	.6/.4	27/27	<.2/<.2	2.8/2.1	22/14	<.02/<.02	1.0/1.0
c	6	18	.3/.2	31/28	<.2/<.2	2.1/-	3/2	<.02/<.02	.5/.5
d	6	<1	1.0/.6	11/8	1.5/.5	1.7/1.7	29/12	<.02/<.02	.5/.5
e	7	200	.3/.1	720/400	<.2/<.2	9.6/9.3	680/650	.53/.53	100/100
Nickel ug/l	Mercury ug/l	Sodium mg/l	Potassium mg/l	Calcium mg/l	Magnesium mg/l	Silicate mg/l	Chlorophyll ug/l	TOC mg/l	Secchi Disc feet
a 2800/2200	.1	13	5.3	82	50				
b 117/17	.2	1.6	.48	3.9	3.7				
c 25/25	.6	1.7	.13	4.2	4.2				
d 6.6/6.6	.2	1.4	.26	3.1	2.7				
e 1200/1000	.2	11.5	3.3	37	33				

1a)

Date Collected Time Collected

[illegible]

Date Received 10-17-75 Samples Collected by E.A. Hickok & Assoc. Analyzed By E.A. Hickok & Assoc. c-1

File Number	Sampling Point and Source of Sample	Date Collected	Time Collected
Site A a	Seep	10-15-75	
Site B b	Culvert	10-15-75	
Site C c	Tributary	10-15-75	
Site D d	Filson	10-15-75	
Sump E e	Sump E	10-15-75	

Sample Number	Temp. °C	Dissolved Oxygen mg/l	Total Coliform col/100ml	Fecal Coliform col/100ml	Fecal Strep. col/ml	Total Solids mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Turbidity JTU
a Site A									
b Site B									
c Site C									
d Site D									
e Sump E									
Color plat. unit	Total Hardness mg/l	Total Alkalinity mg/l	pH	Ortho-phosphorus mg/l	Total Phosphorus mg/l	Nitrite Nitrogen mg/l	Nitrate Nitrogen mg/l	Ammonia Nitrogen mg/l	Organic Nitrogen mg/l
a	1211	42	6.7						
b	113	8	6.0						
c	43	10	6.2						
d	39	12	6.5						
e	836	22	6.7						
COD mg/l	Chloride mg/l	Sulfate mg/l	Iron mg/l	Copper ug/l	Lead ug/l	Zinc ug/l	Manganese ug/l	Cadmium ug/l	Cobalt ug/l
a	8	271	4.4/<.1	100/30	<.2/<.2	5.4/5.4	4100/4000	.29/.13	270/250
b	7	15	.5/.4	22/22	.3/<.2	2.1/2.1	13/9	<.02/<.02	.6/.5
c	5	17	.3/.3	30/27	.3/<.2	6.8/2.3	2/2	<.02/<.02	.5/.4
d	7	0	1.1/.8	11/10	.5/.5	1.8/1.8	39/27	<.02/<.02	.5/.5
e	7	228	.2/<.1	500/390	<.2/<.2	8.0/7.5	960/950	.51/.51	120/120
Nickel ug/l	Mercury ug/l	Sodium mg/l	Potassium mg/l	Calcium mg/l	Magnesium mg/l	Silicate mg/l	Chlorophyll ug/l	TOC mg/l	Secchi Disc feet
a 2100/2000	.4	13	5.0	80	48				
b 16/16	.6	1.6	.19	2.7	3.4				
c 28/24	.6	1.7	.13	3.0	3.8				
d 6.1/5	.2	1.4	.33	2.4	2.5				
e 1200/1200	.8	13	3.2	26	39				

unfiltered/filtered

Date Collected Time Collected

[illegible]

PREOPERATIONAL MONITORING

SAMPLE REPORT FORM

E. A. HICKOK & ASSOCIATES

Date Received 10-22-75

Samples Collected A. Hickok & Assoc. Analyzed By E. A. Hickok & Assoc. 1:

Sample Number	Sampling Point and Source of Sample	Date Collected	Time Collected
Site A a	Seep	10-20-75	
Site B b	Culvert	10-20-75	
Site C c	Tributary	10-20-75	
Site D d	Filson	10-20-75	
Sump F e	Sump F	10-20-75	

Sample Number	Temp. °C	Dissolved Oxygen mg/l	Total Coliform col/100ml	Fecal Coliform col/100ml	Fecal Strep. col/ml	Total Solids mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Turbidity JTU
a Site A									
b Site B									
c Site C									
d Site D									
e Sump F									
Color plat. unit	Total Hardness mg/l	Total Alkalinity mg/l	pH	Ortho-phosphorus mg/l	Total Phosphorus mg/l	Nitrite Nitrogen mg/l	Nitrate Nitrogen mg/l	Ammonia Nitrogen mg/l	Organic Nitrogen mg/l
a	514	128	6.8						
b	81	12	6.0						
c	50	12	6.3						
d	34	12	6.5						
e	516	19	6.6						
COD mg/l	Chloride mg/l	Sulfate mg/l	Iron mg/l	Copper ug/l	Lead ug/l	Zinc ug/l	Manganese ug/l	Cadmium ug/l	Cobalt ug/l
a	6	289	3.50/.07	78/13	<.2/<.2	7.5	5300/5000	.12/.08	250/240
b	5	17	.39/.38	20/20	.3/<.2	1.9	9/9	.08/<.01	<.2/<.2
c	5	19	.20/.19	32/31	<.2/<.2	2.6	2/2	<.01/<.01	<.2/<.2
d	5	<1	1.20/.97	11/11	.5/.4	2.2	26/23	<.01/<.01	.7/.5
e	3	32	.05/.02	500/340	<.2/<.2	5.4	25/20	.20/.18	22/21
Nickel ug/l	Mercury ug/l	Sodium mg/l	Potassium mg/l	Calcium mg/l	Magnesium mg/l	Silicate mg/l	Chlorophyll ug/l	TOC mg/l	Secchi Disc feet
a 2600/2600	.4	14	5.0	80	51				
b 18/18	.1	1.5	.10	3.7	3.5				
c 26/24	.1	1.6	.14	4.2	3.9				
d 6/6	.1	1.2	.30	3.2	2.7				
e 370/350	.1	3.2	.95	7.3	7.4				

unfiltered/filtered

the Tower-Soudan TIMBERJAY

\$1⁰⁰

Now In Our 27th Year Serving Northern St. Louis County!

VOL. 27, ISSUE 31 August 5, 2016

PLANNING AND ZONING COMMISSION

Tower RV park permit denied again

Developer has option of submitting more complete application

by JODI SUMMIT
Tower-Soudan Editor

TOWER- It's back to the drawing board for a prospective new RV park developer after the Tower Planning and Zoning Commission denied a Conditional Use Permit request

at their meeting on Aug. 2.

Dave Rose had submitted an updated application packet to the city that included a plan for the development of a 40-site RV park on the property adjacent to the East Two River and Lake Ave.

City Clerk/Treasurer Linda Keith told commission members

that the initial review of the plan, by the city's engineer and attorney, noted several important pieces of the application that were missing or incomplete.

"This application didn't meet the conditions that we had previously laid out," she said, noting this issue had been before the

Planning and Zoning Commission and Tower City Council previously, when the city did approve changing the zoning on the parcel to allow the potential for a RV park.

She asked the board to deny the permit at this time, noting that Rose would have the ability to

reapply, once the application was complete.

The commission gave Rose a detailed list of issues that still needed to be addressed. The most significant issues were those relating to the property's

See TOWER...pg. 10

MINING

Will sulfate standard changes matter?

by MARSHALL HELMBERGER
Managing Editor

REGIONAL— The Minnesota Pollution Control Agency continues to move ahead with proposed changes to the state's wild rice sulfate standard, that would replace the existing 10 milligrams per liter rule with a new site-specific equation based on two primary criteria.

On July 19, the agency released the technical document that provides the scientific basis for the proposed change in the state's pollution rules. According to MPCA officials, the agency is working to meet a January 2018 deadline to have the final new rule in place.

But it remains unclear whether the agency's effort will ultimately make any difference to the regulation of sulfates in Minnesota, particularly for northeastern Minnesota's taconite industry, one of the state's largest dischargers of sulfates into the environment.

As proposed, the new rule would eliminate Minnesota's strictest-in-the-nation sulfate standard, designed to protect wild rice, and replace it with a flexible standard that MPCA officials argue would provide better protection of wild rice than the current rule. Under the proposed new rule, the MPCA would sample receiving waters for sulfate discharges and establish a sulfate level based on the amount of iron and organic carbon (decomposing vegetation) found in the sediment. While sulfate itself is considered non-toxic to wild

See...MPCA pg. 12



Theater rehab points to a bright future

by KEITH VANDERVORT
Ely Editor

ELY — The lights are back on in Ely, and the smell of popcorn is in the air.

Hundreds of Ely residents and visitors lined Sheridan Street at the top of the hill last Saturday night for a relighting of the State Theater building's exterior lights.

The event was not much on the surface. The lights of the city's landmark went dark some 20 years ago. The theater inside remains a shell of its former self. Any movie showing is likely a year away.

But the relighting of the marquee was more like a rebirth — a rebirth of Ely.

A couple of years ago, a major state newspaper wrote an article about Ely and highlighted the efforts of John Ott and his family and the buildings they had purchased in Ely with an ambitious redevelopment plan.

The Ely High School Timberwolf mascot was on hand for a symbolic relighting of the State Theater marquee on Sheridan Street Saturday night. The event celebrated a renewed effort to improve the city's economy.

photo by K. Vandervort

The Ott family hopes to make the 300-seat venue a space for movies, live music, business conferences, and other community events. The overhaul could cost \$1.5 million, but the Ott family is taking a chance on Ely. The family's Missouri-based firm now owns eight vacant buildings and has ambitious redevelopment plans for all of them.

At about the same time, a tourism and development organization, called Incredible Ely, was formed. Many dedicated people set about making some actual changes in this

See LIGHTS...pg. 11

ST. LOUIS COUNTY

Joint facility planned for Cook area

Center would replace three existing buildings

by MARSHALL HELMBERGER
Managing Editor

COOK — A joint maintenance facility, similar to the one in Ely, could soon be in the works for the Cook area if plans by St. Louis County Public Works come to fruition.

The new facility, as currently envisioned, would shutter three existing county buildings, including public works

garages in Cook and Linden Grove, and the county land department office on Hwy. 53, just north of Cook. The facility would also potentially house other partners, according to county public works director

Jim Foldesi, St. Louis County Public Works Director

Jim Foldesi, including MnDOT highway workers currently stationed in Cook.

The facility could also include maintenance staff for the city of Cook, although the city has yet to decide whether it wants to partner on the project. "We've talked about it, but haven't come to any decisions," said Cook City Administrator Teresa Martinson. "We do need to build a new maintenance facility, but we need to understand the costs involved," she said.

Foldesi outlined the proposal to the county board during a work session back in January. Two months ago, the board approved the hiring of architects LHB to begin initial design.

Foldesi noted that the existing public works garages in Cook and Linden Grove were old and inefficient. "The Linden Grove garage is actually a WPA-era building, with lots of miles on it," he said. "It's very energy inefficient and we don't have enough room to house all

See...COOK pg. 11

MPCA...Continued from page 1

rice, in the natural environment, microbes in aquatic sediments can convert sulfates to sulfides, which are toxic to wild rice. But how much and how quickly sulfates are converted to sulfides, and how toxic those sulfides are to wild rice, depends on the circumstances, according to MPCA officials. "Iron in sediment binds to sulfide and neutralizes it, making it non-toxic to wild rice," states the agency in a press statement announcing the release of their technical document. "Organic carbon, on the other hand, causes more sulfide to be produced. Sulfate is converted to sulfide differently in each body of water, depending on the concentrations of iron and organic carbon in the sediment."

MPCA officials say they have the science to back up their proposal, but that's disputed by Dr. John Pastor, one of the lead scientists that the MPCA hired four years ago to conduct more research on wild rice and sulfates.

In a June 30 report to the Minnesota Sea Grant, which funded a portion of Dr. Pastor's research into wild rice, Pastor notes that he has continued his research, which has found that "iron has no beneficial effect" in reducing the toxicity of sulfides. Indeed, his preliminary findings suggest that the presence of more iron may actually hasten the loss of wild rice, rather than prevent it, although Pastor acknowledges it will take additional study to reach a definitive conclusion on that point.

Several other current and retired professors in related fields have joined Pastor in expressing doubts about the validity of the MPCA's proposed approach. A hearing set for Aug. 18 will give Pastor the opportunity to present his findings to the MPCA's wild rice advisory committee, which gives input on the proposed rule change.

Yet Paula Maccabee, legal counsel for the group Water Legacy, said she's worried that the MPCA will turn a deaf ear to Pastor and other scientists in its rush to push through a rule change demanded by politics, rather than science. "I'm finding it really troubling that the MPCA went full speed ahead, despite John's [Pastor] research," said Maccabee. "They've really opened this up to being a political process, not a scientific process, so we shouldn't be surprised that they will be continually forced to compromise the science."

The MPCA has been under tremendous pressure from the Minnesota Legislature, which has passed laws in recent years intended to hamstring the agency's ability to enforce the state's sulfate rule on the mining industry. In 2015, the Legislature passed a law prohibiting the agency from enforcing the wild rice sulfate standard until it revised the rule.

Yet the state has no authority, on its own, to revise the wild rice standard. The federal Environmental Protection

Agency has approved the existing standard under the auspices of the Clean Water Act, and that means the EPA will need to approve any possible change in the rule before the MPCA could enforce the new standard.

At this point, MPCA officials are keeping the EPA informed of their rule-changing process, but the federal agency has yet to weigh on the proposal, according to Shannon Lotthammer, director of the MPCA's Environmental Analysis and Outcomes Division.

Given the scientific dispute over the merits of the MPCA's new flexible standard, it remains unclear whether the EPA would ever approve of the change, Maccabee said the Legislature isn't helping the MPCA make the case, since laws passed in 2015 and 2016 effectively violate federal law by preventing the MPCA from enforcing the Clean Water Act as it applies to sulfate discharge. "Under the Clean Water Act, unless and until the 10 mg/l change is approved by the EPA, there is a clear requirement to enforce it," said Maccabee. "What the Legislature did is invalid under federal law."

MPCA's Lotthammer said it's too early to say how the EPA will assess the science. "With that said, MPCA is confident in our ability to develop a proposed rule that is scientifically defensible and grounded in sound science," Lotthammer added.

Yet the EPA and the

MPCA have been at odds for years over the state agency's relatively lax enforcement of the Clean Water Act as it applies to the taconite industry. In 2013, the EPA forced the MPCA to sign an agreement to bring dozens of expired mining discharge permits up to current standards over the next five years. EPA officials, in a June 22, 2016, letter, complained that the MPCA has, to date, failed to reissue any of the expired permits. What's more, under current state law it won't be able to do so in most cases until a new wild rice standard is in place.

And when that might

happen is anyone's guess. While the MPCA may complete its rulemaking process by early 2018, there's no such deadline in place for the EPA, and EPA officials are well aware that the current 10 mg/l standard remains in place (and by law must be enforced) until they approve a new rule.

At the same time, Maccabee said the MPCA appears to be leaving the door wide open for litigation around the issue, either by tribes or environmental groups, or by the mining industry if the final standard is seen as too rigorous. If so, it could be years more before the courts finally settle the

question.

"After all this enormous drain of staff time and community resources, the MPCA may end up with the same standard, and may still refuse to enforce it," said Maccabee.

As the rulemaking process drags on, the region's taconite plants will continue to operate with expired permits that don't meet pollution standards. Maccabee questions whether delay is simply part of the Legislature's intent. "This is the opposite of the way in which regulatory agencies are supposed to operate," she said.



the Tower-Soudan TIMBERJAY

\$1⁰⁰

Now In Our 27th Year Serving Northern St. Louis County!

VOL. 27, ISSUE 31 August 5, 2016

PLANNING AND ZONING COMMISSION

Tower RV park permit denied again

Developer has option of submitting more complete application

by JODI SUMMIT
Tower-Soudan Editor

TOWER- It's back to the drawing board for a prospective new RV park developer after the Tower Planning and Zoning Commission denied a Conditional Use Permit request

at their meeting on Aug. 2.

Dave Rose had submitted an updated application packet to the city that included a plan for the development of a 40-site RV park on the property adjacent to the East Two River and Lake Ave.

City Clerk/Treasurer Linda Keith told commission members

that the initial review of the plan, by the city's engineer and attorney, noted several important pieces of the application that were missing or incomplete.

"This application didn't meet the conditions that we had previously laid out," she said, noting this issue had been before the

Planning and Zoning Commission and Tower City Council previously, when the city did approve changing the zoning on the parcel to allow the potential for a RV park.

She asked the board to deny the permit at this time, noting that Rose would have the ability to

reapply, once the application was complete.

The commission gave Rose a detailed list of issues that still needed to be addressed. The most significant issues were those relating to the property's

See TOWER...pg. 10

MINING

Will sulfate standard changes matter?

by MARSHALL HELMBERGER
Managing Editor

REGIONAL— The Minnesota Pollution Control Agency continues to move ahead with proposed changes to the state's wild rice sulfate standard, that would replace the existing 10 milligrams per liter rule with a new site-specific equation based on two primary criteria.

On July 19, the agency released the technical document that provides the scientific basis for the proposed change in the state's pollution rules. According to MPCA officials, the agency is working to meet a January 2018 deadline to have the final new rule in place.

But it remains unclear whether the agency's effort will ultimately make any difference to the regulation of sulfates in Minnesota, particularly for northeastern Minnesota's taconite industry, one of the state's largest dischargers of sulfates into the environment.

As proposed, the new rule would eliminate Minnesota's strictest-in-the-nation sulfate standard, designed to protect wild rice, and replace it with a flexible standard that MPCA officials argue would provide better protection of wild rice than the current rule. Under the proposed new rule, the MPCA would sample receiving waters for sulfate discharges and establish a sulfate level based on the amount of iron and organic carbon (decomposing vegetation) found in the sediment.

While sulfate itself is considered non-toxic to wild

See...MPCA pg. 12

The lights are on in Ely



Theater rehab points to a bright future

by KEITH VANDERVORT
Ely Editor

ELY— The lights are back on in Ely, and the smell of popcorn is in the air.

Hundreds of Ely residents and visitors lined Sheridan Street at the top of the hill last Saturday night for a relighting of the State Theater building's exterior lights.

The event was not much on the surface. The lights of the city's landmark went dark some 20 years ago. The theater inside remains a shell of its former self. Any movie showing is likely a year away.

But the relighting of the marquee was more like a rebirth—a rebirth of Ely.

A couple of years ago, a major state newspaper wrote an article about Ely and highlighted the efforts of John Ott and his family and the buildings they had purchased in Ely with an ambitious redevelopment plan.

The Ely High School Timberwolf mascot was on hand for a symbolic relighting of the State Theater marquee on Sheridan Street Saturday night. The event celebrated a renewed effort to improve the city's economy.

photo by K. Vandervort

The Ott family hopes to make the 300-seat venue a space for movies, live music, business conferences, and other community events. The overhaul could cost \$1.5 million, but the Ott family is taking a chance on Ely. The family's Missouri-based firm now owns eight vacant buildings and has ambitious redevelopment plans for all of them.

At about the same time, a tourism and development organization, called Incredible Ely, was formed. Many dedicated people set about making some actual changes in this

See LIGHTS...pg. 11

ST. LOUIS COUNTY

Joint facility planned for Cook area

Center would replace three existing buildings

by MARSHALL HELMBERGER
Managing Editor

COOK— A joint maintenance facility, similar to the one in Ely, could soon be in the works for the Cook area if plans by St. Louis County Public Works come to fruition.

The new facility, as currently envisioned, would shutter three existing county buildings, including public works

garages in Cook and Linden Grove, and the county land department office on Hwy. 53, just north of Cook. The facility would also potentially house other partners, according to county public works director Jim Foldesi, including MnDOT highway workers currently stationed in Cook.

The facility could also include maintenance staff for the city of Cook, although the city has yet to decide whether it wants to partner on the project. "We've talked about it, but haven't come to any decisions," said Cook City Administrator Teresa Martinson. "We do need to build a new maintenance facility, but we need to understand the costs involved," she said.

Foldesi outlined the proposal to the county board during a work session back in January. Two months ago, the board approved the hiring of architects LHB to begin initial design.

Foldesi noted that the existing public works garages in Cook and Linden Grove were old and inefficient. "The Linden Grove garage is actually a WPA-era building, with lots of miles on it," he said. "It's very energy inefficient and we don't have enough room to house all

See...COOK pg. 11



Piragis Outlet Store Open Daily

SAVE 40% 10 - 6 M-Sat, 10 - 4 Sunday

365-6745 Main Store M-Sat 6 am to 9 pm, 6 am-8 pm Sundays

Contact The Timberjay

218-753-2950
editor@timberjay.com

MPCA...Continued from page 1

rice, in the natural environment, microbes in aquatic sediments can convert sulfates to sulfides, which are toxic to wild rice. But how much and how quickly sulfates are converted to sulfides, and how toxic those sulfides are to wild rice, depends on the circumstances, according to MPCA officials. "Iron in sediment binds to sulfide and neutralizes it, making it non-toxic to wild rice," states the agency in a press statement announcing the release of their technical document. "Organic carbon, on the other hand, causes more sulfide to be produced. Sulfate is converted to sulfide differently in each body of water, depending on the concentrations of iron and organic carbon in the sediment."

MPCA officials say they have the science to back up their proposal, but that's disputed by Dr. John Pastor, one of the lead scientists that the MPCA hired four years ago to conduct more research on wild rice and sulfates.

In a June 30 report to the Minnesota Sea Grant, which funded a portion of Dr. Pastor's research into wild rice, Pastor notes that he has continued his research, which has found that "iron has no beneficial effect" in reducing the toxicity of sulfides. Indeed, his preliminary findings suggest that the presence of more iron may actually hasten the loss of wild rice, rather than prevent it, although Pastor acknowledges it will take additional study to reach a definitive conclusion on that point.

Several other current and retired professors in related fields have joined Pastor in expressing doubts about the validity of the MPCA's proposed approach. A hearing set for Aug. 18 will give Pastor the opportunity to present his findings to the MPCA's wild rice advisory committee, which gives input on the proposed rule change.

Yet Paula Maccabee, legal counsel for the group Water Legacy, said she's worried that the MPCA will turn a deaf ear to Pastor and other scientists in its rush to push through a rule change demanded by politics, rather than science. "I'm finding it really troubling that the MPCA went full speed ahead, despite John's [Pastor] research," said Maccabee. "They've really opened this up to being a political process, not a scientific process, so we shouldn't be surprised that they will be continually forced to compromise the science."

The MPCA has been under tremendous pressure from the Minnesota Legislature, which has passed laws in recent years intended to hamstring the agency's ability to enforce the state's sulfate rule on the mining industry. In 2015, the Legislature passed a law prohibiting the agency from enforcing the wild rice sulfate standard until it revised the rule.

Yet the state has no authority, on its own, to revise the wild rice standard. The federal Environmental Protection

Agency has approved the existing standard under the auspices of the Clean Water Act, and that means the EPA will need to approve any possible change in the rule before the MPCA could enforce the new standard.

At this point, MPCA officials are keeping the EPA informed of their rule-changing process, but the federal agency has yet to weigh in on the proposal, according to Shannon Lotthammer, director of the MPCA's Environmental Analysis and Outcomes Division.

Given the scientific dispute over the merits of the MPCA's new flexible standard, it remains unclear whether the EPA would ever approve of the change, Maccabee said the Legislature isn't helping the MPCA make the case, since laws passed in 2015 and 2016 effectively violate federal law by preventing the MPCA from enforcing the Clean Water Act as it applies to sulfate discharge. "Under the Clean Water Act, unless and until the 10 mg/l change is approved by the EPA, there is a clear requirement to enforce it," said Maccabee. "What the Legislature did is invalid under federal law."

MPCA's Lotthammer said it's too early to say how the EPA will assess the science. "With that said, MPCA is confident in our ability to develop a proposed rule that is scientifically defensible and grounded in sound science," Lotthammer added.

Yet the EPA and the

MPCA have been at odds for years over the state agency's relatively lax enforcement of the Clean Water Act as it applies to the taconite industry. In 2013, the EPA forced the MPCA to sign an agreement to bring dozens of expired mining discharge permits up to current standards over the next five years. EPA officials, in a June 22, 2016, letter, complained that the MPCA has, to date, failed to reissue any of the expired permits. What's more, under current state law it won't be able to do so in most cases until a new wild rice standard is in place.

And when that might

happen is anyone's guess. While the MPCA may complete its rulemaking process by early 2018, there's no such deadline in place for the EPA, and EPA officials are well aware that the current 10 mg/l standard remains in place (and by law must be enforced) until they approve a new rule.

At the same time, Maccabee said the MPCA appears to be leaving the door wide open for litigation around the issue, either by tribes or environmental groups, or by the mining industry if the final standard is seen as too rigorous. If so, it could be years more before the courts finally settle the

question.

"After all this enormous drain of staff time and community resources, the MPCA may end up with the same standard, and may still refuse to enforce it," said Maccabee.

As the rulemaking process drags on, the region's taconite plants will continue to operate with expired permits that don't meet pollution standards. Maccabee questions whether delay is simply part of the Legislature's intent. "This is the opposite of the way in which regulatory agencies are supposed to operate," she said.



Serving All Your Family Medical and Dental Needs In Cook and Tower

COOK MEDICAL 20 5th Street SE, Cook MN Monday-Friday 8am-5pm Saturday 9am-Noon Appointments 218-666-5941 COOK DENTAL 12 South River Street, Cook MN Monday-Thursday 8am-6pm Friday 8am-5pm Appointments 218-666-5958	Bruce Garbisch, M.D. Matthew Holmes, M.D. Harold Johnston, M.D. Josie Norberg Lopez, M.D. Nicholas Vidor, M.D. Wendy Long, CFNP Emily Hadrava, CFNP Richard Devorak, DDS Kathleen Mattison, DDS Ehab Rezk, DDS Duane Sushoreba, DDS
--	---

Cook and Tower Accepting New Patients

TOWER MEDICAL AND DENTAL
415 N 2nd Street, Suite 2, Tower MN
Located in the Former Tower High School Building

MEDICAL Monday, Thursday, Friday 8am-5pm Tuesday, Wednesday 7am-5pm Appointments 218-753-2405 DENTAL Monday-Thursday 8am-5pm Friday 8am-Noon Appointments 218-753-6061	Matthew Holmes, M.D. Nicholas Vidor, M.D. Josie Norberg Lopez, M.D. Wendy Long, CFNP Emily Hadrava, CFNP Bruce Baker, DDS Richard Devorak, DDS Duane Sushoreba, DDS Ehab Rezk, DDS
--	--

Billing Questions: 218-666-5102 ext. 2
www.scenicrivershealthservices.org



CLEAN.DRAIN.DRY.

BOATS, TRAILERS & GEAR STOP INVASIVE SPECIES







www.CleanDrainDry.org

the TIMBERJAY

Wild rice standard

Political meddling undermines credibility of the MPCA

Posted Wednesday, November 1, 2017 5:28 pm

We may now understand why the state's Pollution Control Agency spent more than three decades studiously ignoring a state sulfate standard designed to protect wild rice. The standard—the nation's strictest at 10 milligrams per liter—has put the MPCA in a political and legal vise, with no easy way for agency officials to extricate themselves.

On one side are northern Minnesota Indian tribes and environmental groups, who have been threatening legal action for years over the agency's failure to enforce the existing water quality standard. On the other side is the taconite industry and its supporters, who question whether sulfate is truly harming wild rice and whether it makes sense, in either case, to foist significant clean-up costs on an industry that is already struggling with the effects of a worldwide glut of iron ore and steel.

Enter the politicians, who have gone in multiple directions in hopes of staving off enforcement of the rule to protect the taconite industry. And despite the current uproar over the agency's latest proposed sulfate standard, it's worth noting that the MPCA is doing exactly what the Legislature, at the urging of the Iron Range delegation, told them to do.

A little history may be in order. About five years ago, Iron Range politicians made moves to significantly loosen the sulfate standard as the agency started to take steps to enforce it for the first time. But MPCA officials informed them they couldn't do that without scientific evidence to justify it, so the politicians approved funds for a new study, hoping that it would discredit the 1940s-era science that provided the basis for the current standard.

It didn't go well. Instead, the research—this time led by UMD biology professor Dr. John Pastor—largely confirmed the work of the late DNR biologist Dr. John Moyle.

The MPCA mulled over the findings and did the only thing they could legally do under the provisions of the Clean Water Act: they announced that they would begin enforcing the 10 mg/l sulfate standard on dischargers into wild rice waters.

That's when unpleasant stuff hit the fan in St. Paul. Iron Range legislators and US Steel went to Gov. Dayton and said no way. As a way out, the governor and MPCA officials put forward their so-called "flexible standard," citing some preliminary findings from the Pastor study that suggested that higher levels of iron in the sediments of receiving waters might help to mitigate the harmful effects of higher sulfate levels.

Iron Range legislators lauded the new concept, if only because it likely meant two more years without enforcement of the current standard. After all, just like legislators, regulators can't change a water quality standard without going through a rule-making process, which typically takes about a year and a half to complete under normal circumstances, which these are not. The recent hearing in Virginia was part of that rule-making process.

In the meantime, the Legislature and governor enacted a law in 2015 that prohibited the MPCA from enforcing the existing standard until the rule-making process could be completed, some time in 2017. Last year, the Legislature passed yet another law, this one giving the MPCA until the end of 2018 to develop its new rule. When the MPCA issued a draft of its proposal this past August, Iron Range officials again acted with alarm, apparently assuming they had more time. In fact, the MPCA needs to be at this stage in order to complete the rulemaking in 2018, as the Legislature had ordered.

Now, Iron Range legislators are promising new legislation to prevent the MPCA from finishing the work they had earlier instructed them to do. They've cued up the scaremongering, suggesting bankruptcy for Iron Range communities and the shutdown of the region's taconite industry. None of that is true, of course, but it helps to keep every local official singing from the same hymnbook.

In short, it's a mess. And the more that legislators interfere with the process, the more they bolster the claims of environmental critics who allege that politics, not science, governs the regulation of major industries in Minnesota, particularly mining. After the past five years, it's tough to argue otherwise, and that should concern Minnesotans who are legitimately concerned about protecting the environment.

<http://timberjay.com/stories/wild-rice-standard,13719>

Technical Memo



Date: 04/20/2011

To: Spruce Road Bulk Sample Site Project File - Minerals

From: Jason T. Butcher 
Superior National Forest Aquatic Biologist

RE: Water quality/quantity evaluation on 10/29/2010

Summary:

In October 2010, surface water samples were collected at four sites in a single sampling event in the area adjacent to the Spruce Road Bulk Sampling location. Chemical constituents were compared to similar measurements taken before and after the closure of the site in the mid 1970's to evaluate changes and load contributions to surrounding streams. Ambient loadings for sulfate, copper, and nickel at Filson Creek (upstream) are two orders of magnitude (100 times) higher than loadings originating from the bulk sample site. Concentrations and loads of chemical constituents have not changed substantially since the mid 1970's. No further testing or management action is recommended.

Introduction:

The Spruce Road Bulk Sample Site is located in Lake County, Minnesota near the town of Ely (NW ¼ of the NW ¼ of Section 25, T62N, R11W). In January, 1974 the International Nickel Company (INCO) extracted a 10,000 ton surface sample for metallurgical testing adjacent to the Spruce Road on the Superior National Forest. The site was re-graded and seeded by INCO in the spring of 1974. In the summer of 1975, subsidence of the surface of the site occurred and seepage from the base of the site was noted. At the request of the MN PCA, water quality and quantity data were collected from the site during the summer of 1975 by INCO to characterize the waters leaving the site. Reclamation for the subsidence was completed in the fall of 1975; the site and adjacent waters were monitored during the summer of 1976 (USFS, 1977). The purpose of the current sampling effort (conducted on 10/29/2010) was to investigate the water quality/quantity of the area relative to the monitoring results from the data collected in 1975 (INCO) and 1976 (USFS).

Methods:

Samples were collected at five sites in the area on 10/29/2010 (Figure 1). This single sampling event was used as a simple status check on water quality and quantity compared to more extensive data sets and sampling regimes done in the mid 1970's. Sites corresponded to several of the sites sampled in 1975-76 (Appendix 1), including the Seep (A), Culvert (B) on the tributary receiving the seep, a downstream site on the tributary (C), and Filson Creek both upstream (Gage) and downstream (DS) from the confluence of the tributary. The current samples collected from Filson Creek upstream and downstream of the tributary confluence were closer to the confluence compared to the sites established in the 1976; however, these sites are comparable in position and characteristics to the 1976 sites.

Due to the low volume of water at the seep, the 2010 samples were collected with a hand vacuum pump and hose. All other samples collected in 2010 were grab samples. Flow, Temperature, and Conductivity were taken in the field; all other parameters were stored on ice and analyzed in a certified lab using standard EPA methods. Three water samples were

taken at each site; two samples analyzed unfiltered water (total) and one sample was filtered in the laboratory before analysis (dissolved).

Flow rates at each site were determined using various hydrologic methods including a direct volumetric sample at the seep, continuously recording flow gage at Filson Creek, and an estimate based on flow ratios for the tributary (Appendix 5).

Results:

It is important to note that results and discussions draw on a single sample event in the fall of 2010 and concentrations and flows can change through time (daily, seasonal, and yearly variability). Laboratory results are presented in this report in their raw form in Appendix 2. Summary graphs by site and chemical constituent are listed in Appendix 3a (all sites included) and Appendix 3b (seep site omitted for scale). The percent contribution for each site relative to the total (downstream most site) was calculated for flow and several chemical constituents (Figure 2, Table 1). Loadings were calculated for copper and nickel at two sites and compared to loadings from similar flows that occurred in 1976 (Figure 3); concentrations for each constituent were also compared with results from October, 1975 (INCO) samples (Appendix 4).

Discussion:

Downstream impacts are a function of both the concentration of the constituent and the amount of flow. The product of the estimated daily discharge rate and the concentration yields the daily load. Daily load helps to provide a better understanding of relative influence in space (between sites) and time (between years). Loads for total copper and total nickel at the seep are small compared to those found in Filson creek (Table 1); the seep contributes about 0.07% of copper, 1.11% of nickel, and 0.27% of sulfate to Filson Creek (Figure 2 and Figures 6-8). Mass for these constituents does not balance to the total output at the downstream site (Figures 6-8). This is due to substantial variability in inputs and outputs of flow and concentrations throughout the watershed. In addition, variability is introduced in the form of heterogeneous geology, landform, flow, and chemical interactions relative to the small number of sites and low sample size representing the area.

Compared to data in 1976 under similar flow conditions, loads in 2010 have not changed substantially for total copper and total nickel (Figure 3). Concentrations for chemical constituents in 2010 remain similar to levels found in 1975 when comparing sites during fall sample periods (Appendix 4). Although some constituents seem to show a trend in decreasing concentration through time, statistical significance cannot be determined due to low sample size.

Data indicate that both Filson Creek and the Tributary to Filson Creek have ambient (upstream) sources of copper that are independent of the seep's copper contribution. Copper levels exceed the applicable Class 2B chronic water quality standards (Table 2; Minn. Rule 7050.0222) at all sites sampled in 2010. This exceedance includes the site on Filson Creek that is upstream of the influence of the bulk sample site (Figure 4 and 5). Cobalt and nickel are below the chronic water quality standards for Class 2B Waters of the State at all sites except the outflow of the seep (A). Concentrations at similar sites in 1976 also exceed those standards; in addition, a sample site on the tributary above the influence of the bulk sample site also exceeded the standard (USFS, 1977).

Conclusions/Recommendations:

- Concentrations and loads of chemical constituents have not changed substantially since the mid 1970's.
- Ambient loadings for total sulfate, copper, and nickel at Filson Creek (upstream) are two orders of magnitude (100 times) higher than loadings from the bulk sample site/seep (Figures 6, 7 and 8).
- No further testing is needed to characterize the water quality and quantity at the Spruce Road Bulk Sample Site; however, further testing would be appropriate if future management actions or mitigations occur.
- Provide Minnesota Department of Natural Resources, Division of Lands and Minerals and Minnesota Pollution Control Agency a copy of this document for their review and records.
- No management action is recommended at this time.

References:

Minnesota Rule 7050.0222. Specific Water Quality Standards For Class 2 Waters of the State; Aquatic Life and Recreation. <https://www.revisor.mn.gov/rules/?id=7050.0222>

USFS, 1977. Preliminary Report, Spruce Road Bulk Sample Site Monitoring Results. Superior National Forest. May 26, 1977. 81 pages.

Spruce Road Bulk Sample Site Water Sample Locations 10-29-2010



Figure 1. Map of the Spruce Road Bulk Sample Site area including water sample sites.

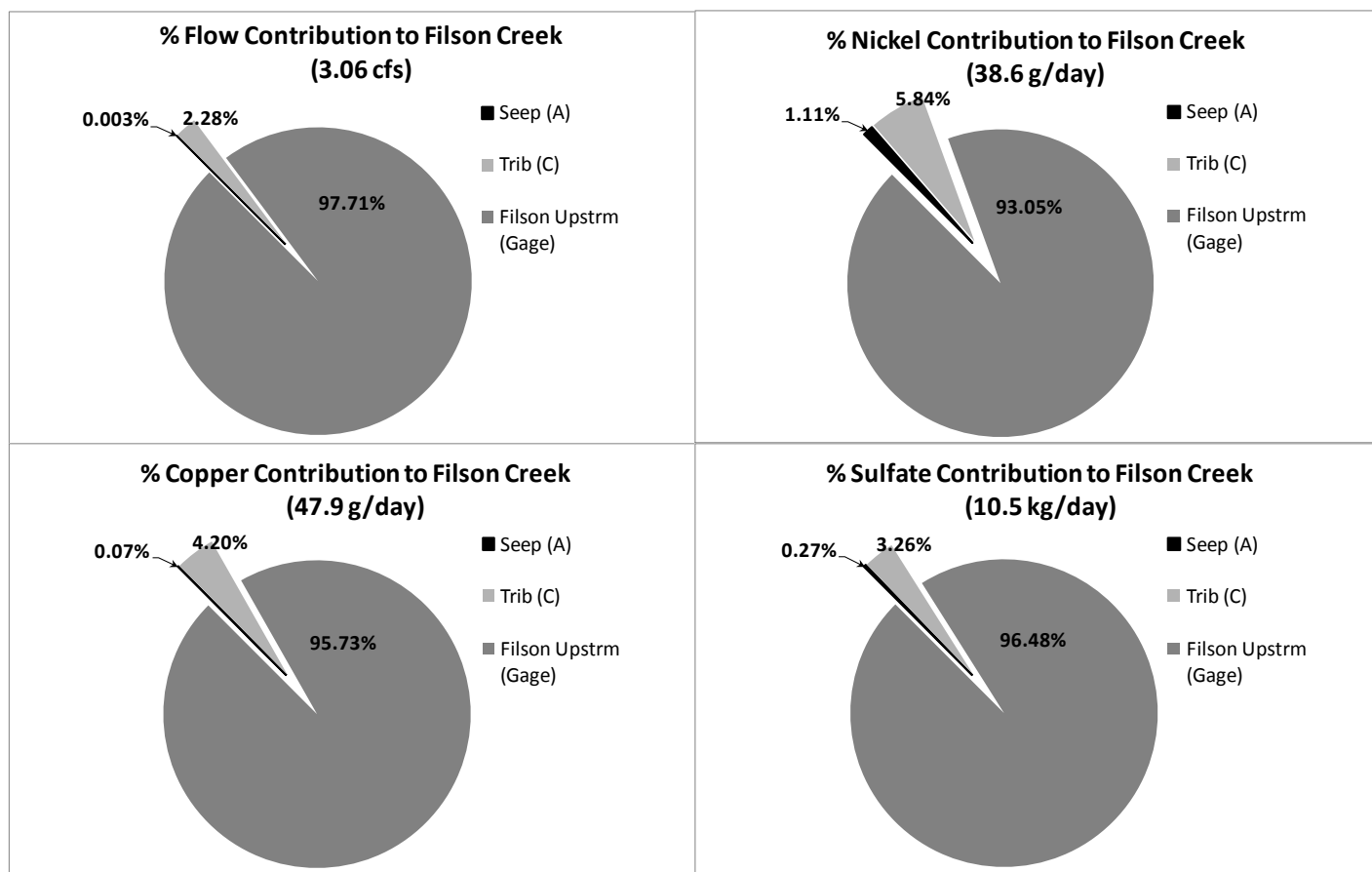


Figure 2. Percent contribution of each upstream site to Filson Creek for flow and total chemical loads. (flow and loads for Filson Creek Downstream of the Bulk Sample Site noted in parentheses)

Table 1. Flow and Load (concentration times discharge) for sites sampled on 10/29/2010.

Site	Flow (cfs)	Total Load (concentration x discharge) by Chemical Constituent			
		Copper (g/d)	Nickel (g/d)	Cobalt (g/d)	Sulfate (kg/d)
Seep (A)	0.00009	0.03	0.34	0.02	0.03
Culvert (B)	0.07	0.9	1.9	0.2	0.28
Trib (C)	0.07	1.8	2.1	0.2	0.33
Filson Upstrm (Gage)	2.99	39.5	28.5	6.6	9.14
Filson Dwnstrm	3.06	47.9	38.6	7.1	10.48

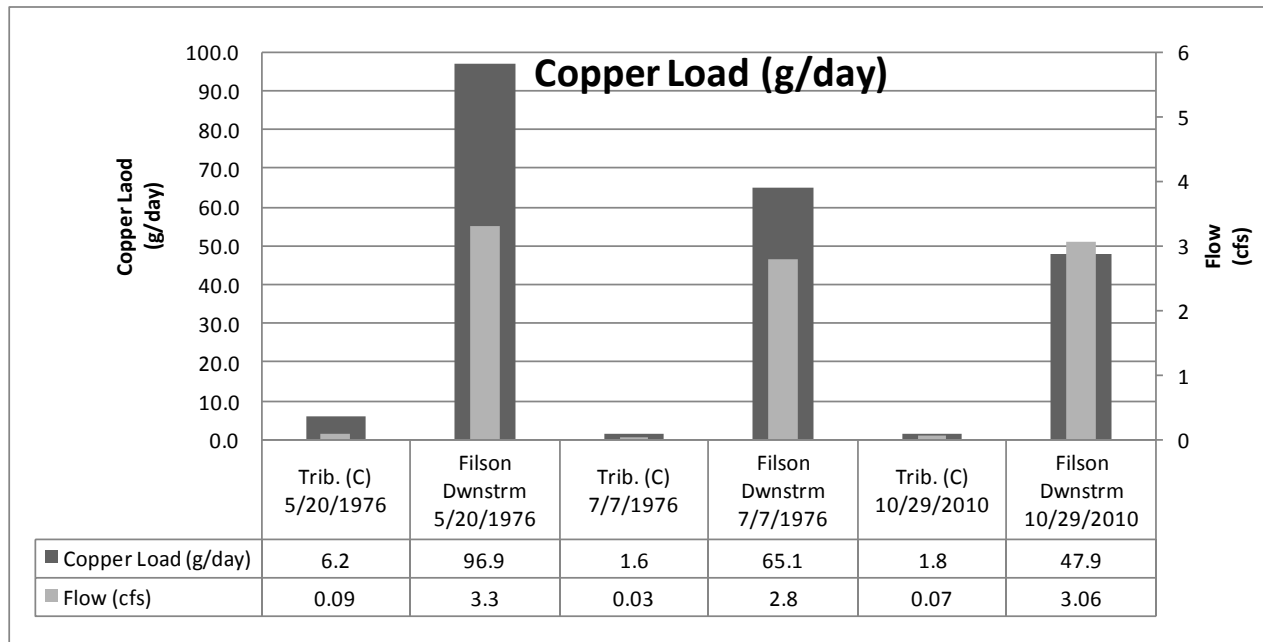
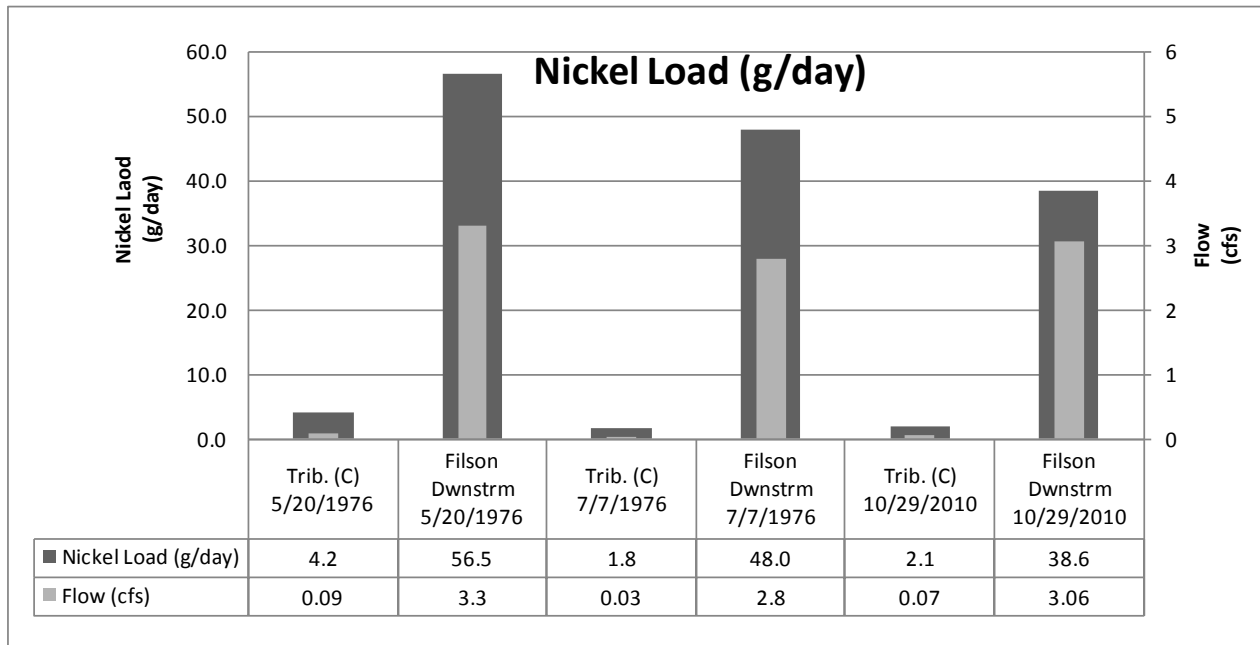


Figure 3. Total copper and total nickel loading for the Tributary to Filson Creek downstream of the Bulk Sample Site and Filson Creek downstream of the Bulk Sample Site for three time periods of similar flow.

Table 2. Applicable Chronic Water Quality Standards for Class 2B waters; asterisk constituents have calculated value according to Minnesota Rule Equation using lowest (conservative) total Hardness value (Minn. Rule 7050.0222)

Constituent	Unit	Chronic Standard
Arsenic, total	ug/l	53
Cobalt, total	ug/l	5.0
*Copper, total	ug/l	3.1
Mercury, total	ng/l	6.9
*Nickel, total	ug/l	33.3

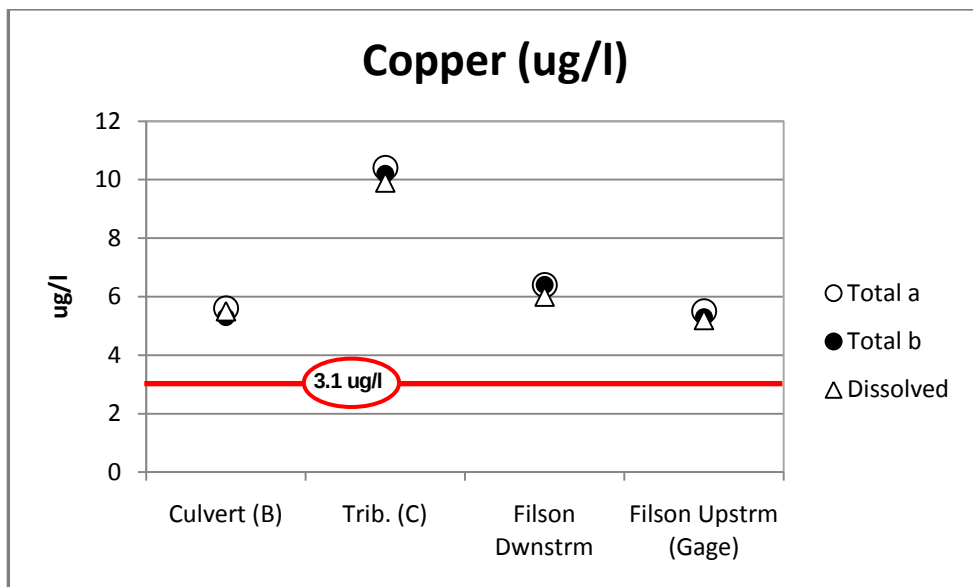


Figure 4. Copper concentrations (ug/l) at sites near the Spruce Road Bulk Sample Site on 10-29-2010. Each symbol represents a sample point; circles represent unfiltered (total) samples and triangles represent filtered (dissolved) samples. The red line denotes the water quality standard (chronic standard, Class 2B waters of the state, aquatic life and recreation). Seep data was not plotted for scale.

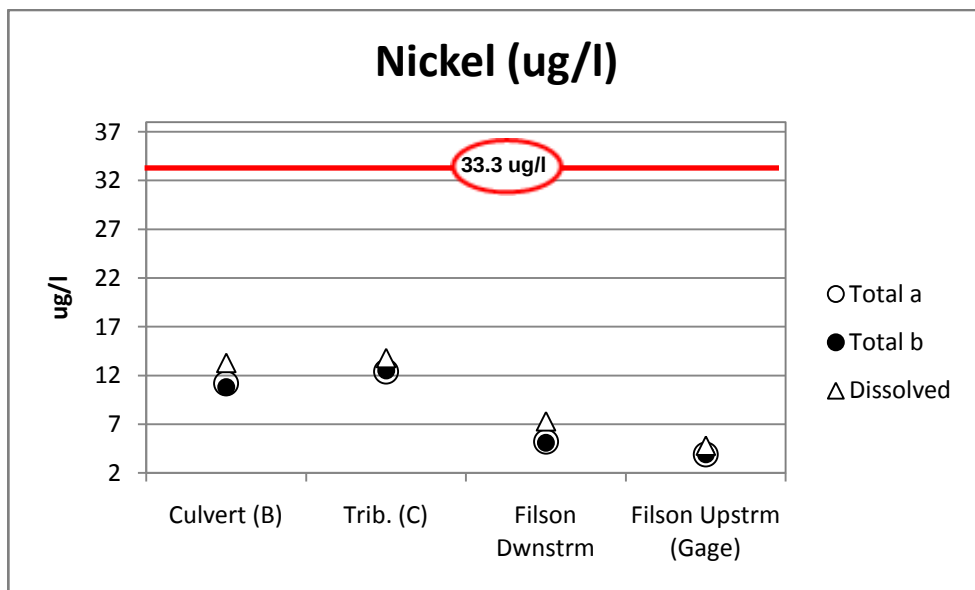


Figure 5. Nickel concentrations (ug/l) at sites near the Spruce Road Bulk Sample Site on 10-29-2010. Each symbol represents a sample point; circles represent unfiltered (total) samples and triangles represent filtered (dissolved) samples. The red line denotes the water quality standard (chronic standard, Class 2B waters of the state, aquatic life and recreation). Seep data was not plotted for scale.

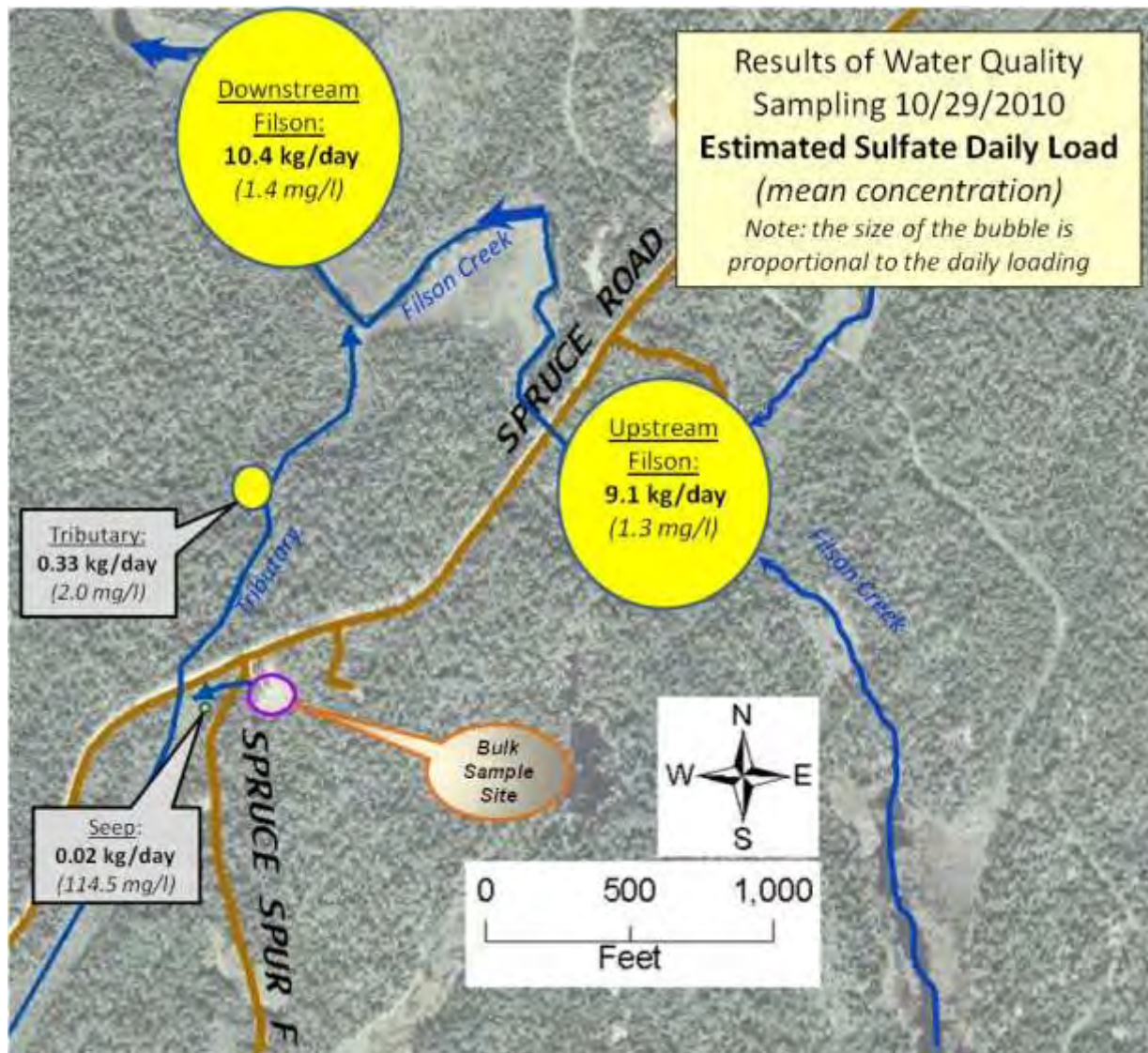


Figure 6. Bubble plot of sulfate daily load at four sites in the Filson Creek watershed. Size of the bubble is proportional to the daily load at each site (mean concentration in parentheses). Loads and concentrations were determined from field data collected on 10/29/2010.

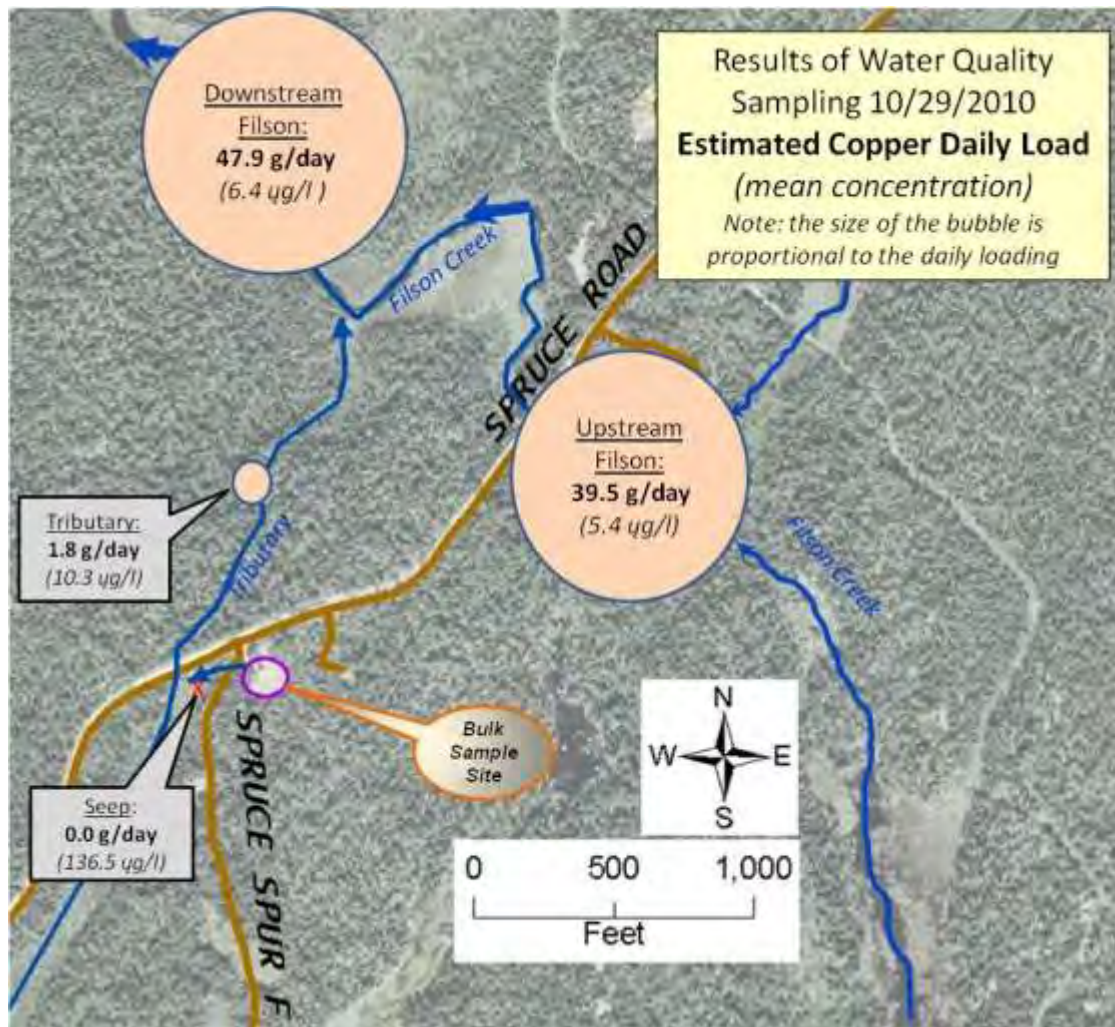


Figure 7. Bubble plot of copper daily load at four sites in the Filson Creek watershed. Size of the bubble is proportional to the daily load at each site (mean concentration in parentheses). Loads and concentrations were determined from field data collected on 10/29/2010.

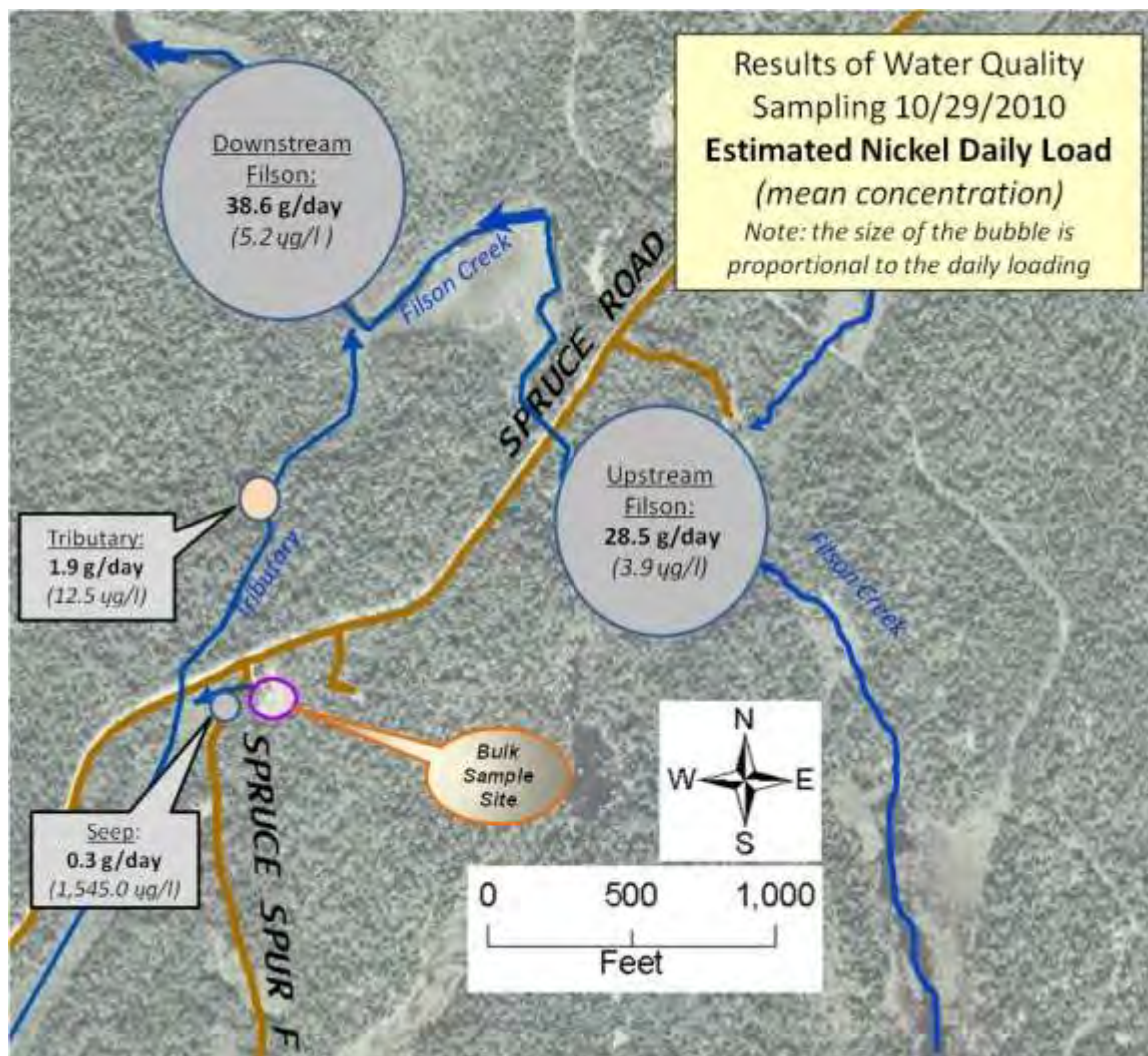
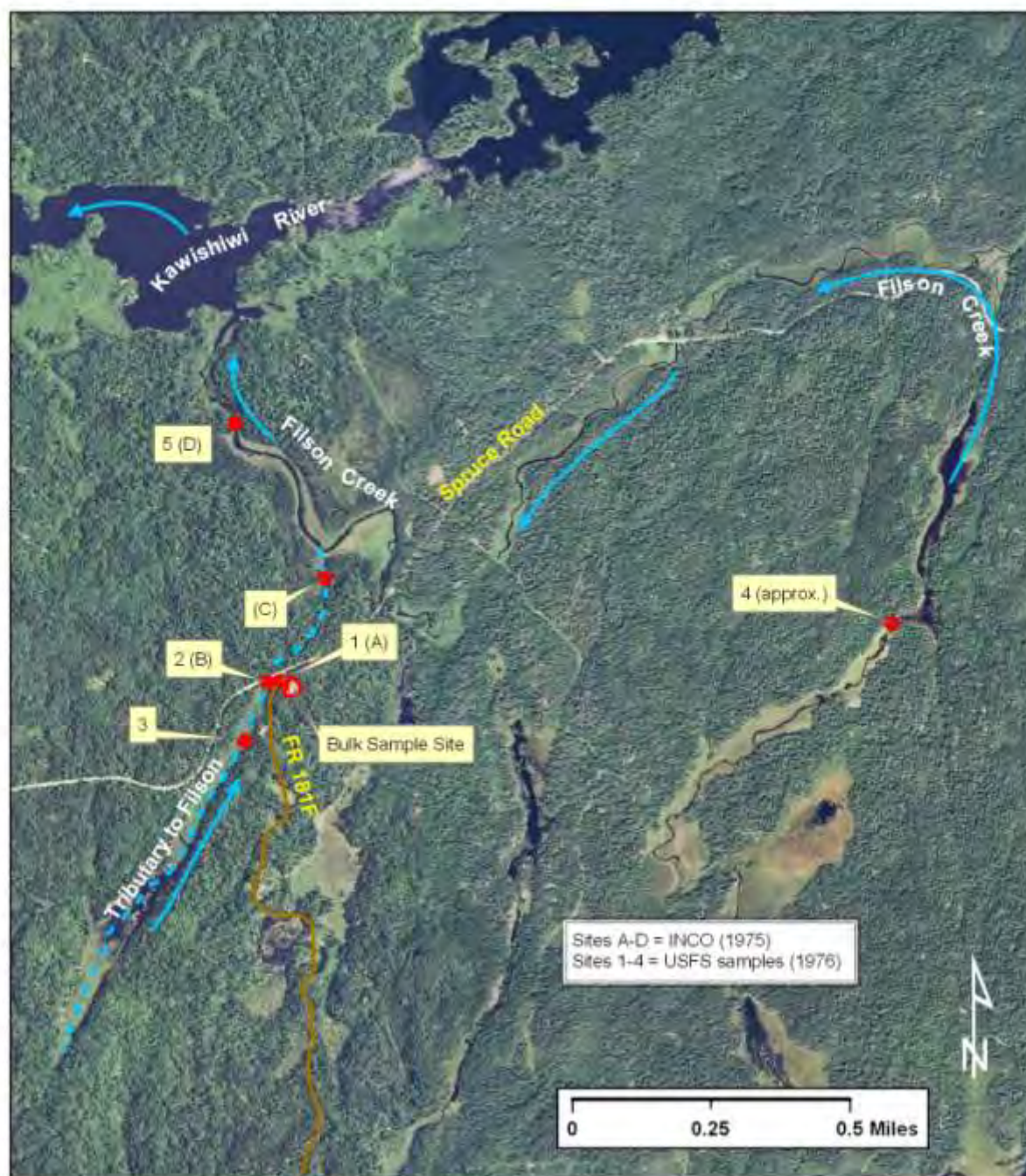


Figure 8. Bubble plot of nickel daily load at four sites in the Filson Creek watershed. Size of the bubble is proportional to the daily load at each site (mean concentration in parentheses). Loads and concentrations were determined from field data collected on 10/29/2010.

Appendix 1:

Sample site locations for past monitoring efforts from INCO (lettered sites; 1975) and the USFS (numbered sites; 1976). Site locations are approximations from previous reports.

Spruce Road Bulk Sample Site Past Sample Locations



Appendix 2:
Laboratory Report for surface water samples taken at
Spruce Road Bulk Sample Site on 10-29-2010



Era Laboratories, Inc.

4730 Oneida Street, Duluth, MN 55807 Telephone: (218)727-6390 Fax: (218)727-3048

Laboratory Report

Project Number: 059409
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Client: JASON BUTCHER
SUPERIOR NAT'L FOREST/US FOREST SER
5601 GRAND AVENUE PLACE
DULUTH MN 55808

Sample ID:	SEEP (A)	059409-1						
Era Project Number:								
Parameter:	Results:	Units:	Analysis Date/Time:	Method:	DF:	LOG:	LOG:	QC Comments:
pH - Lab	6.4	SU	11/5/2010 16:45	SM 4500-H+8-00 CL	1			
Sulfate	113	mg/L	11/7/2010 23:26	EPA 300.0 Rev 2.1	10	5	15	
Arsenic, Total	< 0.4	µg/L	11/12/2010 11:25	EPA 200.8 Rev 5.4	1	0.4	1	
Calcium, Total	26.5	mg/L	11/17/2010 11:40	EPA 200.7 Rev 4.4	1	0.05	0.17	
Cobalt, Total	77.4	µg/L	11/12/2010 11:25	EPA 200.8 Rev 5.4	1	0.4	1	
Copper, Total	127	µg/L	11/12/2010 11:25	EPA 200.8 Rev 5.4	1	0.4	1	
Hardness, Total (as CaCO3)	171	mg/L	11/17/2010 10:46	EPA 200.7 Rev 4.4	1	0.3	1	
Iron, Total	8.9	mg/L	11/17/2010 10:30	EPA 200.7 Rev 4.4	10	0.1	0.4	
Magnesium, Total	25.5	mg/L	11/17/2010 11:40	EPA 200.7 Rev 4.4	1	0.05	0.17	
Mercury, Total	< 0.04	µg/L	11/11/2010 15:13	EPA 245.2	1	0.04	0.05	
Nickel, Total	1580	µg/L	11/12/2010 12:43	EPA 200.8 Rev 5.4	5	2	5	

MIN Certification # 037-137-152

Revised temperature within regulatory guidelines

Page 1 of 15



Era Laboratories, Inc.

4730 Orinda Street, Duluth, MN 55807 Telephone: (216)727-6380 Fax: (216)727-3049

Laboratory Report

Project Number: 050499
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103046

Sample ID:	SEEP (A)	050499-2	Sample Date:	10/29/2010	Sample Time:	11:00	Matrix:	Water
Era Project Number:	050499-2							
Parameter:	Results:	Units:	Analysis Date/Time:	Method:	DF:	LOD:	LOD:	QC Comments:
pH - Lab	6.4	SU	11/5/2010 16:45	SM 4500-H+8-00 CL	1			
Sulfide	116	mg/L	11/6/2010 0:12	EPA 300.0 Rev 2.1	10	5	15	
Arsenic, Total	< 0.4	µg/L	11/12/2010 11:29	EPA 200.8 Rev 5.4	1	0.4	1	
Calcium, Total	257	mg/L	11/17/2010 11:42	EPA 200.7 Rev 4.4	1	0.08	0.17	
Cobalt, Total	76.9	µg/L	11/12/2010 11:29	EPA 200.8 Rev 5.4	1	0.4	1	
Copper, Total	146	µg/L	11/12/2010 11:29	EPA 200.8 Rev 5.4	1	0.4	1	
Hardness, Total (as CaCO3)	160	mg/L	11/17/2010 10:49	EPA 200.7 Rev 4.4	1	0.3	1	
Iron, Total	10.6	mg/L	11/17/2010 10:32	EPA 200.7 Rev 4.4	10	0.1	0.4	
Magnesium, Total	24.6	mg/L	11/17/2010 11:42	EPA 200.7 Rev 4.4	1	0.05	0.11	
Mercury, Total	< 0.04	µg/L	11/11/2010 15:13	EPA 245.2	1	0.04	0.05	
Nickel, Total	1510	µg/L	11/12/2010 13:12	EPA 200.8 Rev 5.4	6	2	6	

MN Certification # 007-137492

Recepi temperature within regulatory guidelines

Page 2 of 15



Era Laboratories, Inc.

4730 Chioda Street, Duluth, MN 55807 Telephone: (216)727-6390 Fax: (216)727-3046

Laboratory Report

Project Number: 050498
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Sample ID:	DEEP (A)	Sample Date:	10/29/2010	Sample Time:	11:00	Matrix:	Water
Era Project Number:	050498-3						
Parameter:	Results:	Units:	Analysis Date/Time:	Method:	DF	LOD:	QC Comments:
pH - Lab, Filtered	8.8	SU	11/5/2010 16:45	SM 4500-H+3.00 CL	1		
Sulfate, Dissolved	114	mg/L	11/8/2010 0:20	EPA 300.0 Rev 2.1	10	5	15
Arsenic, Dissolved	< 0.4	µg/L	11/12/2010 11:47	EPA 200.8 Rev 5.4	1	0.4	1
Calcium, Dissolved	25.8	mg/L	11/12/2010 11:44	EPA 200.7 Rev 4.4	1	0.05	0.17
Cobalt, Dissolved	74.7	µg/L	11/12/2010 11:47	EPA 200.8 Rev 5.4	1	0.4	1
Copper, Dissolved	17.5	µg/L	11/12/2010 11:47	EPA 200.8 Rev 5.4	1	0.4	1
Hardness, Dissolved (as CaCO3)	168	mg/L	11/12/2010 10:49	EPA 200.7 Rev 4.4	1	0.3	1
Iron, Dissolved	0.03	mg/L	11/12/2010 9:55	EPA 200.7 Rev 4.4	1	0.01	0.04
Magnesium, Dissolved	24.8	mg/L	11/12/2010 11:44	EPA 200.7 Rev 4.4	1	0.05	0.17
Mercury, Dissolved	< 0.04	µg/L	11/12/2010 15:13	EPA 245.2	1	0.04	0.05
Nickel, Dissolved	1440	µg/L	11/12/2010 12:58	EPA 200.8 Rev 5.4	5	2	5

MN Certification # 007-137-192

Respect temperature within regulatory guidelines

Page 3 of 15



Era Laboratories, Inc.

4730 Ormida Street Duluth, MN 55807 Telephone: (218)727-8380 Fax: (218)727-3048

Project Number: 059408
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103648

Laboratory Report

Sample ID:	CULVERT (B)	Sample Date:	10/29/2010	Sample Time:	11:43	Matrix:	Water
Era Project Number:	059408-4	Analysis Date/Time:	11/5/2010 16:45	Method:	SM 4500-H-B-00 CL	LOD:	0.5
Parameter:		Units:		DF:		LOD:	0.17
pH - Lab	5.8	mg/L	11/12/2010 3:54	1	EPA 300.0 Rev 2.1	0.5	1.5
Sulfate	1.9	mg/L	11/12/2010 11:51	1	EPA 200.8 Rev 5.4	0.4	1
Arsenic, Total	< 0.4	mg/L	11/12/2010 11:47	1	EPA 200.7 Rev 4.4	0.05	0.17
Calcium, Total	2.59	mg/L	11/12/2010 11:51	1	EPA 200.8 Rev 5.4	0.4	1
Cadmium, Total	1.5	mg/L	11/12/2010 11:51	1	EPA 200.8 Rev 5.4	0.4	1
Copper, Total	5.6	mg/L	11/12/2010 11:51	1	EPA 200.8 Rev 5.4	0.4	1
Hardness, Total (as CaCO3)	15.9	mg/L	11/12/2010 10:48	1	EPA 200.7 Rev 4.4	0.3	1
Iron, Total	0.03	mg/L	11/12/2010 9:57	1	EPA 200.7 Rev 4.4	0.01	0.04
Magnesium, Total	2.3	mg/L	11/12/2010 11:47	1	EPA 200.7 Rev 4.4	0.05	0.17
Mercury, Total	< 0.04	mg/L	11/12/2010 15:13	1	EPA 245.2	0.04	0.05
Nickel, Total	11.2	mg/L	11/12/2010 11:51	1	EPA 200.8 Rev 5.4	0.4	1

MN Certification # 027-137-182

Record temperature within regulatory guidelines

Page 4 of 15



Era Laboratories, Inc.

4750 Creech Street Duluth, MN 55807 Telephone: (218)727-4360 Fax: (218)727-3048

Laboratory Report

Project Number: 059498
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Sample ID: CULVERT (B)
Era Project Number: 059498-5

Parameter:

pH - Lab
Sulfate
Arsenic, Total
Calcium, Total
Cadmium, Total
Copper, Total
Hardness, Total (as CaCO₃)
Iron, Total
Magnesium, Total
Mercury, Total
Nickel, Total

Results	Units	Analysis Date/Time	Sample Date	Sample Time	Matrix	LOD	LOQ	QC Comments
5.8	SU	11/5/2010 16:45	10/29/2010		Water			
1.7	mg/L	11/12/2010 4:09	Method: SM 4500-H-8-00 CL	1		0.5	1.5	
<	mg/L	11/12/2010 11:54	EPA 300.0 Rev 2.1	1		0.4	1	
2.57	mg/L	11/12/2010 11:49	EPA 300.8 Rev 5.4	1		0.05	0.17	
0.6	µg/L	11/12/2010 11:54	EPA 200.7 Rev 4.4	1		0.4	1	
8.3	µg/L	11/12/2010 11:54	EPA 200.8 Rev 5.4	1		0.4	1	
15.9	mg/L	11/12/2010 10:49	EPA 200.8 Rev 5.4	1		0.3	1	
0.59	mg/L	11/12/2010 9:58	EPA 200.7 Rev 4.4	1		0.01	0.04	
2.3	mg/L	11/12/2010 11:49	EPA 200.7 Rev 4.4	1		0.05	0.17	
* 0.04	µg/L	11/12/2010 16:13	EPA 245.2	1		0.04	0.08	
10.8	µg/L	11/12/2010 11:54	EPA 200.8 Rev 5.4	1		0.4	1	

MN Certification # 037-137-162

Receipt temperature within regulatory guidelines

Page 5 of 15



Era Laboratories, Inc.

4730 Chisota Street Duluth MN 55807 Telephone: (218) 727-8380 Fax: (218) 727-3049

Laboratory Report

Project Number: 050459
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103648

Sample ID: CULVERT (B)
Era Project Number: 030499-6

Parameter	Results	Units	Analysis Date/Time	Sample Date	Method	DF	LOD	Matrix	Wells	QC Comments
pH - Lab. Filtered	5.9	SU	11/5/2010 16:45	10/29/2010	SM 4500-H+8-00 CL	1				
Sulfide, Dissolved	1.7	mg/L	11/12/2010 4:24		EPA 300.0 Rev 2.1	1	0.5			1.5
Arsenic, Dissolved	< 0.4	µg/L	11/12/2010 11:56		EPA 200.8 Rev 5.4	1	0.4			1
Calcium, Dissolved	2.51	mg/L	11/12/2010 11:56		EPA 200.7 Rev 4.4	1	0.05			0.17
Cobalt, Dissolved	0.8	µg/L	11/12/2010 11:56		EPA 200.8 Rev 5.4	1	0.4			1
Copper, Dissolved	5.5	µg/L	11/12/2010 11:56		EPA 200.8 Rev 5.4	1	0.4			1
Hardness, Dissolved (as CaCO3)	15.6	mg/L	11/12/2010 10:49		EPA 200.7 Rev 4.4	1	0.3			1
Iron, Dissolved	0.46	mg/L	11/12/2010 10:05		EPA 200.7 Rev 4.4	1	0.01			0.04
Magnesium, Dissolved	2.27	mg/L	11/12/2010 11:56		EPA 200.7 Rev 4.4	1	0.05			0.17
Mercury, Dissolved	0.04	µg/L	11/12/2010 15:13		EPA 245.2	1	0.04			0.05
Nickel, Dissolved	13.3	µg/L	11/12/2010 11:56		EPA 200.8 Rev 5.4	1	0.4			1

MN Certification # 027-137-152

Receipt temperature within regulatory guidelines

Page 6 of 10



Era Laboratories, Inc.

4730 Onondaga Street Duluth, MN 55807 Telephone: (218)727-6390 Fax: (218)727-5048

Laboratory Report

Project Number: 050409
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103846

Sample ID:	TR18 (C)	050409-7	Sample Date:	10/29/2010	Sample Time:	13:30	Matrix:	Water
Parameter:			Analysis Date/Time:		Method:	DF:	LOD:	DF Comments:
pH - Lab	6.3		11/5/2010	16:45	SM 4500-H-B-00 CL	1		
Sulfate	2.1		11/12/2010	4:36	EPA 300.0 Rev 2.1	1	0.5	1.5
Arsenic, Total	< 0.4		11/12/2010	12:02	EPA 200.8 Rev 5.4	1	0.4	1
Calcium, Total	2.9		11/12/2010	12:00	EPA 200.7 Rev 4.4	1	0.05	0.17
Cobalt, Total	1.2		11/12/2010	12:02	EPA 200.8 Rev 5.4	1	0.4	1
Copper, Total	10.4		11/12/2010	12:02	EPA 200.8 Rev 5.4	1	0.4	1
Hardness, Total (as CaCO3)	18.3		11/12/2010	10:49	EPA 200.7 Rev 4.4	1	0.3	1
Iron, Total	0.77		11/12/2010	10:07	EPA 200.7 Rev 4.4	1	0.01	0.04
Magnesium, Total	2.08		11/12/2010	12:00	EPA 200.7 Rev 4.4	1	0.05	0.17
Mercury, Total	< 0.04		11/12/2010	15:13	EPA 245.2	1	0.04	0.05
Nickel, Total	12.4		11/12/2010	12:02	EPA 200.8 Rev 5.4	1	0.4	1

MIN Certification # 027-137-102

Receptor temperature within regulatory guidelines

Page 7 of 15



Era Laboratories, Inc.

4730 Orinoda Street, Duluth, MN 55807 Telephone: (218)727-6360 Fax: (218)727-3046

Laboratory Report

Project Number: 050499
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Sample ID:	TR18 (C	Sample Date:	10/29/2010	Sample Time:	13:30	Matrix:	Water
Era Project Number:	050499-3	Analysis Date/Time:	11/5/2010 16:45	Method:	SM 4500-H4B-00 CL	LOD:	0.5
Parameter:		Units:		DF:		LOD:	0.5
pH - Lab	6.3	SI	11/5/2010 16:45	1	SM 4500-H4B-00 CL	LOD:	0.5
Sulfate	1.8	mg/L	11/12/2010 8:30	1	EPA 300.0 Rev 2.1	LOD:	1.5
Arsenic, Total	0.4	µg/L	11/12/2010 12:06	1	EPA 200.8 Rev 5.4	LOD:	1
Calcium, Total	2.87	mg/L	11/17/2010 12:03	1	EPA 200.7 Rev 4.4	LOD:	0.17
Cobalt, Total	1.1	µg/L	11/17/2010 12:06	1	EPA 200.8 Rev 5.4	LOD:	1
Copper, Total	10.2	µg/L	11/17/2010 12:06	1	EPA 200.8 Rev 5.4	LOD:	1
Hardness, Total (as CaCO3)	18.7	mg/L	11/17/2010 10:49	1	EPA 200.7 Rev 4.4	LOD:	0.3
Iron, Total	0.79	mg/L	11/17/2010 10:06	1	EPA 200.7 Rev 4.4	LOD:	0.01
Magnesium, Total	2.73	mg/L	11/17/2010 12:03	1	EPA 200.7 Rev 4.4	LOD:	0.05
Mercury, Total	< 0.04	µg/L	11/17/2010 15:13	1	EPA 245.2	LOD:	0.04
Nickel, Total	12.5	µg/L	11/17/2010 12:06	1	EPA 200.8 Rev 5.4	LOD:	0.4

MN Certification # 027-137-152

Recapitulate laboratory when regulatory guidelines

Page 8 of 15



Era Laboratories, Inc.

4730 Omaha Street, Duluth, MN 55807 Telephone: (216)727-6360 Fax: (216)727-3048

Laboratory Report

Project Number: 059460
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103648

Sample ID:	TRIS (C)	Sample Date:	10/29/2010	Sample Time:	13:30	Matrix:	Water
Era Project Number:	059460-9	Analysis Date/Time:	11/5/2010 16:45	Method:	SM 4500-HB-00 CL	LOD:	OC Comments:
Parameter:		Units:					
pH - Lab, Filtered	6.6	SLU					
Sulfate, Dissolved	2.2	mg/L	11/12/2010 8:45	EPA 300.0 Rev 2.1	1	0.5	1.5
Arsenic, Dissolved	< 0.4	µg/L	11/12/2010 12:09	EPA 200.8 Rev 5.4	1	0.4	1
Calcium, Dissolved	3	mg/L	11/17/2010 12:05	EPA 200.7 Rev 4.4	1	0.05	0.17
Cobalt, Dissolved	1	µg/L	11/12/2010 12:09	EPA 200.8 Rev 5.4	1	0.4	1
Copper, Dissolved	0.9	µg/L	11/12/2010 12:09	EPA 200.8 Rev 5.4	1	0.4	1
Hardness, Dissolved (as CaCO ₃)	18.8	mg/L	11/17/2010 10:48	EPA 200.7 Rev 4.4	1	0.3	1
Iron, Dissolved	0.49	mg/L	11/17/2010 10:10	EPA 200.7 Rev 4.4	1	0.01	0.04
Magnesium, Dissolved	2.74	mg/L	11/17/2010 12:05	EPA 200.7 Rev 4.4	1	0.05	0.17
Mercury, Dissolved	0.04	µg/L	11/11/2010 15:13	EPA 245.2	1	0.04	0.05
Nickel, Dissolved	13.8	µg/L	11/12/2010 12:09	EPA 200.8 Rev 5.4	1	0.4	1

MM Certification # 027-137-152

Recept temperature within regulatory guidelines

Page 9 of 15



Era Laboratories, Inc.

4730 Canada Street Duluth, MN 55807 Telephone: (216)727-4390 Fax: (216)727-3048

Project Number: 050499
OCC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103548

Laboratory Report

Sample ID: FLSOW DS
Era Project Number: 050499-10

Parameter	Results	Units	Analysis Date/Time	Sample Date	Method	DF	LOD	LOQ	Matrix	Wells	QC Comments
pH - Lab	6.2	SU	11/5/2010 16:45	10/29/2010	SM 4500-H-B-00 OL	1					
Sulfate	1.4	mg/L	11/12/2010 7:50	10/29/2010	EPA 300.0 Rev 2.1	1	0.5	1.5			J
Ammonia, Total	0.4	mg/L	11/12/2010 12:13	10/29/2010	EPA 300.8 Rev 5.4	1	0.4	1			J
Calcium, Total	3.28	mg/L	11/17/2010 12:07	10/29/2010	EPA 200.7 Rev 4.4	1	0.05	0.17			
Copper, Total	0.9	µg/L	11/12/2010 12:13	10/29/2010	EPA 200.8 Rev 5.4	1	0.4	1			J
Copper, Total	8.4	µg/L	11/13/2010 12:13	10/29/2010	EPA 200.8 Rev 5.4	1	0.4	1			
Hardness, Total (as CaCO3)	18.1	mg/L	11/17/2010 10:48	10/29/2010	EPA 200.7 Rev 4.4	1	0.3	1			
Iron, Total	1.06	mg/L	11/17/2010 10:12	10/29/2010	EPA 200.7 Rev 4.4	1	0.01	0.04			
Magnesium, Total	2.41	mg/L	11/17/2010 12:07	10/29/2010	EPA 200.7 Rev 4.4	1	0.05	0.17			
Mercury, Total	0.04	µg/L	11/11/2010 16:13	10/29/2010	EPA 345.2	1	0.04	0.05			
Nitrate, Total	0.2	µg/L	11/13/2010 12:13	10/29/2010	EPA 300.8 Rev 5.4	1	0.4	1			

MN Certification # 027-137-152

Respect temperature within regulatory guidelines

Page 10 of 15



Ergo Laboratories, Inc.

4730 Creech Street Duluth, MN 55807 Telephone: (218) 727-6360 Fax: (218) 727-3048

Laboratory Report

Project Number: 050406
COC Number: 797742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Sample ID: FLSN DS
Ergo Project Number: 050406-11

Parameter	Results	Units	Analysis Date/Time	Sample Date	Method	Sample Time	Matrix	Visc	LOD	LOQ	QC Comments
pH - Lac	6.2	SU	11/5/2010 16:45		SM 4500-H ₂ O-00 OL						
Sulfate	1.4	mg/L	11/12/2010 7:15		EPA 300.0 Rev 2.1				0.5	1.5	1
Arsenic, Total	< 0.4	µg/L	11/12/2010 12:17		EPA 200.8 Rev 5.4				0.4	1	
Calcium, Total	3.16	mg/L	11/17/2010 12:14		EPA 200.7 Rev 4.4				0.06	0.17	
Cobalt, Total	1	µg/L	11/12/2010 12:17		EPA 200.8 Rev 5.4				0.4	1	
Copper, Total	6.4	µg/L	11/12/2010 12:17		EPA 200.8 Rev 5.4				0.4	1	
Hardness, Total (as CaCO ₃)	17.7	mg/L	11/17/2010 10:46		EPA 200.7 Rev 4.4				0.3	1	
Iron, Total	1.07	mg/L	11/17/2010 10:17		EPA 200.7 Rev 4.4				0.01	0.04	
Magnesium, Total	2.36	mg/L	11/17/2010 12:14		EPA 200.7 Rev 4.4				0.05	0.17	
Mercury, Total	< 0.04	µg/L	11/14/2010 15:13		EPA 245.2				0.04	0.06	
Nickel, Total	5.1	µg/L	11/12/2010 12:17		EPA 300.8 Rev 5.4				0.4	1	

MA Certification # 027-137-152

Resists temperatures within regulatory guidelines

Page 11 of 15



Era Laboratories, Inc.

4730 Canada Street Duluth, MN 55807 Telephone: (218) 727-6380 Fax: (218) 727-3048

Laboratory Report

Project Number: 050459
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Sample ID:	FILSON DS	Sample Date:	10/29/2010	Sample Time:	14:00	Matrix:	Water
Era Project Number:	050459-12	Analysis Date/Time:	11/5/2010 16:45	Method:	SM 4500-H+9-00 CL	LOQ:	LOQ
Parameters:		Units:		DF:		OC Comments:	
pH - Lab Filtered	6.4	SU					
Sulfate, Dissolved	1.4	mg/L	11/12/2010 7:30		0.5	1.5	4
Arsenic, Dissolved	< 0.4	mg/L	11/12/2010 12:20		0.4	1	
Calcium, Dissolved	5.2	mg/L	11/12/2010 12:16		0.05	0.17	
Cobalt, Dissolved	7	µg/L	11/12/2010 12:20		0.4	1	
Copper, Dissolved	6	µg/L	11/13/2010 12:20		0.4	1	
Hardness, Dissolved (as CaCO3)	17.9	mg/L	11/17/2010 10:49		0.3	1	
Iron, Dissolved	0.21	mg/L	11/17/2010 10:19		0.01	0.04	
Magnesium, Dissolved	2.4	mg/L	11/17/2010 12:16		0.05	0.17	
Mercury, Dissolved	< 0.04	µg/L	11/14/2010 15:13		0.04	0.05	
Nickel, Dissolved	7.3	µg/L	11/12/2010 12:20		0.4	1	

MAA Certification # 027-137-152

Recept temperature within regulatory guidelines

Page 12 of 15



Era Laboratories, Inc.

4730 Oneida Street, Duluth, MN 55807 Telephone: (218) 727-4300 Fax: (218) 727-3048

Laboratory Report

Project Number: 050459
COC Number: 732742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103645

Sample ID: FILSON GAGE
Era Project Number: 058499-13

Parameters:

Parameter	Results	Units	Analysis Date/Time	Sample Date	Method	DF	LOD	Matrix	Went	OC Comments
pH - Lab	6.2	SU	11/5/2010 16:45	10/29/2010	SM 4500-HV-B-00 CL	1				
Sulfate	1.1	mg/L	11/12/2010 7:45		EPA 300.0 Rev 2.1	1	0.5	1.5	J	
Arsenic, Total	0.4	µg/L	11/12/2010 12:32		EPA 200.8 Rev 5.4	1	0.4	1	J	
Calcium, Total	5.18	mg/L	11/17/2010 12:18		EPA 200.7 Rev 4.4	1	0.05	0.17		
Cobalt, Total	0.8	µg/L	11/12/2010 12:32		EPA 200.8 Rev 5.4	1	0.4	1	J	
Copper, Total	5.5	µg/L	11/12/2010 12:32		EPA 200.8 Rev 5.4	1	0.4	1		
Hardness, Total (as CaCO ₃)	17.7	mg/L	11/12/2010 10:48		EPA 200.7 Rev 4.4	1	0.3	1		
Iron, Total	0.96	mg/L	11/17/2010 10:20		EPA 200.7 Rev 4.4	1	0.01	0.04		
Magnesium, Total	2.36	mg/L	11/17/2010 12:18		EPA 200.7 Rev 4.4	1	0.05	0.17		
Mercury, Total	< 0.04	µg/L	11/11/2010 15:13		EPA 245.2	1	0.04	0.05		
Nickel, Total	3.9	µg/L	11/12/2010 12:32		EPA 200.8 Rev 5.4	1	0.4	1		

MN Certification # 027-137-182

Residue temperature within regulatory guidelines

Page 13 of 15



Era Laboratories, Inc.
4730 Omega Street Duluth MN 55807

Telephone: (216)727-6380 Fax: (216)727-3048

Laboratory Report

Project Number: 059429
OCC Number: 730742
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103646

Sample ID:	FILSON GAGE	Sample Date:	10/29/2010	Sample Time:	14:30	Matrix:	Water
Era Project Number:	059429-14	Analysis Date/Time:	11/5/2010 16:45	Method:	SM 4500-HB-00 CL	LOD:	OC Comments:
Parameter:	Results:	Units:	Analysis Date/Time:	Method:	LOD:	OC Comments:	
pH - Lab	6.2	SU	11/5/2010 16:45	SM 4500-HB-00 CL	1		
Sulfate	1.4	mg/L	11/12/2010 8:01	EPA 300.0 Rev 2.1	1	1.5	J
Arsenic, Total	0.4	µg/L	11/12/2010 12:38	EPA 200.8 Rev 5.4	1	0.4	J
Calcium, Total	3.22	mg/L	11/17/2010 12:20	EPA 200.7 Rev 4.4	1	0.05	0.17
Cobalt, Total	0.9	µg/L	11/12/2010 12:38	EPA 200.8 Rev 5.4	1	0.4	J
Copper, Total	5.3	µg/L	11/12/2010 12:38	EPA 200.8 Rev 5.4	1	0.4	J
Hardness, Total (as CaCO3)	17.9	mg/L	11/17/2010 10:49	EPA 200.7 Rev 4.4	1	0.3	
Iron, Total	1.04	mg/L	11/17/2010 10:22	EPA 200.7 Rev 4.4	1	0.01	0.04
Magnesium, Total	2.4	mg/L	11/17/2010 12:20	EPA 200.7 Rev 4.4	1	0.05	0.17
Mercury, Total	0.04	µg/L	11/11/2010 15:13	EPA 245.2	1	0.04	0.05
Nickel, Total	3.9	µg/L	11/12/2010 12:38	EPA 200.8 Rev 5.4	1	0.4	1

MN Certification # 027-137-152

Receipt timestamp within regulatory guidelines

Page 14 of 15



Era Laboratories, Inc.

4730 Oneida Street, Duluth, MN 55807 Telephone: (218) 727-6380 Fax: (218) 727-3048

Laboratory Report

Project Number: 059409
COC Number: 73274Q
Date Received: 11/4/2010
Report Date: 11/23/2010
Report Number: 103046

Sample ID: FILSON GAGE
Era Project Number: 059409-15

Parameter	Results	Units	Analyte Date/Time	Method	Sample Date	Sample Time	Matrix	Water
pH - Lab, Filtered	8.4	EU	11/5/2010 18:45	SM 4500-H+8-00 CL	10/29/2010	14:30		
Sulfate, Dissolved	1.3	mg/L	11/12/2010 8:16	EPA 300.0 Rev 2.1				
Arsenic, Dissolved	0.4	µg/L	11/12/2010 12:40	EPA 200.6 Rev 5.4				
Calcium, Dissolved	3.11	mg/L	11/17/2010 12:23	EPA 200.7 Rev 4.4				
Copper, Dissolved	0.9	µg/L	11/12/2010 12:40	EPA 200.8 Rev 5.4				
Copper, Dissolved	5.2	µg/L	11/12/2010 12:40	EPA 200.8 Rev 5.4				
Hardness, Dissolved (as CaCO ₃)	17.4	mg/L	11/17/2010 10:49	EPA 200.7 Rev 4.4				
Iron, Dissolved	0.48	mg/L	11/17/2010 10:24	EPA 200.7 Rev 4.4				
Magnesium, Dissolved	2.33	mg/L	11/17/2010 12:23	EPA 200.7 Rev 4.4				
Mercury, Dissolved	< 0.04	µg/L	11/17/2010 15:13	EPA 245.2				
Nickel, Dissolved	4.8	µg/L	11/12/2010 12:40	EPA 200.8 Rev 5.4				

Results are reported on an as received basis.

< Not detected. Less than LOD

J Estimate. Result between LOD and LOQ

Report Approved By:
Robert D. Magnuson
Lab Director

MLL Certification # 027-137-152

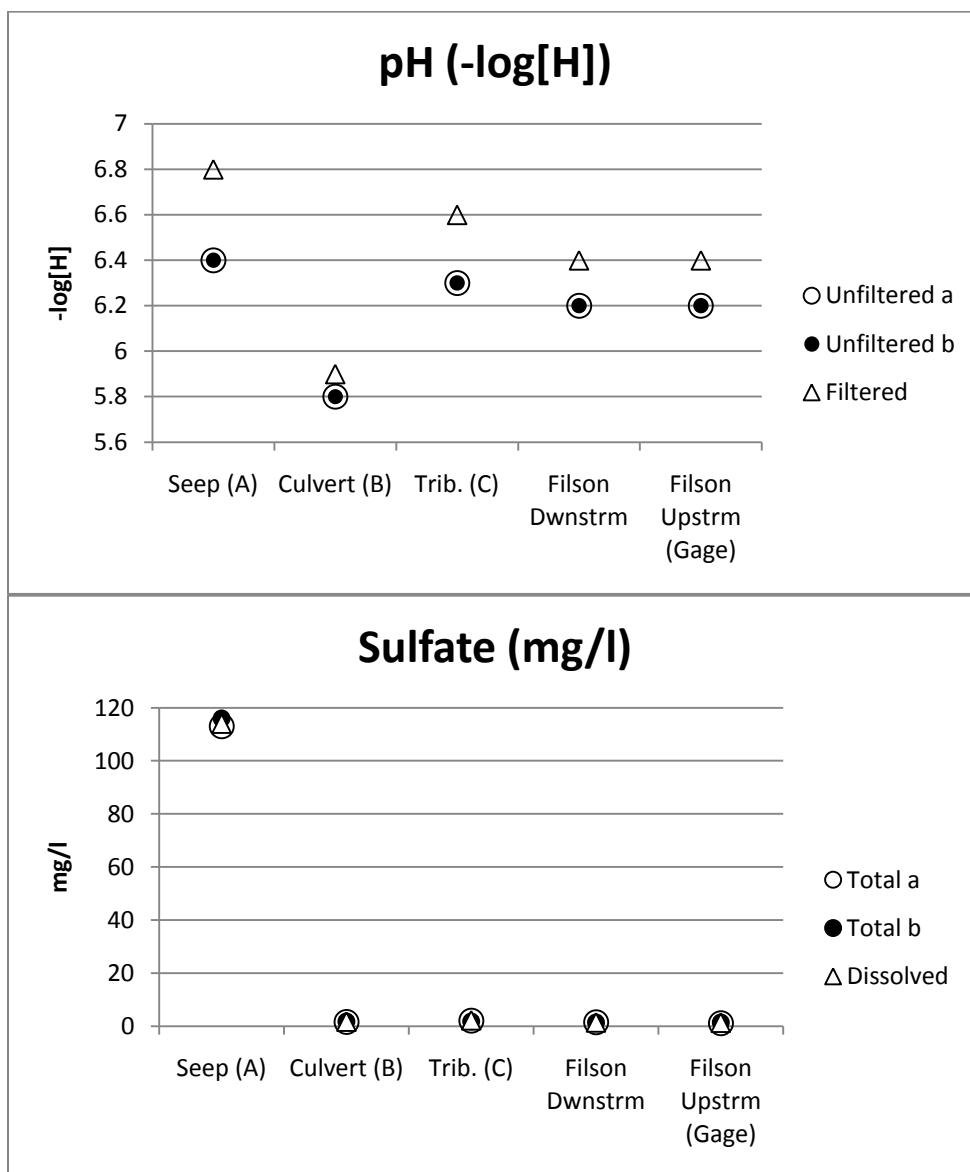
Total results in this report relate only to the samples received on the dates indicated. This report must not be reproduced, except in full, without the written approval from Era Laboratories, Inc. All tests were performed in-house by Era Labs.

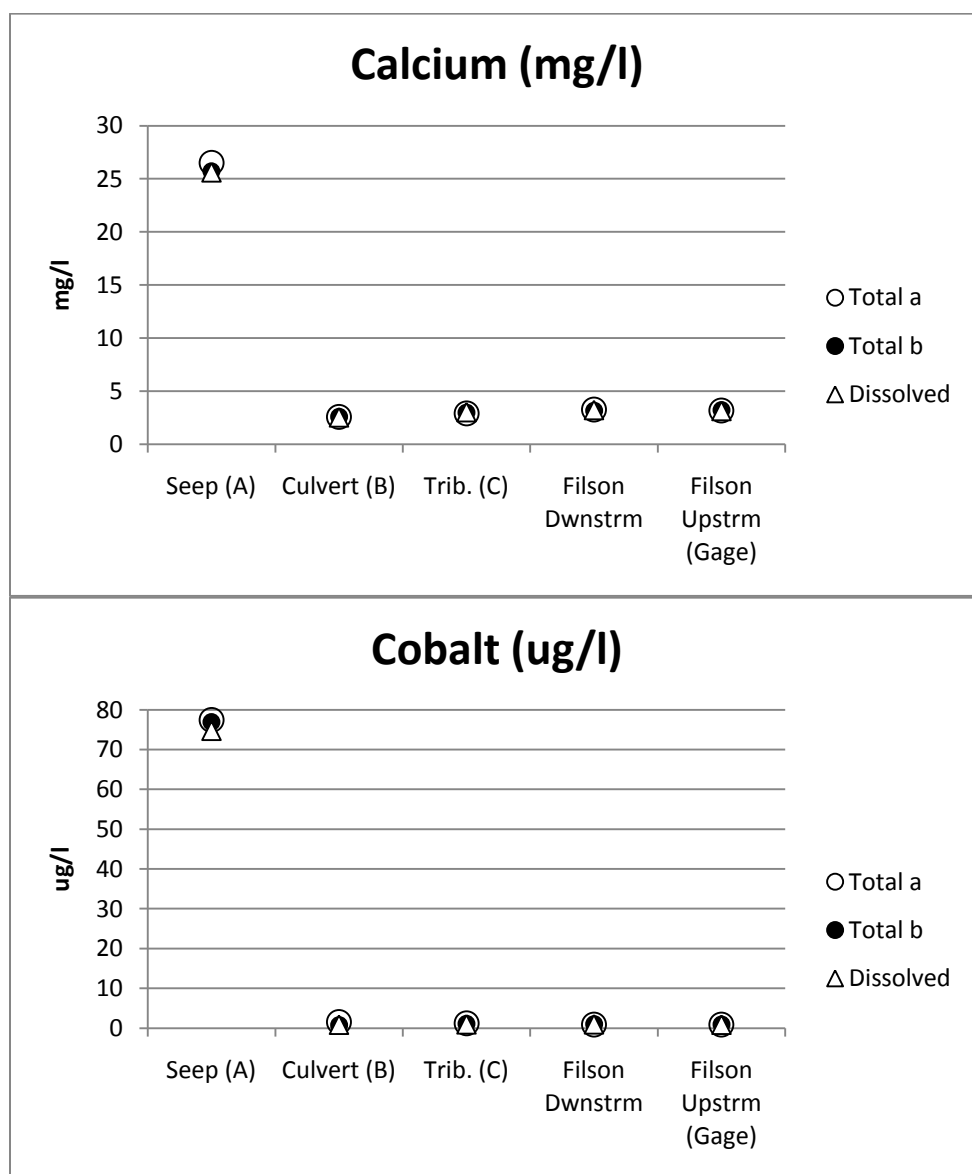
Temperature upon arrival (°C): 3.2
Revised temperature within regulatory guidelines

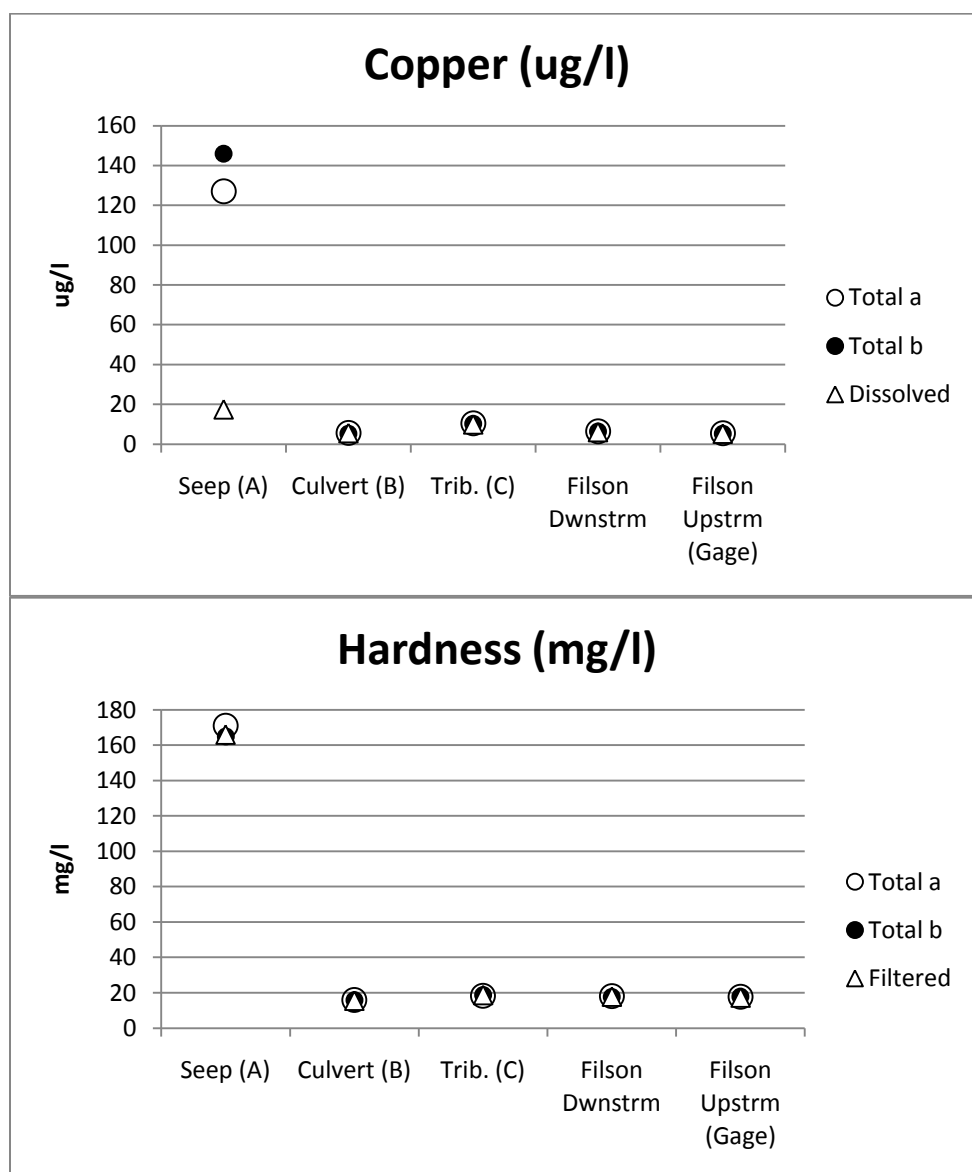
Page 15 of 15

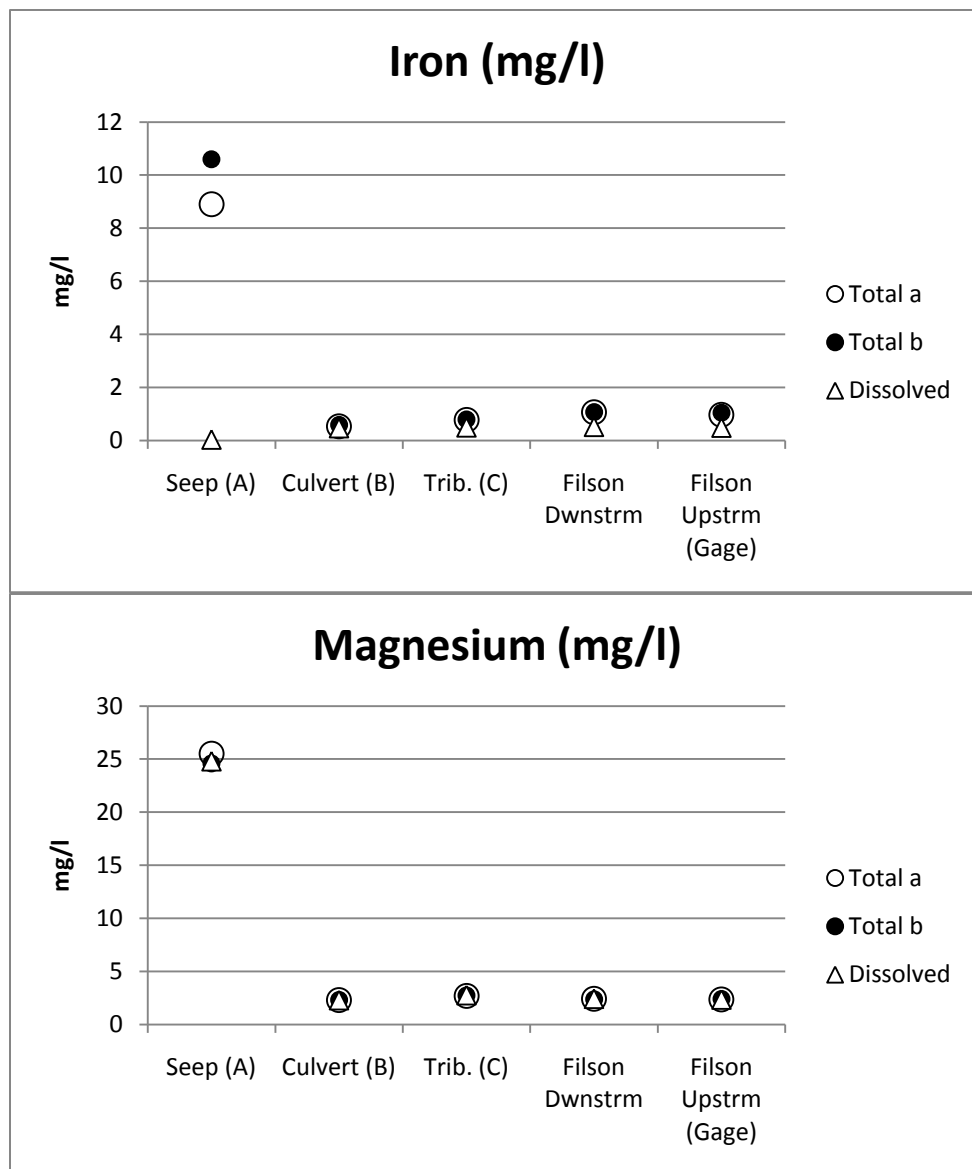
Appendix 3a:

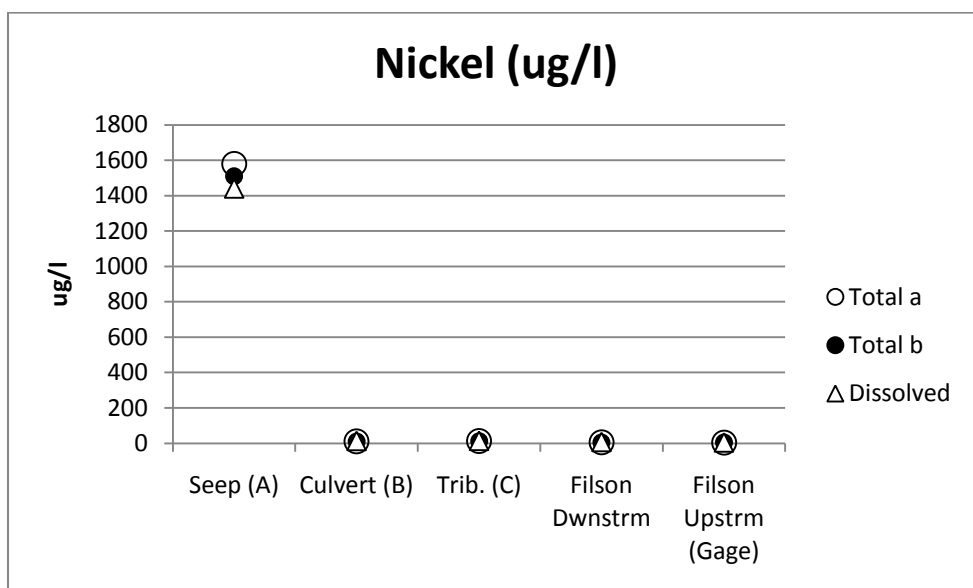
Graphs for surface water samples taken at Spruce Road Bulk Sample Sites on 10-29-2010. Each symbol represents a sample point; circles represent unfiltered (total) samples and triangles represent filtered (dissolved) samples.





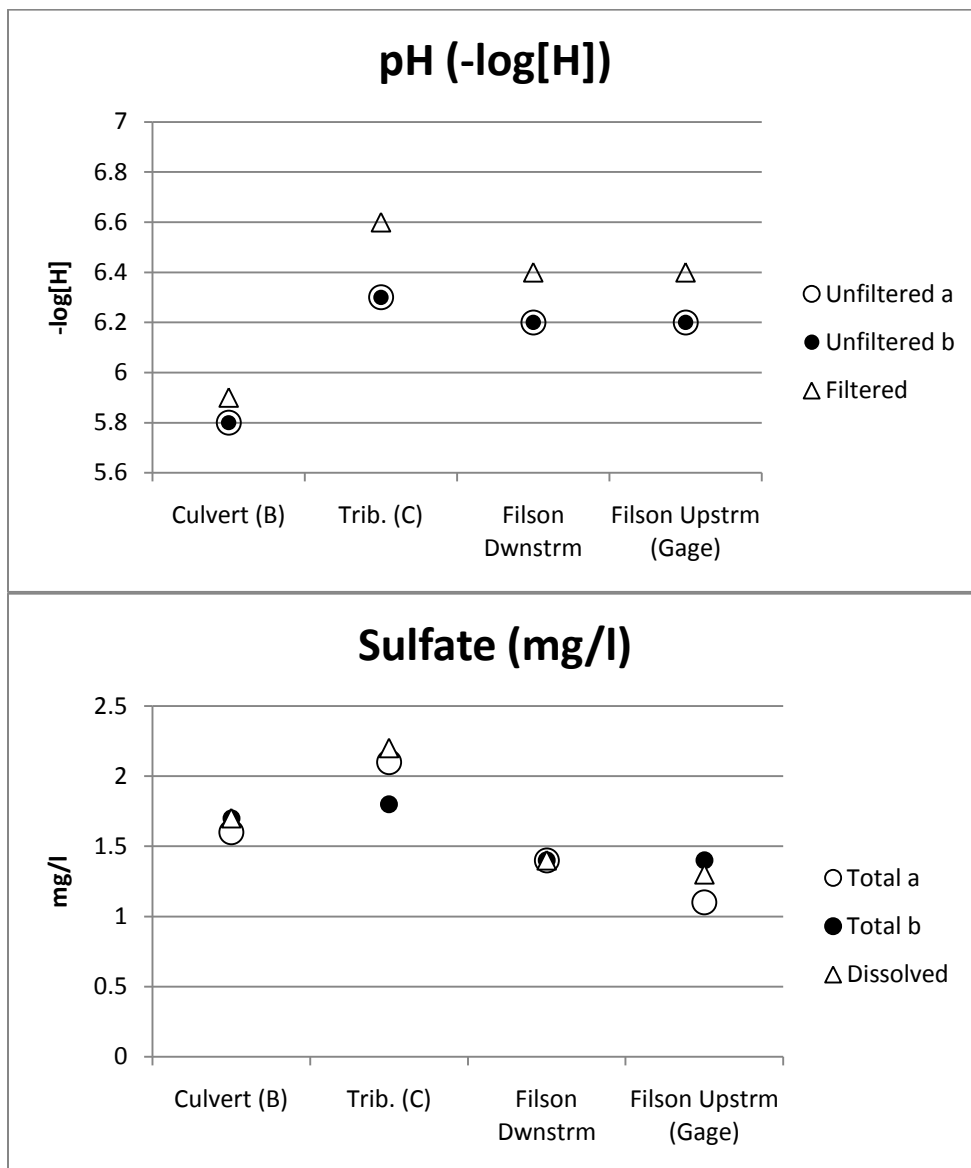


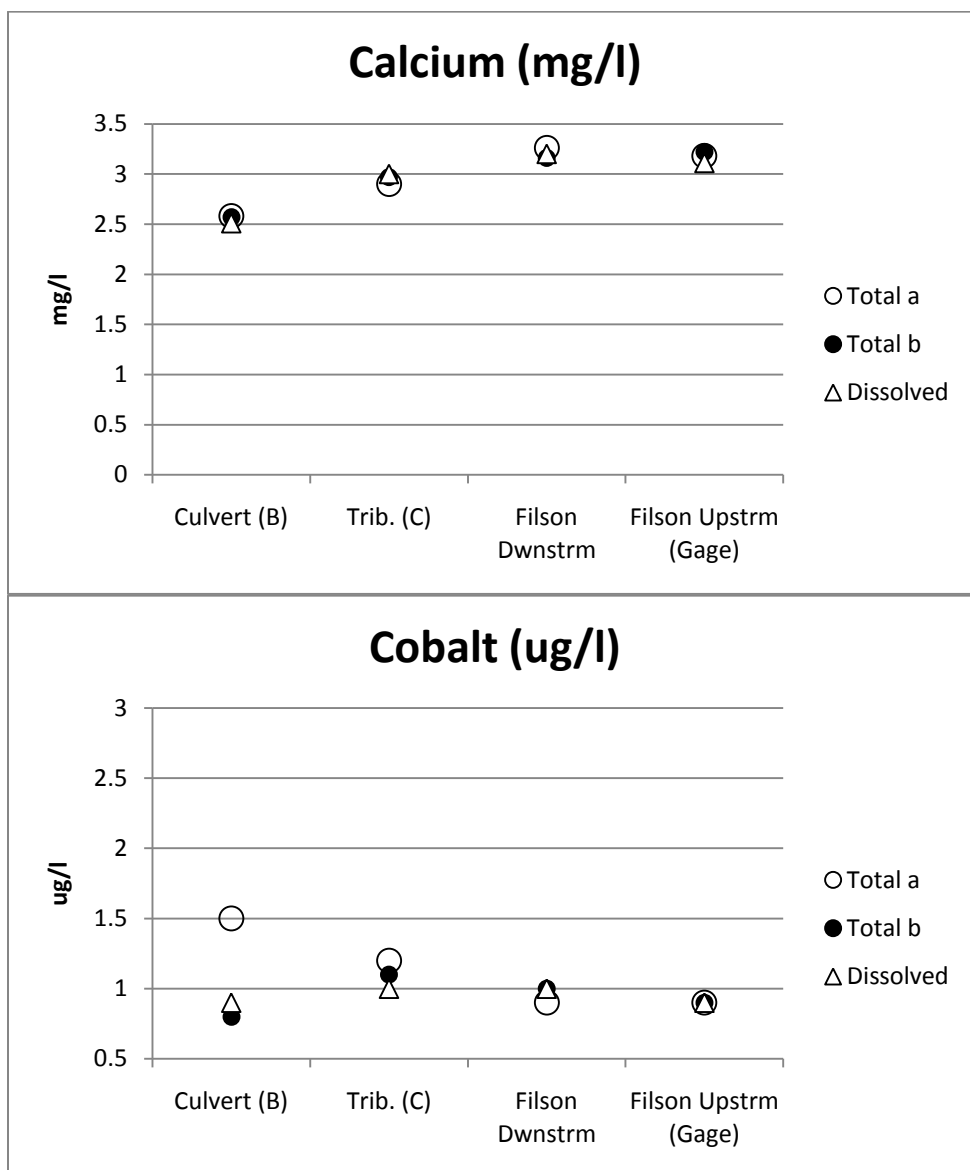


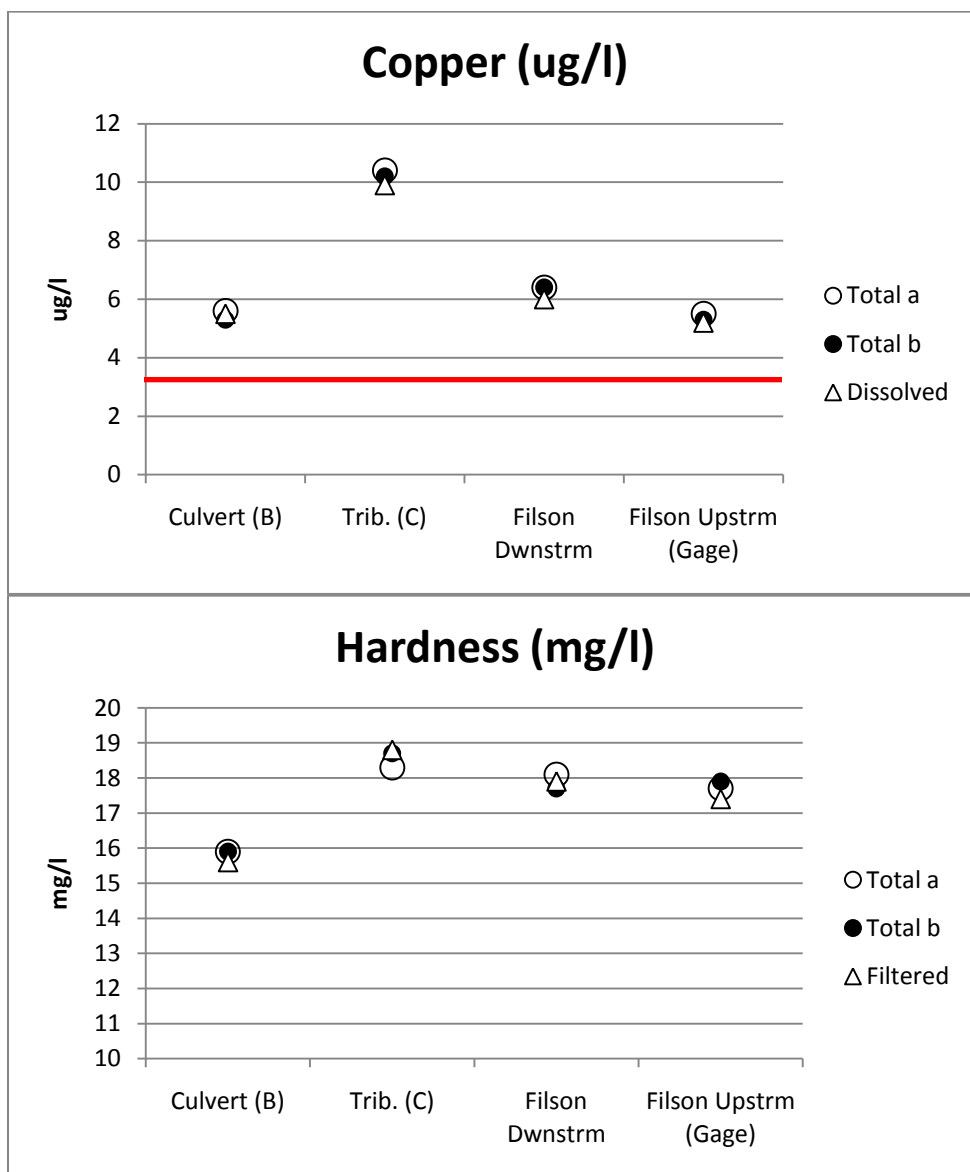


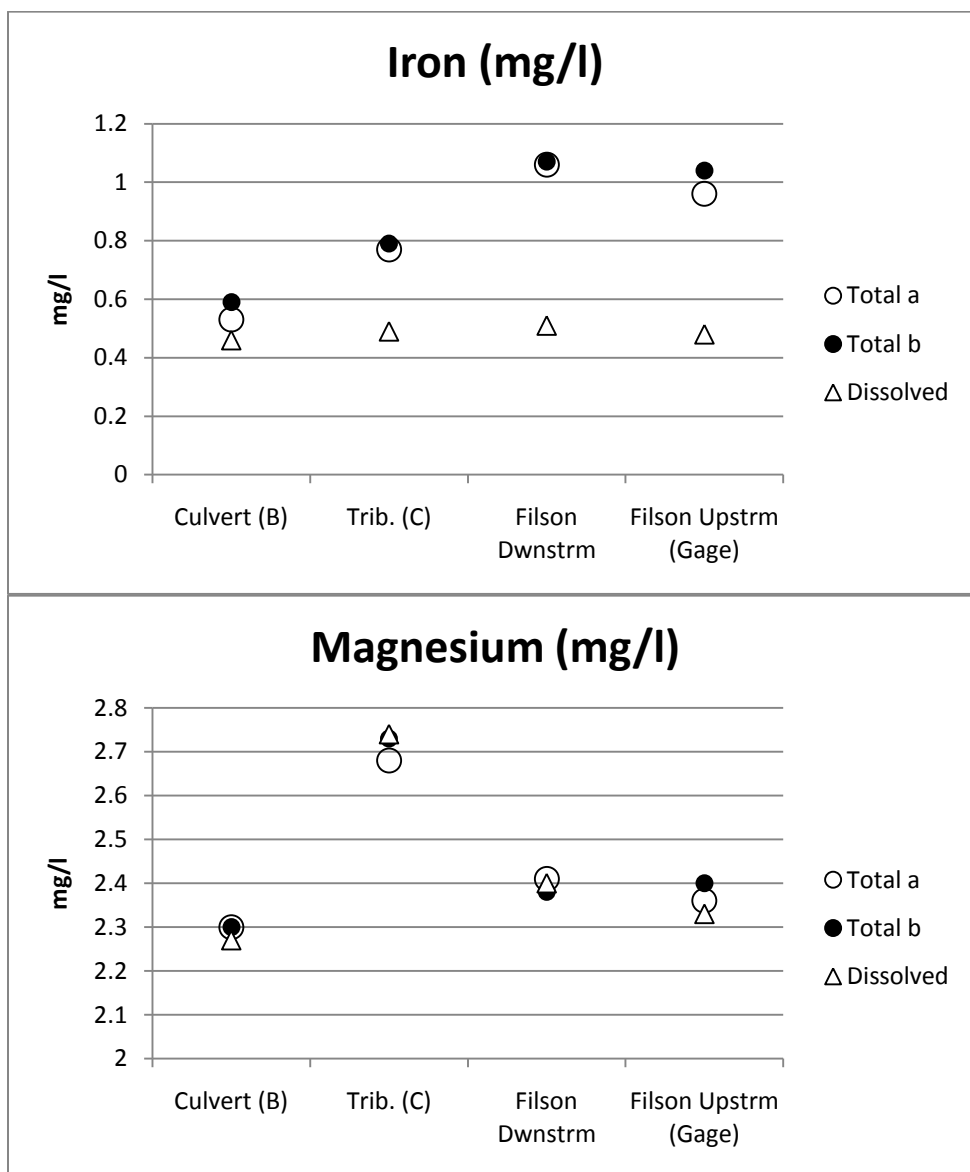
Appendix 3b:

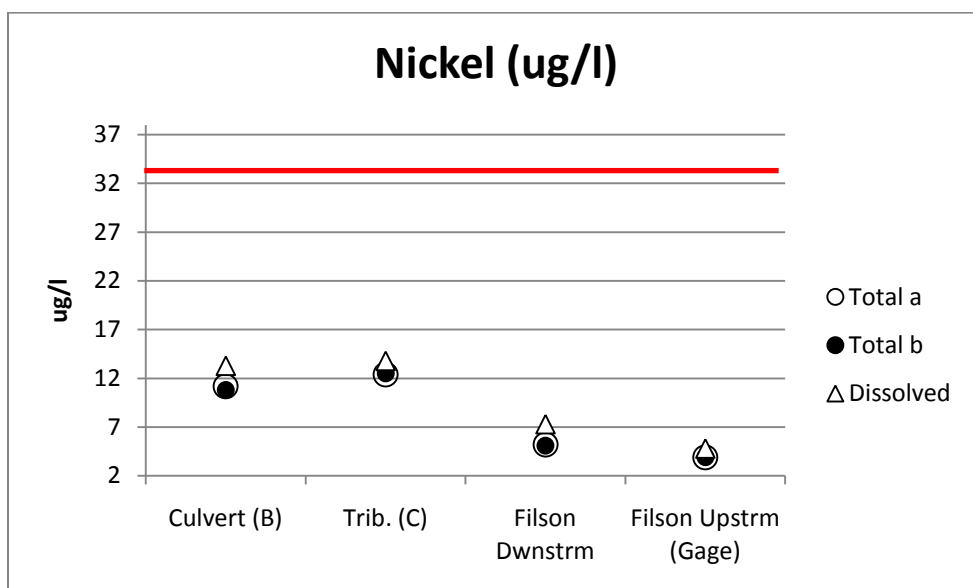
Graphs for surface water samples taken at the Spruce Road Bulk Sample Site on 10-29-2010. Each symbol represents a sample point; circles represent unfiltered (total) samples and triangles represent filtered (dissolved) samples. Seep data was not plotted for scale. When present, a red line denotes the water quality standard for a chemical constituent (Class 2B waters of the state; aquatic life and recreation).





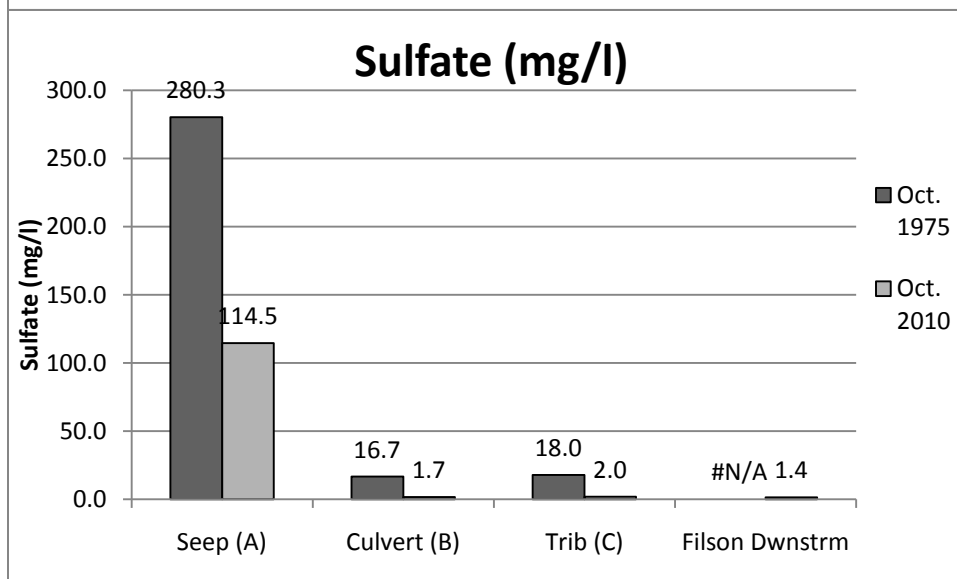
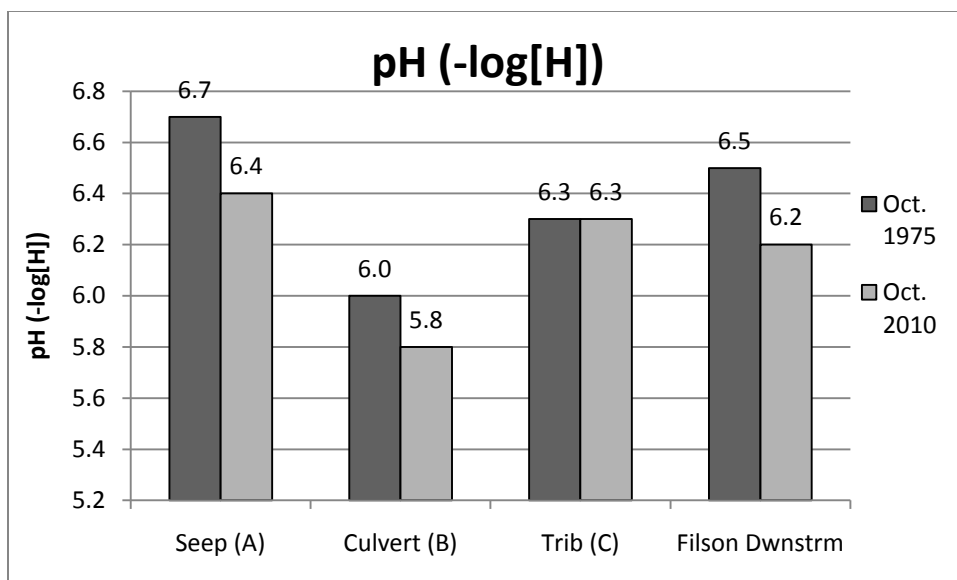


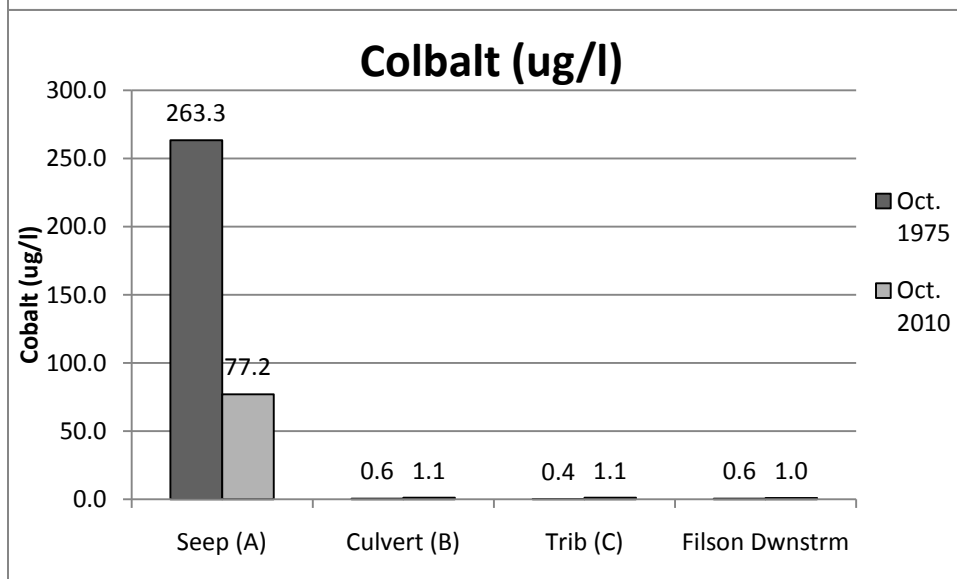
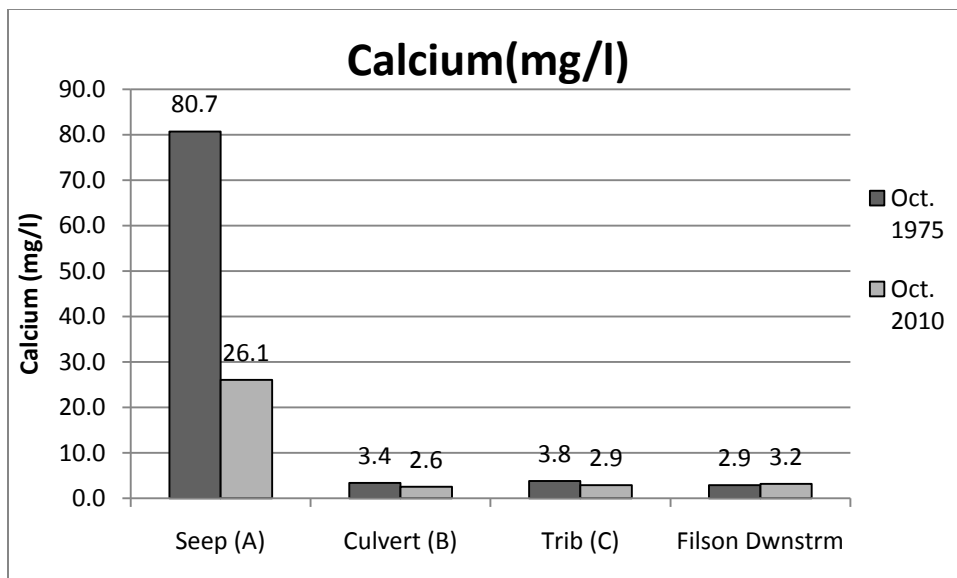


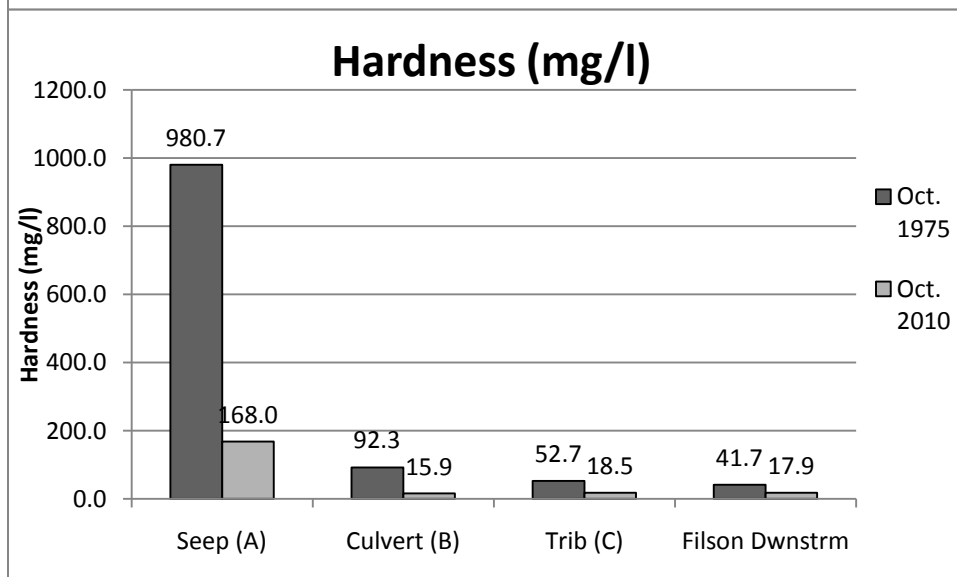
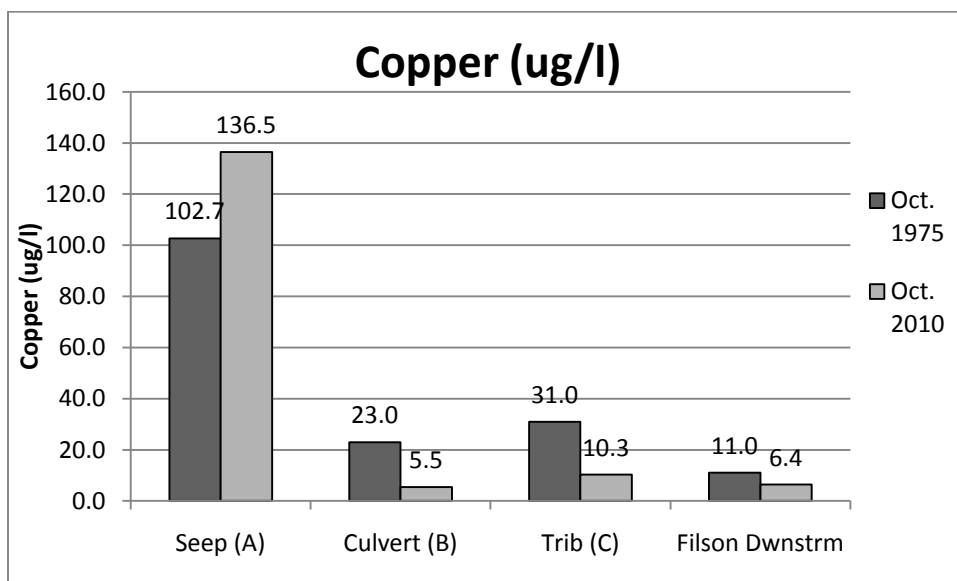


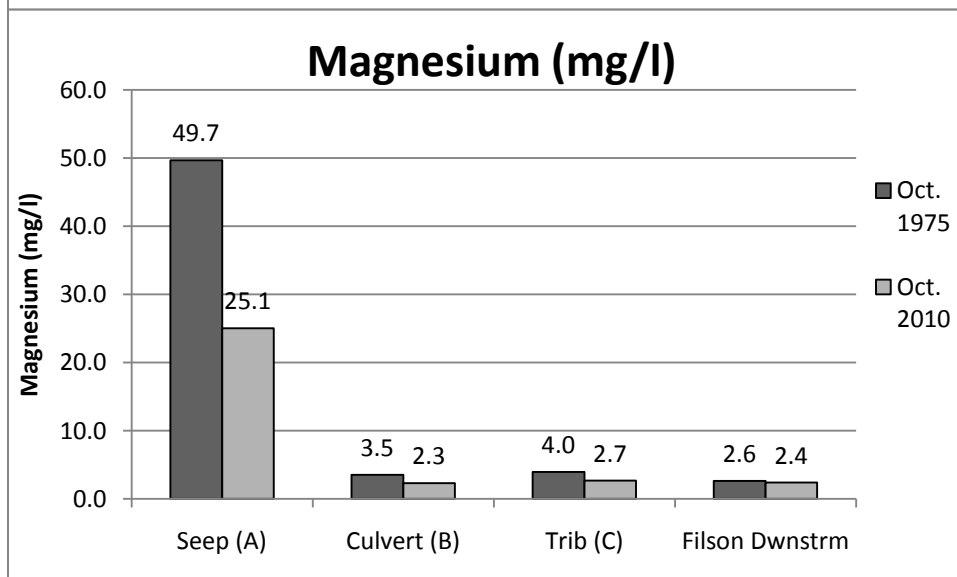
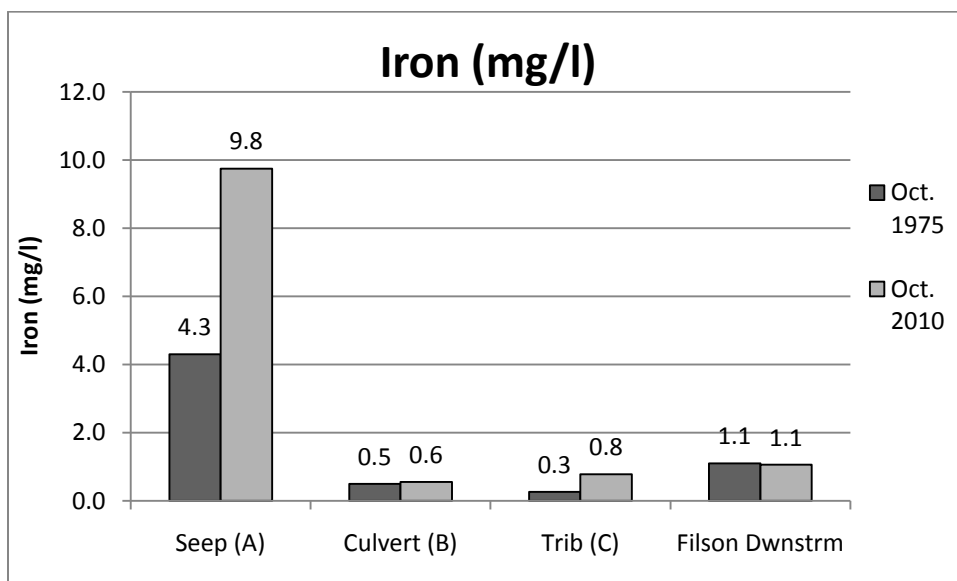
Appendix 4:

Graphs for surface water samples taken at
Spruce Road Bulk Sample Sites comparing chemical constituents during
October, 1975 (n=3) and October, 2010 (n=2).









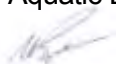
Appendix 5:

Flow Rates of Spruce Road Bulk Sample Seep, Tributary to Filson Creek at Spruce Road, and Filson Creek at Spruce Road on 10/29/2010.

Interoffice Memo

Date: 2/2/2011

To: Jason Butcher, SNF Aquatic Ecologist

From: Marty E. Rye, P.E. 
Superior National Forest Hydrologist

RE: Flow Rates of Spruce Road Bulk Sample Seep, Tributary to Filson Creek at Spruce Road, and Filson Creek at Spruce Road on 10/29/2010

Summary

Water quality samples were collected from the Spruce Road Bulk Sample Seep, the Tributary to Filson Creek at Spruce Road, and Filson Creek at Spruce Road on 10/29/2010. In order to convert concentrations to loading rates the flow or discharge is needed. The discharge rate at the seep was directly measured and there is a continuously recording flow gage at Filson Creek at Spruce Road that is maintained by the Minnesota Department of Natural Resources (MnDNR). Flow within the Tributary to Filson Creek at Spruce Road was estimated based upon observed conditions and a flow ratio with Filson Creek established by previous flow measurements. The flow rates at these locations are summarized below in Table 1.

Table 1. Comparison of Discharge Rates on 10/29/2010

	Spruce Road Bulk Sample Seep	Tributary to Filson Creek at Spruce Road	Filson Creek at Spruce Road
Discharge Rate ^(1,2)	0.00009 cfs (.04 gpm)	0.07 cfs (31 gpm)	2.99 cfs (1,342 gpm)
Computed Ratio to Tributary to Filson Creek Discharge	-----	1 :1	43 :1
Computed Ratio to Seep Discharge	1 :1	778 :1	33,222 : 1
% of Filson Creek Flow Downstream of Confluence with Tributary (assuming total = 2.99+0.07 = 3.06 cfs)	0.003%	2.3%	97.7%

(1) cfs = cubic feet per second (2) gpm = gallons per minute

Methods and Results

Seep

The discharge at the seep was directly measured as 160ml in a minute. Only one measurement was taken using a graduated bottle. This translates to:

$$(160\text{ml/minute}) * (1 \text{ minute} / 60 \text{ sec}) * (1 \text{ cubic ft} / 28,317 \text{ ml}) = 0.00009 \text{ cfs, or}$$

$$(160\text{ml/minute}) * (1 \text{ gallon} / 3,785 \text{ ml}) = 0.04 \text{ gpm}$$

As a comparison a typical bathroom faucet will run at 2 gallons per minute. So, it is approximately 1/50th or 2% of a running bathroom faucet. Alternatively, at this rate it would take about 24 minutes to fill up a gallon bucket.

Tributary to Filson Creek

A water quality sample was collected from the Tributary to Filson Creek upstream of the Spruce Road Crossing. The A direct measurement of discharge was not made during the 10/29/2010 field visit. However, the discharge was indirectly estimated based upon four different methods:

1. Measurement of the headwater and tailwater at the culverts beneath Spruce Road
2. Mass balance of constituencies within Filson Creek
3. Comparison to historic measured flows and flow ratio with Filson Creek, and
4. Personal observation

The headwater and tailwater was measured at the culverts beneath Spruce Road. The crossing consists of twin 15-inch corrugated metal pipes (cmp's) beneath the roadway. A survey of these pipes was completed on 1/31/2011. The tailwater was observed to be below the inverts of the culverts on 10/29/2010 and was therefore considered a free discharge. Photos of the upstream and downstream ends of culverts are shown below in Figures 1 and 2.



Figure 1 – Upstream End
Unnamed Trib to Filson at Spruce Rd
HW ~ 0.7 ft, but likely clogged



Figure 2 – Downstream End
Unnamed Trib to Filson at Spruce Rd
Note: free discharge and magnitude of
discharge << 1 cfs

The headwater was measured to be 0.7 ft at the culverts (see Attachment A). The *computed* discharge rate for this condition is 1.7 cfs (see Attachment B). However, as shown in Figure 3 the observed flow is much less than 1.7 cfs. Some flow could be undermining the culvert outlet if the culvert has failed under the embankment. However, there was no observed failure and the observed flow downstream of the crossing remained much less than 1.7 cfs. Observation of flow conditions on 10/29/2010 at the confluence between the Tributary and Filson Creek confirms that the flow in the Tributary was not close to half of the flow in Filson Creek (estimated to be 2.99 cfs – see below). As a matter of comparison, the contributing watershed area for Fison Creek is approximately 35 times larger than the contributing drainage area for the Tributary. Hence, it is considered that there was internal blockage of the culvert that raised the headwater of the culvert. Observation of the upstream end of the culverts (see Figure 1) confirm the potential for blockage within the culvert. Thus, based upon these considerations the *computed* discharge rate based upon the measured culvert headwater is *rejected*.



Figure 3. Exploded view of downstream end of Spruce Road culverts

In addition, the flow was estimated using a mass balance within Filson Creek downstream of the mouth of the Tributary (see Appendix B). The results of this analysis did not compare well with the observed flow conditions as described above and shown in Figure 3. Coincidentally, the estimated flow using the mass balance is similar to the calculated flow using the culvert headwater. As described above, this is considered to be inconsistent with observed conditions and is rejected. If the estimated flow of 0.07 cfs (as estimated below using historic flow ratios – described below) is used in the mass balance analysis, the concentration constituents

downstream of the mouth of the Tributary in Filson Creek would be less than the observed values. This discrepancy between the observed values and the computed values can be attributed to a combination of natural variability and uncertainty. There is some variability in the discharge rate, mixing zones, and local fluxes. In addition, there is some uncertainty because there is some additional flow that enters the system between the water quality sample locations and additional contact with surface material.

The fourth method used to estimate the flow in the Tributary is to compare the flow in Filson Creek based upon collected data in 1976. The flow in Filson Creek at the gage site upstream of Spruce Road for 10/29/2010 is reported as 2.99 cfs during the day by the MnDNR (see below). As shown in Attachment C the computed flow in the Tributary based upon comparison of values collected in 1976 range from 0.05 to 0.07 cfs. This is consistent with the observed magnitude of flow on 10/29/2010.

Based upon the analysis described above and field observations, it is estimated that the Tributary to Filson Creek at Spruce Road had a discharge of 0.07 cfs during the mid day of 10/29/2010. As a matter of comparison this correlates to:

$$(0.07 \text{ cubic feet / sec}) * (448.8 \text{ gpm / cfs}) = 31 \text{ gpm}$$

It is estimated that the accuracy of this estimate is likely within 20% based upon other available measurements.

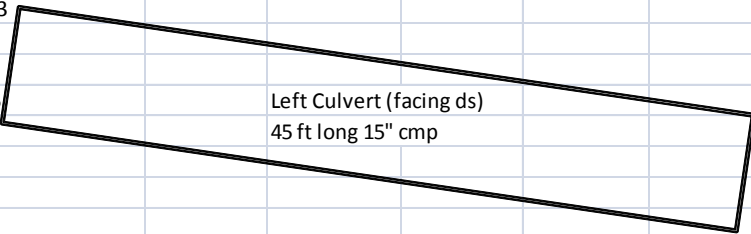
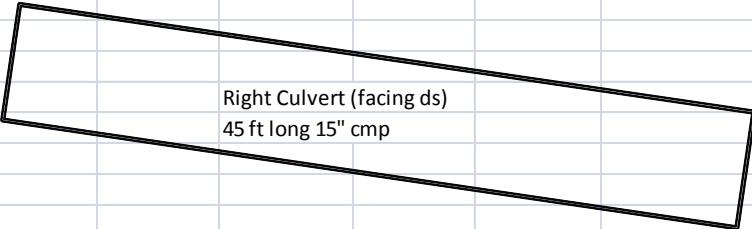
Filson Creek

As mentioned above there is a continuous recording gage at the sample site that is maintained by the Minnesota Department of Natural Resources (MnDNR). The flow was reported by the MnDNR as 2.99 cfs (see Attachment C).

As a matter of comparison this correlates to:

$$(2.99 \text{ cubic feet / sec}) * (448.8 \text{ gpm / cfs}) = 1,342 \text{ gpm}$$

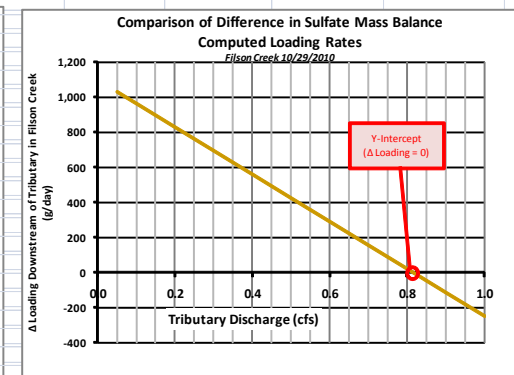
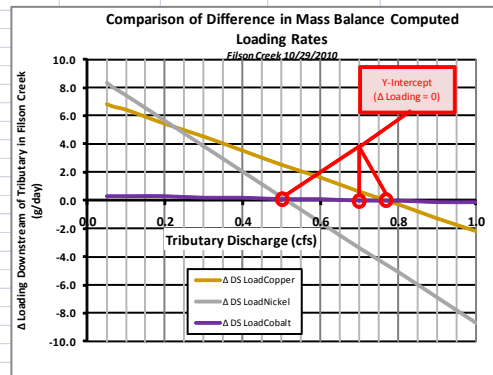
Attachment A
Results of 1/31/2011 Survey of Spruce Road Culverts
at Tributary to Filson Creek

Title of Survey: Survey of culverts on Spruce Road at Unnamed Tributary to Filson Creek near Bulk Sample					
Date of Survey: 1/31/2011					
Personnel: Notes: J. Garcia / Instrument: J. Garcia					
Instrument: Laser level, stadia with mirror, and cloth tape					
Conditoons: Clear ~ 10°F					
<u>Shot Description</u>	<u>Backsight (BS)</u>	<u>Height of Instrument (HI)</u>	<u>Foresight (FS)</u>	<u>Elevation</u>	<u>Notes</u>
TBM1		108.21	8.21	100.00	Temporary Benchmark, downstream top of left 15-inch cmp culvert (facing downstream) - Assumed Benchmark
Upstream Top of Left Culvert	7.98			100.23	15- inch cmp measured 45 ft long
Invert Upstream Left Culvert	9.36			98.85	
Upstream Top of Right Culvert	8.02			100.19	15- inch cmp measured 45 ft long
Invert Upstream Right Culvert	9.39			98.82	
Downstream Top of Left Culvert	8.21			100.00	
Invert Downstream Left Culvert	9.46			98.75	
Downstream Top of Right Culvert	8.40			99.81	
Invert Downstream Right Culvert	9.55			98.66	
Top Centerline of Road	5.23			102.98	
Closure			8.21	108.21	check
Centerline Road = 102.98					
100.23					TBM1
98.85					100.00
					98.75
100.19					99.81
98.82					98.66

Attachment B - Computed Culvert Discharge at Tributary to Filson Creek

- (1) Culvert Headwater Assuming No Blockage, and
- (2) Mass Balance of Constituents in Filson Creek Downstream of Tributary

Flow Conditions on 10/29/2010 on Tributary to Filson Creek at Spruce Road			
Measured by: M.Rye / E. Wirz using staff gage ("pocket rod")			
	HW Depth 10/29/2010 (ft)	HW Elevation (based upon 1/31/2011 survey)	TW Depth 10/29/2010 (ft)
Left Culvert	0.69	99.54	Free Discharge
Right Culvert	0.71	99.53	Free Discharge
Note: orientation of culverts is facing downstream			
From Rating Curve:			
Q Left =	0.79 cfs		
Q Right =	0.92 cfs		
Total Computed =	1.70 cfs		
However, observations (see photo below) indicate the headwater elevation on the Q Left was due to blockage and there was very little flow in the left culvert. In addition, the discharge in the right culvert appears to be <i>much</i> less than the computed value of 0.9 cfs - likely also some blockage.			



**NOTE: COMPUTED VALUES DID NOT CORRESPOND TO OBSERVED
CONDITIONS AND WERE NOT USED FOR LOADING ANALYSIS**

Attachment C

Comparison of Measured Flows in 1976

TABLE II

Flow Ratios: Filson/Tributary

<u>Date</u>	<u>Filson CFS</u>	<u>Tributary CFS</u>	<u>Ratio</u>
4/13/76	74	1.76	42
5/5/76	17	.34	50
5/20/76	3.3	.09	37
6/22/76	14	.35	40
7/7/76	2.8	.03	93
7/20/76	.94	.02	47
8/5/76	.18	--	--

Figure C-1: Filson / Tributary Flow Values and Ratios from:
May 26, 1977 Spruce Road Bulk Sample Site Monitoring Results

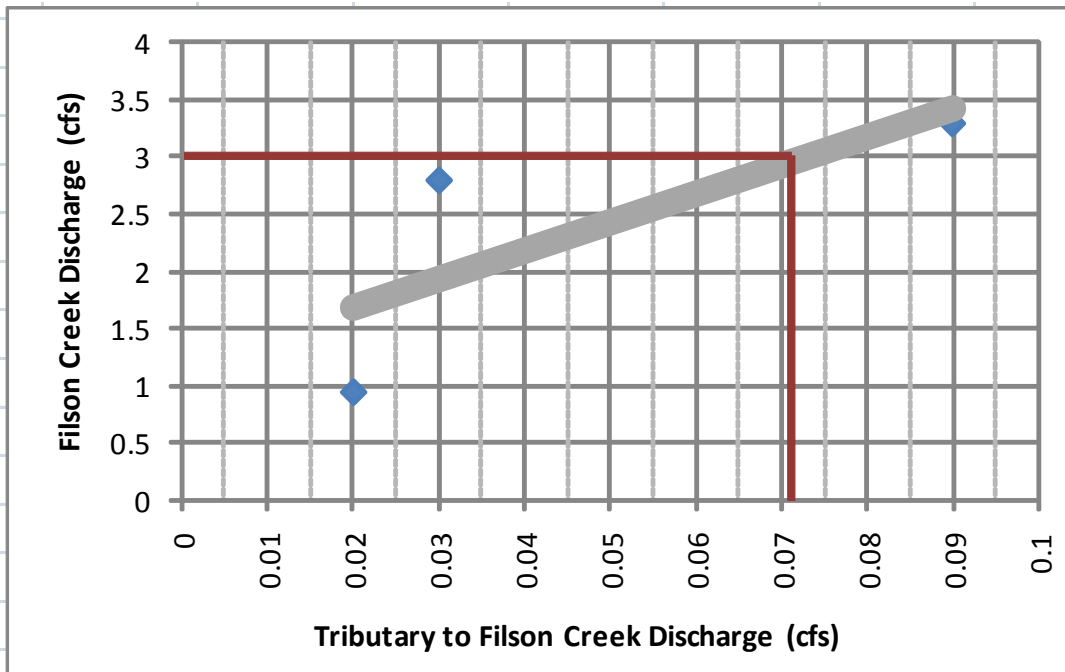


Figure C-2: Filson / Tributary Flow Ratios
Linear Trend Line developed using only $Q_{\text{Filson}} \leq 3.3$ cfs
Based upon this analysis $Q_{\text{Tributary}} = 0.07\text{cfs}$ at $Q_{\text{Filson}} = 2.99$ cfs

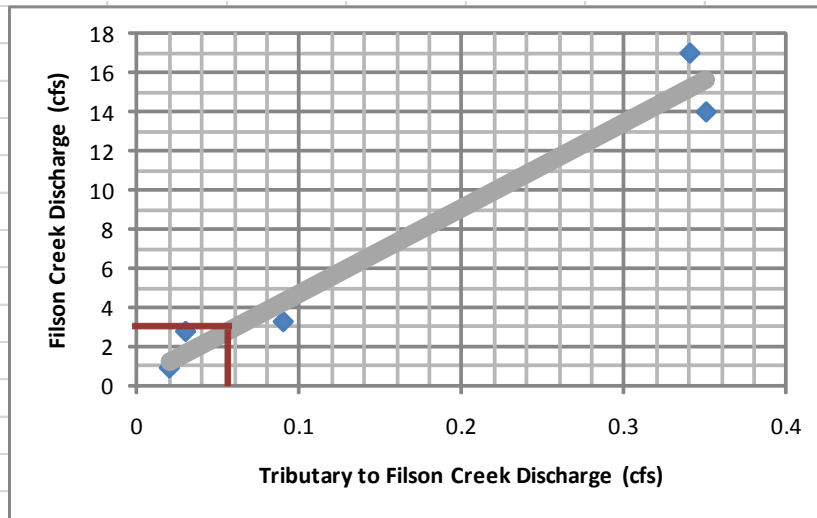


Figure C-3: Filson / Tributary Flow Ratios
Linear Trend Line developed using only $Q_{\text{Filson}} \leq 17$ cfs
Based upon this analysis $Q_{\text{Tributary}} = 0.06$ cfs at $Q_{\text{Filson}} = 2.99$ cfs

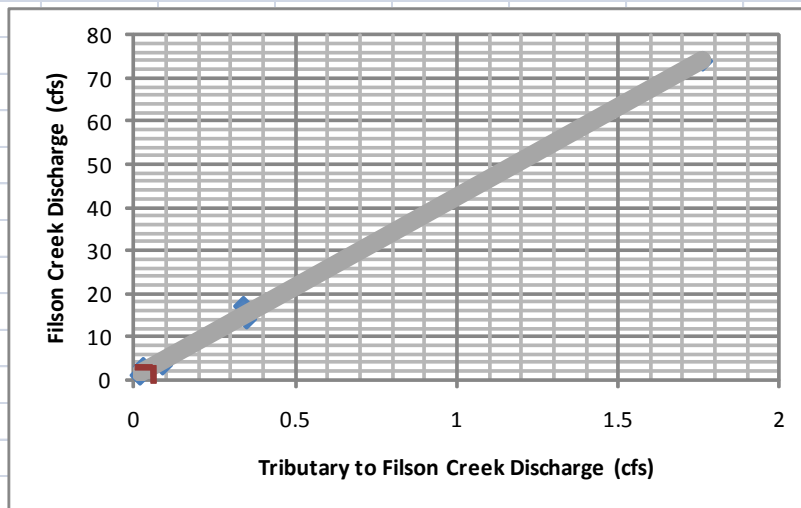


Figure C-4: Filson / Tributary Flow Ratios
Linear Trend Line developed using all 1976 data
Based upon this analysis $Q_{\text{Tributary}} = 0.05$ cfs at $Q_{\text{Filson}} = 2.99$ cfs

Alternatively, if simple linear interpolation is used between the two data points collected in 1976:

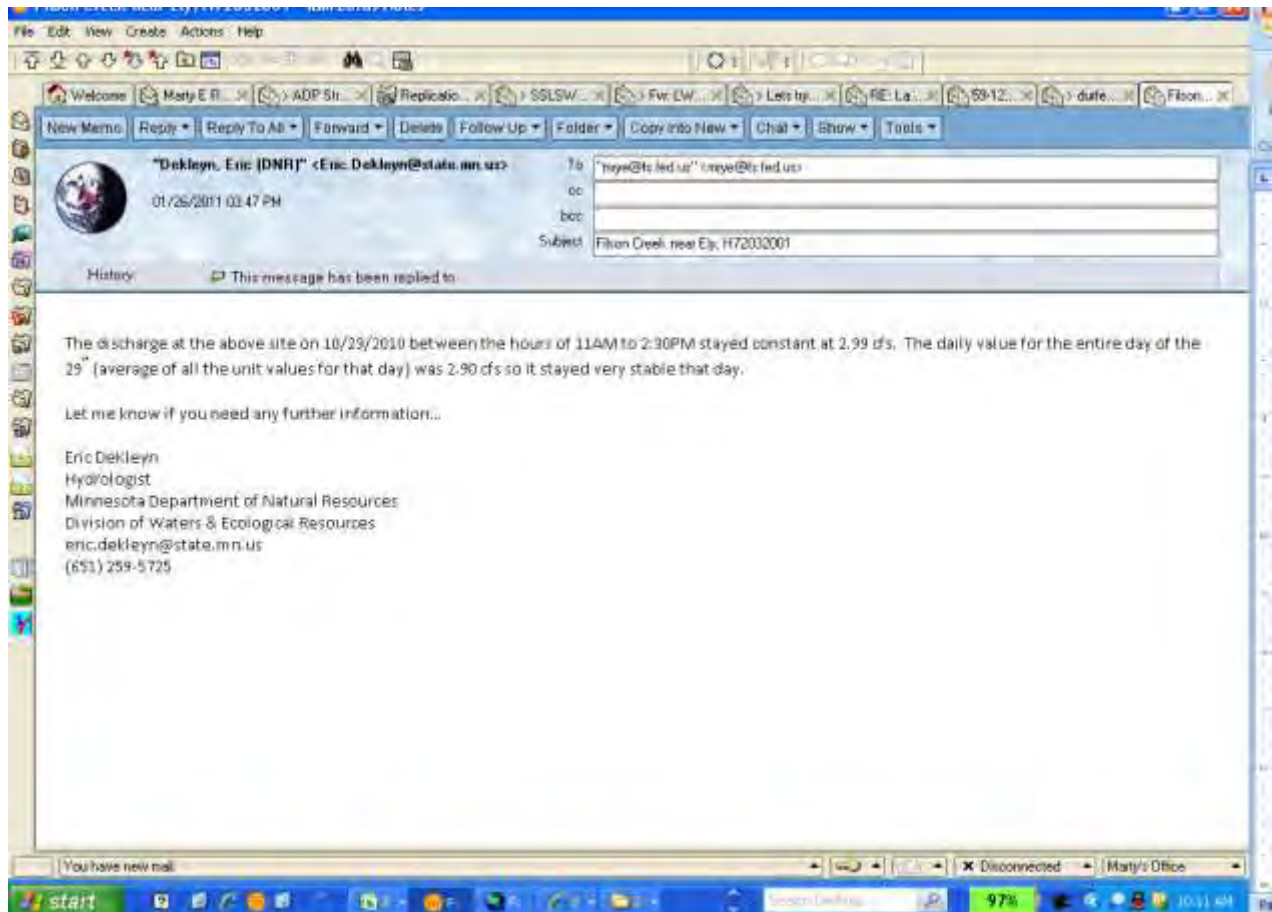
$$\begin{array}{ll} Q_{\text{Filson}} = 2.8 \text{ cfs} & Q_{\text{Tributary}} = 0.03 \text{ cfs} \\ Q_{\text{Filson}} = 3.3 \text{ cfs} & Q_{\text{Tributary}} = 0.09 \text{ cfs} \end{array}$$

Then, $Q_{\text{Tributary}}$ at $Q_{\text{Filson}} = 3.0$ cfs is:

$$(3.0 - 2.8) / (3.3 - 2.8) * (0.09 - 0.03) + 0.03 = 0.05 \text{ cfs}$$

Attachment D
Recorded Flow at Filson Creek on 10/29/2010

Recorded Flow at MnDNR Gage on Filson Creek on 10/29/2010:



Appendix 6:
Photos taken on 10/29/2010 at
Spruce Road Bulk Sample Sites.



Above: Top of Bulk Sample Site;

Below: Collecting water samples at the seep outlet with a hand pump (Left) and sample bottles (Right).





Above, Left: Upstream of Culvert crossing on tributary to Filson Creek below the seep;
 Above, Right; Downstream of crossing on tributary to Filson Creek below the seep

Below, Left; Filson Creek upstream of Spruce Road at Gage site.
 Below, Right; Filson Creek downstream of Spruce Road at Gage site.



March 10, 2011

Commissioner Paul Aasen
Minnesota Pollution Control Agency
520 Lafayette Road N
St. Paul, MN 55155-4194

RE: Dunka Pit NPDES/SDS Permit Inconsistencies with Federal and State Law

Dear Commissioner Aasen:

Paula Maccabee is an attorney representing WaterLegacy and Bruce Johnson is a member of the Advisory Committee of WaterLegacy and a former employee of the Minnesota Department of Natural Resources (MDNR) and the Minnesota Pollution Control Agency (MPCA). In his prior capacity as agency staff, Mr. Johnson had direct responsibility for various aspects of study and control of discharge from the Dunka Mine. Mr. Johnson has since done extensive research regarding the discharge from the Dunka Mine and the federal and state rules that are applicable to this discharge.

Ms. Maccabee and Mr. Johnson jointly submit this letter expressing WaterLegacy's concerns pertaining to the inconsistency of the Dunka Mine National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) permit *MN0042579* with applicable federal and state regulations enacted pursuant to the Clean Water Act.

Although the MPCA entered into a Consent Decree on March 25, 2010 regarding the violation by Cliffs Erie L.L.C. of this Dunka Mine NPDES/SDS permit, the Consent Decree fails to address the underlying and serious concern that the year 2000 NPDES/SDS permit for the Dunka Mine is itself deficient and inconsistent with applicable federal and state regulations. We are requesting that the MPCA, with oversight of the U.S. Environmental Protection Agency (USEPA), review and reissue appropriate permits for the Dunka Mine to address the issues and concerns discussed herein.

As discussed in more detail below, the Dunka Mine NPDES/SDS permit *MN0042579* is deficient and inconsistent with federal and state regulations in the following respects:

1. The initial NPDES/SDS permit for the Dunka Mine predates the USEPA's implementation recommendations to categorize permits as "major" permits based on the level and toxicity of discharge. Since 1990, it does not appear that the Dunka Mine NPDES/SDS permit has been classified as a major discharge permit or that the USEPA has reviewed the permit for compliance with Clean Water Act requirements. The nature of metals and other toxic releases from the Dunka Mine support major permit status and greater scrutiny at both a state and federal level.
2. The year 2000 NPDES/SDS permit for the Dunka Mine does not cover all relevant pollutants and seeps. Two of the five outfalls from the mine have variances and lack discharge standards for copper, nickel, cobalt and zinc. The additive toxicity limit in the permit does not include cobalt. The NPDES/SDS permit does not set a limit for mercury, hardness or specific conductance, although discharges are likely to exceed Minnesota surface water quality standards.
3. The NPDES/SDS permit for the Dunka Mine sets toxicity standards based on high levels of hardness contributed by mine pollution, rather than according to the

uncontaminated background hardness of receiving waters.

4. The NPDES/SDS permit for the Dunka Mine sets toxicity limits based on the Final Acute Value (FAV), although the seven-day 10-year low flows (7Q10) for receiving waters (Unnamed Creek and Flamingo Creek) are zero, so that toxicity should be set using a more protective Chronic Standard (CS).
5. The NPDES/SDS permit for the Dunka Mine contains no limit for sulfates, which are routinely discharged at levels exceeding 1000 milligrams per liter (mg/L), although receiving waters drain into Birch Lake and the Kawishiwi River, both of which are known to contain stands of wild rice.
6. The NPDES/SDS permit for the Dunka Mine expired on June 30, 2005 and has not been reissued, while variances have gone more than a decade without public review. The MPCA has neither required operation of the Dunka water treatment plant nor comprehensive reductions of waste stockpile infiltration.

WaterLegacy would request that the following actions be taken by the MPCA, under the review and scrutiny of the USEPA:

- A. Categorize the Dunka Mine as a major NPDES facility, permits for which are subject to USEPA oversight.
- B. Reissue NPDES/SDS permits for the Dunka Mine, voiding variances from the year 2000 permit and imposing discharge limits as follows:
 - Limits on metals (copper, nickel, cobalt and zinc) for all seeps and outfalls in compliance with federal and state chronic (not acute) water quality standards;
 - Limits on mercury, hardness and specific conductance in compliance with federal and state surface water quality standards;
 - Additive aquatic toxicity standards including cobalt as well as copper, nickel and zinc, based on background hardness of receiving waters;
 - Sulfate limits based on the presence of wild rice in receiving waters.
- C. Require Cliffs Erie L.L.C. to take immediate steps to mitigate toxic discharge and make changes that will reasonably result in compliance with state and federal water quality standards, including but not limited to the following:
 - Operation of the on-site active water treatment plant to treat seepage water;
 - Reshaping of stockpiles so that they can be completely covered by a synthetic membrane to reduce leaching from precipitation;
 - Escrow of funds to allow for active water quality treatment, maintenance and periodic replacement of the synthetic membrane over waste rock stockpiles for at least 200 years.

BACKGROUND

From its inception, enforcement of water quality standards at the Dunka Mine near Babbitt, Minnesota has posed unique challenges due to the presence of Duluth Complex sulfide-mineralized rock at the mine. Although the Erie Mining Company and later LTV Steel Mining Company operated an open-pit taconite mine rather than a metallic sulfide mine, at Dunka their mine encountered and excavated millions of tons of sulfide rock to mine the underlying taconite.

In the mid-1970's, the Minnesota Environmental Quality Board (MEQB) and the MPCA

determined to refrain from water quality enforcement at the Dunka Mine until Minnesota had completed its *Regional Copper Nickel Study 1976-1979* and studied the chemistry of leaching, including toxicity and mitigation.¹ Excavation of sulfide-mineralized rock was recognized to pose distinctive problems.

Dunka Mine waste rock stockpiles drain into the waters of Unnamed Creek and Flamingo Creek, which flow into Bob Bay of Birch Lake. Although LTV requested that Unnamed Creek be classified as an industrial ditch (class 7), the MPCA, MDNR, and USEPA have determined Unnamed Creek should be classified under Minnesota Rules as Minnesota water. Unnamed Creek, Flamingo Creek and Birch Creek are class 2B, 3C, 4A, 4B, 5 and 6 waters under Minn. R. 7050.0430.

Birch Lake drains into the Kawishiwi River, which is classified as a 1B, 2Bd, 3C water. Minn. R. 7050.0470, Subp. 2(A)(29). The waters from the Kawishiwi River ultimately discharge to surface waters in the Boundary Waters Canoe Area, and from there to Canada's Quetico National Park. The watershed is part of the Rainy Lake Basin, is considered international waters and is under International Joint Commissions purview.

DISCUSSION

1. The NPDES/SDS Permit for the Dunka Mine Should be Considered a Major Permit.

In May of 1975 the first NPDES/SDS permit for the Dunka Mine was issued. At that time it was considered to be a "minor" permit.² This may have been because the mine was assumed to be similar to other taconite mines in the district, where discharges were fairly well understood. Major permits receive higher levels of USEPA permit and enforcement review, while minor permits are almost wholly left to states for permitting and enforcement.

In 1990, the USEPA included toxic releases in their evaluation of major permits; since then, the rating worksheet for NPDES permits includes toxic discharge considerations.³ A facility discharging to surface water with an EPA rating score of more than 80 points based on such factors as flow volume, toxic pollutant potential, and public health impact is a "major permit."

Minnesota Rules provide that a facility with an actual or potential discharge of toxic pollutants under section 307(a)(1) of the Clean Water Act, United States Code, title 33, section 1317 must be considered a "major NPDES facility." Minn. R. 7002.0220, subp. 4(D). The list of toxic pollutants under section 307(a)(1) is provided in USEPA regulations at 40 CF.R. §401.15. Copper, mercury, nickel and zinc and compounds containing these metals are explicitly listed by the USEPA as "toxic pollutants." 40 CF.R. §401.15(22), (45), (47), (65).

The MPCA has been aware of discharge of toxic metal pollutants at the Dunka Mine since at least 1976.⁴ Although it is basic to the NPDES program that permits and effluent

¹ MEQB Letter, Paul Eger to Abner Fisch, MPCA (Dec.14, 1976) ("Eger 1976 Memo"), Attachment A.

² USEPA, email response to Bruce Johnson re FOIA Request, #05-FOI-01595-10 (Oct. 25, 2010) Attachment B.

³ USEPA, James Elder, *New NPDES Non-Municipal Permit Rating System* (June 27, 1990) and rating <http://www.epa.gov/npdes/pubs/owm0116.pdf> (last visited Mar. 8, 2011) ("USEPA NPDES Memo").

⁴ Eger 1976 Memo, *supra*.

limitations be reviewed and reissued every five years,⁵ the USEPA has no records that the status of the Dunka permit has ever been reevaluated to determine whether it is a major permit under current rating systems.⁶

Based on its discharge of toxic pollutants, the MPCA should rate the Dunka Mine NPDES/SDS permit as a major NPDES facility, and the USEPA should exercise oversight in developing new NPDES/SDS requirements in compliance with the Clean Water Act. The Discussion below demonstrates that this oversight would demonstrate that, in addition to questions of non-compliance addressed in the Consent Decree, the underlying Dunka Mine NPDES/SDS permit fails to comply with federal and state rules implementing the Clean Water Act.

2. The NPDES/SDS Permit for the Dunka Mine Should Be Rewritten to Cover all Pollutants and all Seeps.

Under the Clean Water Act, it is “national policy that the discharge of toxic pollutants in toxic amounts be prohibited.” 33 U.S.C. § 1251. Copper, nickel, zinc and mercury are “priority toxic pollutants” under Section 304(a) of the Clean Water Act. Federal regulations enacted pursuant to the Clean Water Act require NPDES permits to include effluent limitations for every individual pollutant that causes, has the reasonable potential to cause, or contribute to and excursion above numeric water quality criterion. 40 C.F.R. § 122.44 (d)(1)(iii). The Dunka Pit NPDES/SDS permit fails to comply with the Clean Water Act and these implementing regulations.

In 1976, Dunka Mine waste rock seepages were determined to contain 10 to 10,000 times background levels of copper (Cu), nickel (Ni), cobalt (Co) and zinc (Zn). Total hardness, specific conductivity, and sulfate were found to exceed water quality standards, while some seepages were pH neutral and some had acid pH. Even where Dunka seepages were in a near neutral range for pH, seepages discharged nickel, cobalt, copper and zinc above biologically toxic levels. Nickel was the major trace metal discharged from the seeps.⁷

Since 1978, Dunka Mine stockpile metal releases have been tested by MPCA and others using bioassays and have been determined to be toxic.⁸ Both Unnamed Creek and Bob Bay of Birch Lake have documented impacts on their natural biological characteristics, including elevated concentrations of metals in the fish, clams, and plants.⁹ These impacts are measurable more than three miles from the farthest Dunka seepages.

Even now, 32 years after the completion of Minnesota’s *Regional Copper Nickel Study 1976-1979*, the current Dunka NPDES/SDS permit limits copper, nickel, cobalt and zinc at only three of the five outfalls from the waste rock piles and fails to include cobalt in additive aquatic toxicity calculations. The permit sets no limit for mercury, hardness or specific conductance and, as discussed separately in section 5 of this Discussion, sets no sulfate limit despite discharge into wild rice waters. *See* Dunka Mine NPDES/SDS permit MN0042579.

⁵ See U.S. EPA NPDES Permit Program Basics Frequently Asked Questions, available at http://cfpub.epa.gov/npdes/faqs.cfm?program_id=45 (last visited Mar. 8, 2011).

⁶ USEPA, FOIA Request, #05-FOI-01595-10, Oct. 25, 2010 phone response to B. Johnson.

⁷ MDNR, *Environmental Leaching of Duluth Gabbro In Laboratory and Field Conditions; Oxidative Dissolution of Metal Sulfide and Silicate Minerals*, DNR, 1980, pp. 191 & 202 (“MDNR 1980”), available from authors on request.

⁸ MPCA Memo, Jerry Flom to Curt Sparks, “Mine Dump Seeps,” Sept. 1, 1988, Attachment C.

⁹ MPCA Memo, Mark Schmitt to Carri Lohse, “Birch Lake Fish Tissue Data,” July 26, 1985, Attachment D; MPCA Memo, Virginia Reiner to Ken Haberman, “Bob Bay Monitoring,” Jan. 5, 1984; Attachment E.

After the MPCA and MEQB agreement not to enforce discharge limits on the Dunka Mine until completion of the *Regional Copper Nickel Study*, no subsequent permits contained discharge limits for copper (Cu), nickel (Ni), cobalt (Co), zinc (Zn), hardness, sulfates or specific conductance for an additional 15 years. Only after the Dunka Mine closed in September 1994 did the September 30, 1994 permit establish a few discharge standards and compliance locations. Three out of the five outfalls: 040 (Seep EM-8), 060 (seep W2-3d), and 050 (seep W-1d) were given limits for Cu, Ni, Co, Zn. No limits were set for mercury, hardness, sulfates or specific conductance.

The most recent year 2000 NPDES/SDS permit for the Dunka Mine changed the 1994 permit's approach of using single standards for metals to an additive model, as allowed in Minn. R. § 7050.0222 Subp.7. The 2000 permit used additive calculation values for copper, nickel and zinc, applying a maximum hardness value of 400 mg/L. The permit set a cobalt limit of 50 ug/L,¹⁰ but did not include cobalt in its additive toxicity calculation.

Cobalt's aquatic toxicity does not diminish with increased hardness, but is solely toxicity-based. Minn. R. § 7050.0222. Although cobalt discharge from various seepages at the Dunka Mine have been documented above chronic surface water quality levels (5 ug/L) and even above the level of 50 ug/L set by the MPCA in the 2000 NPDES/SDS permit,¹¹ the MPCA's Dunka Mine permit did not include cobalt in additive calculations to protect aquatic species from toxic metals. This omission makes any toxicity assessment under the permit incomplete and inaccurate.

The most recent NPDES/SDS permit for the Dunka Mine also failed to place permit limits for mercury. Both Birch Lake and the Kawishiwi River, receiving waters for the Mine, are impaired waters for mercury. Minnesota Rules establish a limit of 0.2 parts per million of mercury in edible fish tissue, Minn. R. § 7050.0220, and Minnesota's Statewide TMDL sets a water column water quality standard for mercury in the Northeast Region of 1.3 ng/L.¹² Minnesota's approved statewide TMDL includes the Dunka Mine in the Northeast Region to which this 1.3 ng/L limit applies.¹³ DMR summary data suggests that even discharges from the Dunka Mine's "treatment" wetland have exceeded this level.¹⁴

Minnesota water quality standards limit hardness in Class 3B waters to 250 mg/L. Minn. R. § 7050.0223, Subp. 3. Under Minnesota Rules, exceedance of this hardness standard is among the conditions "indicative of a polluted condition which is actually or potentially deleterious, harmful, detrimental, or injurious with respect to the designated uses." Minn. R. § 7050.0223, Subp. 1. According to the *Regional Copper Nickel Study*, background hardness conditions in ambient waters in northeastern Minnesota range from 2 to 45

¹⁰ The MPCA Dunka Mine permit, MN00042579 pp. 8, 9, sets a cobalt standard of 50 ug/L, rather than the 5 ug/L chronic standard that should be applied based on flow levels, as explained in section 4 of this discussion.

¹¹ MPCA discharge monitoring reports (DMR) for MN00042579, for example, indicate SD009 (Seep X) cobalt discharge exceeding 100 ug/L to the "treatment" wetland in 2009; SD008 (Seep I) regularly exceeding 5 ug/L, with one sample as high as 101 ug/L.

¹² MPCA, *Strategy Framework for Implementation of Minnesota's Statewide Mercury TMDL*, July 7, 2008, p. 23, Appendix 1 to MPCA, *Implementation Plan for Minnesota's Statewide Mercury Total Maximum Daily Load* (Oct. 2009) <http://www.pca.state.mn.us/index.php/view-document.html?gid=11481> (last visited Mar. 8, 2011).

¹³ MPCA, *Minnesota Statewide TMDL Final*, March 27, 2007, p. vii, <http://www.pca.state.mn.us/index.php/view-document.html?gid=8507> (last visited Mar. 8, 2011).

¹⁴ See e.g. 2009 DMR for Dunka Mine, MN00042579, Surface Discharge Station SD007 (Seep EM-8 (041) Wetland Trmt Dschrg), average mercury of 2.2 ng/L.

mg/L.¹⁵

The hardness measured in Dunka Mine seepages ranges between 1000 to 2000 mg/L.¹⁶ Yet, the MPCA has failed to set limits for Dunka Mine hardness, even in the most recent 2000 permit. Given that Dunka Mine seepages are permitted to discharge over one million gallons per day (NPDES/SDS Permit MN00042579, p. 3), failure to limit hardness from Dunka seeps could have a significant impact on receiving waters. The Dunka Mine NPDES/SDS permit also sets no limit for specific conductance.

Minnesota's *Regional Copper Nickel Study* defined specific conductance as follows:

Specific conductance is a measure of water's ability to conduct electrical current, which in turn is the result of the presence of charged ionic species. In undisturbed igneous basins, characterized by insoluble rock, weathering is expected occur slowly. This should be reflected in low concentrations of dissolved ionic species and, consequently, low conductivity levels. This pattern was observed in the Study Area. Sites downstream from disturbed areas had median specific conductance levels almost six times higher than background sites.¹⁷

Peer-reviewed literature concludes that major ion imbalances can produce toxic effects in bioassays.¹⁸ Plant osmotic balances can be sensitive to dissolved ionic species. Elevated charged ionic species such as sulfate, calcium, magnesium, potassium, sodium, chlorides, heavy metals and other combinations of ions, individually or in aggregate, can disrupt plants' osmotic balances, stunting plant growth or killing plants.

Minnesota Rules recognize that significant ecological damage can result from elevated specific conductance levels. A specific conductance limit of 1,000 micromhos per centimeter (umhos/cm) at 25 degrees Centigrade is applicable to classes 2B, 2C, or 2D; 3A, 3B, or 3C; 4A and 4B; and 5 surface waters. Minn. R. §7050.0224, subp. 5a (A)(17). The use of conductivity for dissolved ionic species and osmotic balances is analogous to the MPCA's use of the additivity model for toxic metals; both are established to protect the health of aquatic systems.

Overall specific conductance can be demonstrated with a simple and inexpensive test. Historically, Dunka Mine seepages have routinely exceeded the conductivity standard of 1000 umhos/cm, ranging as high as 4250 umhos/cm.¹⁹ Yet, even the most recent NPDES/SDS permit for the Dunka Mine fails to set a limit for specific conductance.

In compliance with 40 C.F.R. 122.44(d)(1)(iii), which requires NPDES permits to include effluent limitations for every pollutant that causes or contributes to an excursion above a numeric water quality criterion as well as the Minnesota Rules specifically identified above, the Dunka Mine NPDES/SDS permit should be rewritten to include all seeps, to include cobalt in its additive toxicity model, and to set limits for mercury, hardness and specific conductance.

¹⁵ Thingvold D., *Water Quality Characterization of the Copper Nickel Research Area* (Dec. 1979) Table II; Legislative Library # TN443.M6M55#153, ("Thingvold 1979").

¹⁶ See e.g. 2009 DMR for Dunka Mine, MN00042579.

¹⁷ Thingvold 1979, *supra*, p. 18.

¹⁸ See e.g. "Major Ion Toxicity in Effluents: A Review With Permitting Recommendations," *Environmental Toxicology and Chemistry*, Vol. 19, No.1 pp. 175-182, 2000; "Toxicity of Total Dissolved Solids Associated With Two Mine Effluents To Chironomid Larvae And Early Life Stages of Rainbow Trout," *Environmental Toxicology and Chemistry*, Vol. 19, No. 1 pp. 210-214, 2000.

¹⁹ See Dunka Mine DMR, MN00042579; for example, the 7/31/90 DMR for seep 40500 (W1-d).

3. The NPDES/SDS Permit for the Dunka Mine Should Reduce Limits for Copper and other Metals Based on Background Hardness of Receiving Waters.

Water quality standards in relation to hardness in Minnesota have been based on USEPA's last revised National Ambient Water Quality Criteria (AWQC) set in 1985 and adopted by MPCA in 1990. These criteria are published by EPA under requirements of Section 304(a) of the Clean Water Act and analytical methods for the determination of whole effluent toxicity (WET) are provided in 40 C.F.R. §136. In 2004, the USEPA published guidance on the establishment of whole effluent toxicity limits in permits. The USEPA recommended that dilution water for WET limits be "uncontaminated" receiving water or lab synthetic of similar pH and hardness.²⁰

Data taken from the *Regional Copper Nickel Study* suggests that uncontaminated receiving water near the Dunka Mine would have an average hardness of approximately 27 mg/L.²¹ Yet, the hardness value used by MPCA in calculating the limits for Dunka Mine discharge for copper and zinc appears to be 400 mg/L and the hardness for nickel appears to be around 200 mg/L.²² These hardness values fall far outside the uncontaminated natural conditions of the area's receiving waters.

Dunka Mine waste rock seepages above 1000 mg/L, as described previously, suggest that contamination from the leaching process at the mine is the source of any hardness in receiving waters exceeding historical levels. It is well known that rock surface exposure to precipitation leaches cations, increasing hardness levels. Natural water hardness in the area is predominantly from calcium, with approximately 20 percent from magnesium and other minor sources.²³ Leachate from the Dunka Mine has a different chemical composition as well as a higher hardness level than uncontaminated waters. For example, Seep 3 from the Dunka Mine has had hardness calculated to be 1596 mg/L, based almost 50 percent on magnesium leachate.²⁴

Setting Dunka Mine copper, zinc and nickel levels or whole effluent toxicity limits based on a hardness value of 200 or 400 mg/L conflicts with the practice of basing standards on uncontaminated receiving water and inappropriately elevates the allowable concentration of metals in the discharges. A particular risk to the aquatic environment is posed by nickel discharge, since nickel does not form permanent or tight bonds with elements in hard water that might precipitate the nickel or detoxify its effects.²⁵ If large volumes of lower hardness surface water are mixed with mine leachate, the stability of nickel in the aquatic ecosystem cannot be assumed.

The NPDES/SDS permit should use background hardness levels, rather than hardness resulting from Dunka Mine leachate contamination to set whole effluent toxicity permit

²⁰ USEPA, *National Whole Effluent Toxicity (WET) Implementation Guidance Under the NPDES Program*, p. 28, (Dec. 28, 2004)
http://water.epa.gov/scitech/swguidance/methods/wet/upload/2004_12_28_pubs_wet_draft_guidance.pdf
(last visited Mar. 8, 2011).

²¹ Thingvold 1979, *supra*, Table p. 240, pp. 18-19, Tables 13 & 14. Hardness can also be calculated from Minnesota *Regional Copper Nickel Study 1976-1979 Volume 1*, Executive Summary, August 31, 1979, Table 4, <http://www.leg.state.mn.us/docs/pre2003/other/792632.pdf> (last visited Mar. 8, 2011).

²² Compare the numerical limits on p. 15, Dunka Mine NPDES/SDS permit MN00042579 with Minn. R. §7050.0222, subp. 2 and Minn. R. 7050.0205 subp. 2 and 13.

²³ USFS, Superior National Forest, BWCA Lake Data Analysis Report, Bonnie Dovenmuehle, Forest Hydrologist, June 1980, p. 6.

²⁴ MDNR 1980, *supra*, p. 209.

²⁵ *Id.*, p. 202; Thingvold 1979, *supra*, pp. 56-57.

levels for copper, zinc and nickel.

4. Dunka Mine NPDES/SDS Permit Limits for Copper and other Metals Should Be Reduced to Comply with Chronic Standards at the Point of Release.

In addition to using an incomplete additive model for aquatic toxicity and artificially elevating the whole effluent toxicity level by considering hardness pollution from the Dunka Mine, the 2000 Dunka Mine NPDES/SDS permit improperly relaxed toxicity standards by using acute rather than chronic toxicity limits.

The Dunka Mine NPDES/SDS permit calculates toxicity limits using the Final Acute Value (FAV) although MPCA internal documents suggest that water quality staff recognized that “standards derived from chronic criteria would be controlling.”²⁶

The Final Acute Value is only applicable where receiving waters have sufficient flows to dilute the impact of toxic effluent. Minnesota Rules require that water standards be met when a discharge *enters* waters of the state, in this case where seepages are released to Unnamed Creek and Flamingo Creek. The “7Q10” value reflects the stream flow that occurs over 7 consecutive days and has a 10-year recurrence interval period, or a 1 in 10 chance of occurring in any one year. State Rules do not allow mixing zones when the receiving water has a 7Q10 of zero. Minn. R. 7050.0210, subp. 7. Where 7Q10 stream flows are insufficient to dilute effluent, a Chronic Standard (CS) must apply. Minn. R. 7050.0222, subp. 7(C).

Currently, four of the Dunka Mine seepages discharge into Unnamed Creek²⁷ and approximately one-third of the 4.25 square mile Unnamed Creek sub-watershed is covered with waste rock stockpiles.²⁸ Unnamed Creek has a 7Q10 water flow of zero.²⁹

One of the Dunka Mine seepages drains into Flamingo Creek, an intermittent stream that also discharges into Birch Lake. Flamingo Creek also has a 7Q10 water flow of zero. Since the 7Q10 of both Unnamed Creek and Flamingo Creek are zero, the Dunka Mine NPDES/SDS permit must establish toxicity based on a Chronic Standard.

The Dunka Mine Case Study prepared by the MDNR in August 2010 reflects the impacts on water quality standards resulting from setting an artificially high hardness level and substituting an acute limit for the appropriate chronic water quality standard. For example, in the case of copper, the chronic water quality standard at even the hardness level of 50 mg/L would be 6.4 ug/L, while the acute water quality standard at 400 mg/L would be 126 ug/L, *nearly 20 times as high*.³⁰ Chronic water quality standards at actual background hardness levels for these waters (approximately 30 mg/L) would be yet more stringent.

The 2000 Dunka Mine NPDES/SDS did not use valid procedures to determine compliance with the Clean Water Act as required by 40 C.F.R. 122.44 (d)(1)(ii) and must be revised to set appropriate chronic standards for discharge of toxic metals.

²⁶ MPCA Memo, Carri Lohse to Mark Tomasek, “Standards Information Request from Erie Mining Company,” Feb. 28, 1985, Attachment F.

²⁷ See MDNR, Dunka Mine Case Study (August 2010), (“MDNR Dunka Case Study”), Figure 1-1, available at http://www.itcweb.org/miningwaste-guidance/cs_dunka_mine.htm (last visited Mar. 8, 2011)

²⁸ See Thingvold 1979, *supra*, Table 1 regarding watershed size and see Attachment G, Schematic of Dunka Mine waste locations, taken from MDNR Case Study, *supra*.

²⁹ MPCA Memo, Carol Sinden to Richard Clark, “7Q10 Determinations for Unnamed Creek to Bob Bay,” Feb. 1, 1991, Attachment H.

³⁰ MDNR Dunka Case Study, *supra*, Table 5-1, Attachment I.

5. The NPDES/SDS Permit for the Dunka Mine Should Limit Sulfate Discharge in Compliance with the Wild Rice Sulfate Water Quality Standard.

The Dunka Mine NPDES/SDS permit contains no limits for sulfate discharge, although both the Kawishiwi River and Birch Lake contain stands of wild rice. An MDNR conservation officer in Ely recently confirmed that Birch Lake bays upstream of Bob Bay (Kangas and Kramer), where Dunka Mine receiving waters enter Birch Lake, have productive stands of wild rice and that the Kawishiwi River also contains wild rice.³¹

It is highly likely that sulfate discharge from the Dunka Mine to Birch Lake and the Kawishiwi River would exceed Minnesota's water quality standard limiting sulfate to 10 mg/L in wild rice waters during periods when the rice may be susceptible to damage from high sulfate levels. Minn. R. 7050.0224. The rate of sulfate release from the Dunka Mine waste rock stockpiles has been relatively consistent over the past 30 years, averaging approximately 1750 mg/L of sulfates.³² Most of the sulfate data from Dunka Mine seepage ranges from 1000 to 2500 mg/L of sulfate.³³ Releases of sulfate do not demonstrate seasonal variations except in a couple of months in the winter when everything freezes.

Failure to set a sulfate water quality limit in the Dunka Mine NPDES/SDS permit is inconsistent with Minnesota Rule 7050.0224 and with federal regulations requiring permits to include effluent limitations for every individual pollutant that causes, or contributes to an excursion above a numeric water quality criterion. 40 C.F.R. § 122.44(d)(1)(iii).

6. The NPDES/SDS Permit for the Dunka Mine Has Expired - Variances Should be Disallowed and a New Permit Issued.

USEPA limits the effective term of state NPDES/SDS permits to five years. 40 C.F.R. §122.46 (a). The last permit issued by the MPCA for the Dunka Mine was on August 3, 2000. By its own terms, the permit expired June 30, 2005.

Minnesota law also limits variances from water quality standards to a term of three years and requires both agency and public review at least every three years. Minn. R. 7050.0190, subp. 3. The Dunka Mine NPDES/SDS permit explicitly allowed variances from state water quality standards for discharges from two of the wetland "treatment" systems (outfalls SD009 (Seep X) and SD008 (Seep 1)). The agency's rationale for these variances was provided in a June 2000 Public Notice with a comment period ending on July 17, 2000.³⁴ No public review of the variances contained in the Dunka Mine NPDES/SDS permit has taken place since 2000.

The MDNR Case Study suggests that the use of an acute, rather than a chronic water quality standard for Dunka Mine discharge should also be considered as a variance,

³¹ Personal conversation, Bruce Johnson and MDNR Conservation Officer Marty Stage from Ely on or about Dec. 30, 2010.

³² Eger, P. and Lapakko, K, MDNR, *Environmental Leaching of Duluth Gabbro under Laboratory and Field Conditions: Oxidative Dissolution of Metal Sulfide and Silicate Minerals*, (1980), p. 196. Median average sulfate seepages from Dunka stockpiles were approximately 1250, 2500, 1500 mg/L, comparable to MPCA's more recent DMR data for Dunka Mine MN0042579.

³³ See e.g. MPCA DMR Summary Reports for Dunka Mine, MN0042579, SD 005, SD 007, SD 009 for 2007 and 2008.

³⁴ Public Notice of Intent to Reissue NPDES/SDS Permit 0042579, Public Comment Period June 16, 2000 – July 17, 2000, Attachment J.

subject to public review after three years. The Case Study explains:

Originally, permit standards for the mine were based on chronic toxicity values, which were up to an order of magnitude lower than acute values. When the company went bankrupt several years after the mine had closed, it sought a variance for several of the discharges. The new permit based on FAV included biological monitoring.³⁵

The Dunka Mine NPDES/SDS permit is long overdue for review and reissuance. Both explicit variances for seeps contained in the permit and less obvious variances due to application of an acute water quality standard must be subjected to USEPA oversight and to public review as well as to MPCA scrutiny.

7. Measures to Reduce Non-Compliance, Including Operation of the Water Treatment Plant and Redesign of Waste Stockpiles Should be Immediately Implemented.

Review of documents pertaining to the Dunka Mine suggests that there are measures that would be available immediately to reduce discharge of toxic pollutants and exceedance of water quality standards.

The Dunka Mine currently provides passive treatment of seeps through constructed wetlands. The Dunka Mine also has a lime precipitation plant on site for active water treatment, but the NPDES/SDS permit only requires its use as “backup treatment” if monitoring at outfalls SD007, SD2008 or SD009 indicates that additive toxicity effluent limits are being exceeded or at the determination of the MPCA Commissioner. (NPDES Permit MN00042579, pp. 4, 16, 17). Despite continued violations of permit limits, this plant is not in operation and best information suggests that it has not operated for at least two decades.

The MDNR Dunka Case Study explains that rejection of active water quality treatment was a choice made by Cliffs Erie based purely on operating cost considerations:

In 1986, LTV conducted a preliminary feasibility study to determine the best method to mitigate the drainage problem at the Dunka Mine, examining both active treatment systems (lime treatment, reverse osmosis) and passive alternatives (limiting infiltration into stockpiles, wetland treatment) (Barr Engineering 1986). An active treatment plant which would treat all the stockpile drainage was projected to have a capital cost of \$8.5 million and an annual operating cost of \$1.2 million. The passive alternative was projected to cost \$4 million to construct but only \$40,000 in annual maintenance. Since mine drainage problems can persist for over 100 years, LTV decided to pursue passive alternatives.³⁶

The MPCA’s failure to require operation of the Dunka Mine water treatment plant both results in excursions above water quality limits and provides misleading information to future permittees as to the costs of protecting water quality from ongoing acid mine drainage. Consistent and continuous use of an active water treatment system should be required for Dunka Mine discharge.

³⁵ MDNR Dunka Case Study, *supra*, p. 8.

³⁶ MDNR Dunka Case Study, *supra*, p. 2, emphasis added.

Treatment in constructed wetlands reduces some toxic metals discharge, but wetlands removal is inconsistent and as much as 80 percent of nickel from Dunka Mine leachate may remain.³⁷ Capping of stockpiles to reduce infiltration is a more effective way to reduce leachate,³⁸ and is also required by Minnesota mineland reclamation rules.

The majority of the Dunka Mine waste rock was stockpiled using methods that were commonly used in taconite mining for non-sulfide waste rock. As explained in the MDNR Dunka Case Study, this design does not facilitate capping:

[T]he piles were constructed to place the maximum amount of material in the minimum area. Stockpiles were generally built in 10-15 m lifts with 45° side slopes. Only the flat top portions of the stockpiles could be economically covered.³⁹

Regulators have not required Cliffs Erie to reshape the stockpiles so that capping can minimize infiltration through side slopes. In addition, local availability of clay is limited, and clay was rejected in favor of soil for covering the waste rock stockpiles due to transportation costs.⁴⁰

In order to achieve compliance with water quality standards and to accurately determine the costs of mine reclamation in sulfide-bearing rock, MPCA should require operation of active water treatment and work with MDNR to require stockpile redesign and capping of stockpiles with non-permeable material to reduce infiltration.

CONCLUSION

NPDES/SDS permits protect waters of the United States and waters of the State of Minnesota from unacceptable levels of pollutants. As detailed above, the MPCA's existing NPDES/SDS permit for the Dunka Mine fails to provide this protection. By limiting the scope of permit coverage and misapplying water quality standards, these permits may create a misleading impression of compliance or that non-compliance has a limited scope.

Minnesota's continuing lack of appropriate NPDES/SDS limits for copper, nickel, zinc, cobalt, mercury, hardness, specific conductance and sulfates from the Dunka Mine results in failure to protect the waters of Unnamed Creek, Flamingo Creek, Birch Lake and the Kawishiwi River. In addition, these practices could set precedent for much larger scale sulfide mines proposed in the Duluth Complex formation. Providing implicit variances by deviating from appropriate application of water quality standards is a practice that must be rejected as contrary to the Clean Water Act and misleading to the public.

In addition, failure to require Cliffs Erie to utilize active water quality treatment, reshape and cover stockpiles and take such other measures to achieve compliance creates a false understanding of the costs of meeting water quality standards. The MPCA, MDNR and proponents of sulfide mine projects need accurate and complete information as to the

³⁷ MDNR, *Long Term Wetland Treatment of Mine Drainage at LTV Steel Mining Company's Dunka Mine*, December 2000, p. vi, Executive Summary attached to MDNR letter from Paul Eger to Pat Cary, MPCA (Jan. 10, 2001), Attachment K, "Nickel removal within the pretreatment system averaged only 15-20%, and occurred primarily in the vertical down-flow section of the system. The major reduction in nickel load appears to be related to capping of the stockpile, and not to removal within the pretreatment system."

³⁸ *Id.*

³⁹ MDNR Dunka Case Study, *supra*, p. 3.

⁴⁰ *Id.*

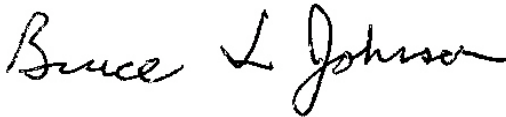
costs of meeting federal and state water quality standards over a period of hundreds if not thousands of years during which mine drainage problems can persist.

Before NPDES/SDS permits are proposed for new proposed mining incursions into sulfide-bearing rock, the MPCA and USEPA must review historic discharge and permitting at the Dunka Mine, establish rigorous and fair application of water quality standards, subject permitting and variance proposals to public scrutiny and require implementation of measures that would bring discharge into compliance with federal and state rules.

We would welcome the opportunity to discuss our issues and concerns with you. Mr. Johnson can be reached at 763-444-4579 or bmjohnson@sprintmail.com and Ms. Maccabee can be reached at 651-646-8890 or pmaccabee@justchangelaw.com.

Thank you for your consideration of our comments and suggestions.

Sincerely yours,

A handwritten signature in black ink that reads "Bruce L. Johnson". The signature is fluid and cursive, with the first name "Bruce" being the most prominent.

Bruce Johnson
Advisory Committee for WaterLegacy

A handwritten signature in blue ink that reads "Paula G. Maccabee". The signature is cursive and elegant, with the first name "Paula" being the most prominent.

Paula Maccabee
Attorney for WaterLegacy

cc: Kevin Peirard, NPDES Branch Chief USEPA Region 5 (pierard.kevin@epa.gov)
Simon Manoyan, Water Quality Scientist, USEPA Region 5 (manoyan.simon@epa.gov)
Ken Westlake, NEP Coordinator, USEPA Region 5 (westlake.kenneth@epa.gov)

Enclosures

Attachments to Dunka Letter

- A. MEQB Letter of Paul Eger to Abner Fisch, MPCA (Dec. 14, 1976)
- B. USEPA, email response to Bruce Johnson re FOIA Request, #05-FOI-01595-10 (Oct. 25, 2010).
- C. MPCA Memo, Jerry Flom to Curt Sparks, "Mine Dump Seeps," Sept. 1, 1988.
- D. MPCA Memo, Mark Schmitt to Carri Lohse, "Birch Lake Fish Tissue Data," July 26, 1985.
- E. MPCA Memo, Virginia Reiner to Ken Haberman, "Bob Bay Monitoring," Jan. 5, 1984.
- F. MPCA Memo, Carri Lohse to Mark Tomasek, "Standards Information Request from Erie Mining Company," Feb. 28, 1985.
- G. Schematic of Dunka Mine waste locations, taken from MDNR Case Study.
- H. MPCA Memo, Carol Sinden to Richard Clark, "7Q10 Determinations for Unnamed Creek to Bob Bay," Feb. 1, 1991.
- I. MDNR Dunka Case Study, Table 5-1.
- J. Public Notice of Intent to Reissue NPDES/SDS Permit 0042579, Public Comment Period June 16, 2000 – July 17, 2000.
- K. MDNR, *Long Term Wetland Treatment of Mine Drainage at LTV Steel Mining Company's Dunka Mine*, December 2000, p. vi, Executive Summary attached to MDNR letter from Paul Eger to Pat Cary, MPCA (Jan. 10, 2001)



STATE OF MINNESOTA

ENVIRONMENTAL QUALITY COUNCIL

Copper-Nickel Project

138~~100~~ Hennepin Square Building

2021 East Hennepin Avenue

Minneapolis, Minn. 55413

Phone: 612-378-7770

December 14, 1976

Abner Fisch
Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55113

Dear Abner:

As you know, the Regional Copper-Nickel Study has been conducting a series of studies at the Erie Mining Company taconite mine four miles east of Babbitt. In this area, the geological formation known as the Duluth Gabbro Complex overlies part of the eastern edge of the Biwabik iron formation. To mine the taconite in the eastern portion of their pit (Dunka Pit) Erie has had to remove and stockpile the overlying gabbro. The Duluth Gabbro formation contains copper and nickel sulfide minerals of potential economic value. The material stockpiled by Erie is presently not considered to be of ore grade—it does represent material that would be classified as lean ore and waste rock. These stockpiles are representative of the type that more than likely would be produced by full-scale open pit copper-nickel mining. Leaching of heavy metals is presently occurring from these stockpiles and the leachate flows into Unnamed Creek and then to Birch Lake.

In November 1974, the Environmental Quality Council requested the preparation of a regional environmental study on possible impacts from potential copper-nickel mining in northeastern Minnesota. This regional study is presently underway. In general, the study has two goals: 1) to characterize the present environment and socio-economic state of the region; and 2) to predict possible impacts resulting from potential copper-nickel development. Neither of these tasks is easy but the prediction of impacts is particularly difficult. Often the only type of information available is that obtained from literature and this information may not describe the actual situation in Minnesota. In an effort to develop better predictive models, field studies have been initiated in the Unnamed Creek watershed and Birch Lake. The data collected from these areas will provide a basis to compare literature values and predict impacts. Several studies were initiated this summer and some are planned for continuation this winter. Information is being collected on the aquatic biology, water chemistry, the leaching process, the transport of heavy metals, the toxic effect of the leachate and heavy metal accumulation in plants, fish and sediments.

12/28/76 REF - LOOKS K.R.M.
Like we may
have to give
them a T.E.
Please advise
Pat
Received and Logged
in by John of CEA

Ch W. Albert & Criswell DEC 16 1976

Erie Mining Company has been cooperating with the Regional Study. Some of this cooperation has necessitated the delaying of some of their proposed mitigation techniques. In particular, one of the proposed control measures is to pump-down and intercept ground water before it reaches the stockpiles. One of our studies underway is centered around the stockpile area and it is important that data continue to be collected without imposing additional changes (pumping) in the system. Erie has temporarily ceased pumping from this area and is willing to delay further testing of this procedure. If testing is discontinued, Erie will be delayed in devising a final plan for control of the stockpile run-off. Under Erie's present permit, the run-off from the Gabbro is to be controlled by June 1977. I feel that it is important to collect data from this area during the spring run-off period. This would mean that pumping should not be resumed until the end of June 1977. This would require that Erie be granted an additional time period to comply with the permit conditions. I would suggest that time be extended to Erie in order that we may collect valuable spring run-off data. This does not mean that other mitigation techniques required under their permit should not be pursued. Recent information that we are developing implies that their present proposal will only be partially successful in stopping the seepage from the stockpile area. It is our plan to have the situation better defined within the next few months.

The data collected from this study will be useful not only in the prediction of impacts resulting from copper-nickel mining but also in the reversibility of those impacts. It is our plan to continue to collect data in this area during and after mitigation procedures have been implemented. This will give us a measure of the degree to which adverse impacts can be controlled and/or reversed. If you have any questions or need more information, please contact me.

Sincerely,



Paul Eger

PE:st

cc: Phil Brick
Steve Chapman
Robert Criswell, PCA
Perry Beaton, PCA
Richard Svanda, PCA
✓ Tim Scherckenback, PCA



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 5

77 WEST JACKSON BOULEVARD

CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF:

WN-16J

OCT 25 2010

Mr. Bruce Johnson
6763 253rd Avenue, NE
Stacy, Minnesota 55079

Re: Freedom of Information (FOI)
(Identification No. 05-FOI-01595-10)

Dear Mr. Johnson:

This is the Water Division's response to your FOI request dated September 29, 2010. You requested from the U.S. Environmental Protection Agency (EPA) a copy of the completed NPDES Permit Rating Worksheet for NPDES Permit MN0042579.

We do not have an NPDES Permit Rating Worksheet for the facility Cliffs Erie LLC-Dunka MN0042579. This facility is a minor facility and EPA does not maintain those records. The facility has been a minor since the original issuance of their permit, which was May 27, 1975.

For information on this facility, you may want to contact the State of Minnesota at:

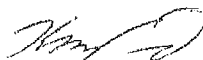
Agency File Manager
520 Lafayette Road North
St. Paul, Minnesota 55155-4194
Telephone: 651-296-6300/800-657-3864

You may appeal this response to the National Freedom of Information Officer, U.S. EPA, FOIA and Privacy Branch, 1200 Pennsylvania Avenue, N.W. (2822T), Washington, DC 20460 (U.S. Postal Service Only), FAX: (202) 566-2147, E-mail: hq.foia@epa.gov. Only items mailed through the United States Postal Service may be delivered to 1200 Pennsylvania Avenue, NW. If you are submitting your appeal via hand delivery, courier service or overnight delivery, you must address your correspondence to 1301 Constitution Avenue, N.W., Room 6416J, Washington, DC 20004. Your appeal must be made in writing, and it must be submitted no later

than 30 calendar days from the date of this letter. The Agency will not consider appeals received after the 30 calendar day limit. The appeal letter should include the 05-FOI-01595-10 as listed above. For quickest possible handling, the appeal letter and its envelope should be marked "Freedom of Information Act Appeal."

If you have any questions regarding this response, please contact Ms. Jackson of my staff at 312-886-3717.

Sincerely,



Kevin Pierard, Chief
NPDES Program Branch

DEPARTMENT : Pollution Control Agency

PHONE : 296-9207

DATE : September 1, 1988

TO : Curt Sparks, Marvin Hora
Doug Hall, Bruce Johnson

Division of Water Quality

FROM : Jerry Flom
Pollution Control Specialist
Program Development Section
Division of Water Quality

SUBJECT : Mine dump seeps

STATE OF MINNESOTA
Office Memorandum

Attached is a brief summation of the toxicity tests Harold and I conducted on mine dump seeps from AMAX and LTV. When metals data are received from MDH we will write a more complete report.

SUMMARY

Forty-eight hour acute static tests using fathead minnows, Ceriodaphnia, and Daphnia magna were conducted on seven mine dump seeps. Five of the seeps were from LTV mine dumps and two seeps were from AMAX mine dumps. Samples were collected August 25, 1988 by Harold Wiegner and the tests were conducted by Harold Wiegner and Jerry Flom at the Minnesota Pollution Control Agency Biomonitoring Laboratory in St. Paul. Water collected from the Dunka River was used as a diluent and as the control water.

DISCUSSION

Ceriodaphnia were the most sensitive organisms tested. All the seeps except LTV W2D showed 100% mortality at the lowest concentration tested, either 3 or 6 percent. The ranking of the seeps from most toxic to least toxic relies on the toxicity shown to all the test species. This may or may not accurately reflect the metals data when they are recieved. There may be discrepancies because the Ceriodaphnia were not tested at low enough concentrations to calculate LC50 values.

RESULTS

The results of the toxicity tests are presented below. An LC50 value shows the concentration of seep water that kills 50 percent of the exposed organisms. Less than values show the lowest concentration tested at which there was 100% mortality. Greater than values indicate no significant acute toxicity. There were no mortalities to any of the control organisms in any of the tests.

MINE DUMP SEEPAGE TOXICITY TEST RESULTS

AMAX B1-IB	LC50	AMAX B2-IB	LC50
Fathead	>100%	Fathead	50%
Ceriodaphnia	< 6%	Ceriodaphnia	< 3%
Daphnia magna	70%	Daphnia magna	5%

LTV EM-8	LC50	LTV S-1	LC50
Fathead	>100%	Fathead	70%
Ceriodaphnia	< 6%	Ceriodaphnia	< 3%
Daphnia magna	>100%	Daphnia magna	16%

LTV S-3	LC50	LTV W1D	LC50
Fathead	>100%	Fathead	>100%
Ceriodaphnia	< 3%	Ceriodaphnia	< 6%
Daphnia magna	8%	Daphnia magna	50%

LTV W2D	LC50
Fathead	>100%
Ceriodaphnia	14%
Daphnia magna	>100%

Most-to-Least toxic ranking

- 1 AMAX B2-IB
- 2 LTV S-1
- 3 LTV S-3
- 4 LTV W1D
- 5 AMAX B1-IB
- 6 LTV EM-8
- 7 LTV W2D

DEPARTMENT : **Pollution Control Agency**

PHONE : 296-7756

DATE : July 26, 1985

TO : Carri Lohse

FROM : Mark D.C. Schmitt
Pollution Control Specialist
Division of Water Quality

SUBJECT : **Birch Lake Fish Tissue Data**

STATE OF MINNESOTA
Office Memorandum

I have completed my analysis of the Birch Lake fish tissue data. The results are attached. I have included only those analyses which are of interest in the context of the ongoing problems at the Erie Mining Company's Dunka Mine. Many additional analyses were performed. If you are interested in these, I have the master copy of all analyses performed in my desk.

The following are my conclusions:

- 1) Nickel concentrations in the livers of fish taken from Bob Bay are significantly higher than those in the livers of fish taken from any of the other locations in Birch Lake.
- 2) Zinc concentrations in the flesh of fish taken from Bob Bay are significantly higher than those in the flesh of fish taken from any of the other locations in Birch Lake.
- 3) Copper and nickel concentrations in the flesh of fish taken from Bob Bay are significantly higher than those in the flesh of fish taken from all locations in Birch Lake.
- 4) Nickel concentrations in the livers of northern pike taken from Bob Bay are significantly higher than those in the livers of northern pike taken from any other location in Birch Lake.
- 5) Nickel and copper concentrations in the flesh of northern pike taken from Bob Bay are significantly higher than those in the flesh of northern pike taken from any other location in Birch Lake.
- 6) Although the numeric differences in this data set are apparent, an individual with greater experience interpreting fish tissue information needs to evaluate these results to determine the biological significance of these statistically significant results.

There is a considerable volume of information attached to this memo. However, the key results from which I have drawn the above conclusions can be found in three places for each of the individual analyses. On the first page of each analysis, there are two values associated with PR > F headings. The first value, which is associated with the model statement, indicates the probability that the metal concentrations in the organisms

DEPARTMENT : **Pollution Control Agency**

PHONE : 296-7756

DATE : July 26, 1985

TO : Carri Lohse

FROM : Mark D.C. Schmitt
Pollution Control Specialist
Division of Water Quality

SUBJECT : **Birch Lake Fish Tissue Data**

STATE OF MINNESOTA
Office Memorandum

I have completed my analysis of the Birch Lake fish tissue data. The results are attached. I have included only those analyses which are of interest in the context of the ongoing problems at the Erie Mining Company's Dunka Mine. Many additional analyses were performed. If you are interested in these, I have the master copy of all analyses performed in my desk.

The following are my conclusions:

- 1) Nickel concentrations in the livers of fish taken from Bob Bay are significantly higher than those in the livers of fish taken from any of the other locations in Birch Lake.
- 2) Zinc concentrations in the flesh of fish taken from Bob Bay are significantly higher than those in the flesh of fish taken from any of the other locations in Birch Lake.
- 3) Copper and nickel concentrations in the flesh of fish taken from Bob Bay are significantly higher than those in the flesh of fish taken from all locations in Birch Lake.
- 4) Nickel concentrations in the livers of northern pike taken from Bob Bay are significantly higher than those in the livers of northern pike taken from any other location in Birch Lake.
- 5) Nickel and copper concentrations in the flesh of northern pike taken from Bob Bay are significantly higher than those in the flesh of northern pike taken from any other location in Birch Lake.
- 6) Although the numeric differences in this data set are apparent, an individual with greater experience interpreting fish tissue information needs to evaluate these results to determine the biological significance of these statistically significant results.

There is a considerable volume of information attached to this memo. However, the key results from which I have drawn the above conclusions can be found in three places for each of the individual analyses. On the first page of each analysis, there are two values associated with PR > F headings. The first value, which is associated with the model statement, indicates the probability that the metal concentrations in the organisms

DEPARTMENT

POLLUTION CONTROL AGENCY

Office Memorandum

TO: Ken Haberman
Permits Section
Division of Water Quality

DATE: January 5, 1984

FROM: Virginia Reiner *VLR*
Monitoring and Analysis Section
Division of Water Quality *JR*

PHONE: 6-7363

SUBJECT: BOB BAY MONITORING

I have reviewed the data submitted by Erie Mining Company on their Bob Bay Monitoring Program conducted in 1983 and have the following observations:

1. Copper and cobalt values do not indicate a problem in this sampling.
2. Zinc values occasionally slightly exceed chronic toxicity limits at stations near the junction with Unnamed Creek.
3. Nickel appears to be very mobile, with elevated concentrations being measured throughout the Bay Stations. Concentrations approximately twice the chronic toxicity level were measured as far as station BB-7.
4. Elevated concentrations are limited to samples drawn from near the bottom of the water column. The Unnamed Creek discharge appears to move as a discrete "slug" of water, high in conductivity, metals and sulfate, through the Bay. It is thought probably to be following the old stream channel, with no evidence of mixing with the water near the surface.

Unacceptable loadings of nickel are being contributed to Bob Bay by Unnamed Creek. Although the Agency has the option of requiring Erie Mining to conduct further biological monitoring on the Bay under clause C.11.b. of their current permit, I believe such a study would likely agree with the conclusions of the 1976 study prepared by the EQB ("Regional Copper-Nickel Study, Erie Mining Project, Biological Sampling," Mark Johnson and Steve Williams, October, 1978). This study concluded the following:

"In Bob Bay of Birch Lake, no effect on phytoplankton production was evident. However, benthic invertebrate density in Bob Bay was significantly less than in Dunka Bay. This was the result of a single genus, Tanytarsus, a genus sensitive to heavy metals which was abundant in Dunka Bay but not Bob Bay. Clams (Anodonta) from Bob Bay have accumulated significant amounts of copper in their tissue while water lilies (Nuphar variegatum) from Bob Bay have accumulated significant amounts of copper and nickel. Whether the source of these metals is the sediments or the water is unclear at this time." (p.37)

This newest study reaffirms that leaching from the metal rich gabbro continues to be a problem in Bob Bay. In 1976-77 exceedances of the copper criterion in the lower part of the Bay were noted. This study documents exceedances of the zinc criterion in the lower Bay and of the nickel criterion at the sampling stations along the entire length of the Bay. Clearly the problem is persisting and the Agency should emphasize the need for Erie to begin implementation of mitigation techniques.

VLR:jae

Curtis J. Sparks, P.E.
Page 2

Third, other parameters are concentrated in the density current. 1983 median sulfate values in Bob Bay were 480 mg/l in July and 510 mg/l in September. Copper-nickel study area streams had a median sulfate level of 6.6 mg/l. Zinc exceeded the chronic toxicity criterion in some density current samples taken in September. The highest recorded values were 60 ug/l, the criterion is 47 ug/l and the median of copper-nickel area streams was 2 ug/l. Copper also occasionally exceeded its site specific chronic toxicity criterion of 5.4 ug/l.

Fourth, according to the 1983 Bob Bay Study, water quality in the bay has worsened since the 1976-77 study. This may be due to the increased concentration of the stockpile runoff and by the elimination of the Dunka Mine dewatering discharge and the stockpiling of more lean ore in the Bob Bay watershed.

Fifth, the need for effective mitigation techniques is obvious. Both Unnamed Creek and Bob Bay are classified as 2B waters. The concentration of metals and associated stockpile runoff parameters in Unnamed Creek and the density current in Bob Bay should be decreased to be within chronic toxicity criteria and 2B water quality standards. Bob Bay monitoring should continue and Erie should be required to begin effective mitigation as soon as possible.

Conclusions

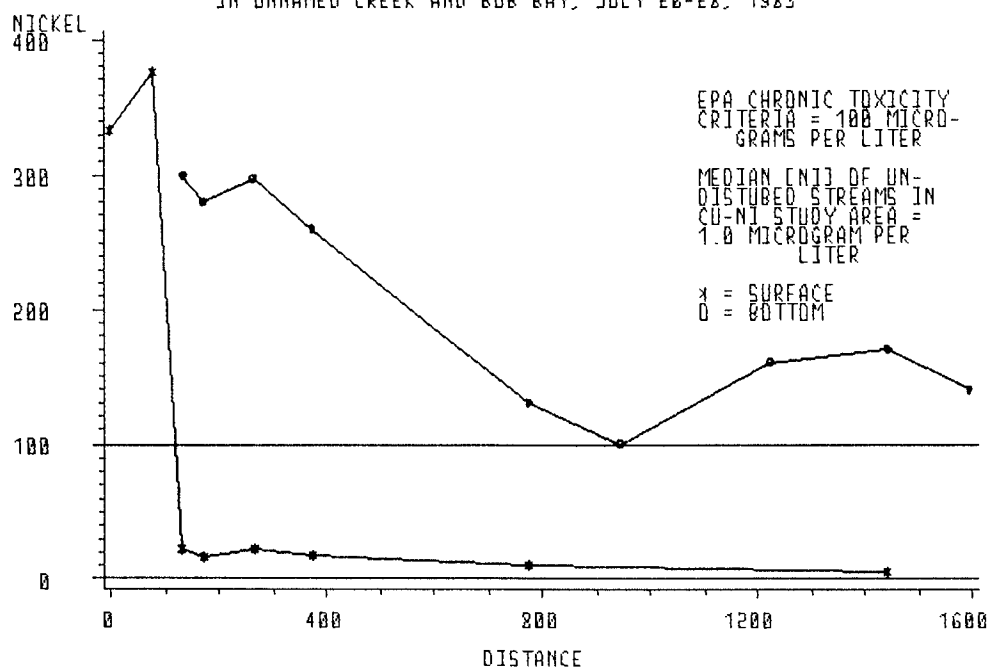
1. Stockpile runoff to Unnamed Creek forms a density current at the bottom of Bob Bay. This density current runs the entire length of the bay and is characterized by high conductivity and metals.
2. The water quality standard for nickel is being consistently violated in Unnamed Creek and at the bottom of Bob Bay. Zinc and copper occasionally exceed standards.
3. Water quality in Unnamed Creek and Bob Bay has deteriorated since the 1976-77 study.
4. Mitigative measures should be initiated to protect the water quality of Unnamed Creek and Bob Bay.

JFM/CL:jae

Attachment

cc: Ken Haberman
Mark Schmitt
Mark Tomasek

FIG. 1 NICKEL CONCENTRATION IN SURFACE AND BOTTOM WATER
IN UNNAMED CREEK AND BOB BAY, JULY 26-28, 1983



NICKEL CONCENTRATIONS ARE REPORTED IN MICROGRAMS PER LITER.
DISTANCE IS REPORTED IN METERS FROM EM-1.

STATE OF MINNESOTA

DEPARTMENT

POLLUTION CONTROL AGENCY

Office Memorandum

TO: Curtis J. Sparks, P.E.
Chief, Permits Section
Division of Water Quality

THRU: John F. McGuire, P.E., Chief
Monitoring and Analysis Section

FROM: Carri Lohse *CLL*
Monitoring and Analysis Section
Division of Water Quality

SUBJECT: REVIEW OF BOB BAY STUDY, 1983

DATE: December 6, 1984

PHONE: 296-7249

The Monitoring and Analysis Section has reviewed the Bob Bay Study, 1983, prepared by the Minerals Division of the Minnesota Department of Natural Resources. The section has previously reviewed the 1983 data (see memo from Virginia Reiner to Ken Haberman attached). Those conclusions and recommendations still stand. Based on the review of the Bob Bay Study, some points need to be emphasized.

First, the runoff from Unnamed Creek flows through Bob Bay in one to three days in a density current along the bottom of the bay. This density current is not greatly diluted as it passes through the bay. For example, a comparison of specific conductivity at different depths in Bob Bay reveals that the highest conductivity is found at the bottom of the water column. The highest recorded specific conductivity in 1983 was 1200 uhmos/cm at 25°C in September at the head end of Bob Bay (BB-0). On the same day, the highest recorded specific conductivity near the mouth of Bob Bay (BB-6.3) was 1000. This relatively small difference indicates that the density current mixes only slightly in the bay.

To put those high values in perspective, consider that the Minnesota Pollution Control Agency's specific conductivity water quality standard for agricultural and wildlife uses is 1000 uhmos/cm. The median conductivity for relatively undisturbed streams in the copper-nickel study area is 55.

Second, dissolved nickel concentrations exceed the U.S. Environmental Protection Agency's chronic toxicity criterion (Figure 1). In surface water in the bay, the nickel concentration (6-23 ug/l) is relatively close to that of copper-nickel area streams (median = 1 ug/l). The criterion is 100 ug/l for the protection of human consumers of fish or lower (depending on hardness) for the protection of aquatic life. Because hardness values are high in the density current, the criterion is fixed at 100 ug/l. However, if the hardness of the natural waters of Birch Lake is taken into account ($\bar{x}$ hardness = 41 mg/l at LBH-2) the criterion is lowered to 49 ug/l. Nickel concentration is quite high in the density current (100-375 ug/l). There is a tendency for the nickel concentration to decrease from Unnamed Creek to the mouth of Bob Bay. However, nickel levels in the density current near the mouth of Bob Bay still exceed the criterion.

To: Mark Tomasek
Enforcement Section
Water Quality Division

2/28/85

From: Carri Lohse
Monitoring & Analysis Section
Water Quality Division

Reviewed by Dave Maschwitz also.

Subject: Standards Information Request from Eric Mining Company

Standards

As class 2B, 3B, 4A, 4B, 5 and 6 waters Unnamed Creek and Bob Bay have standards for the following parameters under Minnesota Rule Part 7050.0220 : copper, pH, conductivity and hardness. Standards for cobalt, nickel and zinc can be developed according to Minnesota Rule Part 7050.0210 Subpart 14.

The nickel water quality standard ~~for water quality limited waters~~ is based on the ~~can be justified using~~ EPA aquatic life criteria. The criteria for most many trace metals are based on a hardness-toxicity relationship expressed by a ~~hardness-related~~ log formula developed by EPA. The

MPCA has further refined the formulas by eliminating nonresident species and salmonid species (the standard is for a warm water) from the data base used to calculate the criteria (for example, chinook salmon).

this results in formulas with higher intercepts that yield less strict criteria.

Minnesota's chronic toxicity criteria ^{for nickel} is $e^{(0.76 [\ln \text{hardness}] + 1.06)}$ as a 24-hr average. This is the formula used in Virginia Reimer's 830321 memo and my 850116 memo.

The zinc criterion is based on chronic toxicity tests in EPA's zinc criteria manual. Unlike nickel, the chronic toxicity of zinc is not affected

by hardness. The national criterion of 47 mg/l as a 24-hr average protects our freshwater resident species.

Dave Maschwitz developed the cobalt criteria from a summary of cobalt bioassay data compiled by David Lind. When my 850116 memo was written the cobalt values were tentative. Since then Dave Maschwitz has confirmed the values and used them for pretreatment standards as well.

I have two additional comments on the standards. First, ^{final} revised EPA criteria are expected within a few months. M&A will check all the state-wide and site-specific standards developed from EPA criteria for possible changes. This will include the standards for Unnamed Creek and Bob Bay.

Second, the acute criteria on my 850116 memo are for effluent standards. Those values would be used to develop standards for a discharge from a treatment system ^{in an effluent limited water}. The chronic values represent standards for waters ^{of the state} and would take dilution and background concentration into account. Because Unnamed Creek should be considered water quality limited the standards derived from chronic criteria would be controlling.

Hardness

The hardness-related log formulas are not designed for very hard water such as the stockpile runoff. 300 mg/l hardness is a general cutoff for using the formulas. Note that the hardness standard for Unnamed Creek and Bob Bay is 250 mg/l (Minn Rule 7050.0200). I used Birch Lake hardness downstream from the mouth of Bob Bay for the criteria in my 850116 memo. Further evaluation of a representative

Good
Harder
appropriate

hardness is needed

In any case, the high hardness in the rockpile runoff is not a factor in the criteria formula. It is the effect of the metals on the softer natural water ~~quality~~ that is of interest

Total vs Active Metals

When the new EPA criteria come out the metals criteria derived by the formulas will be expressed as active metal, rather than as total. Previously, we have used the protective total metal to derive criteria because it is not known how much of the metal in the water is available to organisms. Active metal is measured in samples that have been acidified and then filtered.

It will be to Erie's advantage to measure active metal. However, before they switch completely to active they should run total on the same samples. We want to know what the relationship is between total and active, particularly at the seeps. If there is a consistent significant relationship then we can relate historic total data to new active data.

Note: the copper-nickel study revealed very little difference between dissolved and total metals in copper-nickel area waters.

DUNKA MINE, MINNESOTA

1. SITE INFORMATION

1.1 Contacts

Paul Eger
 Minnesota Department of Natural Resources
 Telephone: 651-259-5384
 E-mail: a.paul.eger@state.mn.us

1.2 Name, Location, and Description

The Dunka Mine is a large, open-pit taconite mine located in northern Minnesota at the eastern end of the Biwabik Iron Formation. The mine covers approximately 160 hectares and has a depth of around 100 m. It sits along the western edge of a small watershed (920 hectares), which is drained by a small stream (Unnamed Creek, Figure 1-1). The watershed is typical for this area of Minnesota and is characterized by a series of upland ridges and low areas containing wetlands. Sulfide-containing waste material from the mine was stockpiled along the eastern edge of the mine and adjacent to these wetlands.

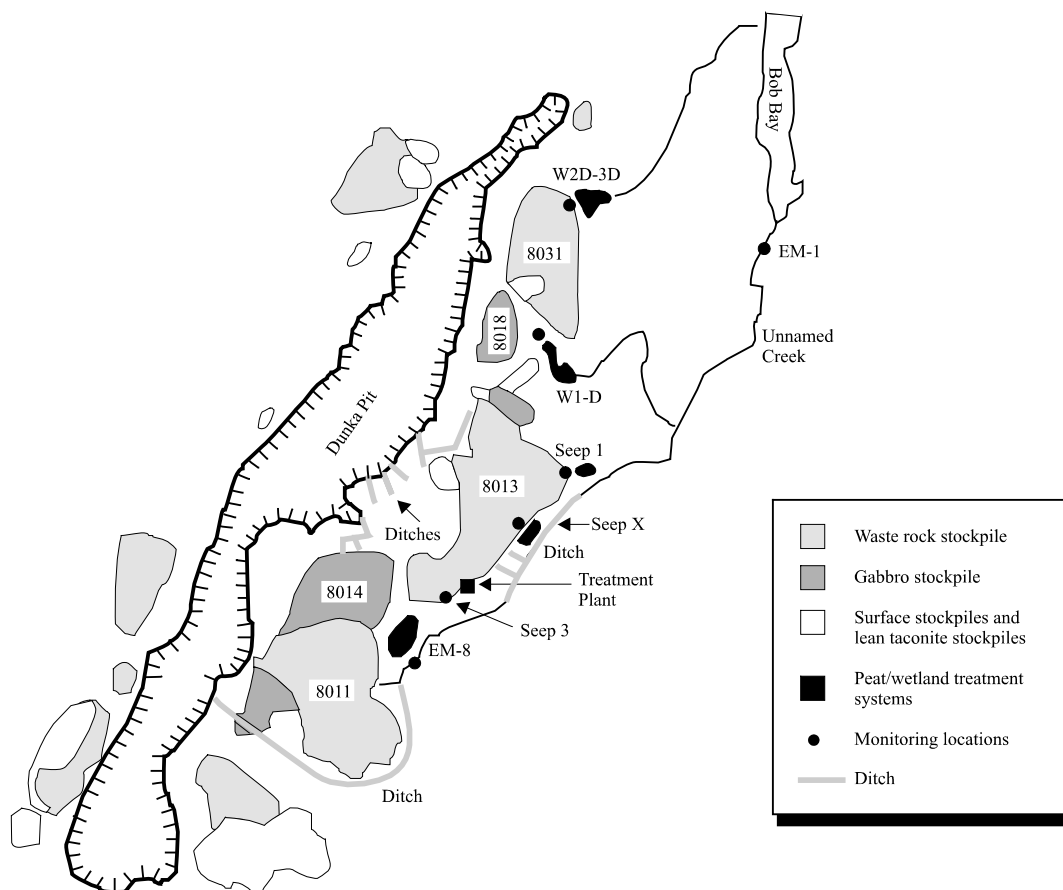


Figure 1-1. Dunka Mine waste location schematic.

DEPARTMENT : Minnesota Pollution Control Agency

PHONE : 296-8870

DATE : Febraury 1, 1991

TO : Richard Clark
Industrial Section
Water Quality Division

FROM : Carol L. Sinden *CS*
Assessment and Planning Section
Water Quality Division

SUBJECT : 7Q10 DETERMINATION FOR UNNAMED CREEK TO BOB BAY

A low flow determination was made for the unnamed creek to Bob Bay, Birch Lake as outlined below. Attached to this memo is a definition of 7Q10 low flow, a summary of the methods used to calculate a 7Q10, and literature references to these methods.

A 7Q10 identified for the purpose of setting effluent limitations is determined to represent low flow characteristics in the receiving water above the point of discharge. Flow data from station EM-1 could not be used in the analysis because EM-1, as described in Minnesota Department of Natural Resources (MDNR) reports, receives flow from mine dewatering and several seeps, in addition to natural runoff.

Information contained in Agency files indicates that stockpile construction began for the Dunka pit around 1965-1967. The overall impact of stockpile seepage on the watershed has been monitored since 1976 at station EM-1. Flow data for the unnamed creek before mining activities began in the watershed is not available.

USGS records were reviewed and continuous record gaging stations were located on the Dunka River near Babbitt and the Stony River near Isabella. The Dunka River station is located in the northeast quarter of section 9, Township 60, Range 12 West, approximately three miles southwest of Bob Bay. This station has a period of record from 1952 to 1980. The Stony River station is located in the northwest quarter of section 17, Township 60, Range 10 West, approximately eight miles southeast of Bob Bay. The period of record for this station is from 1953 to 1964.

A computer analysis of flows for each station was completed and an annual 7Q10 low flow was calculated for each station following USGS procedures. The 7Q10 low flow for the Dunka River station is 0.081 cfs, for the Stony River station, 7.7 cfs. The Dunka River station was chosen as more representative of flow characteristics for translation to the unnamed creek watershed. Flow was proportioned by drainage area for the Dunka station and this flow per square mile was multiplied by the drainage area of the unnamed creek to obtain the 7Q10 low flow estimate of 0.0 cfs (0.005 cfs). The drainage area of the unnamed creek watershed was determined by USGS at 3.57 square miles.

This flow calculation follows established USGS procedures and is in accordance with Minnesota Rules Chapter 7050.0210 Subp. 7. which states "Where stream flow records are not available, the flow may be estimated on the basis of available information on the watershed characteristics, precipitation, run-off, and other relevant data."

STATE OF MINNESOTA
Office Memorandum

7Q10 Low Flow Definition and Methods of Calculation

7Q10 low flow is defined as the lowest average discharge for seven consecutive days, having a recurrence interval of ten years. The year that a low flow will occur can't be predicted, but the probability of such flows occurring during a long time period may be estimated. For example, a low flow discharge of 3.5 cubic feet per second (cfs) having a recurrence interval of ten years indicates that a discharge at least as low as 3.5 cfs will occur as an annual minimum about ten times in one hundred years.

To derive a 7Q10 low flow, the lowest average flow in a seven consecutive day period is identified from daily discharge records at a continuous record gaging station for each year of record. The climatic year (April 1 - March 31) is used for analysis because it does not usually separate the low flow season as does the calendar year or water year. These low flow data are arrayed in order of magnitude and fit to a probability distribution. The probability distribution estimates the low flows that might recur, on the average, as an annual minimum. Data retrieval and analysis is done using a computer program available in STORET, a computerized database maintained by the Environmental Protection Agency.

Where little or no discharge information is available, other techniques are used to estimate 7Q10 low flows. One technique involves establishing a relation or regression line to transfer low flow characteristics from a continuous record gaging station to a nearby station with some flow measurements. Another technique involves calculating a rate of flow per square mile for a continuous record gaging station and translating this to the targeted site.

Procedures for calculating low flow values are outlined in the following United States Geological Survey (USGS) publications:

- Figgs, H.C. 1972. Low Flow Investigations: Techniques of Water Resources Investigations of the U.S. Geological Survey. Book 4, Chapter B1. 18 p.
- Windkov, K.L. 1977. Low Flow Characteristics of Minnesota Streams. U.S. Geological Survey Water Resources Investigations Report 77-48. 197 p.
- Arntson, A.D. and D.L. Lorenz. 1987. Low Flow Frequency Characteristics for Continuous Record Streamflow Stations in Minnesota. U.S. Geological Survey Water Resources Investigations Report 86-4353. 15 p.

7Q10 Low Flow Definition and Methods of Calculation

A 7Q10 low flow is defined as the lowest average discharge for seven consecutive days, having a recurrence interval of ten years. The year that a low flow will occur can't be predicted, but the probability of such flows occurring during a long time period may be estimated. For example, a low flow discharge of 3.5 cubic feet per second (cfs) having a recurrence interval of ten years indicates that a discharge at least as low as 3.5 cfs will occur as an annual minimum about ten times in one hundred years.

To derive a 7Q10 low flow, the lowest average flow in a seven consecutive day period is identified from daily discharge records at a continuous record gaging station for each year of record. The climatic year (April 1 - March 31) is used for analysis because it does not usually separate the low flow season as does the calendar year or water year. These low flow data are arrayed in order of magnitude and fit to a probability distribution. The probability distribution estimates the low flows that might recur, on the average, as an annual minimum. Data retrieval and analysis is done using a computer program available in STORET, a computerized database maintained by the Environmental Protection Agency.

Where little or no discharge information is available, other techniques are used to estimate 7Q10 low flows. One technique involves establishing a relation or regression line to transfer low flow characteristics from a continuous record gaging station to a nearby station with some flow measurements. Another technique involves calculating a rate of flow per square mile for a continuous record gaging station and translating this to the ungaged site.

Procedures for calculating low flow values are outlined in the following United States Geological Survey (USGS) publications:

- Riggs, H.C. 1972. Low Flow Investigations: Techniques of Water Resources Investigations of the U.S. Geological Survey. Book 4, Chapter B1. 18 p.
- Lindskov, K.L. 1977. Low Flow Characteristics of Minnesota Streams. U.S. Geological Survey Water Resources Investigations Report 77-48. 197 p.
- Arntson, A.D. and D.L. Lorenz. 1987. Low Flow Frequency Characteristics for Continuous Record Streamflow Stations in Minnesota. U.S. Geological Survey Water Resources Investigations Report 86-4353. 15 p.

Comments on LTV January 4, 1991 letter:

A 7Q10 is established for setting effluent limitations and represents low flow characteristics in the receiving stream above the point of discharge. Flow data from EM-1 cannot be used to calculate a 7Q10 low flow for the unnamed creek because flow measurements taken at EM-1 include discharge from LTV operations. Flow data before mining operations began in the watershed are not available.

Even if these flow data could be used, the figures identified by LTV in the table on page two of the letter appear to be simple computations of the lowest average discharge for seven consecutive days during the month and year specified in the table. A 7Q10 low flow value is defined as the lowest average discharge for seven consecutive days having a recurrence interval of ten years, and is calculated from an analysis of daily flows from several years of record that are fit to a probability distribution.

cc: Gary Kimball
Bill Lynott
Gene Soderbeck
Dann White

Table 5-1. Minnesota water quality standardsConcentration in $\mu\text{g/L}$; hardness in mg/L CaCO_3 .

Trace metal	Standard	Hardness, 50	Hardness, 100	Hardness, 200	Hardness, 400
Copper	CS	6.4	9.8	15	23
	MS	9.2	18	34	63
	FAV	18	35	68	126
Nickel	CS	88	158	283	508
	MS	789	1418	2549	4568
	FAV	1578	2836	5098	9136
Zinc	CS	59	106	191	343
	MS	65	117	211	3784
	FAV	130	234	421	7567
Cobalt*	CS	2.8	2.8	2.8	2.8
	MS	436	436	436	436
	FAV	872	872	872	872

Standards: CS = chronic standard, MS = maximum standard; FAV = final acute value.

CS is defined as “the highest water concentration of a toxicant to which organisms can be exposed indefinitely without causing chronic toxicity.” This is considered the ambient in stream water quality standard, which must be met on an average basis.

MS is defined as “the highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality. The MS equals the FAV divided by 2.” This is considered the ambient in stream concentration that cannot be exceeded on any given day.

FAV is defined as “an estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant.” By rule, any wastewater discharge must not exceed these standards at end-of-pipe at any time.

*LTV conducted site-specific testing and demonstrated that cobalt toxicity was a function of hardness. The cobalt chronic value for the Dunka Mine was increased to 50 $\mu\text{g/L}$.

Permit MN 0042579
Page 1 of 6



STATE OF MINNESOTA

Minnesota Pollution Control Agency

NORTH DISTRICT
PUBLIC NOTICE OF INTENT TO REISSUE
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) AND
STATE DISPOSAL SYSTEM (SDS) PERMIT MN 0042579

Public Comment Period Begins: June 16, 2000
Public Comment Period Ends: July 17, 2000

Current Permit Issued: July 30, 1991; Modified September 30, 1994
Current Permit Expiration Date: April 30, 1996

Name and Address of Permittee

LTV Steel Mining Company
P.O. Box 847
Hoyt Lakes, MN 55750

Facility Name and Location

Dunka Mine
Sec. 26, 34 & 35, T61N, R12W and Sec. 2, 3,
10 and 11, T60N, R12W
St. Louis County, MN

Receiving Waters: Unnamed Creek, a tributary to Unnamed Creek ('Billiken Creek'), and a tributary to Birch Lake ('Flamingo Creek')

Description of Permitted Facility

The principal activity at this facility was the open pit mining of taconite. Mining began in 1964 and continued through August 1994 when active mining ceased and the facility entered the closure phase. During the 30 years of mining a considerable amount of surface and rock overburden was removed to expose the taconite ore. This material was segregated and stockpiled by type (surficial, lean taconite, waste rock (low copper-nickel %), and gabbro (higher copper-nickel %)) in stockpiles adjacent to the open pit. During later years of operation, a relatively lesser volume of high sulfur/ low copper-nickel hornfels material was removed from the Dunka Mine site and disposed of in LTV's Hoyt Lakes Tailings Basin. Water quality issues, in the form of stockpile seeps containing elevated concentrations of base metals (primarily copper, nickel, cobalt and zinc) and sulfate, became apparent in the 1970s in the vicinity of stockpiles on the east side of the open pit. Previous issuances of this permit have identified the major seepages, established monitoring requirements and effluent limitations applicable to the seepages, required the installation of treatment systems capable of meeting effluent limitations for the seepages and water quality standards for the receiving waters, and the completion of best management practices such as stockpile capping and diversion ditches to reduce the volume and concentration of the seepages. The result has been the construction of a 2.5 million gallon lined equalization basin, a 350 gallon per minute lime precipitation treatment plant, and constructed wetland treatment systems at each of the stockpile seeps.

Permit MN 0042579
Page 2 of 6

Capping of stockpiles 8011, 8012, 8013, 8014, 8018 and 8031 (the 'source' stockpiles) with compacted glacial till or flexible membrane liners, or a combination, also was completed. All of the stockpiles that only required coverage as per Minnesota Department of Natural Resources (MDNR) Mineland Reclamation Rules of 1980 were covered accordingly with (MDNR) approval.

The previous issuance of this permit required the completion and submittal of a Final Closure Plan dealing with water quality issues related to the then impending closure of the mine. The Closure Plan went through several draft submittals and revisions whereby MPCA and MDNR comments were incorporated into the document. The updated Final Closure Plan was submitted on March 15, 1996. This Final Closure Plan has gone through public review and comment in accordance with MDNR Mineland Reclamation Rules. The approved Final Closure Plan describes in more detail activities that have taken place or are proposed since active operations at the mine ceased in 1994. The enhanced stockpile caps and the water diversion structures are considered integral components for the success of the facility's wastewater treatment system. All closure activities contained in the Final Closure Plan, with the exception of the construction of the potential Dunka Lake outlet, have been completed.

Currently, the following approximate wastewater flows are present at each of the seeps:

<u>Seep</u>	<u>97-99 Ave. Flow</u>	<u>97-99 Max. Mo. Flow</u>	<u>Outfall No.</u>
041	0.117 MGD	0.372 MGD	SD007 (070)
043	0.006 MGD	0.032 MGD	SD008 (080)
044	0.058 MGD	0.149 MGD	SD009 (090)
050/051	0.045 MGD	0.144 MGD	SD005 (050)
060/061	0.072 MGD	0.376 MGD	SD006 (060)

Wastewater from seeps 041, 043 and 044 currently does not discharge directly but rather is collected (following wetland treatment) and pumped to the equalization basin during nonfreezing months for subsequent treatment at the lime precipitation plant and discharged through outfall SD004 (040). Under this reissued permit wastewater from these seeps will be discharged directly year-round through new outfalls SD007 (070), SD008 (080) and SD009 (090) respectively. Seep 042, identified in previous issuances of this permit, has been monitored since its discovery at the Dunka Mine. Closure activities that have already been enacted have resulted in improvements to the untreated Seep 042 water quality such that it complies with applicable discharge and water quality standards. Therefore, no further limitations or monitoring of Seep 042 is necessary. Wastewater from seep 051 is treated by wetland treatment and discharged through outfall SD005 (050), however, facilities are in place to collect and pump the wastewater to the equalization basin should the effluent fail to meet discharge limitations. Wastewater from seep 061 is treated by wetland treatment and discharged through outfall SD006 (060) with no ancillary collection or pumping facilities present. Outfalls SD005 (050) and SD006 (060) will remain in place in this permit. The lime precipitation plant and outfall SD004 (040) will remain in place as a backup to the wetland systems, and will be used if the wetland systems fail to achieve effluent limitations or if water quality standards in Unnamed Creek are exceeded. Chronic toxicity testing will be required at Unnamed Creek monitoring station SW001 (701).

Permit MN 0042579
Page 3 of 6

Since the mine is now inactive, mine pit dewatering has ceased and the pit is being allowed to fill with water. Dewatering discharge points and monitoring stations 010, 020 and 030 identified in previous issuances of this permit are currently not in use. Discharge outfalls 020 and 030 will be terminated and eliminated from this permit, however, discharge outfall SD001 (010) will be retained in this permit in the unforeseen event that mine pit dewatering may become necessary. Eventually the mine pit may fill to the point where an artificial discharge point may need to be established to prevent inundation of diversion ditches or stockpiles. Such discharge point, if needed, will likely be constructed at the north end of the pit and discharge to Flamingo Creek or Birch Lake. The filling of the mine pit with water and the establishment of the overflow discharge point is projected to take place at some time subsequent to the expiration of this reissued permit. A requirement to evaluate this issue and propose a discharge solution is being added as a condition to this permit. A map of this facility is on the last page of this notice.

The draft permit includes a variance from Minnesota Rules that reads as follows:

The Permittee is granted a variance from the provisions in Minn. Rules pts. 7050.0212, subp.6, and 7050.0222, subp. 7.B, that require concentrations of toxic pollutants from a point source to not exceed the Final Acute Value (FAV) at the point of discharge, for outfalls SD008 and SD009, in accordance with Minn. Rules pts. 7000.7000 and 7050.0190. The Permittee shall comply with the additive toxicity effluent limitations for outfalls SD008 and SD009, specified in the Limits and Monitoring Requirements Section and further described in Chapter 1.3.1 of this permit.

MPCA staff is recommending that the MPCA Citizen's Board approve the variance request based on the following factors. Firstly, recent biological monitoring has shown that Unnamed Creek contains an abundance and diversity of aquatic species including sensitive fish and invertebrate species demonstrating the ecological health of the stream. Secondly, the hardness concentrations in the wetland treatment systems' effluent and in Unnamed Creek are at a relatively high level that likely reduces the actual toxicity of the metals in the water. Water Quality Rules, from which the effluent limits are calculated, do not take into account the higher hardness-lower toxicity relationship to the extent that it occurs in the Unnamed Creek watershed. Thirdly, the Permittee has completed extensive remediation and reclamation activities at the mine site to reduce the volume and concentration of seepage discharges, including diversion of surface and ground water and capping of stockpiles much beyond what is required by MDNR Reclamation Rules. **Further reductions in flows and metal loads are not practically achievable.** And lastly, the cost to upgrade the existing wastewater collection system and mechanical treatment plant, which currently cannot operate during extended freezing conditions, for winter operation is not warranted for the relatively small volume of water that is discharged during the winter. Continued biological monitoring and toxicity testing of Unnamed Creek, and an evaluation to improve existing wetland treatment system performance are requirements of the proposed permit.

Preliminary Determination on the Draft Permit

The MPCA Commissioner has made a preliminary determination to reissue this NPDES/SDS permit for a term of approximately five years.

[illegible]



Minnesota Department of Natural Resources

1 Lafayette Road
Minnesota 55155-40__45

*Pls send it on
to the file when
you're done. Thx.
Deb*

January 10, 2001

Mr. Pat Carey
MN PCA - Duluth
704 Government Service Center
320 W. 2nd Street
Duluth, MN 55802

Dear Pat:

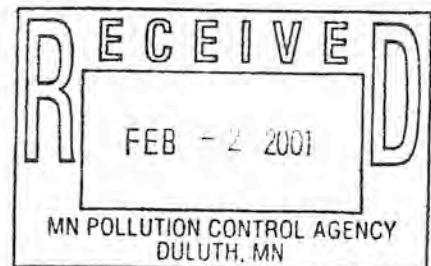
We have recently completed our final report on the long term effectiveness of wetland treatment at LTV's Dunka Mine. I have attached the executive summary, and would be happy to send you the complete report if you are interested.

Sincerely,

Paul

Paul Eger
Principal Engineer

cc: Arlo Knoll



**Long Term Wetland Treatment of Mine Drainage
at LTV Steel Mining Company's Dunka Mine**

December 2000

Paul Eger
Jon Wagner
Glenn Melchert
David Antonson
Andrea Johnson

Minnesota Department of Natural Resources
Division of Lands and Minerals
500 Lafayette Road
St. Paul, MN 55155-4045

Executive Summary

A study was conducted at LTV's Dunka Mine in northeastern Minnesota to examine the long term metal removal in two wetland treatment systems that had operated for seven years. One system was an overland flow wetland that had been constructed to treat neutral drainage with an average nickel concentration of around 5 mg/L. The other was a pretreatment system which was installed to treat a drainage with an average pH of 5.4, and which contained 14.7 mg/L of nickel and 0.69 mg/L of copper.

W1D overland flow wetland

The wetland system was constructed in 1992, and the stockpile that contributed the major load to the wetland was capped with a linear low density polyethylene liner in 1995. Over 90% of the metal input to the wetland occurred before the stockpile was capped. After capping, both flow and nickel concentrations decreased. Flow decreased by 55%, while average nickel concentrations decreased by 82%, from 3.98 mg/L to 0.74 mg/L.

The overall nickel removal in the system prior to capping the stockpile averaged 89%. After capping, the input load to the wetland decreased by over 90% and the average percent removal decreased to 61%. Despite lower input concentrations after capping, nickel removal continued throughout the entire study period.

In order to examine treatment lifetime, a portion of the wetland (W1D study cell), which had accounted for 26% of the total nickel removal, was selected for detailed study. Mass balance calculations conducted for the study cell indicated that essentially all the nickel removed from the water could be accounted for by the estimated nickel mass within the substrate. There was no evidence of nickel being removed from the wetland.

Assuming that the post capping load to the wetland remains unchanged, and that new metal removal sites are formed from decaying vegetation in the wetland, there appears to be a balance between the input metal load and the yearly generation of removal sites. If this situation continues, the wetland may be self-sustaining, and treatment may continue indefinitely.

Seep 1 pretreatment system

The pretreatment system is comprised of a pool with two limestone berms, a peat-mixture substrate, and a vertical down-flow section through which the water flows prior to discharge. The system was constructed in 1992, and has generally been successful in increasing pH from an average of 5.40 to 6.95. Copper concentrations have decreased by about 70% and nickel concentrations have decreased by 55%.

The pH increase and much of the copper removal are related to dissolution of the limestone within the pretreatment system. Although it was not possible to calculate a limestone dissolution rate and an expected lifetime, there is no data to suggest that the rate of dissolution has decreased. Nickel removal within the pretreatment system averaged only 15-20%, and occurred primarily in the vertical down-flow section of the system. The major reduction in nickel load appears to be related to capping of the stockpile, and not to removal within the pretreatment system. In 1999, removal in the vertical down-flow section was only 8%, and additional data should be collected to determine if the system has reached saturation.