

- During August 2008 Flambeau partnered with local prairie enthusiasts to hold a Prairie Workshop.
- The UW-Extension's Healthy Lifestyles for Rusk County held their third annual community walk on the reclaimed Flambeau Mine nature trails in early September 2008.
- During late September 2008, as part of the Leaf it to Rusk Fall Festival, Flambeau and the Flambeau Riders partnered to host trail rides and horse drawn wagon rides on the Copper Park Equestrian Trails. Over 50 community members turned out for the event.
- Flambeau continued its open door policy and upon request conducted tours of the mine site. Included were the Indianhead Headstart and Ladysmith and Flambeau grade school children taking spring and fall hikes on the reclaimed mine site to learn about natural resources.
- Flambeau partnered with the Rusk Area Arts Alliance to produce the 2009 Reclaimed Flambeau Mine calendar featuring local artists. The artists provided artwork of varying media depicting their interpretation of the natural beauty of the reclaimed mine site.

## **2.6 Water Management**

### **2.6.1 Precipitation Runoff**

Since 2000, the reclaimed mine site surface remains stabilized by vegetative growth and there is minimal evidence of erosion. Aerial photographs (color and infrared) taken during August 2006 document surface stabilization of the reclaimed mine site.

Flambeau River water quality samples were collected upstream and downstream from the reclaimed mine site during 2008. Comparing analytical results, there was no notable difference between downstream and upstream samples and this further confirms that the reclaimed site is stable and functioning as designed. A summary of Flambeau River water quality results is found in Appendix B and Appendix C.

### **2.6.2 River Water Withdrawal**

On May 5, 1998 the Department approved Flambeau's application to withdraw water from the Flambeau River for use on site. The Department's approval requires submittal of monthly summaries for months during which a withdrawal occurs. When the irrigation pump system operates it is powered with a portable generator since electrical supply had been removed during 2001. During 2008 no water was withdrawn from the Flambeau River.

Wetland 1 is located immediately west of the reclaimed mine site. With the backfilling of the

- ◆ MW-1013C: Long-term increasing trends were observed for alkalinity, iron and manganese, with iron continuing an increasing trend in the recent (5-year) results. Conductivity has a recent decreasing trend.
- ◆ MW-1014: Manganese and pH have recent decreasing trends.
- ◆ MW-1014A: Decreasing trends were noted for iron and manganese. Iron has generally been at non-detectable levels since 2004. A long-term increasing trend was noted for alkalinity, but reflected relatively smaller concentration changes with no recent trend.
- ◆ MW-1014B: Long-term decreasing trends were observed for hardness, manganese and TDS and conductivity. No recent trends are occurring with hardness, TDS and conductivity, but the decreasing trend continues with manganese in the recent data.
- ◆ MW-1014C: Long-term and recent decreasing trends were observed for hardness, iron, manganese, sulfate, TDS and conductivity. Long-term increasing trends are noted for arsenic and pH, but no recent trends are noted for these parameters.

#### Annual Parameters (Attachment 2)

Similar to past trend results, the annual groundwater parameters of barium, cadmium, calcium, chloride, chromium, lead, magnesium, mercury, potassium, selenium, silver, sodium, and zinc illustrated few statistically significant trends, and of those that are noted, most generally reflect small consecutive changes in actual low concentrations. Of the somewhat moderate trends, MW-1000P-R has had a recent decreasing trend of zinc and long-term decreasing trends (but no recent trends) of calcium and magnesium. MW-1014B has had long-term (but no recent) decreasing trends of cadmium and magnesium. MW-1014C has had recent and long-term decreasing trends of calcium, magnesium and zinc. A long-term increasing trend of barium was also detected in MW-1014C, however this trend is an artifact of the higher method detection limits utilized prior to 2003 than those currently in use.

#### Surface Water (Attachment 3)

Parameters currently included in the surface water monitoring are copper, hardness, iron, manganese, sulfate, zinc, pH and conductivity. No statistically significant trends were observed in either the upstream or downstream surface water monitoring results, with the exception of an increasing trend of zinc in SW-2. This increasing trend, however, is an artifact of the higher method detection limits utilized prior to 2003 than those currently in use.

The increase in manganese at both the upstream and downstream locations during August and September of 2007, which may in part have resulted from Flambeau River work completed by others at the North Dairyland dam, again decreased to historical levels.

#### Hydrographs (Attachment 4)

As observed in the hydrographs, all wells illustrating significant drawdown during the production period of 1993 to 1997 now appear to be substantially stabilized. The wells include MW-1000P-R, MW-1001, MW-1001G, MW-1001P, MW-1003, MW-1003P, MW-1004, MW-1004P, MW-

***Attachment 3***

***Statistical Results***

***Trend Graphs***

***Historical Data***

***(Surface Water)***

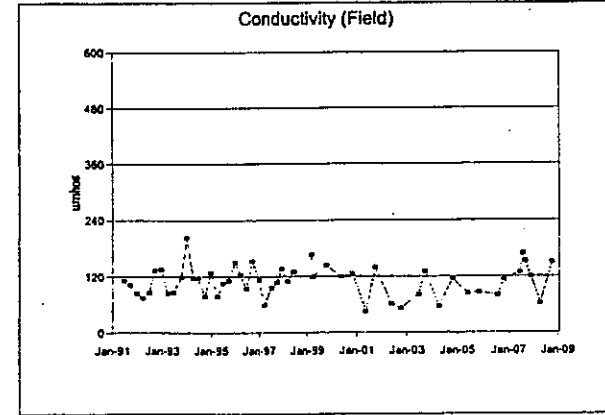
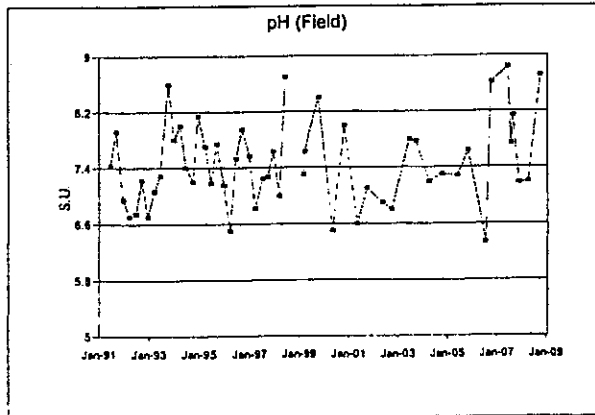
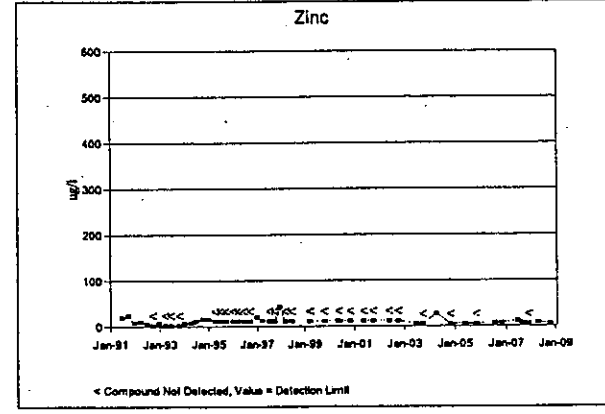
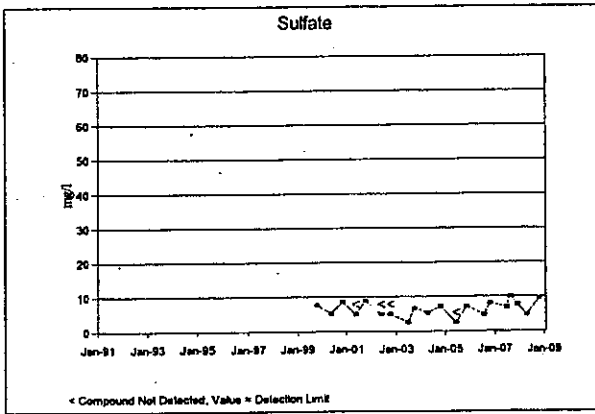
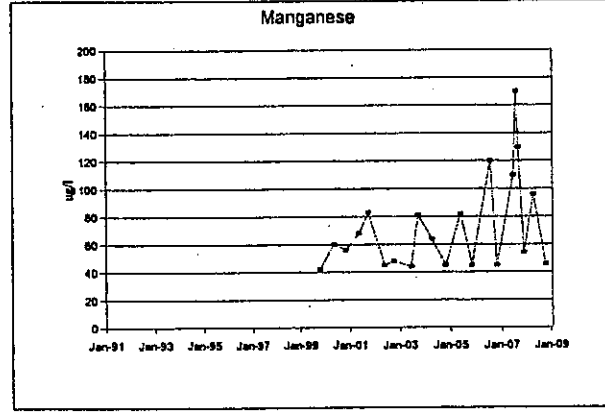
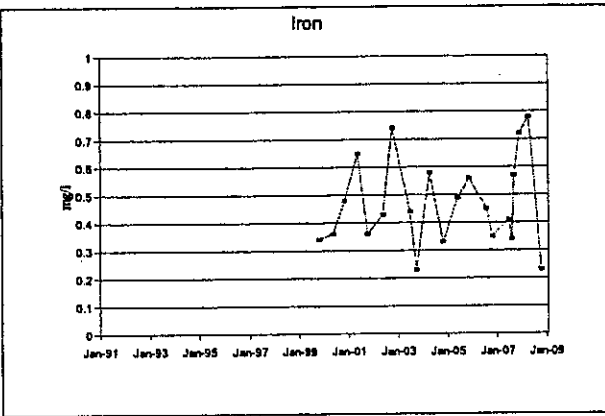
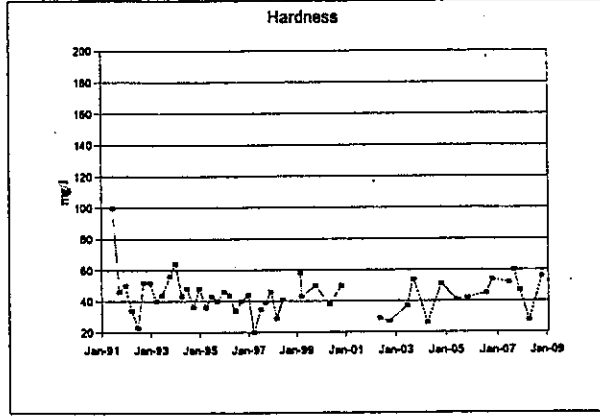
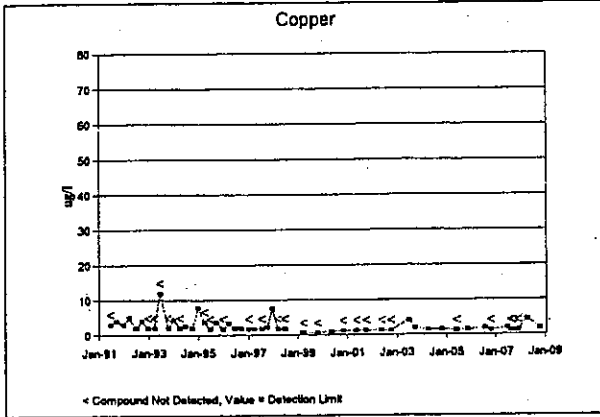
**Trend Analysis Results - Surface Water  
Year Ending 2008**

	Conductivity (Field) (umhos)	pH(Field) (su)	Copper	Hardness	Iron	Manganese	Sulfate	Zinc
<b>SW-1</b>								
<b>Trend Results for Most Recent 5 Years</b>								
Sample Size	12	12	12	11	12	12	12	12
Mann-Kendall S	24	15	5	21	2	11	21	2
p-Level	0.116	0.345	0.789	0.120	0.946	0.503	0.174	0.946
Trend								
<b>Trend Results for All Data Since Oct. 1997</b>								
Sample Size	27	27	27	24	21	21	21	27
Mann-Kendall S	4	46	24	54	19	54	54	112
p-Level	0.951	0.351	0.635	0.190	0.591	0.110	0.110	0.019
Trend								
<b>SW-2</b>								
<b>Trend Results for Most Recent 5 Years</b>								
Sample Size	12	12	12	11	12	12	12	12
Mann-Kendall S	24	20	29	18	-7	6	26	8
p-Level	0.116	0.196	0.053	0.191	0.688	0.738	0.086	0.638
Trend								
<b>Trend Results for All Data Since Oct. 1997</b>								
Sample Size	27	27	27	24	21	21	21	27
Mann-Kendall S	-20	49	70	38	2	39	67	124
p-Level	0.695	0.320	0.152	0.362	0.976	0.255	0.045	0.009
Trend								+

Notes: Overall increasing trend denoted by "+".  
 Overall decreasing trend denoted by "-".  
 All trend tests performed at a Type I (two-tailed) error rate of 0.01.

Flambeau Mining Company  
Surface Water Quality Results

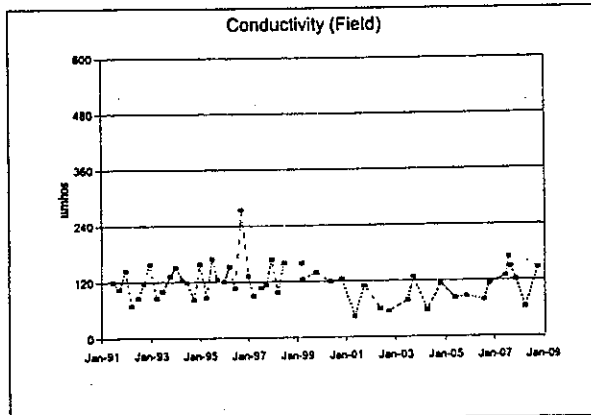
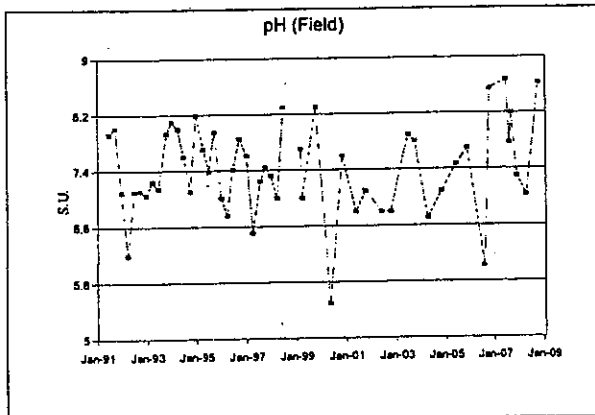
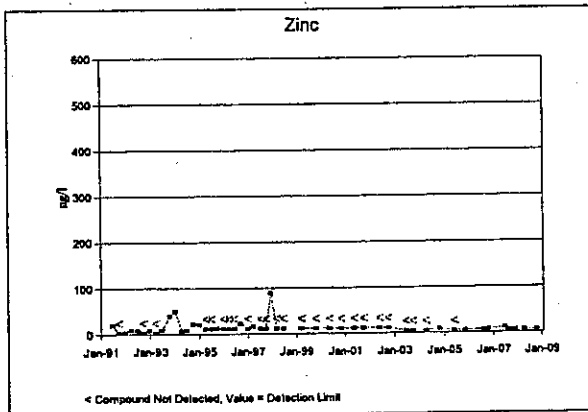
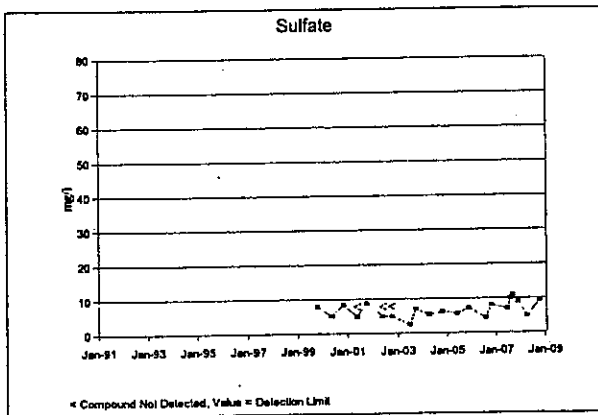
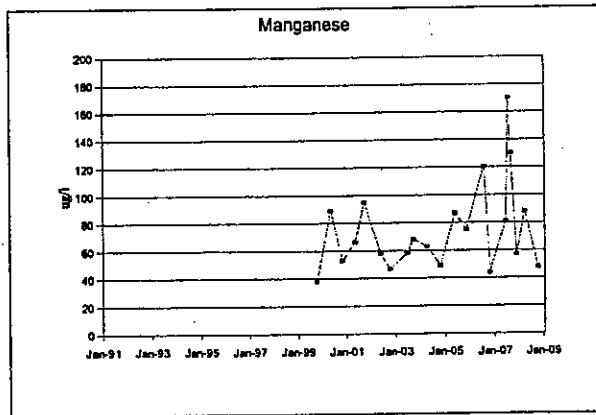
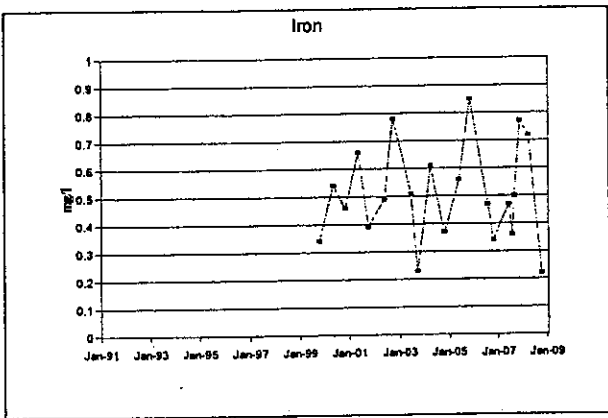
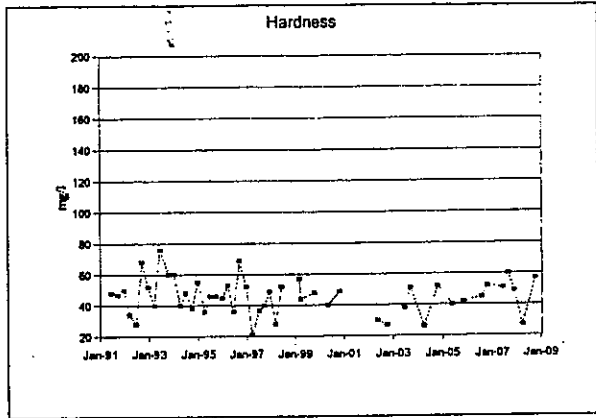
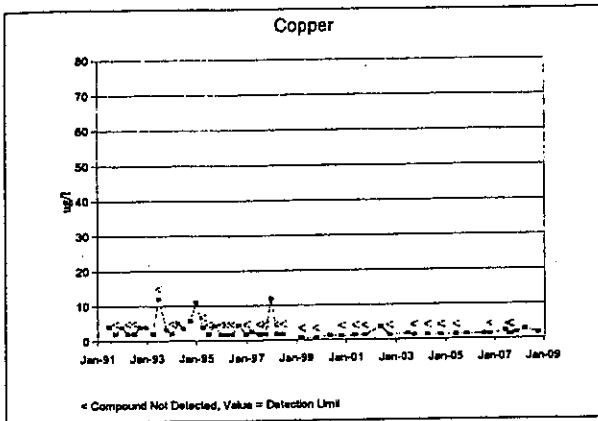
SW-1 (Upstream)



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Surface Water Quality Results

SW-2 (Downstream)



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## Historical Surface Water Results

Date	Sample Point Name	Field pH	Field Cond	Copper (ug/l)	Hardness (mg/l)	Iron (mg/l)	Manganese (ug/l)	Sulfate (mg/l)	Zinc (ug/l)
07/91									
	SW-1	7.43	112	< 3	100				20
	SW-2	7.92	120	4.2	48				20
10/91									
	SW-1	7.92	102	4	46				24
	SW-2	8.01	104	< 2	47			<	3
01/92									
	SW-1	6.95	84	3	50				8
	SW-2	7.09	144	4	50				4
04/92									
	SW-1	6.71	74	5	34				11
	SW-2	6.19	69	< 2	34				9
07/92									
	SW-1	6.75	86	2	23				6
	SW-2	7.1	85	< 2	28				8
10/92									
	SW-1	7.23	134	4	52			<	3
	SW-2	7.11	117	4	68			<	3
01/93									
	SW-1	6.71	136	< 2	52				7
	SW-2	7.05	158	4	52				8
04/93									
	SW-1	7.07	84	< 2	40			<	3
	SW-2	7.25	85	2	40			<	3
07/93									
	SW-1	7.29	87	< 12	44			<	3
	SW-2	7.14	100	< 12	76				9
11/93									
	SW-1	8.59	118.9	< 2	56			<	3
	SW-2	7.93	132.6	3.2	60				40
01/94									
	SW-1	7.8	203	4.4	64				7
	SW-2	8.1	151	< 2	60				50
04/94									

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## Historical Surface Water Results

Date	Sample Point Name	Field pH	Field Cond	Copper (ug/l)	Hardness (mg/l)	Iron (mg/l)	Manganese (ug/l)	Sulfate (mg/l)	Zinc (ug/l)
04/94	SW-1	8	118	< 2	43				9
	SW-2	8	124	5.1	40				7
07/94	SW-1	7.4	117	2.7	48				11
	SW-2	7.6	119	3.6	48				9
10/94	SW-1	7.2	78	2	36				17
	SW-2	7.1	82	5.7	38				23
01/95	SW-1	8.14	128.5	7.8	48				16
	SW-2	8.19	158.3	11	55				21
04/95	SW-1	7.7	78.1	< 3.8	36				< 12
	SW-2	7.7	86.2	< 3.8	36				< 12
07/95	SW-1	7.18	105.5	< 1.7	43				< 12
	SW-2	7.38	170	< 1.7	46				< 12
10/95	SW-1	7.74	112.5	3.7	40				< 12
	SW-2	7.95	126.3	4.3	46				13
01/96	SW-1	7.15	150.5	< 1.7	46				< 12
	SW-2	7.01	120.2	< 1.7	45				< 12
04/96	SW-1	6.5	124	3.3	44				< 12
	SW-2	6.76	153.1	< 1.7	53				< 12
07/96	SW-1	7.53	94.5	2.1	34				< 12
	SW-2	7.41	106.8	< 1.7	36				< 12
10/96	SW-1	7.95	153.5	1.9	40				< 12
	SW-2	7.86	274	4.3	69				23
01/97									

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## Historical Surface Water Results

Date	Sample Point Name	Field pH	Field Cond	Copper (ug/l)	Hardness (mg/l)	Iron (mg/l)	Manganese (ug/l)	Sulfate (mg/l)	Zinc (ug/l)
01/97	SW-1	7.57	113.3	< 1.7	44				21
	SW-2	7.61	132	< 1.7	52				< 12
04/97	SW-1	6.82	58.9	1.8	20				13
	SW-2	6.51	89.6	2.6	21				17
07/97	SW-1	7.25	96.1	< 1.7	35				< 12
	SW-2	7.25	106.8	< 1.7	37				< 12
10/97	SW-1	7.27	107.6	2.2	39				< 12
	SW-2	7.44	113.8	< 1.7	40				< 12
01/98	SW-1	7.63	136.3	7.6	46				43
	SW-2	7.32	167.9	12	49				89
04/98	SW-1	7	110	< 1.7	29				< 12
	SW-2	7	97	< 1.7	28				< 12
07/98	SW-1	8.7	130	< 1.7	41				< 12
	SW-2	8.3	160	< 1.7	52				< 12
03/99	SW-1	7.3	166.7	0.74	58				< 12
	SW-2	7.7	159.6	< 0.6	57				< 12
04/99	SW-1	7.63	119.3	< 0.6	43				< 12
	SW-2	7	124.7	< 0.6	44				< 12
11/99	SW-1	8.4	144	< 0.6	50	0.34	42	7.7	< 12
	SW-2	8.3	139	< 0.6	48	0.34	38	7.9	< 12
06/00	SW-1	6.5	120	0.94	38	0.36	60	5.2	< 12
	SW-2	5.5	120	1.3	40	0.54	89	5.2	< 12
11/00									

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## Historical Surface Water Results

Date	Sample Point Name	Field pH	Field Cond	Copper (ug/l)	Hardness (mg/l)	Iron (mg/l)	Manganese (ug/l)	Sulfate (mg/l)	Zinc (ug/l)
11/00	SW-1	8	126	< 1.2	50	0.48	56	8.6	< 12
	SW-2	7.6	125	< 1.2	49	0.46	53	8.4	< 12
06/01	SW-1	6.6	45	< 1.3		0.65	68	< 5	< 12
	SW-2	6.8	44	< 1.3		0.66	66	< 5	< 12
10/01	SW-1	7.1	140	< 1.3		0.36	83	8.8	< 12
	SW-2	7.1	110	< 1.3		0.39	95	8.9	< 12
06/02	SW-1	6.9	61	< 1.3	29	0.43	45	< 5	< 12
	SW-2	6.8	60	3.7	30	0.49	58	< 5	< 12
10/02	SW-1	6.8	52	< 1.3	27	0.74	48	< 5	< 12
	SW-2	6.8	55	< 1.3	27	0.78	47	< 5	< 12
07/03	SW-1	7.8	81	4.2	37	0.44	44	2.6	5.1
	SW-2	7.9	78	1.8	38	0.51	58	2.6	< 5
10/03	SW-1	7.77	131	2	54	0.23	81	6.7	< 5
	SW-2	7.8	128	< 1.3	51	0.23	68	7.1	< 5
04/04	SW-1	7.2	57	1.5	26	0.58	64	5.4	28
	SW-2	6.7	57	< 1.3	26	0.61	63	5.4	< 5
11/04	SW-1	7.3	115	1.6	51	0.33	45	7.2	< 5
	SW-2	7.09	114	< 1.3	52	0.37	49	6.3	8.8
06/05	SW-1	7.28	84	< 1.3	41	0.49	82	< 2.5	6
	SW-2	7.47	83	< 1.3	40	0.56	87	5.7	< 5
11/05	SW-1	7.64	87	1.5	42	0.56	45	7.2	< 5
	SW-2	7.7	87	1.4	42	0.85	75	7.3	5.9
08/06									

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## Historical Surface Water Results

Date	Sample Point Name	Field pH	Field Cond	Copper (ug/l)	Hardness (mg/l)	Iron (mg/l)	Manganese (ug/l)	Sulfate (mg/l)	Zinc (ug/l)
08/06	SW-1	6.34	80	1.9	45	0.45	120	4.7	7.3
	SW-2	6.02	78	1.5	45	0.47	120	4.3	6.9
11/06	SW-1	8.62	113	< 1.3	54	0.35	45	8.1	7.1
	SW-2 (Dup)			< 1.3	52	0.34	44	8.1	7.8
	SW-2	8.55	113	< 1.3	52	0.34	44	8.1	7.8
07/07	SW-1	8.84	129	2	52	0.41	110	6.9	12
	SW-2	8.67	129	2.3	51	0.47	81	7	11
08/07	SW-1	7.74	169	< 1.3		0.34	170	10	7.5
	SW-2	7.77	169	< 1.3		0.36	170	10	6.4
09/07	SW-1	8.14	152.4	< 1.3	60	0.57	130	10	6
	SW-2	8.2	149	< 1.3	60	0.5	130	11	5.4
12/07	SW-1	7.18	120	< 1.3	47	0.72	54	7.7	< 5
	SW-1 (Dup)			< 1.3	51	0.76	56	8.8	< 5
	SW-2	7.3	122	1.7	49	0.77	57	9.1	6.5
04/08	SW-1	7.2	62.7	4.4	28	0.78	96	4.7	8.5
	SW-2	7.03	63.2	2.8	27	0.72	88	4.9	5.5
10/08	SW-1	8.72	149.9	1.8	56	0.23	46	9.5	6.1
	SW-1 (Dup)			2.2	58	0.24	48	9.8	5.5
	SW-2	8.63	146.6	1.8	57	0.22	48	9.4	6.9

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**TABLE PREPARED BY PHIL FAUBLE  
ENTITLED, "COPPER  
CONCENTRATIONS IN STREAM C  
AND THE BIOFILTER"**

# Copper Concentrations in Stream C and the Biofilter

Biofilter

Stream C

<u>Sample Date</u>	<u>Inflow (BFSW-C1)</u>	<u>Outflow (BFSW-C2)</u>	<u>Upstream (SW-C8)</u>	<u>Downstream (SW-C5)</u>
09/16/2004	1000 ppb	67 ppb	140 ppb	44 ppb
10/23/2004	1000 ppb	28 ppb	200 ppb	26 ppb
04/26/2005	780 ppb	27 ppb	38 ppb	24 ppb
06/09/2005	530 ppb	46 ppb	170 ppb	52 ppb
08/27/2005	2000 ppb	41 ppb	N/A	N/A
09/19/2005	1400 ppb	61 ppb	N/A	N/A
Remedial Action				
08/03/2006	140 ppb	33 ppb	160 ppb	74 ppb
10/04/2006	95 ppb	16 ppb	390 ppb	23 ppb
11/28/2006	80 ppb	34 ppb	NS	46 ppb
05/24/2007	58 ppb	13 ppb	61 ppb	30 ppb
08/21/2007	130 ppb	3.9 ppb	80 ppb	11 ppb
09/21/2007	270 ppb	15 ppb	86 ppb	42 ppb
04/25/2008	80 ppb	22 ppb	33 ppb	14 ppb
10/27/2008	70 ppb	16 ppb	NS	16 ppb
04/25/2009	62 ppb	15 ppb	26 ppb	21 ppb

**"APPENDIX B, SURFACE WATER  
ANALYSIS, FLAMBEAU MINE  
RECLAMATION, LADYSMITH,  
WISCONSIN"**

**Appendix B**

**Surface Water Analysis  
Flambeau Mine Reclamation  
Ladysmith, Wisconsin**

## INTRODUCTION

The tributary area for the Flambeau Mine site which will be reclaimed as a combination of wetlands, prairie, and meadows is limited and is expected to provide only marginal stormwater runoff to support wetland vegetation in the reclaimed area. This analysis will therefore focus on the reclaimed area hydrology and hydraulics and will define the runoff expectations for the area tributary to the reclaimed natural area. The southeastern 23.4 acres of the site (outside of the reclaim area) is proposed to be developed. This area is tributary to Stream C, so analysis of the major storm runoff rates in Stream C after the area would be fully developed were also required. All streams included in this analysis are intermittent systems. The Flambeau River is not addressed in this analysis.

### Existing Conditions

The general tributary area for the Flambeau Mine is shown on the General Area Map (Figure 1). The Map shows that the natural land use area is planned to be divided into north and south sections, with similar topography to that which existed prior to commencement of the mining operations. Each section will include a stream which will be routed through the section to distribute water to and collect excess runoff from the sub-areas within the section and to also convey water through the section.

Approximately 138.7 acres east of Highway 27 is tributary to the site; 51.3 acres now flows into the northern area of the site through a 24-inch culvert under Highway 27 and 87.4 acres flows into the southeastern corner of the site through a 30-inch culvert under Highway 27 as shown on the Figure in Appendix A. The flow to the southeastern corner of the site is presently ditched to the southern boundary of the site. Land use for the offsite tributary area is open woods and meadow except for the frontage along Highway 27 which has low density residential and commercial development.

Hydric soil from the mine area is being stored at the southwestern corner of the site in a temporary wetland area. An outlet structure (Figure 1), which includes a rip-rapped channel, is an outlet point into the Flambeau River. This structure also includes a rectangular opening 3.5 feet wide and a V-notch weir within the opening. The bottom of the rectangular opening is at elevation 1099.15 and the top of the opening is at elevation 1100.9. The bottom of the V-notch is presently set at elevation 1099.4.

A wetland was also constructed at the northeastern corner of the mine site during the development of the mine. Runoff from 51.3 acres of the offsite tributary area east of Highway 27 and 13 acres within the mine site property (including the wetland) is presently routed through this wetland using an adjustable diversion structure. A ditch has been routed around the north and west sides of the mine property to convey water from the wetland. This water presently is discharged to an existing offsite gravel pit.

## Proposed Conditions

The reclaimed Flambeau Mine site is planned to be reconstructed with a central ridge, which will divide the site into north and south drainage areas similar to that which existed prior to the mining operation. Channels will be constructed through both the north and south drainage areas to convey stormwater runoff both from the offsite area east of Highway 27 and the runoff from the site through the reclaimed area. The south channel will discharge into a 1.7 acre biofilter wetland at the southwestern corner of the reclaimed area. Overflow from this biofilter will be routed to the Flambeau River using the 002 route (Figure 1). The north channel will route offsite runoff first into a 8.5 acre mitigation wetland and then to intermittent stream A at the western boundary of the Flambeau Mine site (Figure 1). The southeastern part of the site (not included in the reclaimed area) will be developed and graded as a separate tributary area; its drainage will not be routed through the reclaimed site, but will be routed into Stream C from a biofilter/detention basin. Tributary areas for the Flambeau Mine reclamation area are shown in the Drainage Area Map (Appendix A) for the onsite sub-areas and the offsite tributary areas.

Within the north section of the reclaimed area, several small depressed areas will be constructed and vegetated as sedge meadow or wet prairies. Approximately 1.5 acres of the site will be used for these depressed retention areas. Depressional storage will provide a supply of water for this vegetation during dry periods. The sources of this supply will be:

- snow melt
- rainfall runoff from areas tributary to the depressions
- flow diverted from the north channel

Runoff from 78.9 acres within the reclamation area will be tributary to the south biofilter. The 87.4 acres of offsite tributary area which presently drains to the site through the 30-inch diameter culvert under Highway 27 will continue to be routed in its present drainage pattern in Stream C and will not be diverted to the reclamation area.

The 111.1-acre area tributary to the north channel includes 51.3 acres from east of Highway 27, 45.8 acres of the reclaimed mining site and 14.0 acres from offsite areas northeast of the site and west of Highway 27. Nine acres of the area tributary to the north channel will be first routed through depressional storage areas. These northern depressional storage areas will retain the normal rainfall runoff.

Two wetland areas are proposed within the reclamation area which will require a water supply. At the northeast corner of the site, the existing wetland will be enlarged, relocated, and lowered to provide the necessary mitigation wetland area. The proposed wetland area will be 8.5 acres below the proposed overflow elevation of 1136. The wetland will benefit from a lowered elevation by the additional 5 acres of offsite tributary area which can be routed to a lowered wetland. The northeast mitigation wetland will be constructed to a control water level at elevation 1136.0; its overflow is proposed to be regulated by a 10-foot long earthen overflow weir located at the western edge of the wetland (Appendix C). At the southwestern corner of the site, the present hydric soils stockpile area will be regraded as a 1.7-acre biofilter with a normal water elevation of 1099. Excess water from this biofilter will be discharged through the existing



overflow structure located on the south edge of the present hydric soils stockpile area. The V-notch weir system will be retained, with the plate modified to lower the normal water elevation to 1099.0. Discharge - stage - storage volume relations for the southwestern biofilter are tabulated in Appendix C.

Drainage from the future industrial area of the Flambeau Mine property (south of the reclaimed area) will be conveyed to the existing surge pond at the east side of the site. This surge pond will be reconstructed as a biofilter/detention basin, to improve the water quality and decrease the peak flow rates of runoff from the developed area prior to its discharge into Stream C.

## **METHODOLOGY**

### **Hydrologic Model**

The hydrologic model, Technical Release No. 20 (TR-20) was used to evaluate the surface water flows for the proposed reclamation area. TR-20 was developed and is supported by the United States Soil Conservation Service. Several rainfall events were evaluated in this analysis to define the stormwater runoff impacts and water supply availability for the reclaimed mine area. A rainfall event expected to occur once a year (one year design storm) was modeled to determine the expected water levels and storage which could be expected to occur once annually. Both 10-year and 100-year design storms were modeled to define the flooding effects of larger rainfall events on channel and overflow structure designs. A 2-year design storm was modeled to define water levels and storage for stream bankfull situations (natural stream channels typically flow full while carrying runoff from a two-year flood event). Finally, 1-inch and 1.5-inch rainfall events were modeled to define the available water from the smaller storm events which would be expected to occur frequently during the year. For the smaller rainfall events, some interpretation of the output data (Appendices E and F) was necessary, since the model gave occasional inconsistent results with the smaller rainfall values.

### *Rainfall Parameters*

Rainfall events were modeled for twenty-four hour duration storms. The rainfall values for these events were obtained from the United States Weather Bureau's Technical Paper 40. This document defines the rainfall amounts for the Ladysmith area as shown in Table 1.

**Table 1**  
**24 Hour Storm Rainfall Amounts**

<i>Storm Frequency</i>	<i>Rainfall Amount</i>
1 yr.	2.3 inches
2 yr.	2.7 inches
10 yr.	4.0 inches
100 yr.	5.6 inches

The rainfall was modeled using a Type II distribution of rainfall over the 24 hour storm period, consistent with the recommendations for TR-20 use in Midwestern states.

***Tributary Area Parameters***

The predominant soil types in the tributary area were shown in the "Surface Water Management Plan" (Foth and Van Dyke, 1991) to be classified as Type B soils by the United States Soil Conservation Service. The runoff coefficients for the type B soils as used in this analysis are tabulated below for the different land uses within the tributary area.

**Table 2**  
**TR-20 Model - Runoff Coefficients**

<i>Land Use</i>	<i>Runoff Coefficient (Cn)</i>
Woods/Grass	60/65
Pond	98
Roadway and Pavement	98
Meadow	58
Agriculture	81
Developed	92

Concentration times for the stormwater runoff from the various tributary areas were calculated according to the methodology defined in the Soil Conservation Service Technical Release No. 55 (Appendix B). Tributary areas were quantified by planimeter measurement made on the proposed grading plan. The areas, concentration times (Tc), and the runoff coefficients for the various tributaries within and draining into the Flambeau Mine site are shown on the Drainage Area Map in Appendix A.

The depressional areas which will be planted as sedge meadows or wet prairie will typically retain up to 1-foot of water before beginning to overflow. The retained water will primarily be runoff from the sub-area tributary to the depression. Outflow from the depressional areas above the retention volume was modeled as discharge from a

trapezoidal Cipolletti weir. The weir lengths, storage volumes and discharges for each of the depressional areas are shown in Appendix C.

### **Stream Channel Capacity**

Hydraulic capacities of the stream channels were calculated using the Manning's equation for open channel flow. A ten-foot wide channel was used in the calculations consistent with the expected stormwater discharges through the system. The slope of the south channel varies from slightly less than 1 percent at the eastern beginning of the channel to 1.5 percent at the discharge to the wetland. The elevation of the north channel bottom varies from 1136.0 at the outlet from the northeast wetland to 1120 at the western boundary of the site where the channel connects with intermittent Stream A. The slope of the north channel bottom varies from 1.5 percent at the wetland outlet to 0.5 percent at the western outlet. The Manning's n value used in the calculations for both the north and south channels was 0.035 to reflect the grassed nature of these channels in the reclaimed area.

The calculated hydraulic capacities for both the north and south channels with various depths of flow are included as Appendix B.

The north channel is designed to partially divert larger flows into the depressional areas. This diversion will begin when the water depth in the channel is 0.5 feet (between 11 and 17 cfs). The TR-20 model incorporates this diversion.

### **Snowfall Analysis**

Snow melt in the spring will be required to contribute most of the water required for the sedge meadow vegetation in the depressional storage areas. This vegetation requires saturated soils during the spring growing season. The National Climatic Data Center maintains records of snow pack at Eau Claire, Wisconsin and Duluth, Minnesota (the closest sites to Ladysmith). Five years of record between 1990 and 1994 (Appendix G) were studied to determine expected water availability in the sedge meadow areas. The lowest spring snow pack in Duluth was 11 inches for the five-year time period between 1990 and 1994 and the lowest spring snow pack in Eau Claire was 8 inches during the same 5-year period. For the water analysis, eight inches of snow was assumed to be equivalent to 1.4 inches of moisture (interpolated from Figure 3 in "Estimating Water Equivalent Snow Depth from Related Meteorological Variables", National Oceanic and Atmospheric Administration, 1980).

## **RESULTS AND CONCLUSIONS**

The results of the hydraulic and hydrologic analyses for the north and south areas of the Flambeau Mine reclamation site are discussed separately. Both the north and south areas include a conveyance channel, biofilters, and offsite water release point as shown by Figure 1. Additionally, the north area includes three depressional areas. The detailed calculations supporting these results are included in the appendices at the end of this report.

## North Area

The detailed results for the TR-20 model analysis of the north drainage area are included in Appendix E. Significant results from this analysis are discussed in the following sections.

### *Northeast Mitigation Wetland*

The northeast mitigation wetland will be constructed with a surface area of 8.5 acres below the control water elevation of 1136.0. Table 3 shows the impacts of the various rainfall events on this wetland with the proposed grading plan.

**Table 3**

#### ***Northeast Mitigation Wetland Hydrologic Characteristics***

<i>Rainfall Amount (inches)</i>	<i>Design Storm (year)</i>	<i>High Water Elevation</i>	<i>Maximum Discharge (cfs)</i>	<i>Water Volume Discharged (acre-feet)</i>
1.0	-	1136.00	0.1	0.1
1.5	-	1136.02	0.5	0.6
2.3	1	1136.09	2.3	2.4
2.7	2	1136.14	3.8	3.7
4.0	10	1136.40	10.7	9.6
5.6	100	1136.82	22.0	18.0

### *Depressional Areas*

Locations for the northern depressional areas are shown on Figure 1 and shown with more detail in Appendix A. The rainfall amounts required to fill the depressional areas and the volumes of snowmelt water available (assuming an 8-inch spring snow pack as previously discussed) for the spring growing in these northern depressional areas are listed following in Table 4. The table shows that a 2.7-inch rain (2-year design storm) will be needed to fill both areas 4 and 5. The Table also shows that the melt from a snow pack of 8 inches will provide adequate moisture to inundate both depressional areas during the spring growing season as required for the planned depressional area vegetation.

**Table 4**

**North Drainage Area  
Depressional Area Hydrologic Characteristics**

<i>Reservoir No.</i>	<i>Ponded Depth Below Overflow (feet)</i>	<i>Retention Volume Capacity (acre-feet)</i>	<i>Rainfall Required to Fill Reservoir (inches)</i>	<i>8" Snow Pack Equivalent Water Volume (acre-feet)</i>	<i>Tributary Area (Acres)</i>
4	1.0	0.05	2.7	0.48	4.10
5	1.0	0.16	2.7	0.53	4.52

**Conveyance Channel and Offsite Release**

Table 5 shows the peak discharges, water depths, and the volume of water discharged at the west end of the site into intermittent Stream A for the north area conveyance channel. The Table shows that no significant flow will be carried in the channel after either a 1-inch or 1.5-inch rainfall. The required channel capacity is 27.8 cfs to convey runoff from a 100-year design storm. With a 10-foot wide channel, the water depth for the 100-year design storm will be 0.83 feet. Thus, the 100-year design flow in the north channel is well within the capacity of the channel. The water velocity for the 27.8 cfs discharge in the north channel will be 2.36 feet per second which will not erode the channel if the channel vegetation is established as planned.

**Table 5**

**North Channel Hydrologic Characteristics**

<i>Rainfall Amount (inches)</i>	<i>Design Storm (year)</i>	<i>Maximum Discharge at the West Boundary (cfs)</i>
1	-	0.0
1.5	-	0.5
2.3	1	2.5
2.7	2	4.3
4.0	10	13.0
5.6	100	27.8

## South Area

The detailed results for the TR-20 model analysis of the south drainage area are provided in Appendix F. Significant results from this analysis are discussed in the following section.

### *Southwestern Biofilter*

The southwest biofilter will be constructed with an emergent area of 1.24 acres at the outlet discharge elevation of 1099 and a total biofilter area of 1.7 acres below elevation 1100. Table 6 shows the impacts of the various rainfall events on this biofilter for the proposed plan. The table also shows the water release rates from this biofilter to the Flambeau River for the various rainfall events using the existing outlet control structure with the modified V-notch weir previously discussed. Table 6 shows that no excess water will be provided for a 1-inch rainfall and that only a slight (0.2 acre-feet) excess of water will be discharged to the Flambeau River after a 1.5-inch rainfall event. The table also shows that the maximum discharge from the wetland after a 100-year rainfall event would be 48.0 cfs. The hydrologic analysis shows that the 1.7 acre biofilter proposed can be supported by the water supply available from the onsite tributary area to provide a high quality wetland. The analysis also shows that the proposed biofilter is properly sized for its tributary area.

**Table 6**

#### ***Southwest Biofilter Wetland Hydrologic Characteristics***

<i>Rainfall Amount (inches)</i>	<i>Design Storm (year)</i>	<i>High Water Elevation</i>	<i>Maximum Discharge (cfs)</i>	<i>Water Volume Discharged (acre-feet)</i>
1.0	-	1099.00	0	0
1.5	-	1099.07	0.2	0.2
2.3	1	1099.44	1.1	1.6
2.7	2	1099.74	1.8	2.6
4.0	10	1100.60	9.2	6.9
5.6	100	1101.09	48.0	13.7

### *Conveyance Channel*

Table 7 shows the peak discharges where the southern conveyance channel discharges into the southwest biofilter. The Table shows that no significant flow will be carried in the channel after a 1.5-inch rainfall and that a maximum flow of 72.9cfs will be conveyed in the south channel as it discharges into the mitigation wetland after a 100-year rainfall event. This 72.9 cfs flow will cause a water depth of 1.06 feet in the 10-foot wide channel which is also well within the capacity of the channel. The water velocity will be 4.51 feet per second in the channel (for a 100-year design storm) near the outlet and this velocity will not erode the channel if the channel vegetation is established as planned.

**Table 7**

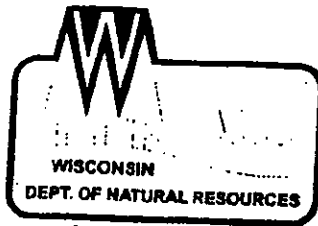
**South Channel Hydrologic Characteristics**

<i>Rainfall Amount (inches)</i>	<i>Design Storm (year)</i>	<i>Maximum Discharge at the West Boundary (cfs)</i>
1	-	0
1.5	-	0
2.3	1	4.6
2.7	2	9.1
4.0	10	33.0
5.6	100	72.9

**Stream C**

Appendix H shows the TR-20 model results for the 10 and 100-year design storm events for the area tributary to Stream C above and including the discharge point from the proposed biofilter assuming the 23.4 acre area on the Flambeau site proposed for development becomes fully developed with an industrial land use. The Appendix shows that the conversion of the surge pond to a biofilter/detention basin will reduce the peak flows into Stream C from the 23.4 acre area from 126.1 cfs to 62.5 cfs for the 100-year design storm event and from 80.9 cfs to 36.7 cfs for the 10-year design storm event. The total peak flow in Stream C south of the surge pond outlet would be 89.9 cfs for the 100-year design storm and 48.4 cfs for the 10-year design storm after the completion of the developed construction with the total tributary area discharging into the Stream.

**MARCH 20, 1998 LETTER FROM  
DNR TO FMC**



March 20, 1998

State of Wisconsin | DEPARTMENT OF NATURAL RESOURCES

Tommy G. Thompson, Governor  
George E. Meyer, Secretary

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Ms. Jana Murphy  
Environmental & Reclamation Manager  
Flambeau Mining Company  
N4100 Highway 27  
Ladysmith, WI 54848

Dear Ms. Murphy:

Flambeau Mining Company personnel and department staff have recently had several conversations concerning surface water management at the Flambeau mining site. This letter is to clarify how the department intends to regulate surface water management at the site.

Currently, the entire mining site, with the exception of the area around the buildings, has been rough graded and provisions have been made for the appropriate collection, diversion and treatment of stormwater. The northern portion of the site flows into the stream "A" watershed with provisions for emergency diversion of high flows into the abandoned gravel pit to the west of the site. The southern portion of the site currently flows to a temporary settling pond located at the extreme west end of the former open pit. This water is pumped to the surge pond for treatment and discharge through outfall 001 and provisions are also in place for pumping water from the settling pond directly to the gravel pit if water is accumulating in the pond at a rate faster than it can be pumped to the surge pond. Since this water is no longer in contact with waste rock, Flambeau would like to modify the water handling process such that diversion of water from the temporary settling pond to the gravel pit is the primary option and treatment and discharge is the secondary choice. Further, the ultimate plan entails removal of the temporary settling pond and reclamation of the west end of the pit area including development of a permanent biofilter with an engineered overflow through outfall 002.

The current water handling procedures are acceptable to the department and are consistent with the Mining Permit, including the Surface Water Management Plan, and the Wisconsin Pollutant Discharge Elimination System (WPDES) Permit. It is our intent that the WPDES permit will continue to regulate discharges from the site through outfalls 001 and 002 as long as water is being pumped from one location to another on the site. Any discharge through those outfalls must comply with the effluent limits and monitoring requirements specified in the WPDES permit, including conditions A.13 and 14, as long as the WPDES permit remains in force. Once all permanent water management structures and facilities are in place and pumping is no longer necessary, discharges through outfall 002 will cease to be covered under the WPDES permit. At that time, stormwater management will fall under the regulatory authority of the Mining Permit and its associated plans.

The department agrees that in times of excess water accumulation, diversion of water from the temporary settling basin in the south end of the pit to the abandoned gravel pit is a reasonable option rather than



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continued treatment in the wastewater treatment plant. However, there is a need for some characterization of that water, prior to switching over to diversion to the gravel pit as the first option. Flambeau must obtain a representative sample of the water which would be pumped to the gravel pit and conduct analyses of the water pursuant to the groundwater monitoring program for the project. These results must be submitted to the department prior to pumping water to the gravel pit as the primary option. Again, prior to obtaining these results, Flambeau may pump water from the temporary settling pond to the gravel pit if water is accumulating in the basin at a rate faster than it can be diverted to the surge pond.

As we have discussed, the department also has concerns with the continued disposal of clarifier underflow material in the area of the west end of the pit. Flambeau should discontinue the practice of placing the underflow material in that location and develop an alternate method of handling the material consistent with our discussions. In addition, Flambeau must collect a representative sample of the underflow material for characterization. At a minimum the samples should be analyzed for copper, zinc and mercury. Please contact Tom Portle if you need more information concerning the procedures for this characterization. In addition you should also notify Tom and Ken Markart prior to implementing an alternate handling method for the clarifier underflow material.

I hope that this helps to clarify the department's position concerning our regulatory oversight of stormwater management at the Flambeau site. Please feel free to contact me if you need additional explanation or clarification.

Sincerely,

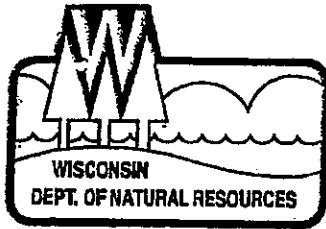


Lawrence J. Lynch, P.G., Hydrogeologist  
Mining Team Leader  
Bureau of Waste Management

LJL:pc

cc: T. Portle - WA/3  
P. Luebke - WT/2  
K. Markart - NOR (Rhineland)  
J. Hansen - NOR (Park Falls)

**DECEMBER 13, 2001 LETTER FROM  
DNR TO THE GLIFWC**



State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Scott McCallum, Governor  
Darrell Bazzell, Secretary

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December 13, 2001

Mr. James H. Schlender, Executive Administrator  
Great Lakes Indian Fish & Wildlife Commission  
P.O. Box 9  
Odanah, WI 54861

Dear Mr. Schlender:

This is in response to your correspondence of September 28, 2001 in which you transmit an analysis of the Flambeau Mine project prepared by Mr. John Coleman, Environmental Section Leader for Great Lakes Indian Fish & Wildlife Commission (GLIFWC). The analysis addresses impacts to groundwater and aquatic resources in the vicinity of the Flambeau Mine.

The memo prepared by Mr. Coleman accurately points out that the results of groundwater monitoring in the backfilled pit shows the concentration of some metals, notably iron and manganese, exceed the predicted values. Flambeau Mining Company (FMC) has evaluated this matter and offered its explanation as to why the concentration of these metals differs from the predictions and the department agrees with that evaluation. Further, as will be discussed below, the analysis demonstrates that the current water quality in the backfilled pit does not pose a threat to the water quality of the Flambeau River.

Mr. Coleman recalculated the flux of water from the pit to the river using different values for a number of parameters as compared to earlier estimates of flux provided by FMC. The most significant differences are in regard to the hydraulic conductivity of the backfilled material and the saturated thickness of the area between the pit and the river. Mr. Coleman chose to use the hydraulic conductivity estimated from slug tests on wells installed after completion of pit backfilling as opposed to laboratory results used by FMC. This is a reasonable adjustment and it results in a significant increase in the predicted flux rate. Next, Mr. Coleman assumed that the entire depth of the pit (200') should be used in determining the cross-sectional area as opposed to the thickness of the pit wall that contributed flow during operation (100'). This is not a substantial difference and results in a doubling of the predicted flow rate in contrast to the approximately fifty-fold increase resulting from the higher hydraulic conductivity. Combining these changes with the minor change in hydraulic gradient results in a predicted flux that is 126 times that predicted by FMC. However, the resulting flux (6885 cubic feet per day [cfd]) is still insignificant in comparison to the flow of the Flambeau River (ave. flow = 151,000,000 cfd) and would not result in a significant change in the analysis of incremental increases in metal concentrations in the river. The predicted incremental increase in metal concentrations would still be orders of magnitude less than the existing concentrations in the Flambeau River.

Mr. Coleman's analysis that results in a flux of 229,944 cfd is flawed. The hydraulic conductivity value used in this analysis is obviously an outlier, when compared to the remainder of the hydraulic conductivity values obtained in the slug tests. Further, the resulting flux would be more than five times

the average rate of inflow to the pit measured during operation of the mine. Clearly, this is not a reasonable scenario.

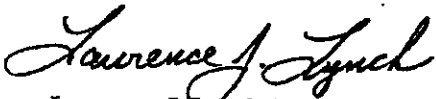
Mr. Coleman's analysis of the surface water quality and impacts on aquatic resources, while perhaps statistically valid, ignores the fact that the levels of metals observed are extremely low and well below established criteria for protection of aquatic resources. The observed metal concentrations at the downstream sampling point and the upstream location have fluctuated over the past 10 years but have not reached levels of concern. In actuality, there were many instances when the concentrations were below the level of detection, which is not recognized in Mr. Coleman's analysis. The fluctuation, consistency between upstream and downstream concentrations, and low levels demonstrated through the FMC sampling was verified through independent sampling of the Flambeau River conducted by the department during 1992-1994. The results confirm that there is very little difference between the upstream and downstream concentrations.

The analysis of metal concentration in crayfish, again, may be statistically valid, but ignores important information. First, the copper concentrations observed in baseline collections (1988 and 1991) showed that the concentrations were higher in the downstream sample as opposed to the upstream sample even before the mining project was initiated. Thus it is difficult to understand how one can conclude that higher downstream concentrations are attributable to the mining operation. Mr. Coleman indicates that there is only sufficient data available for copper and aluminum. Results are also reported for zinc. These results indicate that the upstream concentration is actually higher more frequently than the downstream concentration, contrary to the trend for the metals Mr. Coleman chose to analyze. Finally, as with the surface water quality discussion, the levels of metals observed in crayfish tissue are very low and have not substantially changed over the sampling period.

The existing groundwater monitoring program will continue at the site for the foreseeable future. If results indicate that conditions are not consistent with predictions or the monitoring is not providing necessary information, the department is authorized to require additional monitoring activities and analysis. The reduction in surface water monitoring is in accordance with the permits issued to FMC that allowed cessation of such monitoring following shutdown of the water treatment facility. FMC has proposed to continue limited surface water sampling and, as with the groundwater monitoring program, if conditions at the site demonstrate a need for resumption of extensive surface water sampling in the future, we will take action to modify the monitoring requirements.

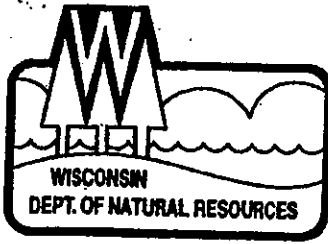
In closing, we do not see any evidence to support the inferences in Mr. Coleman's analysis or the statement in your letter that "...the project may have and may still be adversely affecting the biota of the river." The department will continue its oversight of the mining site and as stated above, should the need arise, we will adjust the monitoring program as needed in response to site conditions.

Sincerely,



Lawrence J. Lynch, P.G., Mining Team Leader  
Bureau of Waste Management

**OCTOBER 26, 2004 LETTER FROM  
DNR TO THE GLIFWC**



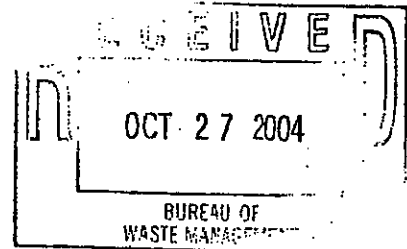
State of Wisconsin | DEPARTMENT OF NATURAL RESOURCES

Jim Doyle, Governor  
Scott Hassett, Secretary

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October 26, 2004

Mr. James H. Schlender, Executive Administrator  
Great Lakes Indian Fish & Wildlife Commission  
P. O. Box 9  
Odanah, WI 54861



Dear Mr. Schlender:

I am writing to you in response to your recent letter to Lawrence Lynch, the Department's Mining Team Leader, in which you suggest that the Department should take formal enforcement action against Flambeau Mining Company for violations of state water quality standards. Since the issue relates to environmental enforcement, Mr. Lynch asked that I respond on his behalf. I am the attorney on the Department's staff who has been assigned mining matters since the mid-1980s. However, my primary responsibility, for even longer, has been staffing the watershed program. Consequently, I am familiar with situations like that which occurred at the Flambeau Mine.

The issue at hand revolves around the question of whether elevated levels of copper in intermittent Stream C near the Flambeau Mine as a result of runoff from the mining site, constitutes an incident for which the Department should have pursued formal enforcement action. One aspect of water law often misunderstood is that an exceedance of a water quality standard is not, by itself, an enforceable action—there needs to be some other regulatory authority that requires an activity to comply with water quality standards. That is why point sources of pollution have long had to comply with water quality standards, but non-point sources have historically not. Perhaps a better example arises out of accidental spills of hazardous substances. When such spills are properly reported and remedied, they usually will not constitute a violation of any law, even when the spills have caused exceedances of water quality standards.

In the case of the Flambeau Mine situation, we have not been able to attribute the copper exceedances to a violation of a statute, administrative code, permit or plan approval. Thus we have no basis upon which we could allege a violation or seek penalties. In many ways, the Flambeau Mine situation is very similar to a spill case in which the responsible party properly informed the Department and proceeded to cooperate with the Department in a response to the spill. This conclusion has not been arrived at without careful consideration of the circumstances. Prior to Lawrence Lynch's earlier response to John Coleman's email on this issue, Mr. Lynch consulted with me as well as with Steven Sisbach, the Department's head of environmental enforcement. As a result of your follow-up letter to Mr. Lynch, I checked further with Mr. Sisbach as well as with several other attorneys on our staff who have experience on these and related matters. All concurred with the conclusions stated in this letter.

Although the Department determined it was not in a position to proceed with an enforcement action, the Department did react to the situation. An investigation verified that Stream C is an intermittent stream of

limited aquatic life and the levels of copper and the rate of flow are such that the water quality of the Flambeau River was not substantially threatened. The Department followed the typical regulatory response for such a situation by working with the owner/operator to address the situation by characterizing the problem then, as in most instances, implementing corrective action to remedy it. Based on monitoring results from the 0.9-acre biofilter and Stream C and other observations at the site, a potential problem was identified. Subsequently, following completion of a soil sampling program, the company removed the upper two feet of material in the railroad spur west of Highway 27, which is believed to have been the source of the copper. The Company will continue regular monitoring of the site.

Department staff has asked that I assure you that they are treating this matter very seriously and will carefully evaluate the results of the follow-up monitoring. If the ongoing monitoring indicates water quality conditions have not been sufficiently improved through removal of the rail spur material, the Department will require that additional corrective measures be implemented.

Sincerely,



Charles R. Hammer  
Staff Attorney

Cc: John Gozdziński - NOR  
Larry Lynch - WA/3  
Steve Sisbach - LE/5

**JANUARY 18, 2006 LETTER FROM  
DNR TO LAURA FURTMAN**



**State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES**

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Scott Hassett, Secretary

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FAX 608-267-3579  
TTY 608-267-6897

January 18, 2006

Ms. Laura Furtman  
27426 County Road H  
Webster, WI 54893

Dear Ms. Furtman:

This is in response to your letter of January 3, 2006 requesting additional information pertaining to the Flambeau Mine site in Rusk County. I will address your requests in the order they are presented in your letter.

1. A biofilter is a man made wetland constructed in such a way that they are effective at removing sediment from the incoming waters. At the Flambeau site, the 0.9 acre biofilter is engineered with a sinuous and low velocity flow pattern through the vegetated pond thereby facilitating the settling of suspended sediment in the pond.
2. The water within a biofilter is not subject to water quality criteria and standards.
3. The sampling points you mention are simply areas within the drainage system that are amenable to collection of water sample. Specifically, they are sites where there is a concentration of flow or a pooling effect to allow for collection of a sample during a storm event. They are not "man-made holes" nor are they "naturally occurring swampy spots". Again, they are simply areas at which it is physically possible to collect a sample.
4. All of the sampling locations mentioned in your letter are contained within the drainage basin of the biofilter. Water within that area flows through the biofilter prior to discharging to Stream C and ultimately the Flambeau River.
5. Geotextiles are special synthetic fabrics made for use in 'geological' situations or applications. They are resistant to rotting and are permeable to water. Landscape fabric is one form of geotextile with which you may be familiar. In engineering applications, geotextiles are commonly used as a filtering or separation media to prevent drainage systems from clogging or mixing of dissimilar geologic materials, or used to reinforce soils.
6. Yes, geotextiles are permeable to water. For most applications, the fabric is either woven or needle-punched to allow the passage of water.
7. The geotextile will help in providing structural stability to the soils and will also serve as a physical barrier to prevent mixing of the different substrate materials.
8. Samples have not been collected from the sampling point designated as SW-C4 in the location specified in the August 2004 submittal. Flow in that area is too disbursed and not amenable to collection of a sample. This was acknowledged as a potential issue at the time that the monitoring plan was developed and inclusion of that sampling point was basically conditional in that sample results were to be submitted if it was physically possible to get a sample in that location. The location of SW-C4 was



changed to a site on a small tributary to Stream C south of the mining site. Its location and sample results are shown on Figure 2 from the October 24, 2005 submittal from Flambeau Mining Company. This site is basically serving as a "control" site.

9. These results have not yet been reported. Typically, they are contained in the Annual Report which is submitted in late January.
10. I believe this site is located immediately downstream of the confluence of the Flambeau River and Meadowbrook Creek. I am not aware of any other data for this location.
11. Sampling point STR-C is essentially the same as sampling point SW-C5.
12. I am not aware of any water quality sampling having been conducted in Wetland 11.
13. Flambeau Mining Company collected samples at the monitoring points designated SW-1 and SW-2 in 2005. The results have not yet been submitted. They will be contained in the Annual Report which should be submitted in the next couple of weeks.
14. The sampling points were sampled for copper and the results are indicated on Figure 1 of the November 22, 2005 letter from Foth & Van Dyke that I sent to you in December. I have enclosed another copy of that figure in case it was not included in my earlier correspondence.
15. The biofilters, particularly the 0.9 acre biofilter, may need occasional maintenance consisting of removal of sediment when the capacity or the efficiency of the biofilter is compromised. The only biofilter with a liner is the 0.9 acre biofilter and it is unlikely that the liner would ever be replaced. It is not a critical element in the design or operation of the biofilter.
16. There is no specific mention of the maintenance of the biofilters. The department will retain a portion of the reclamation bond for at least twenty years after issuance of the certificate of completion for the entire mining site. As long as we have that financial instrument, the company will retain some level of responsibility for maintenance of the biofilters.
17. There are no plans to conduct extensive monitoring programs of the 1.7 acre biofilter or the 8.5 acre wetland. Based on the monitoring results to date, such an extensive monitoring program is not warranted.
18. I will send you a copy of the 2005 Annual Report when I receive my supply of them from the company.
19. I will send you a copy of Flambeau Mining Company's request for certification when it is submitted and will also send you a copy of any public notices concerning the certification request.

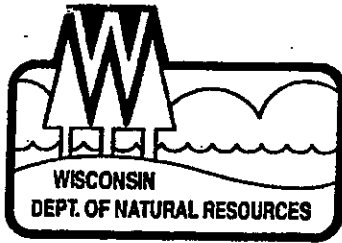
Again, feel free to contact me if you have other questions or need additional clarification.

Sincerely,



Lawrence J. Lynch, P.G., Mining Team Leader  
Bureau of Waste Management

**FEBRUARY 14, 2006 LETTER FROM  
DNR TO LAURA FURTMAN**



**State of Wisconsin | DEPARTMENT OF NATURAL RESOURCES**

Jim Doyle, Governor  
Scott Hassett, Secretary

101 S. Webster St.  
Box 7921  
Madison, Wisconsin 53707-7921  
Telephone 608-266-2621  
FAX 608-267-3579  
TTY 608-267-6897

February 14, 2006

Ms. Laura Furtman  
27426 County Road H  
Webster, WI 54893

Dear Ms. Furtman:

This is in response to your letter of February 8, 2006 in which you ask follow-up questions in response to my letter of January 18, 2006. You also requested copies of various monitoring results. Before receiving your letter, I sent you a copy of the 2005 Annual report which contains the results that you requested. If you have not received that report or do not receive it within the next few days, please contact me and I will send another one

- 1. Does that mean that even at the biofilter's outlet to a lake or stream, the water does not have to meet water quality criteria and standards?**

Yes, in this instance, that is correct. While there are instances in which water quality standards are required by law to be met, there are other water-related regulatory programs that focus on performance measures, but do not require actual compliance with water quality standards. This is one such instance.

Water quality criteria and use standards are published statements of what are generally considered to be acceptable water quality conditions, and they are usually written to err on the side of resource protection. But the standards, themselves, are just that—standards—they do not carry with them any legal mandates that they be met. Such a requirement must come from some other specific legal authority.

Some water related regulatory programs make compliance with water quality standards a requirement, other do not. For example, the program that regulates many activities on lakes and streams, under Chapter 30 of the Wisconsin Statutes, regularly looks to water quality standards in its decision-making, but there is no requirement that a given project has to meet water quality standards prior to being approved. The mining administrative rules require that discharges from waste facilities meet water quality standards, however there is no such requirement for other discharges from other mining related activities. Those activities more closely resemble non-point pollution regulation, which focuses on identifying and meeting performance standards. The performance standards are designed to protect water quality but neither require nor guarantee that each and every application of a performance standard actually will achieve compliance with water quality standards.

There is one other thing that is sometimes misunderstood. Even for programs that do require compliance with water quality standards, the waste stream, itself, is most often not required to meet water quality standards. Rather, compliance is usually determined by evaluating the condition of the receiving water, after the waste has entered and been assimilated.

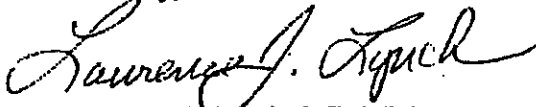
- 2. Has FMC typically been late in reporting its monitoring data and results to the DNR?**

Flambeau Mining Company is required to submit the monitoring results within 30 days of completion of

the analyses of the samples. This has been interpreted to mean that the results are reported within 30 days of completion of all associated Quality Control/Quality Assurance aspects related to the analyses. It does not mean that Flambeau must submit the results within 30 days of the date on which the sample was collected. This approach is similar to that taken for other types of facilities that are also required to submit monitoring results to the Department and recognizes the amount of time needed by the laboratories and operators to conduct the requisite analyses and adequately verify the sampling results.

I should also tell you that I am leaving the mining program as of February 17th. Future inquiries and information requests regarding the Flambeau Mine should be directed to Tom Portle, Bureau of Waste & Materials Management (WA/3), P.O. Box 7921, Madison, WI 53707-7921.

Sincerely,

A handwritten signature in cursive script that reads "Lawrence J. Lynch".

Lawrence J. Lynch, P.G., Mining Team Leader  
Bureau of Waste Management

**SEPTEMBER 23, 1998 LETTER  
FROM DNR TO FMC**



State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Tommy G. Thompson, Governor  
George E. Meyer, Secretary

Box 7921  
101 South Webster Street  
Madison, Wisconsin 53707-7921  
TELEPHONE 608-266-2621  
FAX 608-267-3579  
TDD 608-267-6897

CERTIFIED MAIL  
RETURN RECEIPT REQUESTED

September 23, 1998

MS JANA MURPHY  
ENVIRONMENTAL & RECLAMATION MANAGER  
FLAMBEAU MINING COMPANY  
N4100 HIGHWAY 27  
LADYSMITH WI 54848

SUBJECT: WPDES Permit No. WI-0047376-2  
No Permit Required

Dear Ms. Murphy:

We understand the wastewater treatment system serving the Flambeau Mine in Ladysmith has permanently shut down as of August 13, 1998. Therefore, the Department has decided to close the wastewater permit for the discharge described in the Wisconsin Pollutant Discharge Elimination System Permit No. WI-0047376-2, issued on March 29, 1996.

Please inform us within 15 days in writing if you disagree with this determination or if any other factors exist which would directly affect the Department's decision. If you do not respond, the presently issued permit will be closed prior to the December 31, 2000 expiration date. No further discharges to waters of the State of Wisconsin will be allowed under the WPDES permit. All existing wastewater discharge points from the wastewater treatment system must be abandoned, with the exception of Outfall 002 which may discharge stormwater runoff through the biofilter overflow regulated under the Mining Permit.

A significant change in the operations or discharge described, or any changes in applicable Wisconsin Statutes or Administrative Codes may, however, require that a permit be obtained in the future. If you are in doubt or have any questions, at this time or in the future, please so advise the Department promptly by writing to the Bureau of Watershed Management, Department of Natural Resources, P.O. 7921, Madison, WI 53707.

If you believe that you have a right to challenge this decision, sec. 283.63, Wis. Stats., and ch. NR 203, Wis. Adm. Codes require that you file a verified petition for review with the Secretary of the Department of Natural Resources within 60 days of the date of this decision. This notice is provided pursuant to sec. 227.48, Wis. Stats.



Quality Natural Resources Management  
Through Excellent Customer Service



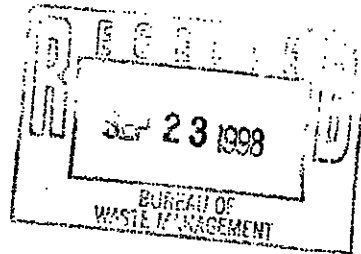
Please call me at 608-266-0234 if you believe the information in this letter is incorrect, or have any questions regarding the wastewater discharge permit. Thank you.

Sincerely,

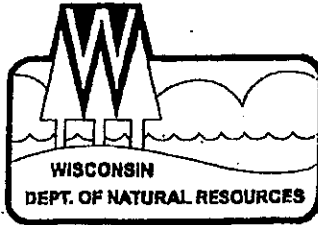
*Paul W. Luebke*

Paul W. Luebke  
Specialized Discharge Management Section  
Bureau of Watershed Management

copy: Jim Hansen - NOR Park Falls  
Larry Lynch - WA/3  
Ken Markart - NOR Rhinelander  
Gail Mills - WT/2



**MAY 17, 2000 LETTER FROM DNR  
TO FMC**



State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Tommy G. Thompson, Governor  
George E. Meyer, Secretary

101 S. Webster St.  
Box 7921  
Madison, Wisconsin 53707-7921  
Telephone 608-266-2621  
FAX 608-267-3579  
TTY 608-267-6897

May 17, 2000

Ms. Jana Murphy  
Flambeau Mining Company  
N4100 Highway 27  
Ladysmith, WI 54848

Dear Ms. Murphy:

This letter is to clarify the Department's interpretation of the groundwater quality standards applied to the Flambeau Mining Company project site pursuant to the mining permit issued to Flambeau. The Department and Flambeau Mining Company have had a number of discussions over the past several years concerning the appropriateness of the standards specified in the permit. This letter will summarize the issue and present my understanding of its current status.

Shortly after initiation of construction activities at the Flambeau Mine it was pointed out that background groundwater quality for some parameters in a number of monitoring wells exceeded the standards established in the mining permit. Subsequently, on August 17, 1994, Flambeau Mining Company submitted a letter to the Department relating to the issue of the groundwater standards that apply to the Flambeau mining site. In that letter Flambeau suggested that new standards be established for iron and manganese and that alternative concentration limits be specified for iron, manganese and total dissolved solids at certain monitoring wells.

The Department does not agree that the standards for iron and manganese need to be revised as suggested in the August 17, 1994 letter. This is the case because we do not believe it is appropriate to include the data from monitoring well MW-1005 in the calculation of baseline conditions for the site. The water quality measured in MW-1005 is clearly anomalous and inclusion of that well skews the designation of baseline water quality for the remainder of the site and hence would inappropriately influence the designation of an alternate groundwater standard. We understand that Flambeau generally agrees with the Department's conclusion. However, we also acknowledge that Flambeau believes a more rigorous statistical analysis of the baseline levels of iron and manganese would be a better approach to establishment of groundwater standards for those parameters rather than the approach used in support of the mining permit.

Given the above discussion, I would like to restate the Department's interpretation of the groundwater standards specified in the mining permit and the applicability of various provisions in Chapter NR 182 concerning application of the groundwater standards. First, if the mean background concentration of a parameter exceeded the secondary standard for that parameter, the groundwater standard applicable at the compliance boundary shall be the mean background concentration. This is reflected in the mining permit through designation of site-specific standards for manganese. Second, if the background or baseline concentration of a parameter at a given monitoring location exceeded the standard for that parameter, that

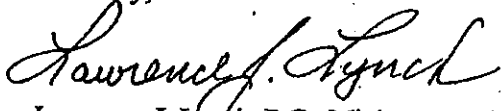
background concentration shall serve as the base level against which future concentrations measured at that monitoring point are compared for determining statistical significance as required in Ch. NR 182. In other words, if the background concentrations at a specific monitoring well exceeded the specified standard, that fact will be taken into consideration when evaluating the significance of future monitoring results that may indicate an exceedance of the project's groundwater standards at that location.

As indicated above, in its August 17, 1994 letter to the Department, Flambeau suggested that alternative concentration limits be designated for certain parameters at a number of monitoring wells. The proposed alternative concentration limits were summarized in Table 2 of that letter. The Department agrees with the alternative concentration limits suggested for monitoring wells, MW-1002, MW-1004, MW-1004P, MW-1005, and MW-1005S. However, we do not believe that the alternative concentration limits suggested for monitoring wells MW-1000R and MW-1000P are necessary and we feel that the proposed alternative concentration limit for iron at well MW-1005P should not have included the clearly anomalous value from August 1990. By your letter of April 25, 2000, a revised alternative concentration limit for well MW-1005P was proposed and the Department concurs with that recalculated limit. Therefore, for the six monitoring wells (MW-1002, MW-1004, MW-1004P, MW-1005, MW-1005S and MW-1005P) specified above, evaluation of groundwater monitoring results, including determination of statistical significance and the need for implementation of portions of the contingency plan, should be conducted in the context of these alternative concentration limits in addition to the groundwater standards delineated in the mining permit. The alternative concentration limits for the six wells are summarized in the following table.

Monitoring well	Iron	Manganese	TDS
MW-1002		0.21	
MW-1004		0.28	1,234
MW-1004P	0.60		
MW-1005	27.6	1.31	1,000
MW-1005S	4.88	0.32	
MW-1005P	1.4		

Please feel free to contact me if you have any questions or need additional clarification concerning this matter.

Sincerely,



Lawrence J. Lynch, P.G., Mining Team Leader  
Bureau of Waste Management

LJL:pc

cc: J. Sevick - Foth & Van Dyke  
Ken Markart - NOR (Rhineland)

**WIS. ADMIN. CODE S NR  
182.075(1) IN EFFECT IN 1991**

Chapter NR 182

REGULATION OF METALLIC MINING WASTES

NR 182.01 Purpose (p. 1259)	NR 182.12 Inspections (p. 1289)
NR 182.02 Applicability (p. 1259)	NR 182.13 Monitoring (p. 1291)
NR 182.04 Definitions (p. 1261)	NR 182.135 Requirements for certified or registered laboratory (p. 1293)
NR 182.05 License periods and fees (p. 1265)	NR 182.14 Recordkeeping and reporting (p. 1294)
NR 182.06 General submittal requirements (p. 1266)	NR 182.15 Closure (p. 1295)
NR 182.07 Location criteria (p. 1268)	NR 182.16 Financial responsibility for closure (p. 1296)
NR 182.075 Groundwater standards (p. 1269)	NR 182.17 Financial responsibility for long-term care (p. 1296)
NR 182.08 Feasibility report (p. 1274)	NR 182.18 Waste management fund (p. 1308)
NR 182.09 Plan of operation (p. 1282)	NR 182.19 Exemptions and modifications (p. 1310)
NR 182.10 Construction and completion reports (p. 1288-1)	
NR 182.11 Minimum design and operation requirements (p. 1287)	

**NR 182.01 Purpose.** The purpose of this chapter is to identify metallic mining and prospecting wastes and to regulate the location, design, construction, operation, maintenance, closure and long-term care of the site and facilities for the storage and disposal of metallic mining and prospecting wastes. The rules consider the special requirements of metallic mining operations in the location, design, construction, operation and maintenance of sites and facilities for the disposal of metallic mining wastes as well as any special environmental concerns that will arise as the result of the storage and disposal of metallic mining wastes.

History: Cr. Register, August, 1982, No. 820, eff. 9-1-82.

**NR 182.02 Applicability.** (1) These rules govern all solid waste disposal sites and facilities for metallic mineral mining and prospecting operations as defined in s. 144.81 (5) and (12), Stats.

(2) To the extent that prospecting and mining wastes are identified by the department as hazardous under s. 144.62 (2) (a), Stats., the disposal of such wastes in a waste site governed by this chapter shall be governed and licensed under this chapter, and not under ch. NR 181, subject to amendment, if necessary, to comply with applicable federal regulations adopted pursuant to the resource conservation and recovery act of 1976, PL 94-580, or otherwise to adequately protect the environment. Prior to a hearing under s. 144.836, Stats., the department shall designate those mining and prospecting wastes which are identified by the department as hazardous under s. 144.62 (2) (a), Stats.

(3) Owners of sites utilized for the disposal of mining waste, where the mining operation was in existence on May 21, 1978 may seek approval of any feasibility study or plan of operation for such sites. Such sites shall be licensed after a determination by the department that the disposal of nonhazardous waste is being undertaken in an environmentally sound manner. Upon such determination, compliance with the licensing requirement shall be administered in a manner which does not require substantial structural modification of the existing site, expenditure which is not appropriate for the nonhazardous nature of the waste or interruption of the mining operation, provided however, that only ss. NR 182.01, 182.02 (1) to (5) and (7), 182.03 to 182.05, 182.12 to 182.15, 182.18 and 182.19 shall be applicable to such sites.

NR 182.075 Groundwater standards. (1) GROUNDWATER QUALITY. The policy of the state of Wisconsin is to prevent degradation of natural groundwater quality. Recognizing that some human activities have and will impact groundwater, the state management practices must maximize protection of this resource by minimizing those impacts. All land disposal sites have varying soil properties, such as permeability and attenuation capacity, and none can provide the perfect containment, regardless of engineering design and operation standards, which would allow achievement of an absolute nondegradation standard. An important element of groundwater protection is the attenuation capacity and permeability of the soil material between the source of a potential pollutant and underlying aquifers. The attenuation capacity and permeability of the soil material underlying a waste disposal site and of any soil material used as a liner should be determined and utilized in conjunction with the waste characterization requirements of this chapter for protection of groundwater quality. This section sets forth the procedures and criteria by which the specific groundwater quality protection standards and requirements for a mining waste disposal site will be established. The intent is to provide a site specific definition of the policy of minimizing impacts on groundwater quality, in order to assure that deviations from baseline groundwater quality will be limited to deviations which will not violate the groundwater quality standards of this section or render the groundwater unfit for present or future use as determined by this section.

The department shall, pursuant to a hearing under s. 144.836, Stats., establish the groundwater quality standards that site must meet; establish a compliance boundary for meeting such standards; establish an intervention boundary; and determine the adequacy of the contingency plan relating to achieving such compliance. This "intervention" in accordance with the contingency plan is intended to ensure that appropriate actions are taken by the operator to maintain the required groundwater quality at the compliance boundary.

(a) A mining waste site shall be located, designed, constructed, operated, reclaimed and maintained under long-term care requirements under s. 144.441, Stats., in a manner which complies with the requirements of this chapter, including the consideration of alternatives under s. NR 182.08 (2) (k). A waste site shall not cause concentrations of substances in groundwater at or beyond the compliance boundary in excess by a statistically significant amount of the groundwater quality standards provided for in this section.

1. Not less than 180 days prior to the hearing, the department shall propose a single compliance boundary for the site, and except as provided in subd. 3; the groundwater quality standard at the compliance boundary for each substance reasonably expected to have an adverse impact on the groundwater quality as a result of the mining waste disposal operations. If the proposed compliance boundary is less than the maximum compliance boundary under par. (b) 1. or the groundwater standards include a more stringent standard under par. 2. a. 2) or a standard determined under par. (a) 2. d., the department shall, at the hearing, present evidence supporting its proposals. The applicant or any other party may present evidence in support of or in opposition to the department's proposed groundwater quality standards or compliance boundary. Any party may propose alternative groundwater quality standards or an alternative compliance boundary by filing such proposal with the department no later than 90 days prior to the hearing.

**OCTOBER 17, LETTER FROM FMC  
TO DNR, WITH ATTACHED  
REPORT COMPLETED BY FOTH &  
VAN DYKE/SRK CONSULTING  
TITLED "BACKFILLED PIT WATER  
QUALITY ASSESSMENT" DATED  
OCTOBER 12, 2000**

Flambeau Mining Company  
N4100 Highway 27  
Ladysmith, WI 54848  
(715) 532-6690  
FAX (715) 532-6885

**Kennecott  
Minerals**

October 17, 2000

Mr. Lawrence J. Lynch  
Mine Reclamation Unit  
Bureau of Solid and Hazardous Waste Management  
101 S. Webster Street, GEF II  
PO Box 7921  
Madison, WI 53707

Dear Mr. Lynch:

RE: Backfilled Pit Water Quality Assessment  
Flambeau Mining Company

Flambeau Mining Company (Flambeau) is providing the attached memorandum prepared at Flambeau's request by SRK Consulting and Foth & Van Dyke evaluating data obtained since the pit was backfilled to assess the current and future performance of the reclaimed mine site with respect to compliance with groundwater quality permit standards and the protection of water quality in the Flambeau River.

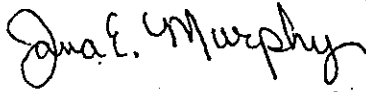
As part of the permitting effort for the Flambeau Project, assessments were completed to determine if the reclaimed site would comply with permitted groundwater quality standards at the compliance boundary and protect surface water quality in the Flambeau River. The original assessment relied on predicted post-mining hydrologic conditions to conclude that the Flambeau River would act as a hydrologic boundary for pore water migrating from the pit backfill and that backfill pore water would not migrate to the downgradient compliance boundary. In addition, the original analysis showed that the flux of backfill pore water into the river would be so small relative to the flow in the river that surface water quality would not experience a measurable change.

Environmental monitoring data from the reclaimed site supports the original analysis. Given the hydrologic conditions at the site, the environmental monitoring data show that the Flambeau Mine is in compliance with groundwater quality permit conditions and that water quality in the Flambeau River is protected.

Mr. Lawrence J. Lynch  
October 17, 2000  
Page 2

If you have any questions regarding this submittal, please contact me at 715-532-6690  
Ext. 2.

Sincerely,



Jana E. Murphy  
Environmental & Reclamation Manager

Attachment

Cc: Al Christianson, City of Ladysmith  
Fred Fox, Kennecott Minerals Company  
Jim Hutchison, Foth & Van Dyke  
Ken Markart, WDNR  
Thure Osuldsen, Rusk County  
Tom Riegel, Town of Grant  
Jerry Sevick, Foth & Van Dyke  
CeCe Tesky, Rusk County Zoning

## Foth & Van Dyke/SRK Consulting Memorandum

October 12, 2000

TO: Jana Murphy, Flambeau Mining Company

CC: Jim Hutchison, Foth & Van Dyke  
Master File

FR: Daryl Hockley, SRK Consulting  
John Chapman, SRK Consulting  
Jerry Sevick, Foth & Van Dyke  
Steve Donohue, Foth & Van Dyke

RE: Flambeau Project --Backfilled Pit Water Quality Assessment

### 1. Overview

Backfilling of the Flambeau pit was completed in the fall of 1997. Since that time, groundwater elevation and quality in and around the backfilled pit, and surface water quality data in the Flambeau River, have been collected. This memorandum consists of an evaluation of the data obtained since the pit was backfilled to assess the current and future performance of the reclaimed mine site with respect to compliance with groundwater quality permit standards and the protection of water quality in the Flambeau River.

As part of the permitting effort for the Flambeau Project, assessments were completed to determine if the reclaimed site would:

- ♦ comply with permitted groundwater quality standards at the compliance boundary; and
- ♦ protect surface water quality in the Flambeau River.

The original assessment, which was based on predicted post-mining hydrologic conditions, concluded that the Flambeau River would act as a hydrologic boundary for pore water migrating from the pit backfill and that backfill pore water would not migrate to the downgradient compliance boundary. In addition, the original analysis showed that the flux of backfill pore water into the river would be so small relative to the flow in the river that surface water quality would not experience a measurable change. This memorandum concludes that recent environmental monitoring data from the reclaimed site remain consistent with the original analysis.

Trends in the data collected through April 2000 for the backfill pore water indicate that the pH, alkalinity, and major element chemistry are stable, with possible slight increases in pH.

Calculations of dissipation times confirm that the carbon dioxide levels in the backfill are stable, and will change only over hundreds of years. Given the stable pH, alkalinity, and major ion chemistry, future increases in iron and manganese concentrations are unlikely. However, trends in redox potential cannot be discerned yet, because results from only one round of measurements are available. Increases in iron concentrations would be expected if redox potential decreases.

Data collected in April 2000 from monitoring of the pit backfill shows that carbon dioxide and alkalinity measurements are closely correlated, and that alkalinity measurements are more repeatable. Although measured CO<sub>2</sub> concentrations are well above atmospheric levels, they overlap the range of natural soil and groundwaters elsewhere.

Analysis of the data collected through April 2000 shows that backfill pore water is in equilibrium with calcite and gypsum, indicating that complete neutralization of the acidity originally present in the backfilled material has occurred. Iron and manganese concentrations in the backfill pore water are above those predicted by the 1997 geochemical modeling. The combination of higher than expected redox potential and higher than expected carbon dioxide may be responsible for the elevated iron concentrations. Slow equilibration of manganese, or formation of a carbonate solid-solution phase (rather than a pure manganese-carbonate like rhodochrosite), may be responsible for the elevated manganese concentrations.

Finally, the memorandum concludes that, with the exception of two minor items, monitoring of groundwater within and around the backfilled pit should continue to be performed in accordance with the program contained in the project's approved monitoring plan (Foth & Van Dyke, 1991). Also, an annual review of the data should be included in the project's annual report to determine if conditions affecting the conclusions reached in this memorandum remain consistent. As additional data are collected and the continuation of stable conditions is documented; per the approved monitoring plan, consideration can be given to reducing the frequency of monitoring within the backfilled pit.

## 2. Introduction

As part of the permitting process for the Flambeau Project, Flambeau Mining Company (Flambeau) evaluated post-mining groundwater flow and pit backfill geochemistry to demonstrate that the reclaimed mine would:

- ♦ comply with permitted groundwater quality standards; and
- ♦ protect water quality in the nearby Flambeau River.

Prior to the commencement of reclamation, a series of groundwater and geochemical studies (Engineering Technologies Associates, 1998; and Foth & Van Dyke, 1997) were completed to update the original assessment and to guide the reclamation process that was designed to maintain future compliance with permitted groundwater quality standards at the compliance boundary and to protect water quality in the Flambeau River.

Backfilling of the pit was completed in the fall of 1997. Since then, groundwater elevation, groundwater quality, and surface water quality data in the Flambeau River have been collected. In addition, nested monitoring wells were installed in September 1998 to monitor the quality of backfill pore water.

Flambeau requested Foth & Van Dyke and SRK Consulting (SRK) to evaluate the backfill pore water quality data obtained since 1999 from the backfilled pit monitoring well nests in order to assess the future performance of the facility with respect to compliance with groundwater quality permit standards and the protection of water quality in the Flambeau River. This memorandum describes that assessment and the conclusions reached.

The memorandum first presents a summary of the routine monitoring data that has been collected in the backfill monitoring well nests, including carbon dioxide and Eh data that have been collected periodically. The assessment of the data includes a comparison of actual monitoring results to predictions and a discussion of expected future changes in pore water quality. The next section of the memorandum addresses the protection of the Flambeau River and groundwater quality. Finally, the memorandum presents summary comments and recommendations.

### 3. Summary of Collected Data

#### 3.1 Groundwater Monitoring Wells

Flambeau conducts a quarterly groundwater monitoring program to assess the elevation and characteristics of groundwater in and around the backfilled pit. The locations of the groundwater monitoring wells used in the program are shown in Figure 1. The wells have varied screen lengths. The mid-point depths below surface of the well screens for those wells used for groundwater quality sampling are listed in Table 1.

#### 3.2 Analyses

Table 2 summarizes the parameters monitored for groundwater quality at the Flambeau site. Samples from all wells included in the groundwater quality monitoring program are analyzed for a routine suite of parameters during the January, April, and October quarterly monitoring events. In July of each year the parameter list is expanded to include additional metals. For the July and October 1999 and the April 2000 quarterly sampling events, samples from the wells in the saturated portion of the backfill (i.e., the MW-1013 and MW-1014 well nests) were analyzed for an expanded suite of parameters. A complete data base for the Flambeau groundwater monitoring program is included in Attachment 1. Note that data do not exist for all monitoring wells in the two backfilled pit well nests over the period of record, since the formations in which the well screens are located have progressively resaturated over time.

Samples taken from well nests MW-1013 and MW-1014 (in the backfilled pit), and well MW-1005P (upgradient of the backfilled pit) in October 1999 and April 2000 were also analyzed for dissolved carbon dioxide. Field Eh, or redox potential, was determined for these same wells in April 2000. Methods for these measurements are described in the following sections.

#### 3.3 Carbon Dioxide Analysis

The dissolved carbon dioxide (CO<sub>2</sub>) analyses were performed by Advanced Technology Laboratories Inc., using a modification of a method known as RFKSOP-175. In a previous report prepared by SRK Consulting (SRK, 1999), there had been some uncertainty about the meaning of the resulting CO<sub>2</sub> measurements. To resolve this uncertainty, SRK and Foth & Van Dyke contacted the laboratory directly, and obtained the method description, as well as raw data sheets and calculations from the April 2000 analyses.

The RFKSOP-175 method was developed for analysis of organic compounds such as methane, ethane and ethylene in water (Kampbell & Vandegrift, 1998). As initially developed, the method included sampling by carefully dribbling a stream of water down the side of a 60 ml serum bottle. That method of sampling is intended to minimize mixing with air and loss of volatile material. The sample is then acidified and the bottle sealed with a septa cap. The samples are kept in an ice chest during transport. In the laboratory, approximately 10% of the sample is removed by syringe, and replaced with helium gas. The bottle, now containing about 54 ml of sample and 6 ml of head space, is then shaken at room temperature for 24 hours. A sample of the

head space gas is then removed and analyzed by gas chromatography. The direct result of the analysis is a concentration of the target compound in the helium-filled head space. That value is converted to the original concentration of the target compound in the water by a series of calculations. The calculations are based on Henry's Law, which states that the concentration of a volatile compound above an aqueous solution of that compound is related to the concentration in the solution by a simple linear relationship, i.e.,

$$P = K_H C$$

where P is the concentration of the compound in the gas (commonly expressed as a partial pressure with units of atm), C is the concentration of the compound in the solution (commonly expressed in units of M), and  $K_H$  is the Henry's Law constant for the compound (commonly with units of  $M^{-1} \text{ atm}$ ) at the appropriate (room) temperature.

When applying the procedure to  $\text{CO}_2$ , three changes to the standard procedure or data interpretation are necessary:

- ♦ The method of sampling by dribbling the water down the side of the bottle may lead to loss of  $\text{CO}_2$ . The analytical results need to be interpreted recognizing some loss of  $\text{CO}_2$  likely occurred during sample collection.
- ♦ Acidification of the sample would tend to promote  $\text{CO}_2$  volatilization. Samples taken in both October 1999 and April 2000 were not acidified.
- ♦ The use of a Henry's Law constant for  $\text{CO}_2$  is complicated by the fact that  $\text{CO}_2$  dissolved in water forms many species, including  $\text{CO}_2(\text{aq})$ ,  $\text{H}_2\text{CO}_3$ ,  $\text{HCO}_3^-$  and  $\text{CO}_3^{2-}$ . In strong ionic solutions, dissolved  $\text{CO}_2$  can also form complexes such as  $\text{FeHCO}_3^+$  and  $\text{MnHCO}_3^+$ . A review of the methods used and data obtained shows that the Henry's Law constants used in the laboratory calculations refer to the sum of the dissolved species  $\text{CO}_2(\text{aq})$  and  $\text{H}_2\text{CO}_3$ . That sum is commonly referred to as  $\text{H}_2\text{CO}_3^*$  in the geochemical literature. Hence the Henry's Law constant used by the laboratory relates the measured partial pressure of  $\text{CO}_2$  in the helium to the concentration of  $\text{H}_2\text{CO}_3^*$  in the solution. The reported values should therefore be interpreted as concentrations of  $\text{H}_2\text{CO}_3^*$ .

### 3.4 Field Eh Analysis

A hydrolab minisonde, in combination with a surveyor 4, was used to measure redox potential at specified monitoring well locations during the April 2000 monitoring event. Two methods were used, depending on various field conditions. The first involved inserting a probe downhole to the well screen and then taking a reading without purging. The second method involved connecting the meter to the tubing from the dedicated pumps located in the well, and then taking a reading. The downhole method was used on monitoring wells MW-1000PR, MW-1005P, MW-1004P, MW-1010P, and MW-1014. The inline method was used for MW-1013A, MW-1013B, MW-1013C, MW-1014A, MW-1014B, and MW-1014C.

## 4. Data Assessment

### 4.1 Carbon Dioxide, Alkalinity, and Total Inorganic Carbon

Concentrations of carbon dioxide ( $\text{H}_2\text{CO}_3^* = \text{CO}_2(\text{aq}) + \text{H}_2\text{CO}_3$ ) and alkalinity ( $0.5 \text{HCO}_3^- + \text{CO}_3^- + 0.5 \text{OH}^-$ ) are inter-related. If the pH of a solution is known, both quantities can be related to total inorganic carbon ( $\text{H}_2\text{CO}_3^* + \text{HCO}_3^- + \text{CO}_3^-$ ). In reviewing the reported  $\text{CO}_2$  measurements, it was helpful to compare them to measured alkalinities, and to convert both to units of total inorganic carbon.

Table 3 presents the carbon dioxide and alkalinity concentrations measured in the April 2000 and October 1999 samples. A series of simple equilibrium calculations were completed to relate each measured value to an equivalent total inorganic carbon. The equilibrium calculations neglected metal carbonate complexes for simplicity, but that simplification introduces only a small inaccuracy (i.e., less than a few percent).

The table shows that the April 2000 measurements of carbon dioxide and alkalinity lead to similar calculated values of total inorganic carbon. The total inorganic carbon values calculated from the carbon dioxide measurements from April 2000 samples are generally in good agreement with or slightly greater than those calculated from the alkalinity measurements. There is more disagreement between the total inorganic carbon values calculated from the October 1999 measurements of carbon dioxide and alkalinity. In the October 1999 data, total inorganic carbon values calculated from the carbon dioxide measurements are consistently much lower than those calculated from the alkalinity measurements.

Table 3 also shows that there are significant inconsistencies between the October 1999 and April 2000 measurements of carbon dioxide from each well in the backfilled pit. In contrast, the October 1999 and April 2000 measurements of alkalinity from each well are consistent.

The indication is that the alkalinity measurements are more reliable than the measurements of carbon dioxide. The difficulty in preventing carbon dioxide loss during sample collection and analysis is a likely reason.

It is noteworthy that the conclusions drawn from the comparison of calculated total inorganic carbon are supported by other methods of comparison. For example, it is also possible to calculate an estimate of alkalinity from a measurement of carbon dioxide, and vice versa. Several possible calculations of that type were made but not reported here for the sake of brevity. Complete equilibrium models of representative solutions were also run. The conclusion that the alkalinity data are consistent, and the carbon dioxide data are not, was supported in all cases.

A consequence of this conclusion is that it is inappropriate to use the October 1999 and April 2000 carbon dioxide measurements to discern temporal trends. The higher carbon dioxide values reported in April 2000, when compared to the October 1999 sampling, appear to be an artifact of the sampling method or analytical method. Comparison of the alkalinity measurements is more informative, and indicates no significant change between October 1999 and April 2000.

## 4.2 Estimation of Carbon Dioxide Partial Pressure

The Henry's Law method calculation discussed in Section 3.3 can also be used to estimate the concentration of CO<sub>2</sub> in a gas in equilibrium with the samples. Table 4 shows the results of the following calculations, applied to the April 2000 samples:

- ◆ H<sub>2</sub>CO<sub>3</sub>\* concentrations estimated from the (more reliable) alkalinity data.
- ◆ Use of Henry's Law to estimate the equilibrium partial pressure of CO<sub>2</sub> gas. The Henry's Law constant was corrected for *in situ* temperature.
- ◆ Use of the hydrostatic head on the sample to estimate the total gas pressure at the sample depth.
- ◆ The use of partial pressure of the CO<sub>2</sub> gas divided by the total gas pressure to estimate the mole fraction of CO<sub>2</sub> in the gas.

The resulting estimates of CO<sub>2</sub> gas concentration in the backfilled pit wells are generally in the range of 2% to 7%. The relatively high CO<sub>2</sub> concentrations are consistent with carbonate neutralization of acidic water. As expected, the CO<sub>2</sub> concentration estimate of 0.4% for sample MW-1005P from outside the backfill was significantly lower than the in-pit wells, though still significantly above atmospheric CO<sub>2</sub> concentrations of 0.032%.

For comparison, Table 5 presents measurements of CO<sub>2</sub> gas concentrations from other studies. Although the CO<sub>2</sub> concentrations in the Flambeau backfill are well above atmospheric levels, they overlap the range of natural soil and groundwaters elsewhere.

## 4.3 Major Ions

The major ion concentrations measured in the April 2000 sample results were reviewed through a series of calculations. Ion balance and total dissolved solids calculations were completed to check the internal consistency of each data set. In order to complete the ion balances, it was necessary to take the dominant carbonate species, HCO<sub>3</sub><sup>-</sup>, into account. The CO<sub>2</sub> analyses (and the measured pH) were used to estimate the HCO<sub>3</sub><sup>-</sup> concentrations. With the HCO<sub>3</sub><sup>-</sup> estimates included, the calculations showed:

- ◆ The April 2000 samples from MW-1013C, MW-1014A, and MW-1014B had ion balances within 5%, and measured and calculated TDS values agreed within 10%.
- ◆ The April 2000 sample from MW-1013B was deficient in anions. To improve the ion balance, the sulfate concentration would need to be 1500 mg/L versus the reported value of 1200 mg/L. The 1500 mg/L value is, in fact, more consistent with earlier samples, suggesting that the reported sulfate value is likely erroneous.

- ♦ The April 2000 sample from MW-1014C was slightly deficient in cations. The ion balance would be improved if the measured calcium value was 290 mg/L versus the 260 mg/L reported value.
- ♦ Even after making the above adjustments to the data set for MW-1013B and MW-1014C, measured and calculated TDS values were different by more than 10%.
- ♦ The April 2000 sample from MW-1005P (upgradient of the backfilled pit) was not analyzed for cations. When results of the July 1999 expanded analysis are combined with the April 2000 alkalinity and Eh analysis, the ion balance is improved, but still 20% deficient in cations. Although the data from MW-1005P are considered reliable, they were not used in geochemical modeling since sufficient cation data was not available.

Water type calculations were completed on all of the samples. All of the April 2000 backfill samples classify as Ca-Mg-SO<sub>4</sub>-CO<sub>3</sub> waters, which is consistent with neutralization of sulfate acidity by limestone. The July 1999 sample from MW-1005P upgradient of the backfill classifies as a Ca-Mg-CO<sub>3</sub> water.

The geochemical equilibrium model PHREEQ-C was used to compare the (corrected) solution compositions from the April 2000 samples to solubility limits for expected mineral phases. All runs were completed using the alkalinity data (rather than the CO<sub>2</sub> data) and measured temperature redox conditions. Complete results are included in Attachment 2. Table 6 summarizes the results in terms of saturation indices of calcite and gypsum. A saturation index of greater than zero indicates supersaturation of a mineral phase, and an index less than zero indicates under-saturation. A saturation index of near zero indicates that the mineral phase is probably present, and in equilibrium with the solution.

The table indicates that most of the samples are likely to be in equilibrium with calcite (or aragonite, a similar calcium carbonate phase) and gypsum. The samples with the best ion balance and TDS measurements, MW-1013C and MW-1014B, are clearly in equilibrium with these phases. These results show the acid that was present in the waste rock has been consumed by limestone dissolution and that the sulfate concentrations are now controlled by gypsum precipitation. The control of sulfate by gypsum precipitation was predicted in the 1997 study (Foth & Van Dyke, 1997). (Observed sulfate concentrations are slightly higher than predicted due to the presence of additional cations, particularly magnesium released from limestone dissolution.) The fact that the resulting solution is in equilibrium with calcite indicates that acid neutralization is complete. These results demonstrate that the acidity present in the backfill has been effectively neutralized.

#### 4.4 Iron, Manganese, and Redox Potential

Iron and manganese concentrations are higher than predicted by the 1997 geochemical modeling (Foth & Van Dyke, 1997) in some of the backfilled pit monitoring wells. The 1997 modeling

considered a range of CO<sub>2</sub> gas concentration from 1% to 10% (at atmospheric pressure), and equilibration of iron and manganese with the carbonate phases siderite and rhodocrosite.

The values of the Fe(OH)<sub>3</sub> saturation index calculated by the PHREEQ model, and shown in Table 6, indicate the backfill samples are near equilibrium with amorphous iron hydroxide. Amorphous iron hydroxide commonly forms when acidic mine drainage is neutralized. The slight undersaturation suggests that iron hydroxides may be dissolving and/or converting to more stable phases such as goethite or hematite. However, it is not unusual to see some disequilibrium in model runs that use a measured redox potential as input. The reason is that the Fe(II)/Fe(III) redox couple is often out of equilibrium with the measured redox potential.

The PHREEQ-C results presented in Table 6 show that the backfill samples are undersaturated with respect to siderite and supersaturated with respect to rhodocrosite. The undersaturation with respect to siderite is apparently due to the complexation of ferrous iron with HCO<sub>3</sub><sup>-</sup>. The supersaturation with respect to rhodocrosite was also noted in the column test data presented with the 1997 predictions (Foth & Van Dyke, 1997). At that time, the explanation was that formation of the rhodocrosite was expected to be very slow. That explanation may also hold for the field data. Another possibility is that manganese concentrations may be controlled by equilibration with a mixed carbonate phase.

#### 4.5 Other Metals

Concentrations of other metals in the backfill pit monitoring wells are generally within the ranges measured or predicted in the 1997 study (Foth & Van Dyke, 1997). For example, copper concentrations were predicted to be less than 0.56 mg/L at 10% CO<sub>2</sub>. The monitoring data show copper concentrations to be at or below that value in all but the February 1999 sample from monitoring well MW-1014B. The February 1999 outlier was 0.81 mg/L, only slightly above the prediction.

Zinc concentrations were not modeled in 1997, but show an interesting pattern in the monitoring data. Concentrations range from 5 mg/L in MW-1014B to <0.12 mg/L in MW-1013B. The variability in zinc concentrations likely reflects differences in the extent of oxidation that took place while the waste rock was stored on the surface. The fact that both MW-1013B and MW-1014B exhibit consistently neutral pH indicates that despite this variability, the limestone addition has been effective.

#### 4.6 Future Pore Water Quality in Backfill

##### 4.6.1 pH

As Figure 3 shows, pH measurements in the backfill are constant or increasing slightly with time. Results of the PHREEQ-C modeling confirmed that the pH of the samples taken from the backfill is controlled by equilibrium with the carbon dioxide and the solid carbonate mineral phases (calcite in the limestone). The calcite is present in excess, and the calculation shown in the next section indicate that the CO<sub>2</sub> would only dissipate over hundreds of years. Therefore, the pH in the backfill can be expected to remain near current levels for a similarly long time.

As the CO<sub>2</sub> concentrations drop, the pH will rise. Attachment 3 shows results of a PHREEQ-C run simulating the removal of carbon dioxide from the April 2000 sample from MW-1013C, in equilibrium with calcite. The pH rises from 6.6 to 7.6 as the CO<sub>2</sub> drops by a factor of ten. However, it would be incorrect to attribute the observed slight increases in pH, as shown in Figure 3, entirely to this effect, given the lack of evidence for a change in CO<sub>2</sub>.

#### 4.6.2 CO<sub>2</sub> Degassing

The rate of diffusion of carbon dioxide out of the backfill was estimated using Fick's Law. Diffusion through both the saturated backfill and an unsaturated soil layer were considered. The following assumptions were made:

- ◆ Dissolved H<sub>2</sub>CO<sub>3</sub>\* is present in the pore water at the average for the April 2000 measurements.
- ◆ CO<sub>2</sub> (g) is present at equilibrium with the average H<sub>2</sub>CO<sub>3</sub>\*.
- ◆ The unsaturated soil layer is 20 ft thick and has an effective diffusion coefficient of  $1 \times 10^{-7} \text{ m}^2/\text{s}$ .
- ◆ The saturated backfill has an effective diffusion coefficient of  $1 \times 10^{-9} \text{ m}^2 \text{ s}^{-1}$ . Only the upper 10 ft of the saturated backfill was considered.
- ◆ Steady state diffusion, i.e.  $\text{flux} = nD_e C_o / L$ .

The results are summarized in Table 7, and indicate that the overall rate of CO<sub>2</sub> release will be limited by the rate of diffusion out of the saturated backfill, which is roughly two orders of magnitude lower than the rate of diffusion through the unsaturated soil. At these low rates, complete diffusion of the CO<sub>2</sub> out of the upper 10 feet of saturated backfill would take several hundred years.

#### 4.6.3 Iron, Manganese, and Redox Potential

Figures 4 and 5, respectively, show that iron and manganese concentrations have been relatively constant. The implication is that the mechanisms controlling iron and manganese concentrations are stable. Any future changes in iron and manganese concentrations in the backfill would need to be driven by changes in pH or redox potential.

As discussed in Section 4.5.1, pH is expected to remain at current values until the carbon dioxide dissipates. Once the carbon dioxide dissipates and the pH rises, new solid phases may form. Results of the PHREEQ-C run in Attachment 3 show that the increased pH will favor the precipitation of ferrihydrite (Fe(OH)<sub>3</sub>). The saturation indices for siderite and rhodocrosite do not change significantly as the pH increases. Therefore, a future decrease in iron concentrations can be expected, but only over the long time frame required to dissipate the CO<sub>2</sub>.

Redox potential in the backfill is likely controlled by the amorphous ferric hydroxide formed during the acid neutralization. There is a possibility that redox could change slowly over time, for example if the ferric hydroxide is reduced by contact with sulfide phases. However, it is not possible to draw conclusions about trends in redox potential, because only one set of Eh measurements is available.

It is possible to theorize about the effects of possible redox changes on iron and manganese solubility. A lowering of the redox potential would lead to increased solubility of (ferrous) iron, at least to the point of saturation with siderite. An increase in the redox potential would lead to precipitation of (ferric) iron. Manganese concentrations could be affected by an increase in redox potential. A significant increase in redox potential, say to the level associated with surface waters, would cause precipitation of the manganese as an oxide. A decrease in redox potential would not affect manganese concentrations.

In summary, given the stable pH, alkalinity, and major ion chemistry, future increases in iron and manganese concentrations are unlikely. Increases in iron concentrations would be expected if redox potential decreases.

#### 4.6.4 Other Metals

The concentrations of other metals, such as copper and zinc, have also been relatively constant over the monitoring period. Copper concentrations are sensitive to pH. Any future increases in pH are likely to lead to lower copper concentrations. Neither zinc nor copper are strongly sensitive to redox potential within the expected range. Therefore, future increases in their concentrations are not expected. The spatial variability mentioned in Section 4.5 is likely to continue to be evident in future monitoring.

## 5. River and Groundwater Protection

To address the issue of Flambeau River and groundwater protection, it is important that an understanding of the conceptual model of hydrologic conditions relevant to facility compliance be understood. With this as background, a review of current hydrologic conditions and a comparison of the conceptual model to actual measured conditions can be completed.

### 5.1 Conceptual Model of Hydrologic Conditions Relevant to Facility Compliance

At the Flambeau site, regional groundwater generally flows from east/northeast to west/southwest. The Flambeau River to the west of the pit acts as a regional boundary for the discharge of groundwater flowing in the vicinity of the pit. During operations, pit dewatering depressed the water table locally around the open pit, thereby altering the local pattern of groundwater flow. During operations, localized groundwater in the immediate vicinity of the pit flowed into the pit, where it was pumped out and treated. In addition, water from the Flambeau River was drawn into the dewatered pit through fractured Precambrian bedrock that formed the western wall.

The original analysis of post-reclamation groundwater flow and compliance with groundwater quality standards predicted that after reclamation was completed, the groundwater system would recover and groundwater flow would be similar to pre-mining conditions (Prickett & Associates, 1989; and Foth & Van Dyke, 1989). Under this scenario, groundwater flowing through the pit would once again discharge at the regional groundwater discharge point formed by the Flambeau River. As such, it was concluded that dissolved constituents migrating out of the backfilled pit would also discharge to the regional groundwater discharge point (i.e., the Flambeau River). Furthermore, it was demonstrated that the small rate of pore water discharge to the Flambeau River, relative to the flow in the river, would not have a measurable impact on water quality in the Flambeau River.

### 5.2 Current Hydrologic Conditions/Verification of Conceptual Model

Since completion of the backfill program, the groundwater levels in the vicinity of the pit have been increasing. Figure 1 shows the regional groundwater potentiometric surface based on April 2000 data depicting the pattern of groundwater flow in the vicinity of the backfilled pit. The data displays an overall pattern of groundwater flow toward the Flambeau River. The contour map also shows a substantial amount of groundwater recovery around the backfilled pit, with locally convergent flow toward the backfilled pit. Lastly, the figure shows that higher heads exist within the backfill relative to downgradient groundwater monitoring points. The positive hydraulic gradient toward the river indicates that under current conditions pore water in the pit backfill is migrating, as was predicted to occur (Prickett & Associates, 1989; Foth & Van Dyke, 1989; and Engineering Technologies Associates, 1998), in a general direction toward the Flambeau River.

Overall, the water level trends indicate that the groundwater system is recovering and that the groundwater flow system is equilibrating to a condition that is similar to the pre-mining condition. The data collected to date also indicate that, as predicted at the time of permitting, pore water from the pit backfill is migrating toward the river. This conclusion is supported by the groundwater quality data collected from monitoring wells that surround the pit (Flambeau, 2000).

Groundwater elevation and quality data will continue to be collected in and around the backfilled pit in accordance with the project's monitoring plan. As the groundwater system recovers, the groundwater elevation and quality data will be evaluated to assess long term patterns of migration from the pit backfill.

Trend graphs of groundwater quality provided in Flambeau (2000) were also reviewed for this assessment. With the exception of well MW-1000PR, none of the wells show a noticeable increase in constituent concentrations relative to historical trends. MW-1000PR does show an increase in conductivity, alkalinity, hardness, iron, manganese, sulfate, and total dissolved solids. This increase is consistent with the original conceptual model developed at the time of permitting. Well MW-1000PR is screened within a weathered and highly fractured schist with disseminated pyrite that forms a strong hydraulic connection to the backfill. As the system has recovered, pore water has begun migrating through this fracture zone from the backfill toward the Flambeau River and well MW-1000PR. As such, this well is expected to yield water quality data and trends that are in fact similar to the backfill pore water quality discussed in Sections 3 and 4 above.

Surface water quality trends for the Flambeau River presented in Flambeau (2000) for sampling points SW-1 and SW-2, which are located upstream and downstream, respectively, of the backfilled pit, were also reviewed. The surface water quality trends show no change in water quality relative to historical trends. This data supports the original conceptual model (Foth & Van Dyke, 1989) that the small amount of pore water predicted to discharge into the Flambeau River will not affect water quality in the river.

As the groundwater system fully recovers, the gradient between the backfilled pit and river will increase, leading to a greater flux of pore water to the river. To assess this future condition, the volumetric flux from the backfill under completely recovered conditions has been calculated using Darcy's law. Using post-mining steady-state predictive results from the regional groundwater flow model (Engineering Technologies Associates, 1998), the following parameters were used in the Darcy calculation:

- ♦ the permeability (K) of the backfill is 0.028 ft/d;
- ♦ the hydraulic gradient (I) between the western end of the pit and the Flambeau River is 0.03 ft/ft; and
- ♦ the cross-sectional area (A) is equal to the approximate pit width (w) of 650 ft and thickness of the upper Precambrian aquifer (b) of 100 ft.

~~2.8 g pm~~

2.1 g pm

$6.3 \times 10^{-4}$  cfs

Based on these parameter values, the flux of pore water ( $Q = K \cdot I \cdot A$ ) to the river was calculated to be 54.6 cubic feet per day (cfd), or  $6.3 \times 10^{-4}$  cubic feet per second (cfs). The average flow in the Flambeau River is 1,749 cfs. The 10-year, 7-day low flow in the Flambeau River is 412 cfs. Given these flow values, the concentration reduction factor for mixing the pore water with the flow in the river is arrived at by dividing the pore water flux by the flow in the river, and ranges from 0.0000015 under low flow conditions to 0.00000037 under average flow conditions. The incremental increases in solute concentrations in the river due to the pore water flux can then be estimated by multiplying the concentration reduction factor by the pore water concentration.

Using the April 2000 highest measured pore water concentrations at well nests MW-1013 and MW-1014, or monitoring well MW-1000PR, the range of the incremental increase in the river under fully recovered groundwater conditions are as shown in Table 8.

Based on the surface water quality trends presented in Flambeau, 2000, the background copper concentration in the Flambeau River is on the order of 0.004 mg/L. The potential increase in copper concentration is orders of magnitude below existing conditions, and would be immeasurable. Background concentrations for iron, manganese, and sulfate are provided in the project's *Environmental Impact Report* (Foth & Van Dyke, 1989a). The background concentration of iron in the Flambeau River ranged between 0.16 mg/L and 0.54 mg/L. The potential increase in iron concentration is orders of magnitude below this range, and would be immeasurable. Likewise for manganese, the background concentration ranged from <0.05 mg/L to 0.08 mg/L. The potential increase in manganese is several orders of magnitude below background, and would be immeasurable. Finally, with respect to sulfate, the background concentrations ranged between <5 mg/L and 15 mg/L. Again, the potential increase in sulfate is orders of magnitude below background and would be immeasurable.

In summary, the potential for backfill pore water to impact water quality in the Flambeau River is virtually non-existent because the potential incremental increases are orders of magnitude below background. Finally, note that the above analysis is conservative, since attenuating reactions such as adsorption are not considered.

54 cfd  
~~= 2.8 g pm~~  
 = 0.375 cfm  
 = 2.8 g pm

(0.28 ft/d)  
 .03  
 (65000 ft<sup>2</sup>)  
54 cfd

$3.5 \times 10^{-4}$

## 6. Summary

As part of the permitting effort for the Flambeau Project, assessments were completed to determine if the reclaimed site would comply with permitted groundwater quality standards at the compliance boundary and protect surface water quality in the Flambeau River. The original assessment relied on predicted post-mining hydrologic conditions to conclude that the Flambeau River would act as a hydrologic boundary for pore water migrating from the pit backfill and that backfill pore water would not migrate to the downgradient compliance boundary. In addition, the original analysis showed that the flux of backfill pore water into the river would be so small relative to the flow in the river that surface water quality would not experience a measurable change.

Environmental monitoring data from the reclaimed site supports the original analysis. This conclusion is based on the following:

- ◆ Groundwater elevation measurements show that regional groundwater, including backfill pore water, is again flowing toward the Flambeau River as predicted.
- ◆ Backfill pore water is in equilibrium with calcite and gypsum, indicating complete neutralization of the acidity.
- ◆ Consistent results in samples collected from 1998 through 2000 demonstrate that the concentrations of solutes in the backfill pore water are stable.
- ◆ Groundwater quality from the western end of the backfilled pit has, as expected, a signature that is consistent with the backfilled pit pore water, while all other monitoring wells show no change in water quality relative to historical trends.
- ◆ Surface water quality data show that the pit backfill is not affecting water quality in the Flambeau River.
- ◆ Calculations also show that after the hydrogeologic system is completely recovered, the flux of pore water from the backfill will be negligible with respect to its potential impact on water quality in the Flambeau River.

Given the hydrologic conditions at the site, the environmental monitoring data show that the Flambeau Mine is in compliance with groundwater quality permit conditions and that water quality in the Flambeau River is protected.

## 7. Recommendations

Based on the above assessment and conclusions, SRK and Foth & Van Dyke recommend that:

- ♦ Flambeau continue to monitor Flambeau River water quality for iron, manganese, and sulfate to provide current data on concentrations of these parameters.
- ♦ With the exception of the two items listed below, monitoring of groundwater within and around the backfilled pit should continue to be performed in accordance with the program contained in the project's approved monitoring plan (Foth & Van Dyke, 1991). An annual review of the data should be included in the project's annual report to determine if conditions affecting the conclusions reached in this memorandum remain consistent. As additional data are collected and the continuation of stable conditions is documented, consideration can be given to reducing the frequency of monitoring within the backfilled pit.
- ♦ CO<sub>2</sub> sampling be performed according to the April 2000 method for one more sampling period. If CO<sub>2</sub> and alkalinity data continue to be correlated, CO<sub>2</sub> sampling and analysis should be discontinued, with alkalinity data used to assess any future changes in the effects of CO<sub>2</sub> pore water quality in the backfilled pit.
- ♦ Eh measurements should be taken each quarterly sampling event until trends, or lack thereof, become evident.

## 8. References

- Brook, G. A., M. E. Folkoff, and E. O. Box, 1983. A World Model of Soil Carbon Dioxide. *Earth Surf. Proc.*, Vol. 8, pp. 79-88.
- Engineering Technologies Associates, Inc. 1998. Addendum to Groundwater Flow Model.
- Flambeau Mining Company, 2000. 1999 Annual Report. January 2000.
- Foth & Van Dyke. 1989. Prediction of Groundwater Quality Downgradient of the Reclaimed Pit for the Kennecott Flambeau Project.
- Foth & Van Dyke, 1989a. Environmental Impact Report for the Kennecott Flambeau Project.
- Foth & Van Dyke, 1991. Updated Monitoring Plan for the Flambeau Project. July 1991.
- Foth & Van Dyke, 1997. 1997 Backfilling Plan for Stockpiled Type II Material.
- Harmon, R. S., W. B. White, J. J. Drake, and J. W. Hess, 1975. Regional Hydrogeochemistry of North American Carbonate Terrains. *Water Resour. Res.*, Vol. 11, pp. 963-967.
- Kampbell, Don H. and Steve A. Vandegrift, 1998. Analysis of Dissolved Methane, Ethane, and Ethylene in Ground Water by a Standard Gas Chromatographic Technique. *Journal of Chromatographic Science*, Volume 36. May 1998.
- SRK Consulting, 1999. Flambeau Project - 1999 Backfill Porewater Quality Monitoring Results. Memorandum from John Chapman to Gerald Sevick, Foth & Van Dyke, dated December 29, 1999.
- Thomas A. Prickett & Associates, Inc., 1989. Groundwater Model for the Kennecott Flambeau Project, Ladysmith, Wisconsin.

Table 1

Monitoring Wells and Screen Gravel Pack Mid-Point Elevations

Well	Mid-Point Elevation (ft) <sup>1</sup>	
MW-1000R	1089.75	
MW-1000PR	1049.00	
MW-1002	1092.13	
MW-1002G	1053.71	
MW-1004	1109.55	
MW-1004S	1091.25	
MW-1004P	1040.81	
MW-1005	1129.95	
MW-1005S	1095.59	
MW-1005P	1054.17	
MW-1010P	988.68	<u>1127.1</u>
MW-1013	1102.9	24.25
MW-1013A	1080.7	46.4
MW-1013B	1040.8	186.5
MW-1013C	926.1	201.0
MW-1014	1111.8	<u>1145.5</u> 33.7
MW-1014A	1081.6	63.9
MW-1014B	1040.6	104.8
MW-1014C	988.8	156.7

<sup>1</sup> Elevation of the mid-point of the gravel pack around the well screen.

**Table 2**

**Summary of Monitored Parameters**

Parameter	Units	Quarterly <sup>1</sup>	Annual <sup>2</sup>	Expanded <sup>3</sup>
Alk, T	(mg/L)	x	x	x
As	(ug/L)		x	x
Ba	(ug/L)		x	x
Cd	(ug/L)		x	x
Ca	(mg/L)			x
Cl	(mg/L)			x
Cr, T	(ug/L)		x	x
Cu	(ug/L)	x	x	x
Hardness, T	(mg/L)	x	x	x
Fe	(mg/L)	x	x	x
Pb	(ug/L)		x	x
Mg	(mg/L)			x
Mn	(ug/L)	x	x	x
Hg	(ug/L)		x	x
Field pH	(s.u.)	x	x	x
Lab pH	(s.u.)	x	x	x
K	(mg/L)			x
Se	(ug/L)		x	x
Ag	(ug/L)		x	x
Na	(mg/L)			x
TDS	(mg/L)	x	x	x
Sulfate	(mg/L)	x	x	x
Zn	(ug/L)		x	x
Color	(After Filter)	x	x	x

Table 2 (Continued)

Parameter	Units	Quarterly <sup>1</sup>	Annual <sup>2</sup>	Expanded <sup>3</sup>
Field Cond	(µmho)	x	x	x
Odor		x	x	x
Turbidity	(Purging)	x	x	x
CO <sub>2</sub>	(ug/L)			See Note 4
Redox	(mv)			See Note 4

<sup>1</sup> Quarterly parameter list for all wells for January, April, and October sampling events.

<sup>2</sup> Annual parameter list for all wells for July sampling event.

<sup>3</sup> Expanded parameter list was performed in July and October 1999 and April 2000 for monitoring well MW-1005P and for those wells included in the MW-1013 and MW-1014 well nests that contained water to assist in the assessment described in this memorandum.

<sup>4</sup> CO<sub>2</sub> tests were conducted in October 1999 and April 2000, and field redox potential tests were performed in April 2000 for monitoring well MW-1005P and for those wells included in the MW-1013 and MW-1014 well nests that contained water to assist in the assessment described in this memorandum.

**Table 3**

**Comparison of Carbon Dioxide and Alkalinity Measurements**

Well	Sample Date	Temperature °C	Measured H <sub>2</sub> CO <sub>3</sub> * (mmol/L)	Measured Alkalinity (meq/L)	Total Inorganic Carbon (mmol/L)	
					Calculated from CO <sub>2</sub>	Calculated from Alkalinity
MW-1013B	Apr-00	8.7	10.7	10.4	24	18
MW-1013C	Apr-00	8.7	6.1	9.2	16	15
MW-1014A	Apr-00	11.2	3.4	7.8	13	11
MW-1014B	Apr-00	14.2	12.6	9.6	24	20
MW-1014C	Apr-00	11.9	5.8	6.4	16	10
MW-1005P	Apr-00	6.4	0.7	5.0	5.4	5.8
MW-1013B	Oct-99	14.2	4.1	10.8	10	18
MW-1013C	Oct-99	9.6	3.2	8.0	10	12
MW-1014B	Oct-99	12.1	6.8	11.4	13	24
MW-1014C	Oct-99	9.9	3.6	7.6	8.6	13
MW-1005P	Oct-99	9.8	0.6	4.8	4.6	5.5

Note: Data for monitoring wells MW-1013, MW-1013A, MW-1014, and MW-1014A are not available in October 1999 since the wells were dry at the time of sample collection. Similarly, monitoring data for monitoring wells MW-1013, MW-1013A, and MW-1014 are not available for the April 2000 sampling event.

Note: H<sub>2</sub>CO<sub>3</sub>\* = CO<sub>2</sub>(aq) + H<sub>2</sub>CO<sub>3</sub>

Table 4

Estimates of Carbon Dioxide Gas in Equilibrium with April 2000 Samples

Well	Sample Date	H <sub>2</sub> CO <sub>3</sub> * (mmol/L)	K <sub>H</sub> <sup>1</sup> (mol atm <sup>-1</sup> )	pCO <sub>2</sub> (atm)	Head on Sample (feet)	P <sup>2</sup> (atm)	Mole Fraction CO <sub>2</sub> in gas
MW-1013B	Apr-00	7.7	17.8	0.138	55	2.62	5.2%
MW-1013C	Apr-00	5.6	17.8	0.100	171	6.04	1.7%
MW-1014A	Apr-00	2.9	19.2	0.055	28	1.83	3.0%
MW-1014B	Apr-00	10.3	20.5	0.211	68	3.01	7.0%
MW-1014C	Apr-00	3.6	19.7	0.071	116	4.42	1.6%
MW-1005P	Apr-00	0.8	16.2	0.013	83	3.45	0.4%

<sup>1</sup> Corrected for sample temperature

<sup>2</sup> Absolute pressure at sample depth.

Table 5

Comparison of Carbon Dioxide Gas Concentrations to Measurements Elsewhere

Measurements In	Source	Range of CO <sub>2</sub> (g)
Flambeau Backfill (MW-1013 & MW-1014)	Table 4	1.6% - 7.0%
Flambeau Background (MW-1005P)	Table 4	0.4%
Survey of data from world soils	Brook et al. (1983)	0.2% to 3.2%
Survey of data from calcareous springs	Harmon et al. (1975)	log pCO <sub>2</sub> = -3.3 + 0.08 T CO <sub>2</sub> = 0.13% at 5°C CO <sub>2</sub> = 0.79% at 15°C

Table 6

Summary of PHREEQ-C Runs to Check Saturation of Calcite and Gypsum

Sample Data Set	Conditions			Saturation Index				
	T (°C)	pH	pe <sup>5</sup>	Calcite/ Aragonite	Gypsum	Fe(OH) <sub>3</sub> (am)	Siderite	Rhodocrosite
MW-1013B <sup>1</sup>	8.7	6.63	4.11	0.24 / 0.08	-0.03	-0.23	-1.01	1.36
MW-1013C <sup>2</sup>	8.5	6.73	3.17	0.15 / 0.00	-0.01	-0.08	-0.25	0.73
MW-1014A	11.2	6.87	2.93	0.13 / -0.02	-0.36	-0.23	-0.49	0.91
MW-1014B <sup>3</sup>	14.2	6.43	5.09	-0.02 / -0.17	-0.07	-0.34	-1.16	0.99
MW-1014C	11.9	6.65	1.56	-0.02 / 0.17	-0.64	-0.82	0.76	0.49
MW-1005P <sup>4</sup>	15.9	6.91	1.08	-0.37 / -0.52	-2.83	-2.66	-1.24	-1.00

- <sup>1</sup> April 2000 data with sulfate adjusted upward to 1500 mg/L to improve ion balance.
- <sup>2</sup> April 2000 data with calcium adjusted upward to 290 mg/L to improve ion balance.
- <sup>3</sup> In the April 2000 data, the iron detection limit was anomalously high (0.15 mg/L). In the PHREEQ runs, the iron concentration was set to 0.06 mg/L, as measured in other samples from this well.
- <sup>4</sup> Combination of analytical data from the July 1999 sample with Eh and alkalinity data from the April 2000 sample.
- <sup>5</sup> The PHREEQ model uses "pe" as a measure of redox potential. The "pe" values were obtained by converting measured Eh values (at the measured temperature).

Table 7

Estimated CO<sub>2</sub> Fluxes through Unsaturated Soil and Saturated Waste Rock

Component	C <sub>o</sub> (mol/m <sup>3</sup> )	D <sub>e</sub> (m <sup>2</sup> /s)	Porosity <i>n</i>	L (ft)	CO <sub>2</sub> Flux (mol m <sup>-2</sup> s <sup>-1</sup> )
Unsaturated Soil (Gas)	1.3	1.0 x 10 <sup>-6</sup>	0.3	20	6.5 x 10 <sup>-8</sup>
Saturated Backfill (Water)	6.56	1.0 x 10 <sup>-9</sup>	0.3	10	6.5 x 10 <sup>-10</sup>

- C<sub>o</sub> = Initial Concentration
- D<sub>e</sub> = Effective Diffusion Coefficient
- L = Diffusion Distance

Table 8

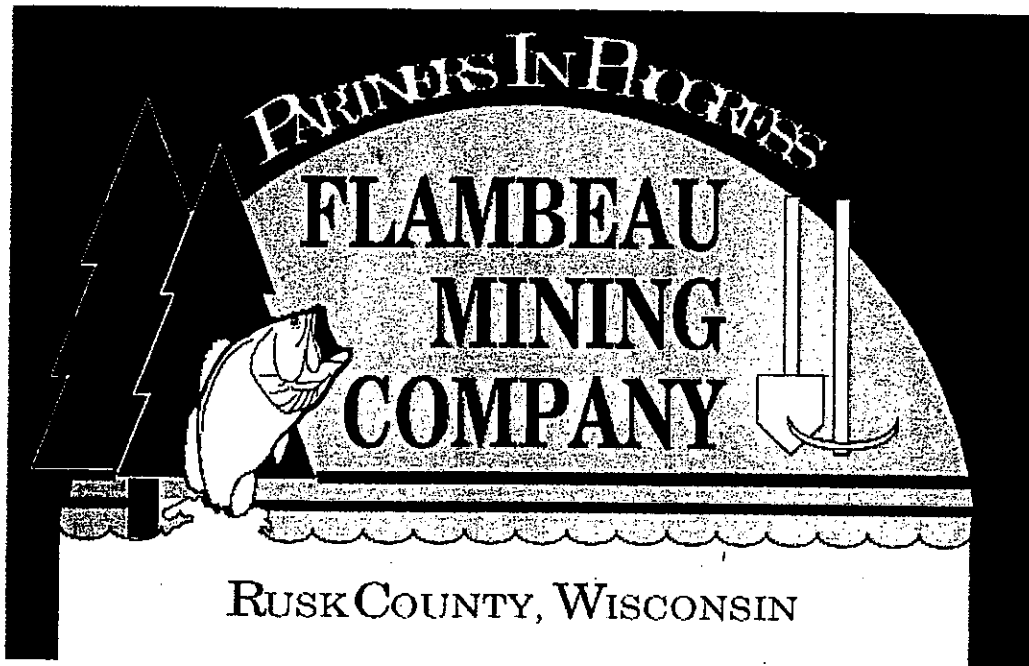
Range of Estimated Incremental Increases in the Flambeau River

	Incremental Increase	
	Average Flow (mg/L)	Low Flow (mg/L)
Copper	0.00000029	0.0000012
Iron	0.0000054	0.000022
Manganese	0.000012	0.000048
Sulfate	0.00072	0.003

## FIGURES

**APPENDIX B OF THE 2008  
ANNUAL REPORT**

# 2008 Annual Report



January 2009

Flambeau Mining Company  
N4100 Hwy 27  
Ladysmith, WI 54848



## Memorandum

January 29, 2009

TO: Jana Murphy, Flambeau Mining Co.

CC: Jim Hutchison, Foth Infrastructure & Environment, LLC  
Steve Donohue, Foth Infrastructure & Environment, LLC  
Master File, 08F777-5001

FR: Stephen Lehrke, Ph.D., Foth Infrastructure & Environment, LLC  
Sharon Kozicki, C.E.M., P.G., Foth Infrastructure & Environment, LLC

RE: Flambeau Mining Company - 2008 Annual Report Groundwater and Surface Water Trends

### Background

Groundwater and Flambeau River surface water sample results collected for the 2008 monitoring program were added to the analytical monitoring historical database as in previous years. These results were statistically tested and graphically displayed to determine whether any significant increasing or decreasing trends are occurring in the groundwater or surface water chemistry. Groundwater quality results, trend graphs and statistical test results are included as Attachment 1 for the quarterly monitoring parameters and Attachment 2 for the annual monitoring parameters. Surface water quality results, trend graphs and statistical test results are included as Attachment 3. Hydrographs are included as Attachment 4.

Intervention boundary wells included in the trend analyses are MW-1000P-R, MW-1002, MW-1002G, MW-1004P, MW-1004S, MW-1005, MW-1005P, MW-1005S, and MW-1010P. The in-pit wells included in the trend analyses are MW-1013, MW-1013A, MW-1013B, MW-1013C, MW-1014, MW-1014A, MW-1014B and MW-1014C. Wells MW-1015A and MW-1015B (also included in the analyses) were constructed in January 2001 approximately 1000 ft. northwest of the backfilled pit and adjacent to the compliance boundary.

### Statistical Methods

In previous Annual Reports October of 1997 was selected as the start date for trend tests since it is the beginning of the post-mining period. However, trend tests performed on these increasingly large data sets lose their ability to effectively identify shorter term or recent trends. To remedy this, an additional set of trend tests is included for the first time in this analysis. As in the past, trend tests beginning in October of 1997 are included to identify long-term trends during the post-mining period. However, trend tests based on the most recent five years worth of data are also included to identify recent trends.

Note that the long-term trend analyses begin in February, 1999 for the in-pit wells MW-1013B, MW-1013C, MW-1014A, MW-1014B and MW-1014C, and April, 2001 for wells MW-1015A and MW-1015B, which is when monitoring began. Trend analyses are also included for wells MW-1013, MW-1013A and MW-1014 beginning in October, 2005, at which time sufficient groundwater recovery occurred to collect samples.

For the annual monitoring parameters of barium, cadmium, calcium, chloride, chromium, lead, magnesium, mercury, potassium, selenium, silver, sodium and zinc, the long-term trend analyses begin with July 1999 since this was the recent start date of monitoring for these parameters.

The non-parametric Mann-Kendall test for trend was used to statistically determine existing trends in both the long-term and recent (5-year) data sets. This test indicates whether any general increasing or decreasing trends have occurred during these time frames. The results of the trend tests are best used in conjunction with the trend graphs of Attachments 1, 2 and 3 to properly evaluate trend conditions in the context of the broader site hydrology. It should be noted that a statistically increasing or decreasing trend does not necessarily indicate a substantial increase or decrease in actual parameter concentrations. There are situations where variation in the data is small, allowing slight consecutive concentration changes to be detected as a statistically significant trend. Although these minor trends may occur, they should not be construed as an indication of a broader impact on water quality.

The procedure for the Mann-Kendall test is given in Gilbert (1987)<sup>1</sup>. The Type I error for each test was set to 0.01 (two-tailed), with the exception of the 5-year trend tests for the annual parameters. In that case the Type I error (two-tailed) was set to 0.05 to increase the power of the test (power of detecting existing trends) to counteract the decrease in power due to small sample sizes. All non-detected values were replaced with a common value below the lowest detected value.

In the trend test results of Attachments 1, 2 and 3, a "+" indicates a statistically increasing trend and a "-" indicates a statistically decreasing trend. If neither a "+" or "-" is given, no statistically significant trend is present.

## **Trend Results**

### Quarterly Parameters (Attachment 1)

The majority of observable trends, increasing and/or decreasing, were exhibited in the groundwater results for the quarterly parameters of alkalinity, copper, hardness, iron, manganese, sulfate, TDS, conductivity and redox. A number of the observed trends are similar to those noted in the 2007 annual report.

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<sup>1</sup>Gilbert, R.O., 1987. "Statistical Methods for Environmental Pollution Monitoring", Van Nostrand Reinhold, New York.

Trends reflecting either more recent concentration changes or greater changes in actual concentration levels are noted in the intervention boundary wells MW-1000PR, MW-1004S, MW-1005, MW-1010P and MW1015B, and the in-pit wells MW-1013B, MW-1013C, MW-1014A, MW-1014B and MW-1014C. Many trends indicated as statistically significant in other wells are the result of only small consecutive concentration changes over the post-mining period, with overall concentration change being very low.

The following narrative provides a more detailed discussion of the statistical trend results for each well, utilizing the historical trend graphs of Attachment 1 to interpret the results.

#### Intervention Boundary Wells

- ◆ MW-1000PR: Several parameters exhibited an immediate increase in concentrations at the beginning of the post-mining period. These are alkalinity, hardness, iron, manganese, sulfate, TDS and conductivity. Of these, hardness, manganese, sulfate, TDS and conductivity quickly began to again decrease, with sulfate and conductivity continuing decreasing trends in the recent (5-year) data. Alkalinity continues an increasing trend, however, with the rate of increase slowing considerably following 2002. Iron concentrations, while elevated between 1999 and 2004, significantly dropped between 2005 and the third quarter of 2007, but increased again during the fourth quarter of 2007. Iron concentrations then significantly dropped again during 2008.
- ◆ MW-1002: No recent (5-year) trends exist. Long-term decreasing trends are indicated for iron, sulfate and conductivity, but reflect only small consecutive changes in actual low concentrations.
- ◆ MW-1002G: No recent (5-year) trends exist. Long-term decreasing trends are indicated for sulfate and TDS, but reflect relatively small concentration changes.
- ◆ MW-1004P: An increase in iron and manganese concentrations occurred generally around 2002, however the 5-year trend tests indicate no current trends exist. Both parameters remain at concentrations similar to or below pre-mining conditions (pre-1993). Copper has a long-term decreasing trend, reflecting an isolated period of increased concentrations during 1997 and 1998.
- ◆ MW-1004S: Alkalinity, hardness, sulfate and conductivity have had small increasing trends since 2002, but concentrations remain generally low with alkalinity and hardness below pre-mining (pre-1993) concentrations. Statistical decreasing trends were noted for copper, iron and manganese but reflect only slight changes in already low concentrations.
- ◆ MW-1005: Moderate long-term decreasing trends have occurred for alkalinity, iron, and manganese. Of these, alkalinity continues to have a decreasing trend in the recent (5-year) data. Also, while the following have no recent statistical trends, hardness, TDS and conductivity had observable concentration decreases from 1993 through 2002, then

increases during 2003 with stabilized readings thereafter. Note this follows a moderate short term increase in groundwater elevation during 2002.

- ◆ MW-1005P: Copper, sulfate and redox have long-term decreasing statistical trends, but reflect only slight concentration changes. TDS also statistically has an overall long-term decreasing trend, however several 2008 sample concentrations increased again to levels observed in the pre-1993 data. This increase was not yet observed in enough samples however to be concluded as a significant trend. Conductivity has had a recent (5-year) increasing trend and iron, a long-term increasing trend, but both are at or below pre-1993 levels.
- ◆ MW-1005S: Alkalinity, hardness, manganese and conductivity observed increasing trends, but reflect only small changes in actual concentration levels which are near or below pre-1993 results.
- ◆ MW-1010P: Conductivity and redox have increasing 5-year trends after observing significant decreases during 2002, with current concentrations similar to pre-2002 levels. Long-term increasing trends were also observed for alkalinity, hardness, manganese and sulfate, however current concentrations have stabilized with no existing recent trends and levels still similar to, or below, pre-mining (pre-1993) conditions.
- ◆ MW-1015A: Several statistical trends were noted for alkalinity, manganese, sulfate and conductivity, however these reflect very small consecutive concentration changes. Concentrations remain generally stable and at lower levels.
- ◆ MW-1015B: Redox and conductivity have recent increasing trends, while manganese has a recent decreasing trend. Iron concentrations increased during 2002 to 2003, but have been generally consistent since.

#### In-Pit Wells

- ◆ MW-1013: No statistically significant trends were noted for the quarterly monitoring parameters in the available data, however, groundwater elevation generally increased between 2000 and 2004.
- ◆ MW-1013A: Conductivity and redox have had decreasing trends generally since 2005.
- ◆ MW-1013B: Copper continues to have an increasing trend since 2002. Concentrations appear somewhat seasonal, with the higher concentrations appearing during the summer or fall months. Iron was also following a significantly increasing trend until 2004, when concentrations suddenly fell to non-detectable levels and have remained ever since (now reflecting a long-term decreasing trend). TDS has had a moderately decreasing trend since 2002.

- ◆ MW-1013C: Long-term increasing trends were observed for alkalinity, iron and manganese, with iron continuing an increasing trend in the recent (5-year) results. Conductivity has a recent decreasing trend.
- ◆ MW-1014: Manganese and pH have recent decreasing trends.
- ◆ MW-1014A: Decreasing trends were noted for iron and manganese. Iron has generally been at non-detectable levels since 2004. A long-term increasing trend was noted for alkalinity, but reflected relatively smaller concentration changes with no recent trend.
- ◆ MW-1014B: Long-term decreasing trends were observed for hardness, manganese and TDS and conductivity. No recent trends are occurring with hardness, TDS and conductivity, but the decreasing trend continues with manganese in the recent data.
- ◆ MW-1014C: Long-term and recent decreasing trends were observed for hardness, iron, manganese, sulfate, TDS and conductivity. Long-term increasing trends are noted for arsenic and pH, but no recent trends are noted for these parameters.

#### Annual Parameters (Attachment 2)

Similar to past trend results, the annual groundwater parameters of barium, cadmium, calcium, chloride, chromium, lead, magnesium, mercury, potassium, selenium, silver, sodium, and zinc illustrated few statistically significant trends, and of those that are noted, most generally reflect small consecutive changes in actual low concentrations. Of the somewhat moderate trends, MW-1000P-R has had a recent decreasing trend of zinc and long-term decreasing trends (but no recent trends) of calcium and magnesium. MW-1014B has had long-term (but no recent) decreasing trends of cadmium and magnesium. MW-1014C has had recent and long-term decreasing trends of calcium, magnesium and zinc. A long-term increasing trend of barium was also detected in MW-1014C, however this trend is an artifact of the higher method detection limits utilized prior to 2003 than those currently in use.

#### Surface Water (Attachment 3)

Parameters currently included in the surface water monitoring are copper, hardness, iron, manganese, sulfate, zinc, pH and conductivity. No statistically significant trends were observed in either the upstream or downstream surface water monitoring results, with the exception of an increasing trend of zinc in SW-2. This increasing trend, however, is an artifact of the higher method detection limits utilized prior to 2003 than those currently in use.

The increase in manganese at both the upstream and downstream locations during August and September of 2007, which may in part have resulted from Flambeau River work completed by others at the North Dairyland dam, again decreased to historical levels.

#### Hydrographs (Attachment 4)

As observed in the hydrographs, all wells illustrating significant drawdown during the production period of 1993 to 1997 now appear to be substantially stabilized. The wells include MW-1000P-R, MW-1001, MW-1001G, MW-1001P, MW-1003, MW-1003P, MW-1004, MW-1004P, MW-

1004S, MW-1010P, OW-7, OW-39, OW-42, PZ-1006G, PZ-1006S, PZ-1007S, PZ-1008, PZ-1008G, PZ-1012, PZ-R1, PZ-S1, PZ-S3, ST-9-23 and ST-9-26.

Groundwater elevations increased steadily from 1999 through 2002 for the in-pit wells of MW-1013A, MW-1013B, MW-1013C, MW-1014, MW-1014A, MW-1014B and MW-1014C, but stabilized and began a decreasing trend in 2003. This trend once again reversed during 2008 with increasing elevations. Elevations for MW-1013 rose through 2004, but appear to have stabilized during 2005 and remained consistent since then.

## **Conclusions**

Many of the concentration trends noted from the statistical trend tests reflected small but consecutive changes in actual concentration. The more significant trends occurred mainly with the quarterly monitoring parameters in the intervention boundary wells MW-1000PR, MW-1004S, MW-1005, MW-1010P and MW1015B, and the in-pit wells MW-1013B, MW-1013C, MW-1014A, MW-1014B and MW-1014C. Of the trend results listed above, the following are the main conclusions:

### Intervention Boundary Wells

- ◆ Several parameters in MW-1000PR (alkalinity, hardness, iron, manganese, sulfate, TDS and conductivity) exhibited concentration increases following the rebounding of water levels after the production period ended. Of these parameters, alkalinity continues to increase, but the rate of increase slowed significantly following 2002. Sulfate and conductivity continue decreasing trends. The remainder have no trend occurring in the recent (5-year) data.
- ◆ Alkalinity, hardness, sulfate and conductivity in MW-1004S continue small increasing trends which began around 2002, but concentrations remain generally low with alkalinity and hardness below pre-mining (pre-1993) concentrations.
- ◆ Alkalinity continues a moderately decreasing trend in MW-1005.
- ◆ Conductivity and redox in MW-1010P have increasing trends in the recent (5-year) data after observing significant decreases during 2002, with current concentrations similar to pre-2002 levels.
- ◆ MW1015B has recent increasing trends of conductivity and redox, while a decreasing trend continues with manganese.

### In-Pit Wells

- ◆ Copper has had a significantly increasing trend in MW-1013B since 2002. Concentrations appear somewhat seasonal, with the higher concentrations appearing during the summer or fall months. Iron was also following a significantly increasing

trend in this well until 2004, when concentrations suddenly fell to non-detectable levels and have remained since then.

- ◆ Between 1999 and 2008 a significantly increasing trend of iron has been noted in MW-1013C, and between 1999 and 2005 an increasing trend of manganese was also noted. Significantly decreasing trends of the same two parameters have been noted in MW-1014A. A significantly decreasing trend of manganese also continues in MW-1014B.
- ◆ Decreasing trends continue in MW-1014C for hardness, iron, manganese, sulfate, TDS and conductivity.

Few or no trends were noted for the annual groundwater parameters of barium, cadmium, calcium, chloride, chromium, lead, magnesium, mercury, potassium, selenium, silver, sodium, and zinc. Of the somewhat moderate trends, MW-1000PR has had a recent decreasing trend of zinc, and MW-1014C has had recent decreasing trends of calcium, magnesium and zinc.

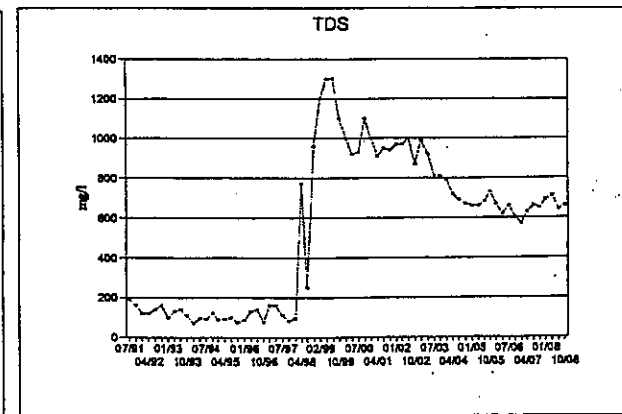
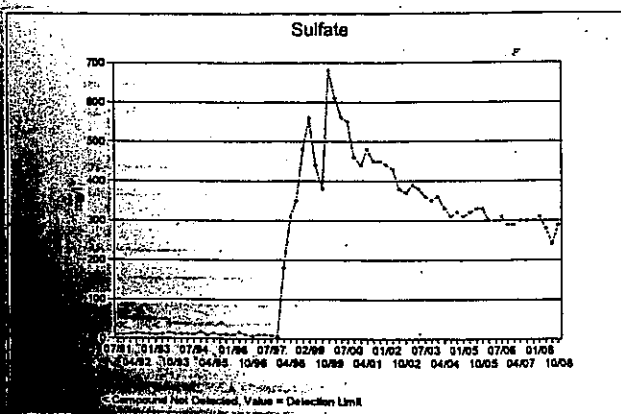
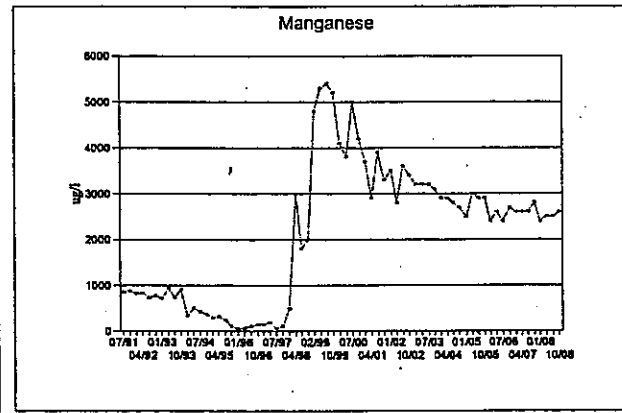
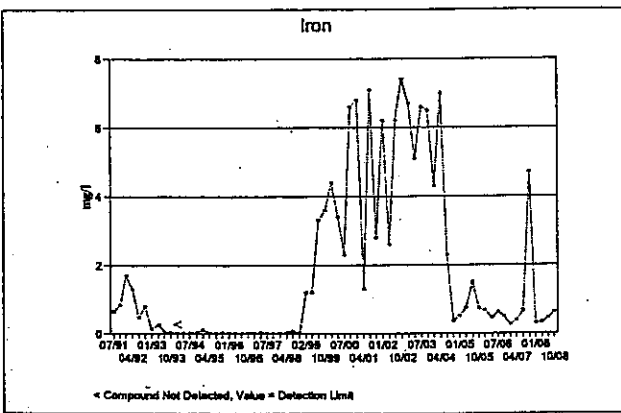
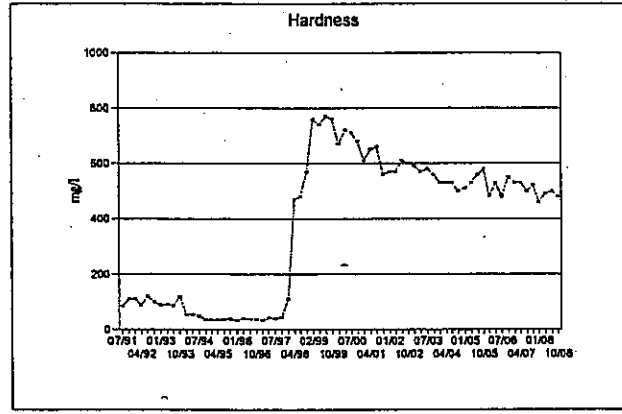
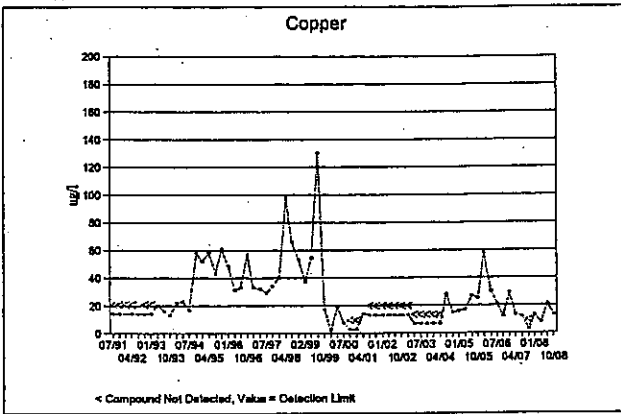
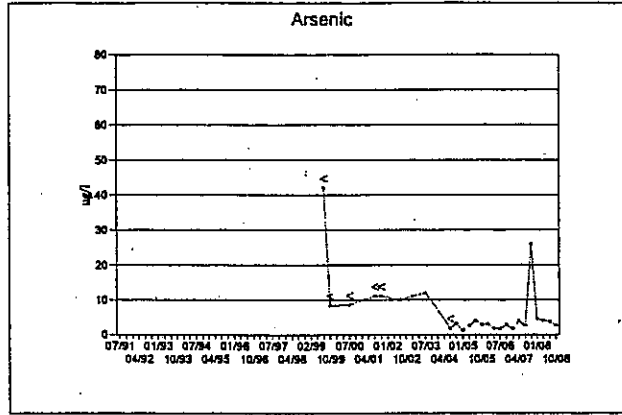
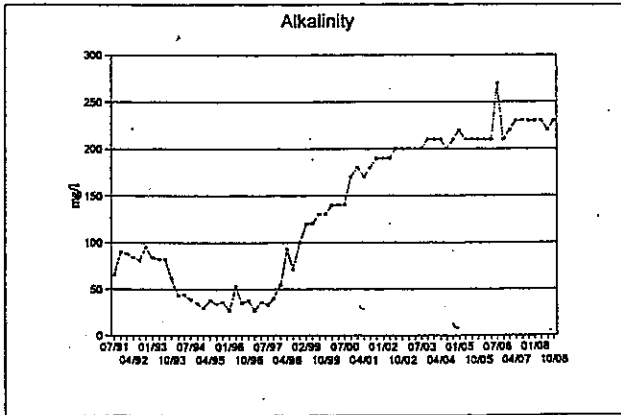
No trends were noted for the Flambeau River surface water parameters (either upstream or downstream) of copper, hardness, iron, manganese, sulfate, zinc, pH and conductivity, with the exception of an increasing trend of zinc in SW-2. This increasing trend, however, is an artifact of the higher method detection limits prior to 2003 than those currently in use.

**Trend Analysis Results - Groundwater (Quarterly Parameters)  
Year Ending 2008**

	Alkalinity	Arsenic	Copper	Hardness	Iron	Manganese	Sulfate	TDS	Field pH (su)	Field Cond (umho)	Redox (mV)	Grd Water El (Feet)
<b>MW-1000PR</b>												
<b>Trend Results for Most Recent 5 Years</b>												
Sample Size	20	18	20	20	20	20	20	20	20	20	19	20
Mann-Kendall S	92	42	-14	-61	-73	-72	-111	-60	19	-108	29	-10
p-Level	0.002	0.122	0.678	0.050	0.018	0.020	0.000	0.054	0.564	0.000	0.332	0.774
Trend	+											
<b>Trend Results for All Data Since Oct. 1997</b>												
Sample Size	45	26	45	45	45	45	45	45	45	45	31	45
Mann-Kendall S	852	97	-119	-424	-103	-418	-554	-448	210	-596	-78	114
p-Level	0.000	0.034	0.239	0.000	0.318	0.000	0.000	0.000	0.041	0.000	0.192	0.269
Trend	+											
<b>MW-1002</b>												
<b>Trend Results for Most Recent 5 Years</b>												
Sample Size	20	18	20	20	20	20	20	20	20	20	0	20
Mann-Kendall S	-57	22	-5	-53	-20	-33	36	2	-22	0	0	-13
p-Level	0.069	0.432	0.898	0.092	0.542	0.303	0.260	0.974	0.500	1.000		0.701
Trend												
<b>Trend Results for All Data Since Oct. 1997</b>												
Sample Size	45	23	45	45	45	45	45	45	45	45	0	45
Mann-Kendall S	46	37	-201	-48	-347	-196	-209	-247	-46	-357	0	-66
p-Level	0.659	0.346	0.005	0.645	0.000	0.006	0.042	0.016	0.658	0.000		0.525
Trend												
<b>MW-1002G</b>												
<b>Trend Results for Most Recent 5 Years</b>												
Sample Size	20	18	20	20	20	20	20	20	20	20	0	20
Mann-Kendall S	-45	5	0	6	-19	-30	37	22	-29	68	0	-10
p-Level	0.155	0.882	1.000	0.872	0.564	0.352	0.247	0.500	0.369	0.028		0.774
Trend												
<b>Trend Results for All Data Since Oct. 1997</b>												
Sample Size	45	23	45	45	45	45	45	45	45	45	0	45
Mann-Kendall S	233	-13	-51	217	-204	-13	-385	-265	23	-154	0	-85
p-Level	0.022	0.754	0.169	0.027	0.010	0.842	0.000	0.009	0.829	0.134		0.411
Trend												
<b>MW-1004P</b>												
<b>Trend Results for Most Recent 5 Years</b>												
Sample Size	20	18	20	20	20	20	20	20	20	20	20	20
Mann-Kendall S	-7	16	-11	38	14	35	72	9	15	62	47	12
p-Level	0.847	0.575	0.749	0.234	0.678	0.274	0.020	0.798	0.654	0.046	0.137	0.724
Trend												
<b>Trend Results for All Data Since Oct. 1997</b>												
Sample Size	45	25	45	45	45	45	45	45	45	45	32	45
Mann-Kendall S	161	30	-372	172	291	438	-148	-177	85	-76	57	223
p-Level	0.018	0.502	0.000	0.058	0.004	0.000	0.092	0.083	0.410	0.463	0.367	0.030
Trend	+											
<b>MW-1004S</b>												
<b>Trend Results for Most Recent 5 Years</b>												
Sample Size	20	18	20	20	20	20	20	20	20	20	19	20
Mann-Kendall S	155	13	-22	135	-5	-16	155	57	-26	160	-5	20
p-Level	0.000	0.654	0.500	0.000	0.898	0.630	0.000	0.069	0.422	0.000	0.890	0.542
Trend	+											
<b>Trend Results for All Data Since Oct. 1997</b>												
Sample Size	45	25	45	45	45	45	45	45	45	45	31	45
Mann-Kendall S	437	27	-288	598	-341	-239	733	25	85	321	-52	224
p-Level	0.000	0.548	0.001	0.000	0.000	0.004	0.000	0.813	0.410	0.002	0.389	0.029
Trend	+											

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Groundwater Quality Results

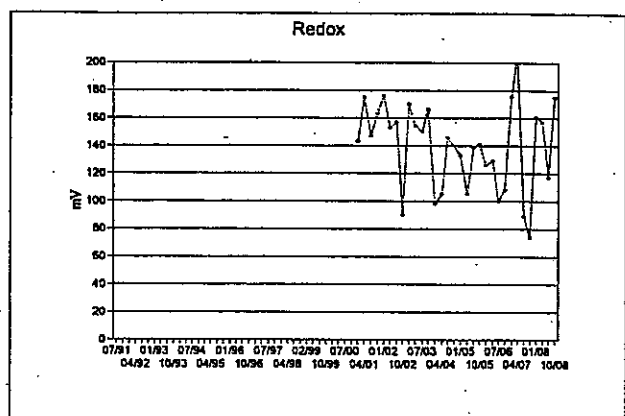
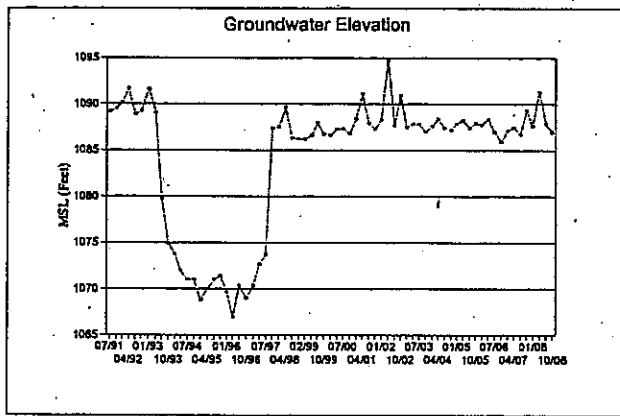
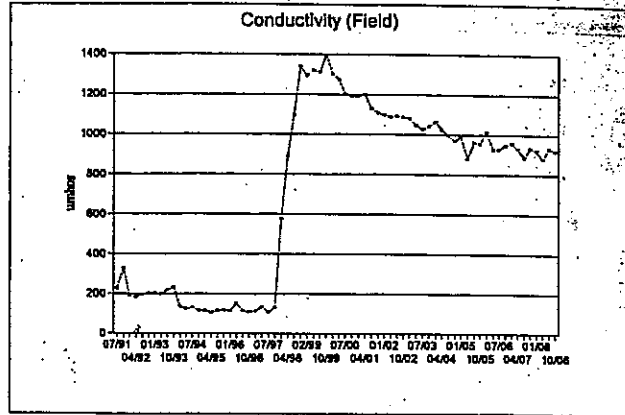
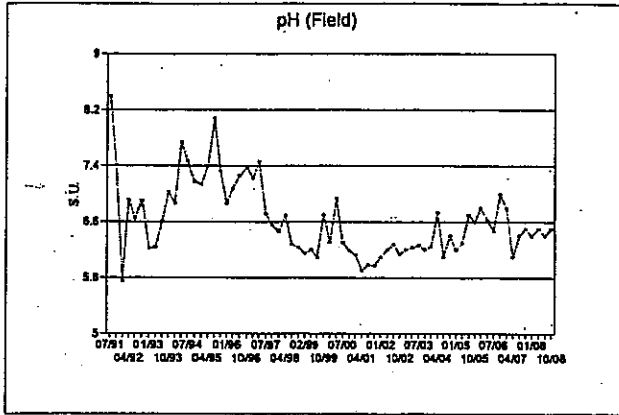
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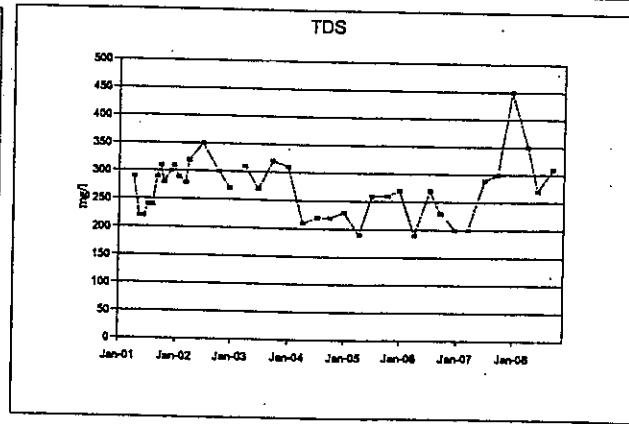
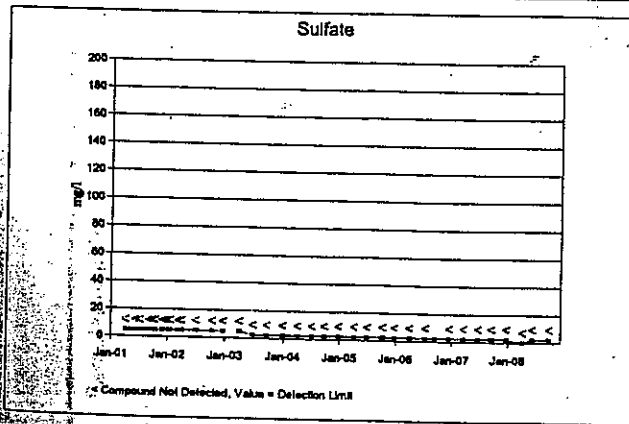
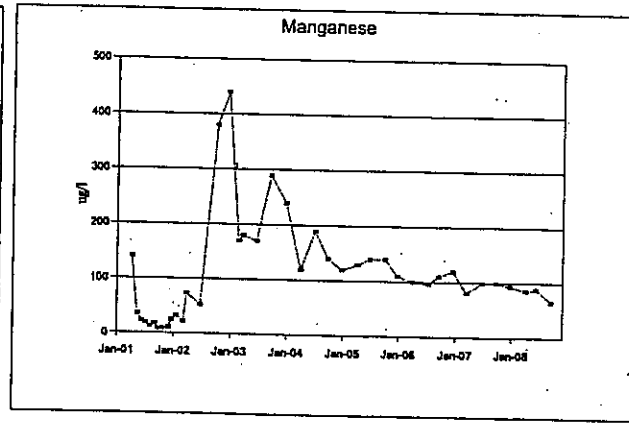
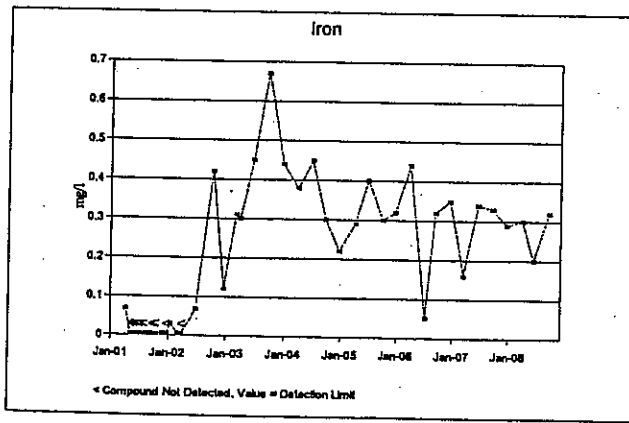
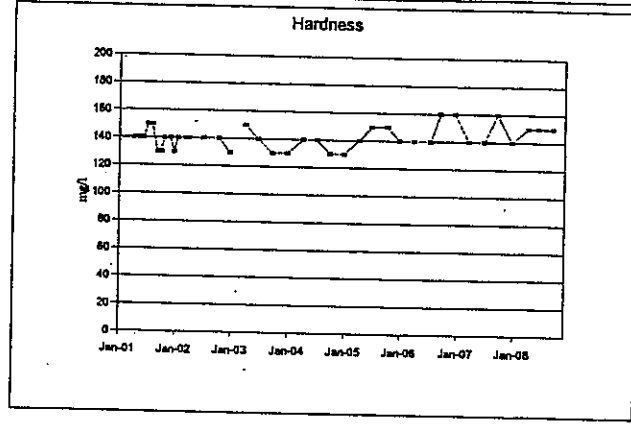
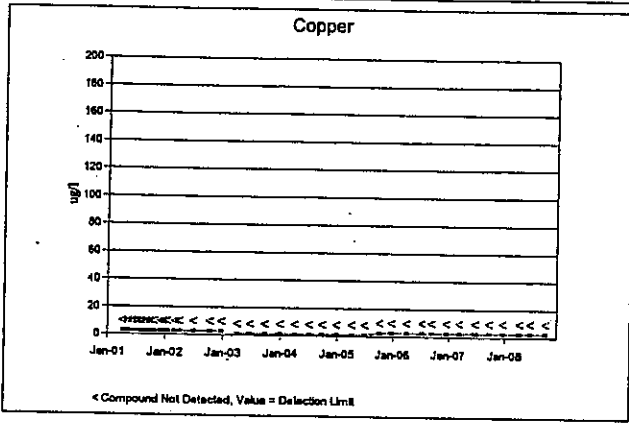
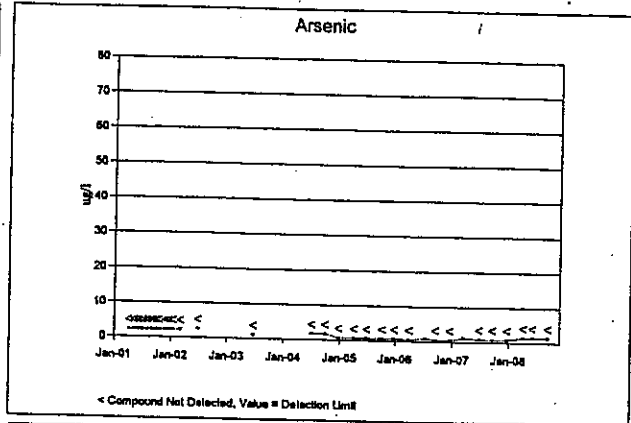
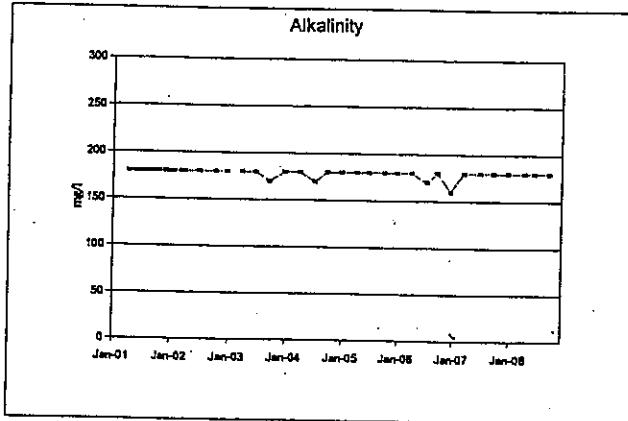
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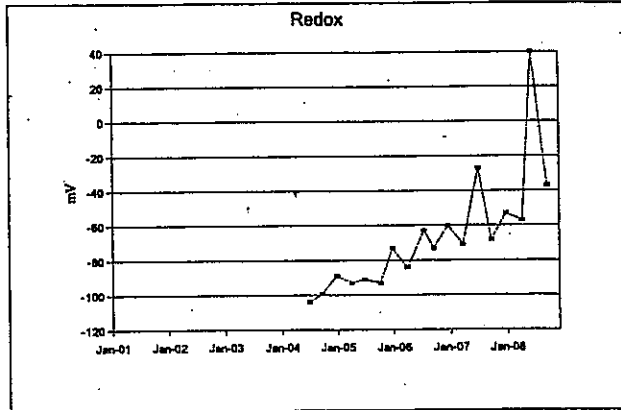
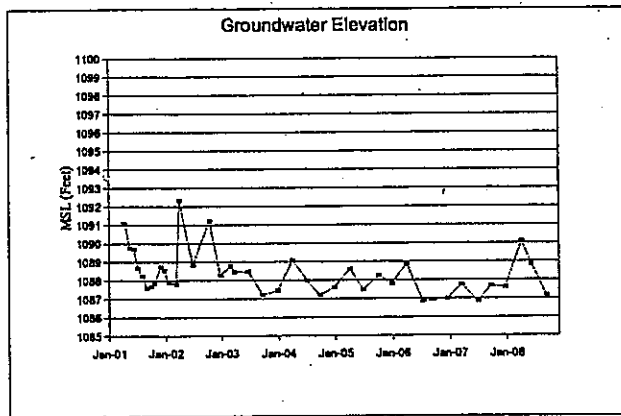
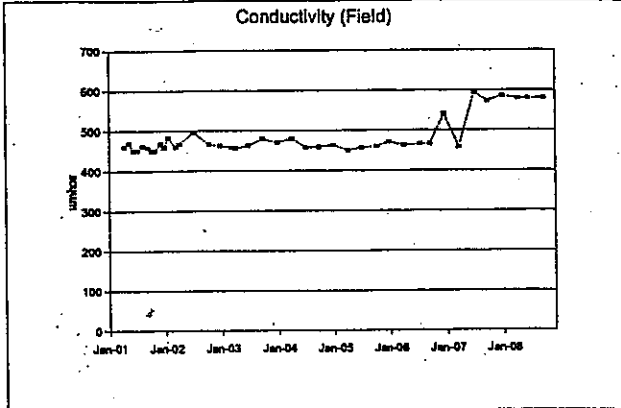
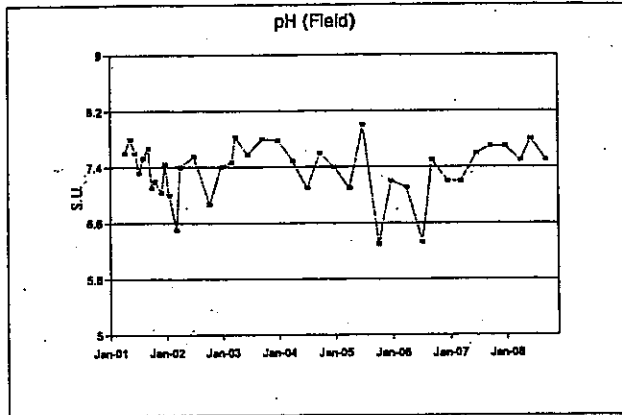
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RESOURCES INVESTIGATIONS  
REPORT 90-4171, 1995, *GROUND-  
WATER FLOW AND QUALITY IN  
WISCONSIN'S SHALLOW  
AQUIFER SYSTEM***

# **GROUND-WATER FLOW AND QUALITY IN WISCONSIN'S SHALLOW AQUIFER SYSTEM**

**By P.A. Kammerer, Jr.**

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U.S. GEOLOGICAL SURVEY  
Water-Resources Investigations Report 90-4171

Prepared in cooperation with the  
WISCONSIN DEPARTMENT OF NATURAL RESOURCES



Madison, Wisconsin  
1995

## 4.0 GROUND-WATER QUALITY--Continued

### 4.1 Chemical characteristics--Continued

#### 4.1.11 Iron and manganese

\* [ **Iron and manganese concentrations exceed State drinking-water standards in water**  
\* **from many wells in the shallow aquifer system. Extreme local differences in concentration**  
\* **of these elements are common.**

Iron and manganese are widely distributed in rocks and soils. Their solubility and mobility in ground water are affected by combinations of complex chemical and biological processes. Solubilities of these elements depend on their oxidation state, which is strongly affected by the intensity of oxidation or reduction conditions in the aquifer. Solubility also depends on pH. Rapid changes in oxidation state, commonly mediated by biological processes, can affect solubility and cause extreme local concentration differences.

Maximum concentrations of iron and manganese specified in Wisconsin's secondary drinking-water standards are 300 and 50 µg/L (micrograms per liter) (Wisconsin Department of Natural Resources, 1978). Neither constituent poses a health hazard at the concentrations normal for natural water, but both can cause a variety of aesthetic problems, such as objectionable taste, staining of laundry and plumbing fixtures, and encrustation and clogging of well screens and distribution systems. An iron or manganese concentration greater than 200 µg/L is objectionable for many industrial uses of water (Durfor and Becker, 1962, p. 16).

Rapid changes in oxidation state and, hence, solubility of iron and manganese complicate both the collection and interpretation of concentration data for these constituents. Extreme local differences in concentration of these elements make the preparation of areal distribution maps for iron and manganese impractical. Solubility can change between the times of sample collection and of analysis. Improper processing of samples can lead to discrepancies between concentrations determined

in the laboratory and the concentrations of the constituents in the aquifer.

The distribution of iron and manganese concentrations in water from the shallow aquifer system is shown in the bar graphs on the facing page. The data used in these bar graphs are from analyses in which concentrations are reported as dissolved iron and manganese, as iron and manganese "in solution when analyzed," and as total iron and manganese. The "in solution when analyzed" classification applies particularly to historical data where sample collection and analytical procedures are unknown or poorly documented.

Iron concentrations in water from about one-third of the wells exceed Wisconsin's drinking-water standard, and manganese concentrations in water from about one-fourth of the wells exceed the State's drinking-water standard. This generalization is fairly consistent Statewide for manganese. Iron concentrations that exceed drinking-water standards are more common in eastern Wisconsin, where the shallow aquifer system consists of Ordovician or Silurian rocks overlain by glacial deposits, than in the rest of the State. In the east, the drinking-water standard for iron was exceeded in water from about half of the wells sampled.

More detailed summaries of iron and manganese concentrations for water in individual geologic units, including those that comprise the shallow aquifer system, are given by Kammerer (1984, p. 16, 24, 32, and 40). These summaries are further subdivided by ground-water province to reduce the effects of areal differences of hydrogeology.