

**Flambeau River Monitoring
at the Flambeau Mine
Rusk County, Wisconsin**

1. FLAMBEAU RIVER SEDIMENTS
Analysis, Comments and
Recommendations

Prepared for
Wisconsin Resources Protection Council

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INTRODUCTION

Lentic (lake and pond) and lotic (river and stream) sediments are a complex matrix, whose present composition is determined by historical, natural and anthropogenic factors. In northern Wisconsin, most lake and stream sediments were deposited as the last glaciers receded, and further modified by post-glacial natural forces such as storms, floods, the activities of fish and wildlife, forest fires and the subsequent aerial deposition of particulates, and so on. These natural forces established the sediment characteristics, which especially in river and streams are continually worked and re-worked. Human (anthropogenic) activities impacted lakes and streams for thousands of years, but that impact grew significantly with the arrival of European immigrants into Wisconsin in the 18th and 19th centuries. These impacts continue, and include agricultural, residential, and commercial activities such as mining.

River sediments such as those in the bed of the Flambeau River in northern Wisconsin provide an important ecosystem inhabited by mostly invertebrate species such as immature insects, clams, and so on. The chemistry of the sediments, itself consisting of complex dynamic interactions with the surface waters and affected to some extent by the organisms themselves, impacts that ecosystem. Potentially toxic materials in the sediment, whether natural or anthropogenic, not only affect the sediment inhabitants, but since many of these species are food for organisms higher on the trophic pyramid, by bioaccumulating these potential toxins the sediments, via the sediment organisms, directly affect species perhaps of more interest to humans, such as the fish community, or other vertebrates such as birds which prey on the invertebrates.

Because of the importance of the sediments to the riverine community, and because sediment chemistry is one measure of human impacts on the river, industries located along riverways are sometimes required to conduct sediment sampling. Such was the case with Flambeau Mining Company (FMC), a subsidiary of Kennecott Minerals of Salt Lake City, Utah that constructed an open pit copper sulfide mine on the banks of the Flambeau River in the mid 1990s. The river formed the western boundary of the project area, and the pit itself was constructed to within 150 feet of the river. The Flambeau Mine was operational for four years. It ceased production in 1997 and has since been reclaimed.

The sediment monitoring program instituted by Flambeau Mining Company was part of a broader monitoring program designed to ascertain any effects the Flambeau Mine might have on the Flambeau River ecosystem, including surface water, sediment and aquatic life. These effects could occur during excavation of the mine, during its operation, and beyond the date of its operation if substances such as metals or other potential toxins or erosional runoff might be making their way through surface or groundwater into the river or its tributaries.

The present report is an assessment of FMC's Flambeau River sediment data as well as data from Stream C, a small tributary of the Flambeau River that receives surface water runoff from the mine site.

FLAMBEAU RIVER AND STREAM C SEDIMENT STUDIES

In 1988, FMC conducted baseline sediment testing at three different sites in the Flambeau River, one upstream and two downstream of the mine site. This was followed by an annual series of sampling events that took place between 1991 and 2000 and again from 2006 to 2008. In addition, sediment was tested in 2008 at two different locations in a navigable stream (Stream C) that carries storm water runoff from the mine site to the Flambeau River and also receives overflow from a 0.9 acre wetland/biofilter situated in the southeast corner of the mine site.

During the time period in question, a number of different activities took place at the Flambeau Mine site which had the potential to impact Flambeau River and Stream C sediments. These included:

- 1991-1993: Pre-production stripping and preparation of the site for excavation
- 1993-1997: Blasting and ore production
- 1997-2001: Partial reclamation of the site (backfilling the pit, recontouring the surface, revegetation)
- 2003+: Sporadic and ongoing reclamation/remediation activities (e.g., removal of contaminated soils in the Industrial Outlot portion of the mine site)

Over the years, six different sites in the Flambeau River were utilized at one time or another for sediment analysis. Local landmarks associated with the sampling sites include Gokey Road, Blackberry Lane, the Stream C outfall, Sister's Farm, the site of the former Port Arthur Dam (the dam was removed in 1968) and Thornapple Dam, as described below and shown on the maps included in Appendices I, II and III:

1. Gokey Road (about 1 mile upstream of the open pit site and 0.3 mile upstream of Blackberry Lane; sampled 1988 only)
2. Blackberry Lane (about 0.7 mile upstream of the open pit site; sampled 1991-2000 and 2006-2008)
3. Stream C Outfall (about 0.3 mile downstream of the project area, below the mouth of Stream C but above the mouth of Meadowbrook Creek; sampled 2008 only)
4. Sister's Farm (about 1.5 miles downstream; sampled 1993-2000 and 2006-2008)
5. Port Arthur (about 3.1 miles downstream, in the vicinity of the former Port Arthur Dam; sampled 1988 and 1991-1993)
6. Thornapple Dam (about 7.6 miles downstream, within the dam's impoundment; sampled 1988 only)

With regard to the studies conducted between 1991 and 2008, samples were collected using sediment traps that consisted of one-quart canning jars. Three (1991-1994) or four (1995-2008) jars were placed at each sampling location and retrieved after exposure windows ranging from 22-80 days. Samples from each site were then composited and analyzed for a suite of trace elements (aluminum [Al], silver [Ag], arsenic [As], cadmium [Cd], chromium [Cr], copper [Cu], iron [Fe], mercury [Hg], manganese [Mn], nickel [Ni], lead [Pb], selenium [Se] and zinc [Zn]). In 2007 and 2008 samples were only analyzed for copper, iron, manganese and zinc. Sediment was also characterized in terms of % total solids, % total volatile solids and grain size. As discussed below, sampling site location and procedures were not always consistent from year to year.

Sediment sampling in Stream C took place as a one-time event in 2008. As described in FMC's *Stipulation Monitoring Results, December 30, 2008*, two locations within the stream bed were sampled, one which was "downstream from the overflow of the 0.9 acre biofilter and approximately 20 yards south of Copper Park Lane where Stream C is a gaining stream, in an area of sediment deposition." The second sampling site was chosen to be "approximately 120 yards downstream of Copper Park Lane, where Stream C is a losing stream, in an area of deposition." As reported by FMC, Stream C sediment samples were collected "using a hand trowel to dig below ground surface due to dry conditions in the stream bed." It appears that only a single sediment sample was collected at each of the two sampling sites. Samples were analyzed for copper, iron, manganese, zinc and % total solids.

BASELINE STUDIES – 1988

Before presenting and analyzing the Flambeau River and Stream C sediment data reported by FMC between 1991 and 2008, it would be prudent to first examine any baseline data collected by the company. No such information was reported for Stream C, but the company did perform some baseline sediment studies in the Flambeau River in 1988. As reported in the *Volume 2: Environmental Impact Report, April 1989*, a single sediment sample was taken at the Gokey Road (upstream) and Port Arthur (downstream) sampling sites in August of 1988 using a polyvinyl chloride (PVC) core sampler. Each sample was analyzed for arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, zinc and sulfur. Measurable levels of each element were detected, except for cadmium, lead and mercury.

Three sites within the Thornapple Dam impoundment (FL-1, FL-2 and FL-3) were also sampled in March of 1988 as part of the baseline study, with three, two and three cores taken from each site, respectively. Cores were separated into soft and stiff components, which were composited and analyzed for the same panel of elements listed above. Cadmium and sulfur were below the detection limits at all three sites within the impoundment.

Table 1 below shows the coefficient of variation, expressed as a percentage, from data provided in Table 3.7-2 of the *Volume 2: Environmental Impact Report, April 1989*. These cores were all taken at Thornapple Dam, FL-1, FL-2 and FL-3. The “soft” portions of the core were the upper portion, the “stiff” portions lower. The coefficient of variation is the standard deviation divided by the mean, and provides a rough estimate of the amount of variation in the samples vs. the mean. Coefficients of variation could not be calculated for the Gokey Road and Port Arthur samples because only one sediment sample was collected at each site.

Table 1: Coefficients of variation (as %) for various metals sampled in August, 1988, at the Thornapple Dam site.

	Coefficient of Variation “soft” samples	Coefficient of Variation “stiff” samples
Arsenic	18 %	35 %
Chromium	6.5 %	26 %
Copper	5.9 %	34 %
Iron	17 %	20 %
Lead	10 %	40 %
Manganese	29 %	37 %
Mercury	21 %	31 %
Zinc	14 %	20 %
Mean coefficient of variation	15 %	30 %

Just for matter of comparison, the coefficient of variation for height in adult human populations, according to two studies^{1,2}, is about 3.8%. The coefficients of variation shown in Table 1 indicate relatively high variation in metal concentrations among samples taken at the Thornapple Dam site (though we should remember that each of these samples is itself a composite of several subsamples; the individual variation could even be higher). When population or sample variance is higher, the number of samples required to achieve a desired degree of confidence in statistical tests increases rapidly. For example, only 2 replicates at each site are required to conclude that a doubling of the copper concentration from 17 (the average for the “soft” samples in Table 1) to say 34 mg/kg is statistically significant with 95% confidence, using a coefficient of variation of 5.9% such as found in the “soft” samples above. (Minitab-15 power calculation.) But the number of replicates required goes up to 8 at each site to demonstrate

that a doubling of copper concentration is statistically significant at 95% confidence when the coefficient of variation increases to 34%, as found in the “stiff” samples for copper. In other words, significant changes in sediment metal concentrations might occur, but not be statistically demonstrable, under conditions of relatively high variability, unless adequate replication is used. The evaluation of sampling variability is therefore crucial when designing monitoring programs such as those undertaken by FMC.

Coefficients of variation can and likely will vary depending on sampling location and sampling methodology. This became an issue when reviewing FMC’s baseline and follow-up sediment data, as will be discussed below.

I. SAMPLING & REPORTING ISSUES REGARDING BASELINE DATA COLLECTION

Flambeau Mining Company failed to gather adequate baseline data regarding Flambeau River sediment composition upstream and downstream from the mine site prior to commencement of the mine project. In addition, no baseline data whatsoever was gathered for Stream C. Noted sampling and reporting issues fall into the following four categories which are further discussed below:

1. Lack of replication
2. Changes in sampling site location
3. Inconsistency in sampling methodology
4. Failure to gather any baseline data for Stream C

1. Lack of replication at the Gokey Road and Port Arthur sediment sampling sites

As mentioned above, coefficients of variation could not be determined for the Gokey Road (upstream) and Port Arthur (downstream) sampling sites in the Flambeau River, since only a single sediment sample was collected at each of these locations in 1988. As a result, it is not possible to know how many replicate samples would be needed at each site to conclude with any degree of statistical confidence that baseline sediment composition at the two sites was either the same or that it differed. To make such a determination, FMC would have had to conduct a more extensive evaluation of baseline sediment composition, similar to what was done at the Thornapple Dam site (see specific recommendations below).

In other words, because only one replicate was taken at the Port Arthur and Gokey Road Sites, we have no idea what the among-sample variability was for these sites. The relatively high coefficients of variation demonstrated for the Thornapple samples (Table 1) may or may not represent variance at the other two sites, and without some reasonable estimate of that variance it is not possible to make any statistically reliable statements comparing samples among or between the sites. Consequently one can have little confidence in the statement made by FMC regarding the two sediment samples collected at the Gokey Road and Port Arthur sampling sites: “The results of laboratory analysis of these samples ... indicate no significant difference between upstream and downstream samples” (*Volume 2: Environmental Impact Report, April 1989*).

A separate but related issue concerning coefficients of variation in the FMC study is that the values used to calculate those coefficients for the Thornapple Dam site in 1988 (Table 1) were from analyses of core samples, a different sampling procedure than that adopted for the remainder of sediment monitoring (sediment traps.) FMC did not provide any baseline replication data for sampling with sediment traps. As a result, variation cannot be estimated for the sediment traps, which again prevents one from determining the power of any statistical test to demonstrate significant differences between sampling sites within a given year. As mentioned

above, without the confidence replication provides statistical tests, statements regarding whether or not there has been a mining effect in any given year cannot be made with any reasonable certainty.

Because of the importance of establishing baseline monitoring information, replicate rather than single or composite samples should always be taken at each site, and the same sampling methodology should be utilized throughout the duration of the study. One suggested procedure might involve at least five replicate samples taken at each site, from which an estimate of variance in the values can be calculated. Based on this a power calculation for the metal/site combination with highest variance can be done which will provide the number of replicates necessary to demonstrate a significant difference, if it exists, at a chosen level of confidence, say 90% or 95%. That number of replicates should then be taken at each sample site for each year sampled, using the same sampling methodology. If this procedure is followed, inferences about the presence or absence of significant differences between sample sites will be greatly strengthened.

2. Changes in sampling site location when transitioning from baseline to follow-up sediment studies

Flambeau Mining Company changed the locations of its sediment sampling sites in the Flambeau River when transitioning from baseline to follow-up studies. Only one of the three sites used for collecting baseline data in 1988 (Port Arthur) was in the same approximate location of any of those sampled in later years. In addition, the Port Arthur site was eliminated from the sampling program altogether after 1993. This inconsistency in sampling locations adds unwanted confounding effects to interpretation of the data. See Table-2 for a side-by-side comparison of where the various sampling sites were located and when they were sampled.

Table 2. Flambeau River Sediment Sampling Sites

Sampling Location	Code	Years in which Site was Sampled						
		1988 Baseline	1991	1992	1993	1994- 2000	2006- 2007	2008
Gokey Road (about 1 mile upstream of open pit site)	-	√	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled
Blackberry Lane (about 0.7 mile upstream of open pit site)	S-1	Not Sampled	√	√	√	√	√	√
Stream C Outfall (about 0.3 mile downstream of project area)	S-4	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	√
Sister's Farm (about 1.5 miles downstream of project area)	S-3	Not Sampled	Not Sampled	Not Sampled	√	√	√	√
Port Arthur Vicinity (1) (about 3.1 miles downstream of project area)	-	√	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled
Port Arthur Vicinity (2) (about 600 feet upstream of 1988 Port Arthur site) ^a	S-2	Not Sampled	√	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled
Port Arthur Vicinity (3) (about 120 feet downstream of 1991 Port Arthur site)	S-2	Not Sampled	Not Sampled	√	√	Not Sampled	Not Sampled	Not Sampled
Thornapple Dam (about 7.6 miles downstream of project area)	FL-1 FL-2 FL-3	√	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled	Not Sampled

^a Location of 1991 Port Arthur site relative to the 1988 sampling location was determined by comparing Figure 3.7-1 (*Volume 2: Environmental Impact Report, April 1989*) with Figure 4-2 (*Flambeau Mining Company 1993 Annual Report*). No diagrams of sampling site locations were included in FMC's 1991 or 1992 annual reports.

3. Inconsistency in sampling methodology when transitioning from baseline to follow-up sediment studies

As mentioned above, sediment sampling done in the Flambeau River from 1991 onward used a different sampling procedure than that used for the 1988 baseline study. Instead of PVC core samples, three (up until 1995) and subsequently, four sediment traps (one-quart Mason jars) were used at each site to collect sediments. This change in procedure alone throws the 1988 data into question as useful background information; because of the change in sampling procedure it cannot be reliably compared to that obtained at later dates. In addition, the 1988 sampling & analyses contained four fewer elements (aluminum, silver, nickel and selenium) than were done in 1991 – 2006.

Since the sampling methodology adopted in 1991 remained somewhat consistent for the duration of the study, and since blasting and ore production did not commence at the mine site until May of 1993, on first glance it might appear that the 1991-1992 data could be used to establish baseline sediment composition. This, however, presents its own set of problems. First, the downstream sediment sampling site utilized in 1991 and 1992 (Port Arthur) was switched to a new location in 1993 (Sister's Farm), making the 1991-1992 data less useful for comparative purposes. Second, using the 1992 data as baseline is suspect because by the time the sediment

jars were installed in the river in May of 1992, nearly 90 acres of land at the mine site had already been cleared of vegetation and topsoil during the pre-production stripping phase of the project. In addition, the company's erosion control system had washed out at three different control points in early September 1991 after a rainfall of 5.2 inches over several days. (This erosional input occurred *after* the 1991 sediment sampling and *before* the 1992 sediment sampling.) WDNR officials issued a report confirming that "water laden with fine sediments" had entered the Flambeau River after the erosion control system failed and that "existing sediment basins and bail dikes did not provide nearly enough retention time to settle out clay size particles." As a result, the mine project had already impacted the Flambeau River prior to the 1992 sediment study, invalidating use of that data as a true baseline.

4. Failure to gather baseline sediment data for: (1) Stream C; and (2) Flambeau River at Stream C outfall

Stream C, as described in the 1991 Flambeau Mine Permit, "originates on the east side of Highway 27, drains the southeast corner of the project site and enters the Flambeau River immediately north of the mouth of Meadowbrook Creek." The permit also states that "based on flow records and physical evidence at the site, Stream C has ... been determined to be navigable."

Part of the Stream C channel was rerouted during mine construction and culverts were installed to facilitate drainage in the vicinity of the mine's rail spur and access road. As of 1998, drainage from the southeast corner of the mine site has also been routed to Stream C from a biofilter/detention basin located where a surge pond was situated during mine operation. Stream C enters the Flambeau River about 0.3 mile downstream of the boundary of the mine itself.

Despite the clear potential for Stream C to be impacted by mine activities (1991-1997) and reclamation activities (construction of the biofilter/detention basin in 1998), until 2008 no baseline or follow-up sediment data was ever collected in this tributary. Nor til then was there any baseline or follow-up sediment sampling in the Flambeau River, immediately downstream of the Stream C outfall.

In May 2007, per the terms of a Stipulation and Order negotiated during a contested case hearing, FMC agreed to sample sediment in Stream C at two different locations within the stream channel and to also sample sediment in the Flambeau River in the vicinity of the Stream C outfall. The one-time sampling event took place in 2008, approximately eleven years after cessation of mining. While the study results are of great interest, having no baseline data makes it more difficult to interpret the results.

II. SAMPLING & REPORTING ISSUES REGARDING DATA COLLECTION IN FOLLOW-UP STUDIES

Sampling and reporting issues exist not only with regard to the baseline sediment studies conducted by FMC (1988), but the follow-up studies conducted to assess potential mine impacts (1991-2008). The most significant issues of concern regarding FMC's follow-up sediment studies fall into the following categories:

1. Insufficient baseline data (discussed above and summarized below)
2. Changes in sampling site location
3. Inconsistency in sampling methodology
4. Insufficient replication

1. Insufficient baseline data

Flambeau Mining Company failed to gather adequate baseline data regarding Flambeau River sediment composition upstream and downstream from the mine site prior to commencement of the mine project. As discussed in the previous section, the insufficiencies were related to: (a) lack of replication; (b) changes in sampling site location when transitioning from baseline to follow-up studies; (c) inconsistency in sampling methodology; and (d) failure to gather any baseline data for Stream C.

Adequate and reliable baseline data is the foundation of any sound scientific study. FMC's failure to sufficiently characterize baseline sediment conditions in the Flambeau River and Stream C severely limits one's ability to make reliable inferences about the effect of the Flambeau Mine on the associated ecosystem.

2. Changes in sampling site locations

FMC did not keep the same upstream and downstream sampling sites when transitioning from baseline to follow-up sediment studies. The Gokey Road site, about 1 mile upstream from where the open pit was eventually constructed, was replaced by the Blackberry Lane site in 1991, about 0.7 mile upstream from the open pit. Downstream, the Thornapple Dam site was sampled only once in 1988 and then eliminated from the sediment monitoring program altogether. Diagrams submitted by FMC also suggest that in 1991 the remaining downstream site at Port Arthur was moved about 600 feet upstream of its original (1988) location. River sediments are relatively heterogeneous environments, requiring consistency in sample sites. These changes in site location, as well as the change in sampling methodology discussed above, seriously detract from the usefulness of the 1988 baseline data.

During follow-up sediment studies (1991-2008) the company consistently used the Blackberry Lane site to gather upstream data. For various reasons, however, the downstream monitoring site at Port Arthur was itself moved twice.

First, for the 1992 study, because of streambank erosion observed in 1992 in the vicinity of the Port Arthur sampling site, the site was moved approximately 120 feet downstream from its original (1991) location. When the 1992 data was analyzed, results for Blackberry Lane were fairly consistent with the 1991 results. At the Port Arthur site, however, the sediment showed a large decrease in percent solids (from 77 to 35%), an increase in volatile solids, and an increase in concentrations of 12 different metals, relative to 1991. In a letter to the Wisconsin Department of Natural Resources dated September 24, 1992 (*FMC 1992 Annual Report: Appendix H*), FMC's consultant suggested this was due to erosional sedimentation of old Port Arthur Dam impoundment sediments near the sampling site (the Port Arthur Dam was removed in 1968) rather than a mine effect. No specific mention was made in the report of the September 1991 breach of the mine's erosion control system, which may or may not have affected the 1992 study results as well. The consultant did, however, include a side-by-side comparison of the 1992 Port Arthur results with the composition of topsoil and till at the mine site (1988 data) and concluded that "project activities have had no bearing on the 1992 Port Arthur Dam sediment results."

In 1993, due to continued concerns over proximal erosion and the additional concern that the new Port Arthur site had a much different substrate matrix (more organic and more silty) compared to the upstream Blackberry Lane site (primarily cobble and gravel), FMC's consultants decided to move the downstream sampling site once more, this time to a location known as Sister's Farm. The new site was about 9500 feet upstream of the 1992 sampling location and, as discussed in the *FMC 1993 Annual Report*, had a substrate similar to that found at the Blackberry Lane site. In addition, the river-bank at Sister's Farm, where the river is in a

straight run, was characterized as “not highly susceptible to erosion” (*FMC 1993 Annual Report: Appendix E*).

While changing conditions do sometimes require changing sampling procedures, the necessity to change downstream sampling sites not once but twice during monitoring suggests the first downstream sites (Thornapple Dam and Port Arthur) were not well chosen. Variables such as local river curvature and velocity (affecting stream-bank erosion) and substrate composition could have and should have been evaluated previous to beginning the annual series of samples. Moving the Port Arthur site 120 feet downstream from the original location in 1992 and subsequently moving that site to the Sister’s Farm location in 1993, of course, adds unwanted confounding effects to interpretation of the data.

2. Inconsistency in sampling methodology in follow-up sediment studies (1991-2008)

FMC changed its sampling methodology when transitioning from baseline (1988) to follow-up studies, utilizing a PVC core sampler in the former and sediment jars in the latter instance. After initiating follow-up studies in 1991, the company further altered its sampling techniques, as will be discussed below. This, of course, again confounds data analysis.

In 1994 (*FMC 1994 Annual Report: Appendix D*) the observation was made by FMC’s consultant that sediment jars in previous years sometimes contained crayfish or minnows, which seemed to have stirred up the sediment in the jar, possibly allowing for re-suspension of the sediment and affecting the results. The solution, placing a mesh on the sediment jars, seems appropriate, but the necessity of doing so brings into question some or all of the sediment results from previous years. Also because of the change in sampling procedure, in 1994 sufficient sediment for total solids and total volatile solids analyses were not collected, requiring additional sediment jars to be put in place in subsequent years. These details of sampling methodology should be worked out beforehand, not during actual sampling.

Another variable that was not kept constant from year to year in the FMC sediment studies was the exposure window for the sediment jars. For example, in 1991 the jars (3 upstream at the Blackberry Lane site and 3 downstream at the Port Arthur site) were installed on May 30 and retrieved on July 2, giving an exposure window of 33 days. In 2000, the jars (4 upstream at the Blackberry Lane site and 4 downstream at the Sister’s Farm site) were installed on June 12 and retrieved on August 29, giving an exposure window of 78 days, more than double that of the 1991 exposure window. Throughout the course of the study exposure windows varied from 22 days (2007) to 80 days (1999). It is unclear what such a wide variation might mean for the resultant data and its interpretation.

An additional unfortunate and unintentional change in sampling methodology took place in the 2007 sediment study. The sediment jars were removed from the downstream site at Sister’s Farm on October 4, but when FMC’s consultant went to the Blackberry Lane site later that day to remove the upstream jars, they could not be retrieved due to heavy rain and high water. The jars were eventually retrieved on October 15, eleven days after the downstream jars (*FMC 2007 Annual Report: Appendix C*). While FMC did not have control over stream conditions, it’s important to point out that when either upstream or downstream sediment jars remain in situ for a longer period than the other, upstream-downstream comparisons become questionable. E.g. if there was a pulse of metals which came downriver between Oct. 4 and Oct. 15 from some non-mining-related source, the upstream sediment jars would have picked up that pulse while the downstream jars would not have. A better procedure would have been to have left the downstream jars in situ until Oct. 15.

3. Insufficient replication in follow-up sediment studies (1991-2008)

Coefficients of variation or other measures of sample variance were not determined by FMC for the upstream (Blackberry Lane) and downstream (Port Arthur and later Sister's Farm) sampling sites or for the sampling methodology utilized (sediment traps). Hence, it is not possible to know how many replicate samples would be needed at each site to conclude with any degree of statistical confidence that, within a given year, sediment composition at the upstream and downstream sites was either the same or that it differed. Instead, the company composited samples from the 3 or 4 upstream sediment jars into a single sample for analysis each year and did the same thing with the downstream jars.

The availability of only 1 composite sample/site/year (1991-2008) limited the ability to do statistical analyses and draw meaningful conclusions regarding potential changes in sediment composition. This is especially true for any given year's data. While it was possible, using data gathered over a number of years, to make statistical inferences concerning metal concentrations in sediment, without in-year replication, this is not possible for any given year. E.g. in 1993 the copper concentration in sediment collected upstream (at the Blackberry Lane site) appeared to be slightly higher than in the downstream (Sister's Farm) sample (7.0 mg/kg vs. 6.7 mg/kg.) But in 1994 those differences had reversed themselves (5.8 mg/kg vs. 7.1 mg/kg.) The change in copper levels is noteworthy; but without replication we can't know anything about the statistical significance of that difference. In other words, without in-year replication, we have to wait for a number of years' data to make statistical inferences about the differences observed. An important goal of monitoring is to provide current information about the status of an ecosystem, so management decisions can be made in a timely fashion, based on reliable statistical analyses. As it is, without in-year replication, these decisions require waiting for multi-year sampling results which only allow statements such as "Yes, there *was* a difference in parameter X between sampling sites," rather than, "Yes there *is* a difference in parameter X between sampling sites."

Additional in-year replication will naturally also increase the reliability of statistical inferences when comparing data over a number of years.

RESULTS

Keeping in mind the caveats mentioned above regarding sampling issues which detract from the reliability of the data, Figures 1-7 below show upstream and downstream concentrations of sediment metals over time. Vertical lines at 1993 and 1997 indicate the period of active mining.

The appropriate use of data-points below analytical detection limit in statistical analyses is controversial, so for those analyses which sometimes provided values below detection limits, neither figures nor statistical analyses are shown (arsenic, cadmium, sulfur, mercury, silver and selenium.)

When examining Figures 1-7, several factors should be borne in mind:

1. 1988, 1991 and 1992 data points were not included in the graphs because of sampling methodology differences in 1988 (sediment samples were collected in 1988 using a PVC core sampler, from 1991 on using sediment traps), and sampling site issues (downstream sediments were collected in 1988, 1991 and 1992 at Port Arthur, from 1993 on at the Sister's Farm site.)
2. The Flambeau River experienced a 100-year flood in mid-September 1994 due to excessive precipitation events. This resulted in a breach of the Ladysmith Dam, roughly 3 miles upstream of the Blackberry Lane sediment sampling site. In addition,

surface water runoff at the mine site flooded the bottom of the open pit, was subsequently routed to an on-site wastewater treatment plant and from there discharged into the Flambeau River. The 1994 sediment study was completed before the flood occurred (jars were retrieved on August 9, 1994) and therefore was not impacted by the event.

3. Blackberry Lane (upstream) and Sister's Farm (downstream) sediments were sampled three times in 2007 (August, October and November) to correlate with a three-phase work project on the North Dairyland Dam on the Flambeau River. This dam is located roughly 4.5 miles upstream of the Ladysmith Dam and 7.5 miles upstream of the Blackberry Lane sediment sampling site. FMC was apparently concerned that the renovation project might mobilize metals in the sediment of the Dairyland Flowage (Lake Flambeau), thereby confounding the results of the company's Flambeau Mine sediment study. During the August 2007 sampling event, sediment jars at Blackberry Lane became exposed due to low river levels. Because the August sediment metal values appear to be outliers, data used in the following figures and statistical analyses for 2007 are an average of the October and November values.
4. Starting in 2007, sediment was tested only for copper, iron, manganese and zinc.

Fig. 1: Flambeau River Sediment Aluminum, mg/kg

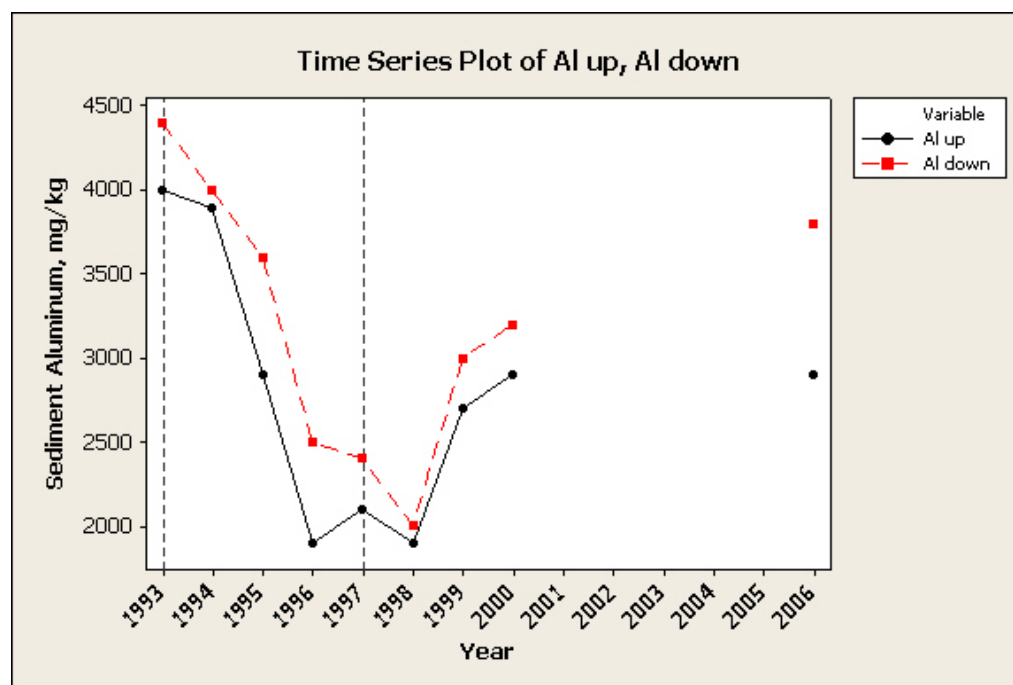


Fig. 2: Flambeau River Sediment Chromium, mg/kg

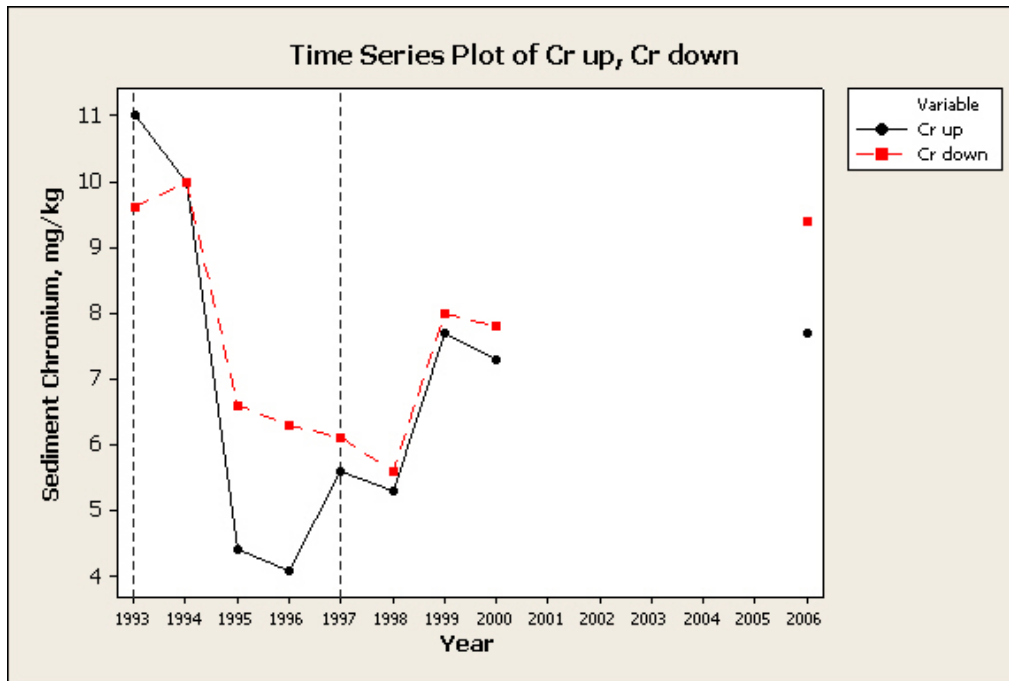


Fig. 3: Flambeau River Sediment Copper, mg/kg

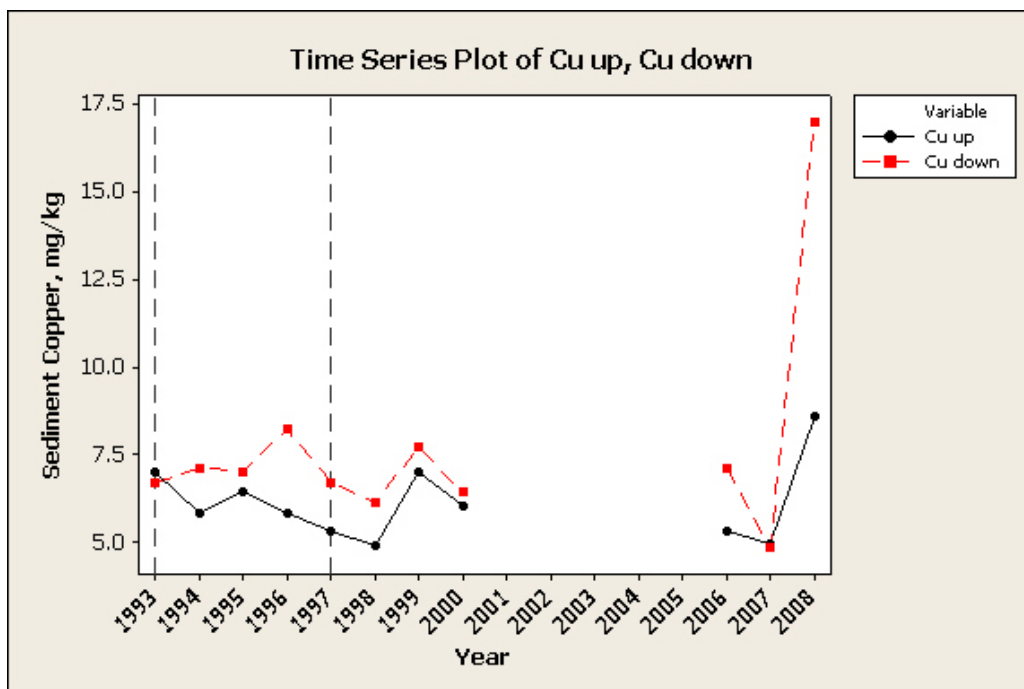


Fig. 4: Flambeau River Sediment Iron, mg/kg

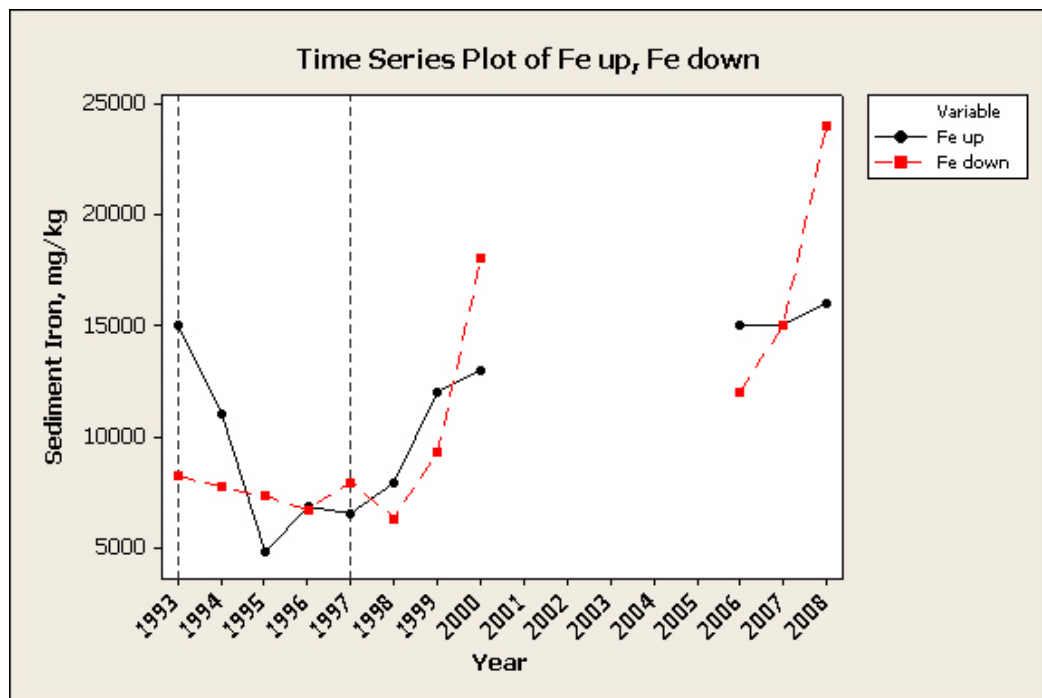


Fig. 5: Flambeau River Sediment Manganese, mg/kg

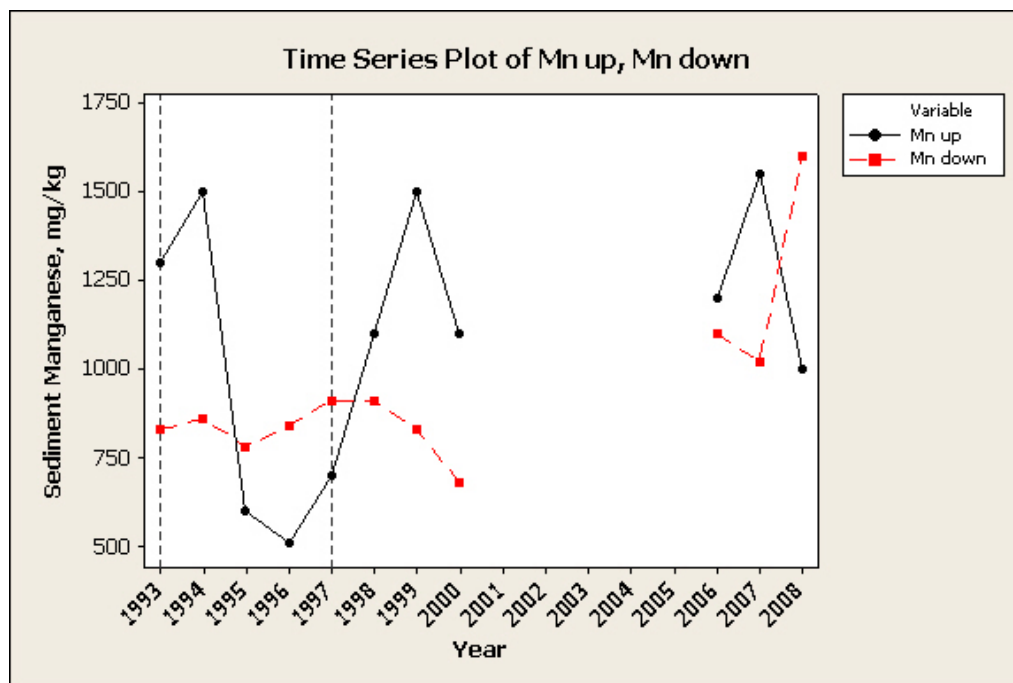


Fig. 6: Flambeau River Sediment Nickel, mg/kg

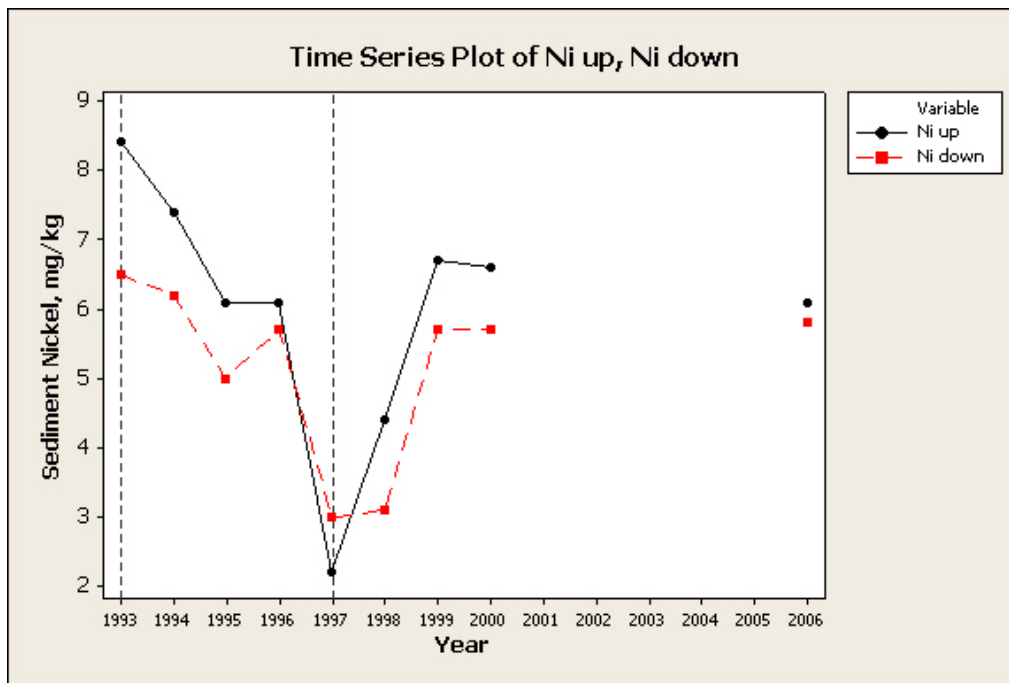


Fig. 7: Flambeau River Sediment Zinc, mg/kg



DISCUSSION OF RESULTS

The following discussion focuses on study results reported between 1993 and 2008, since these are the years in which FMC consistently used the same upstream (Blackberry Lane) and downstream (Sister's Farm) sampling sites and the same basic sampling methodology (sediment traps). While it would be preferable to have baseline data included in the present discussion, it simply does not exist for the Sister's Farm sampling site.

Lacking reliable baseline data on which to make stronger, statistically-based inferences, it is still possible to make some comments on the results shown in Figures 1-7.

1. Chromium, copper and zinc concentrations were almost always higher downstream of the mine than upstream, both during and after operation of the mine. The only sample in which the downstream values are below upstream values for these metals is the first reliable sample, in 1993, at the beginning of ore production.
2. Aluminum concentrations were always higher downstream of the mine site than upstream, both during and after operation of the mine, even at the very beginning of ore production in 1993.
3. Aluminum, chromium, iron and to some extent zinc show generally decreasing concentrations in Flambeau River sediments, both upstream and downstream of the mine, during the period of mine operation (1993-1997.) Visual inspection of the data also suggests that the 100-year flood of the Flambeau River in September 1994 (after the 1994 sediment study had already been completed) did not result in higher levels of these metals being measured at either of the two sediment sampling sites in the river. If anything, sediment concentrations of these particular metals appear to have decreased in 1995. Most of the metals show minimum or near-minimum levels at the time of cessation of mining activities, and appear to be on the increase since 1998 (the mine pit was backfilled in 1997).
4. For years for which there is data, copper concentrations were generally stable, with the exception of the 2008 analysis, which showed a spike in downstream copper levels.
5. Manganese levels varied greatly, especially at the upstream sampling site. Since 1998, downstream manganese levels have always been lower than upstream levels, but a spike in downstream manganese levels occurred in 2008 while upstream levels showed a decline.
6. Nickel concentrations were almost always higher upstream of the mine than downstream, both during and after operation of the mine. The only sample in which the upstream value is below the downstream value is the 1997 sample, at the end of ore production. Nickel appears to have decreased in Flambeau River sediments, both upstream and downstream of the mine, during the period of mine operation (1993-1997), but has increased since, with some evidence of subsequently leveling off.
7. Trends in zinc sediment concentrations very closely mimic trends in copper concentrations in the sediments, including a spike in downstream zinc levels in 2008.

8. Sediment samples collected upstream and downstream of the mine site during the second and third phases of the North Dairyland Dam renovation project in 2007 showed levels of copper, iron, manganese and zinc fairly consistent with levels measured in previous years (as explained earlier, data collected during the first phase of the renovation project was excluded from consideration because the sediment jars became exposed due to low water levels in the river). The 2007 study results suggest that the North Dairyland Dam project had no immediate impact on FMC's monitoring program.

While the visual observations noted above are of interest, it is important, from a scientific viewpoint, to ascertain whether or not those observations would hold up under the scrutiny of statistical analysis. Due to limitations imposed by FMC's study design (most notably, lack of replication within any given year), some, but not all of the above observations can be put to such a test.

An example of FMC data that cannot be confirmed by statistical analysis is the downstream vs. upstream levels of chromium, copper and zinc measured in sediment samples in 1993. It would be helpful to know whether or not the levels measured in the single composite downstream sediment sample were in fact lower than the levels measured in the composite upstream sample, as suggested in Figures 2, 3 and 7. Whether or not these downstream values are significantly below the upstream values cannot, of course, be determined because of the lack of sample replication at each site. To further illustrate this point, I refer you to Figure 7 in the Walleye report. Only when a sufficient number of replicate samples are collected within a given year (as FMC did when determining mercury levels in walleye fillets) can 95% confidence intervals be established for that year's data. Only then is it possible to determine whether downstream and upstream values overlap, or if they are indeed distinct.

A second issue regarding the evaluation of FMC's data is that there is no reliable background data on sediment metal concentrations. Therefore, it is not possible to compare pre-mining with mining or post-mining levels, a critically important if not the primary purpose of the monitoring. However, it is possible using statistical analyses such as those shown in Table 3 below to at least test for differences in these concentrations over time, and between upstream and downstream sites, starting with the 1993 data set.

Table 3. Results of Two-Way ANOVA and Mann-Whitney- U analyses of sediment metal concentrations, using available data for 1993-2008

Metal	ANOVA Significance 1993-2008 data**	Mean or median concentration, mg/kg	Mann-Whitney – U test on site difference, Significance at C.I. 95%
Aluminum (1993-2006)	Year p <0 .001 Site p = 0.002	mean Up = 2800 mean Down = 3211	N.A.
Chromium (1993-2006)	Year p = 0.001 Site p = 0.11	mean Up = 7.0 mean Down = 7.7	N.A.
Copper*	Year p = 0.003 Site p = 0.002	median Up = 5.8 median Down = 7.0	p = 0.05
Iron	Year p = 0.01 Site p = 0.97	mean Up = 11,180 mean Down = 11,130	N.A.
Manganese	Year p = 0.45 Site p = 0.26	mean Up = 1096 mean Down = 942	N.A.
Nickel* (1993-2006)	Year p < 0.001 Site p = 0.001	median Up = 6.1 median Down = 5.7	p = 0.11
Zinc*	Year p = 0.002 Site p = 0.001	median Up = 23.0 median Down = 30.0	p = 0.06

*Minitab-15 flagged copper, nickel, and zinc data as non-normal at p = 0.05; in these cases ANOVA analyses were done after Johnson Transformation; results of Mann-Whitney-U nonparametric tests for these metals are also shown in the right-hand column.

**For the year 1993, the Flambeau River was sampled at both the Port Arthur and Sister's Farm downstream sites. ANOVA analyses used data for the Sister's Farm site.

In terms of changes over time (1993-2008), Table 3 indicates that at a significance level of p < .05, all the metals except manganese show significant changes.

ANOVA analyses indicate that significant site differences existed for aluminum, copper, nickel and zinc. Median or mean values of all but nickel were higher downstream than upstream, while nickel was higher upstream than downstream, using transformed data when necessary. These statistical analyses corroborate the comments made above based on visual observation of Figures 1-7.

Mann-Whitney-U nonparametric tests for those data suggested to be non-normal verified the downstream/upstream differences at a significance of p = .05 for copper, and also suggest differences at or near p = 0.10 for nickel and zinc. Given the lack of reliable baseline data, an important question that cannot be answered, however, is how the upstream (Blackberry Lane) and downstream (Sister's Farm) metal concentrations compared *before* any mining activities (including pre-production stripping of the surface) took place.

The 2008 downstream copper sample (17 mg/kg) is flagged by Minitab-15 as an outlier. Analyses were repeated having removed the 2008 data. By removing the 2008 data, the copper data were considered normal and it was possible to do a two-way ANOVA analysis on untransformed data. Neither year (p = 0.66) nor site (p = 0.47) were considered significant after removing the 2008 values. Without the 2008 values, median copper concentrations were 6.85 mg/kg downstream and 5.80 mg/kg upstream (means 6.79 mg/kg and 5.85 mg/kg, respectively).

Sediment copper concentrations appear to be higher downstream than upstream (whether statistically significant or not depends on whether the 2008 downstream data-point is left in or

removed as an outlier.) In addition whole-body crayfish copper concentrations and walleye liver copper concentrations were found to be significantly higher downstream than upstream, suggesting a possible mine effect (see Crayfish and Walleye Reports.) Continued monitoring of the river sediments and its biota are necessary to determine if the 2008 sediment copper sample is an outlier or not, and whether the trend of somewhat higher downstream copper concentrations in sediment continues. Additional replications for each year's sediment analyses would also help very much in clarifying whether the within-year sediment copper differences upstream vs. downstream are in fact significant or not.

In its 2006 sediment report (*Flambeau River Sediment Memorandum, FMC 2006 Annual Report*) FMC's consultants state that... "Data from the years of sediment analysis indicate that, in general, no increase or decrease in parameter concentration in sediments is occurring. Moreover, downstream samples continue to compare favorably with upstream sediment samples indicating no impacts due to mine activities during the closure time window."

Because of lack of baseline information, and the sampling issues mentioned above (most importantly, lack of within-site replication), and also when considering the results of statistical analyses in Table 3, which show in some cases significantly higher downstream than upstream metal concentrations in sediment, the statement from the 2006 sediment report that there is "no increase or decrease in parameter concentration in sediments...[and that] downstream samples continue to compare favorably with upstream sediment samples" is questionable. It is also certainly not possible, especially given the limitations of the monitoring outlined above, to state with any reasonable certainty whether there has or has not been impacts due to mine activities.

RESULTS FOR STREAM C SAMPLING

Table 4 shows the results of analyses for several metals in sediment samples collected in 2008 at two different locations in intermittent Stream C (Sites SC-1 and SC-2). This one-time sampling event also included sediment testing at a new location in the Flambeau River (Site S-4, in the vicinity of the Stream C outfall). In addition, the traditional sediment sampling sites in the Flambeau River at Blackberry Lane (Site S-1) and Sister's Farm (Site S-3) were tested. All of these sampling locations are shown in the map found in Appendix III.

FMC was asked to expand its sediment monitoring in 2008 to include the SC-1, SC-2 and S-4 sampling sites because of some evidence Stream C could be carrying potentially toxic levels of some substances into the Flambeau River. Site SC-1 is in the bed of intermittent Stream C, downstream from the overflow of the mine's 0.9-acre biofilter/detention basin and at the approximate boundary of the mine site itself. Site SC-2 is not quite halfway along that streambed toward its mouth at the Flambeau River, and Site S-4 is in the Flambeau River, close to the mouth of Stream C. The exact location of Site S-4, however, is uncertain. FMC's consultants describe it as being "below the mouth of Stream C but above the mouth of Meadowbrook Creek," (*Stipulation Monitoring Results, Flambeau Mining Company, December 30, 2008*). But on the map provided in the same report it appears to be *above* the mouth of Stream C (See Appendix III for map). For purposes of discussion, it is assumed that the former is correct. We turn to FMC for clarification of this, however, because these different locations are important in teasing out the potential impact of Stream C on the Flambeau's sediments.

Table 4: Metal concentrations in sediments of intermittent Stream C and the Flambeau River, sampled in 2008, all mg/kg ¹

Metal	Metal Concentration in Sediment, July 2008 (mg/kg)				
	Stream C		Flambeau River		
	Site SC-1	Site SC-2	Site S-1 (Blackberry Lane)	Site S-3 (Sister's Farm)	Site S-4 (Close to Stream C Outfall)
Copper	180	7.2	8.6	17	24
Iron	20,000	8,400	16,000	24,000	22,000
Manganese	490	150	1,000	1,600	1,200
Zinc	330	27	32	80	81

¹ Source: *Stipulation Monitoring Results – Flambeau Mining Company, December 30, 2008.*

While it is very difficult to draw conclusions from one year's sampling without replication, sediments at the SC-1 site in Stream C do show very high copper concentrations compared with those found in Flambeau River sediments at any other time or place in the FMC study. The next highest value encountered (prior to 2008) was 24 mg/kg, at the downstream (Port Arthur) sampling site in 1992. As mentioned above, median copper concentrations upstream (Blackberry Lane) or downstream (Sister's Farm) of the mine site for the 1993 - 2008 sampling regime were less than 10 mg/kg. The reported value of 330 mg/kg for zinc at Site SC-1 in Stream C is also notably higher than those found at the Flambeau River sampling sites, the next highest (prior to 2008) having been measured in 1992 as 79 mg/kg at the downstream (Port Arthur) site. Iron and manganese concentrations encountered in the sediments of Stream C do not exceed those encountered in the river. The unusually high copper and zinc sediment concentrations in the bed of intermittent Stream C suggest sampling at these sites, as possible avenues of entrance of metals into the Flambeau River, would have been useful before and throughout the history of the mining activity.

Metal levels measured at the new Flambeau River sediment sampling site (S-4) are also of interest. The reported copper level of 24 mg/kg and zinc level of 81 mg/kg are among the highest encountered by FMC in the bed of the Flambeau River during the entire study period (1991-2008). Only in 1992, when the company's consultant attributed the high metal levels measured at Port Arthur to erosional sedimentation of old Port Arthur Dam impoundment sediments, have copper and zinc levels been as high as those reported in 2008 at Site S-4 (S-4 is upstream of the Port Arthur sampling site). As in the case of the Stream C sediments, this suggests that sampling at the S-4 site in the river would have useful before and throughout the history of the mining activity.

RECOMMENDATIONS

Because some of the suggested improvements to FMC's Flambeau River sediment monitoring program that were mentioned earlier cannot be implemented retroactively but could be useful in the design of monitoring programs in the case of future mining activity, recommendations are listed in two different categories: (1) General recommendations, based on perceived shortcomings of monitoring in the present case, to improve the utility of similar monitoring programs undertaken by others in the future; and (2) Recommendations for how to

continue and augment the present study to better track potential impacts of the Flambeau Mine on the associated ecosystem.

1) The FMC sediment study does not provide adequate baseline data to make any reasonable conclusions about the long-term effect of the Flambeau Mine on the sediment chemistry of the Flambeau River. Samples were taken in 1988, upstream and downstream from the mining site, but were done with a different sampling procedure (PVC cores) than used at later times (sediment traps.) In addition, the 1992 samples, supposedly “background” i.e. before mining began, were actually taken after the failure of erosion-control fences which might have introduced sediment into the river due to on-site pre-mining activity. Gathering useful background information about an ecosystem potentially impacted by human activities is critical to understanding whether those activities have or have not had an effect on that ecosystem. Changing sampling procedures (and sites, see below) greatly reduces our ability to make any inferences about the effect of that human activity on that ecosystem.

Recommendation for similar studies in the future: *Sampling protocol should specify that baseline studies be conducted using the same sampling methodology employed in follow-up studies. In addition, baseline studies must be completed before any significant pre-mining activity such as pre-production stripping takes place.*

2) In addition to changing sampling procedures from the 1988 to later samples, exposure windows for the sediment jars were not held constant from year to year. Slight changes were also made to the sediment jar procedure between 1994 and subsequent years, to keep larger organisms from disturbing the collected sediments. The admission of the presence of some of these organisms in earlier samples reduces the reliability of those samples, and once again a change in procedure is made “mid-stream” as it were in the sampling period.

Recommendation for similar studies in the future: *Sampling methodology should be thought out ahead of time and remain, as much as humanly possible, unchanged during the sampling regime.*

3) The FMC sediment study provided inadequate replication to make inferences with any reasonable degree of confidence visavis possible mining effects on the sediments of the Flambeau River. As pointed out in the “Sampling & Reporting Issues” section of this report, replicate rather than composite samples would greatly improve the procedure.

Recommendation for similar studies in the future: *Early on in background sampling, enough replicate samples (I suggest at least five) should be taken to provide a reasonable estimate of variance in metal concentrations at each site. The metal/site combination with highest variance should be used in a power calculation to provide the number of replicates necessary to demonstrate a significant difference, if it exists, at a chosen level of confidence, say 90% or 95%. That number of replicates should then be taken at each sample site for each year and metal sampled. If this procedure is followed, inferences about the presence or absence of significant differences between sample sites will be greatly strengthened.*

4) FMC changed its upstream and downstream sediment sampling sites in the Flambeau River when transitioning from baseline (1988) to follow-up (1991-2008) studies. In addition, the downstream sampling site established in 1991 at Port Arthur was changed twice during the period of follow-up sampling. Between 1991 and 1992, the Port Arthur site was moved approximately 120 feet downstream, and starting in 1994 was moved about 9500 feet upstream, to the Sister's Farm site. This unfortunately confounds the ability to make comparisons of year-to-year results.

A separate but related issue regarding sampling site location was the belated addition of Site S-4 to the sampling regime. Site S-4 is located in the Flambeau River, immediately below the Stream C outfall. Despite the fact that Stream C was and is being utilized as a drainage-way from the mine site to the Flambeau River, Site S-4 was not tested until 2008, eleven years after the cessation of mining activities. Additional information related to Stream C is included in Point # 6 below.

Recommendation for similar studies in the future: More thought should be put into carefully choosing sampling sites BEFORE the annual sampling regime is begun. Once those sites are chosen, sampling protocol should specify that the same sampling locations be utilized for the duration of the study (baseline and follow-up).

5) When FMC moved its downstream sediment sampling site from Port Arthur to the Sister's Farm site in 1994, the collection sites for macroinvertebrates and crayfish were not moved to the same location, despite the fact that the monitoring plan referenced in the Flambeau Mine Permit specified that the downstream monitoring site was to “coincide with the sediment sampling location near the old Port Arthur Dam”³ (emphasis added).

Crayfish body copper concentrations were found to be significantly greater downstream than upstream of the Flambeau Mine site (see Crayfish Report), and several macroinvertebrate species appear to have declined (see Macroinvertebrate Report). But having different sampling sites for sediment chemistry and the crayfish and macroinvertebrate communities themselves makes it difficult to draw inferences about the organismal copper concentrations. The sediment microhabitat is an environmental matrix whose chemistry and potential toxicity have a profound influence on these organisms. Events, whether anthropogenic or natural, affecting the sediment chemistry and mineral dynamics, can occur at one location while not at another. The sediments are a notoriously heterogeneous matrix, even at relatively small scales. It is therefore difficult to make reasonable inferences about putative effects of mining activities on the macroinvertebrate and crayfish communities when the sediment metal concentrations are not being monitored in situ, but at a site distant from where the organisms are collected.

Recommendation to augment FMC's sediment monitoring program: In my Macroinvertebrate Report a recommendation is made for an additional six to ten years of sampling, perhaps done every other year. In my Crayfish Report a recommendation is also made that monitoring continue on a regular basis for at least 10 years. The historic downstream sampling site for macroinvertebrates and crayfish coincides with Site S-4 in the Flambeau River, where sediment was sampled as a one-time event in 2008. It is recommended that sediments at Site S-4 continue to be sampled in conjunction with the recommended macroinvertebrate and crayfish studies. Sediment sampling should also continue at Site S-1 (Blackberry Lane), which coincides with the upstream macroinvertebrate and crayfish sampling location, and Site S-3 at Sister's Farm.

6) Stream C is an intermittent stream that drains the southeast corner of the Flambeau Mine site and receives overflow from a 0.9-acre biofilter/detention basin constructed by FMC in 1998. Stream C, classified as navigable, enters the Flambeau River about 0.3 mile downstream of the project area. Discussions indicated the possibility of water and sediments being carried through this intermittent stream, some possibly with high levels of potential toxins, into the Flambeau River. Consequently for 2008 FMC agreed to sample sediment within the bed of Stream C and in the Flambeau River, immediately below the mouth of this stream. Elevated levels of copper and zinc were detected. The belated testing of the sediment in a navigable stream used as a drainage-way from the mine site to the Flambeau River, as well as the belated testing of the sediment in the Flambeau River immediately below the stream's outfall, suggest that choice of sediment sampling sites for the entire period of monitoring was not as carefully done as one would expect.

Recommendation to augment FMC's sediment monitoring program: *Sediment sampling at Site S-4 in the Flambeau River, immediately below the Stream C outfall, should continue for at least ten years. This sampling should be coordinated with sediment testing at sites S-1 and S-3 and the macroinvertebrate and crayfish sampling indicated above. If significant changes are detected during the expanded monitoring period, an additional five years sampling beyond the ten years recommended should be required. These changes could be triggered statistically (the precautionary principle suggests using $p = 0.10$) by the monitoring results, or even if not exactly statistically significant, by apparent unexplained spikes in metal concentrations in the sediment.*

Additional sediment sampling within Stream C could also provide useful information, especially should relatively high sediment metal concentrations be encountered within the river during the extended sediment sampling period.

7) The measured level of metal concentrations in biota and sediments during monitoring are to an important degree affected by surface water metal concentrations. The interplay of sediment and surface water toxins on the biotic community is complex and differs for particular metals, species, and ecotypes. In case continued monitoring of the biota and sediments discloses unforeseen changes in the community structure or metal concentrations, it would be useful in attempting to explain those changes to have as much information on hand as possible visavis all possible causal mechanisms. It would therefore be amiss to not continue surface water monitoring of the Flambeau River.

Recommendation to augment FMC's sediment monitoring program: *Surface water monitoring of the Flambeau River should continue for as long as sediment studies are being conducted in the river (at least ten years), drawing on water quality data collected as part of the expanded monitoring programs recommended for macroinvertebrates, crayfish and walleye (see other reports). Additional surface water sampling should be undertaken co-located temporally and spatially with sediment monitoring if significant increases in sediment metal concentrations (statistically significant at $p = 0.10$ or notable spikes which may or may not result in statistical significance) are observed.*

CONCLUSIONS

Inadequate baseline data and sample replication, combined with changing sampling procedures make it very difficult to draw any conclusions regarding the presence or absence of a mining-related effect on the sediment of the Flambeau River. The combined observation of statistically significant increased copper concentrations in crayfish (whole-body specimens), walleye (liver tissue) and sediment (when 2008 downstream copper measurements are included) downstream from the mine site raises the possibility of a causal relationship. Unusually high copper and zinc concentrations in a sampling site within the bed of intermittent Stream C indicate a possible entrance-point for some potential toxins into the Flambeau River. In hindsight, having additional historic data from Stream C and the Flambeau River would prove very useful.

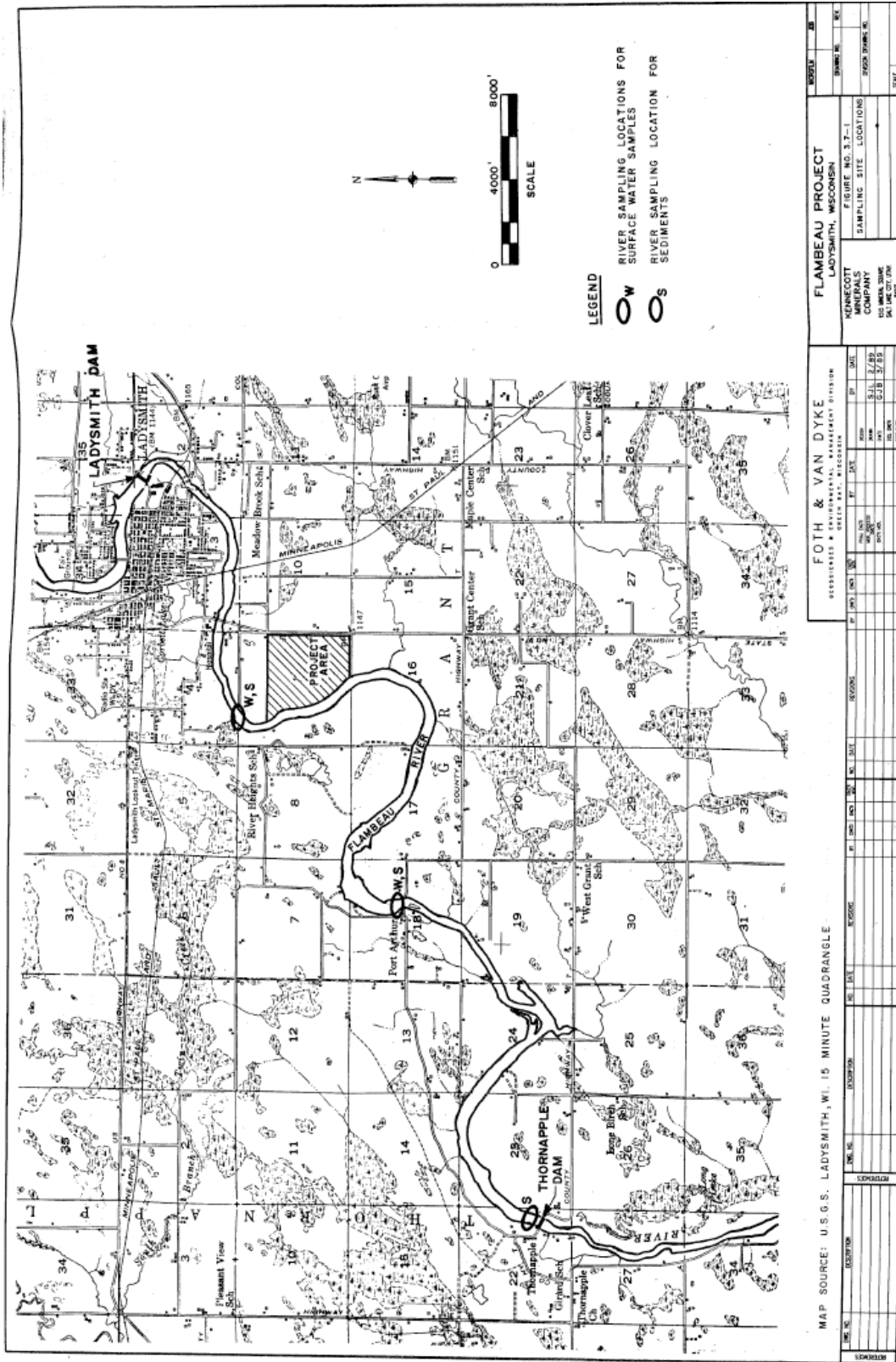
¹. *J. Am. Med. Assoc.* (1938) 110: 651

². *Annals Human Biol.* (2003) 30(5): 563

³. *Updated Monitoring Plan for the Flambeau Project* (1991)

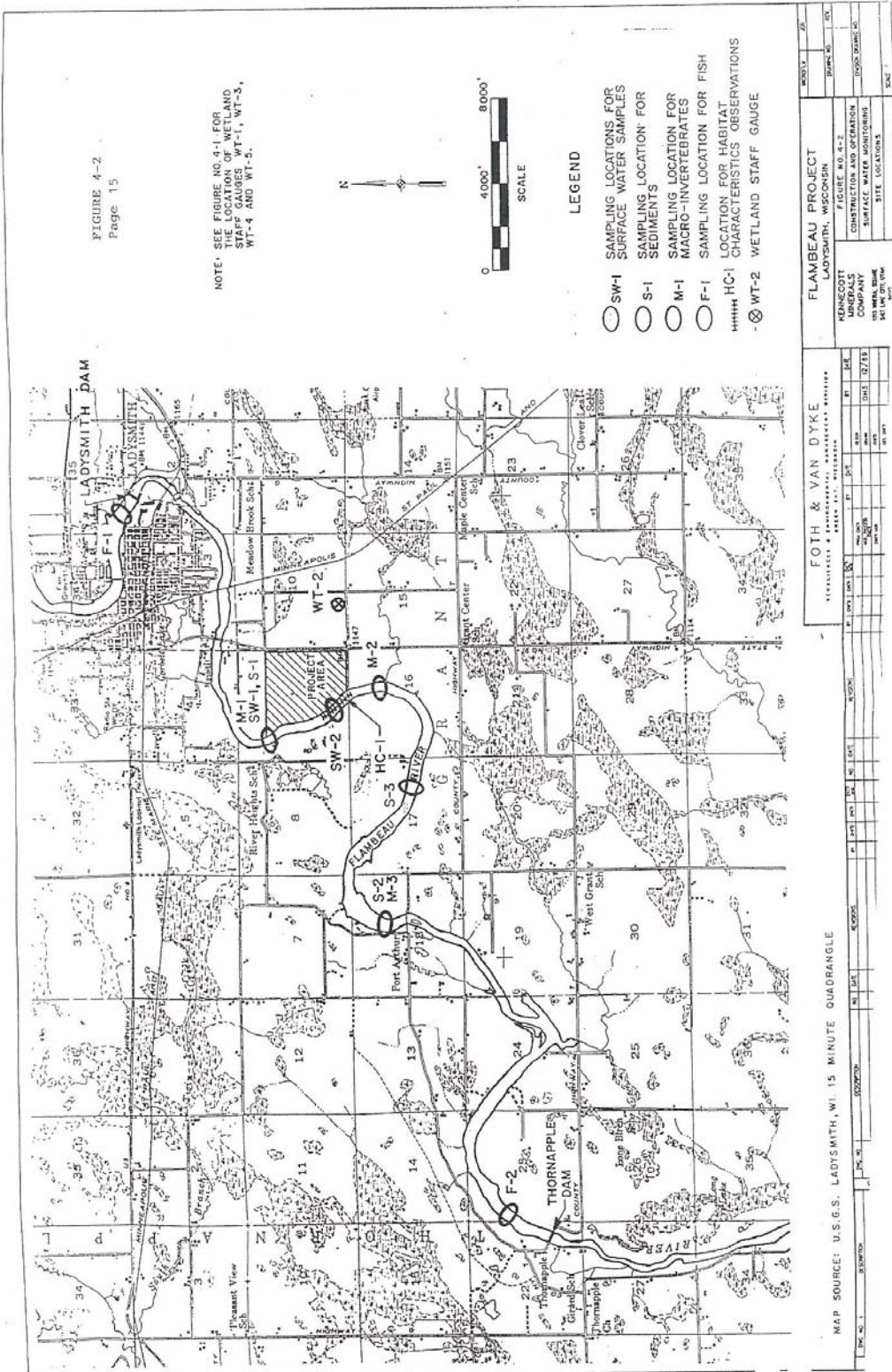
Appendix I

Flambeau River Sediment and Surface Water Sampling Sites used in Baseline Studies (1988)
 (Source: Volume 2: Environmental Impact Report for the Kennecott Flambeau Project, 1989)



Appendix II

Flambeau River Surface Water, Sediment and Biota Sampling Sites Used at One Time or Another between 1991 and 2007 (Source: Flambeau Mining Company 1993 Annual Report)



Appendix III

Soil and Sediment Sampling Sites (2008)

(Source: Stipulation Monitoring Results, Flambeau Mining Company, December 30, 2008)

