Aquatic Life Use Attainment Assessment of Streams Influenced by the Elizabeth Copper Mine site in Strafford, Vermont

RM 3.8 Pre 2007

RM 3.8 Post 2011

<u>F I N A L</u>

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Introduction and Background

The Elizabeth Mine is an abandoned copper mine located off of Mine Road in the Towns of Strafford and Thetford within Orange County, Vermont. The mine operated from the early 1800s until its closure in 1958. Acid mine drainage from the Elizabeth Mine has impaired the downstream waters of the West Branch of the Ompompanoosuc River (WBOR) and two small tributary streams: Copperas Brook and Lords Brook. The VTDEC first reported the biological impacts to the surrounding waters in 1986 and again in 1998 after which 3.8 miles of stream were placed on the states "impaired" waters listing:

(http://www.watershedmanagement.vt.gov/mapp/docs/mp_2012_303d_Final.pdf).

Elizabeth Mine was placed on the National Priorities List (a.k.a. the Superfund List) on June 14, 2001. In 2001, the Environmental Protection Agency (EPA) initiated a Baseline Ecological Risk Assessment , which confirmed the findings of previous studies and further documented the longitudinal extent of both aquatic life and water quality impacts on the surface waters draining the mine site.

EPA began response actions at the site in 2003 to stabilize the largest tailing dam/pile (TP-1) to prevent a catastrophic failure. The major focus of the non-time critical response actions beginning in 2006 is to mitigate the three largest sources of acid mine drainage (AMD): the two tailing piles (TP-1 and TP-2) and an approximately 12-acre waste rock pile known as TP-3. The response actions of these three features consisted primarily of surface water and groundwater diversions, the removal of approximately 250,000 cubic yards of waste rock from TP-3 to the top of TP-1. In 2008, EPA installed a temporary water treatment system to treat AMD draining from the toe of TP-1 during construction activities. EPA plans to operate this system for at least two more years (2013 and 2014). In 2011 and 2012, a cover system was placed over TP-1 and TP-2 completing this mitigation effort of AMD at the site.

Because EPA needed material to create the necessary grades for TP-1 and TP-2 cover system, the waste rock pile, known as TP-4 was removed along with waste rock from the South Mine area. These two mine features are located with the Lords Brook watershed. EPA is determining what additional remedial measures are necessary to mitigate the AMD from these mine features that are discharging into the Lords Brook Watershed.

The VTDEC began annual macroinvertebrate community sampling in 2005 on three reaches of the WBOR to track the condition of the aquatic life during the implementation of the above mitigation efforts. The major source of AMD from Elizabeth Mine is through Copperas Brook, which drains directly into the WBOR. Beginning in 2008, fish assemblage sampling was added just prior to when the active iron treatment system came on line. In late summer 2009 some improvement to the macroinvertebrate and fish communities was reported, with additional improvements reported in 2010. Waste rock pile TP-3 was removed in the winter of 2009 and the summer of 2010. In 2011 no biomonitoring took place due to extreme flooding from Tropical Storm Irene which occurred only a few days previous to the biomonitoring index sampling period for that year. In early 2012 most of the TP-1 cover system, including the portion containing the TP-3 waste rock, was in place, and stream monitoring was increased to document conditions in the first year of post mitigation. In 2012 biomonitoring of macroinvertebrates and fish was conducted and an increased effort of water quality monitoring was exerted. This increased monitoring effort also included the resampling of the impaired reaches of Copperas and Lords brooks which drain the Elizabeth Mine site. This report chronicles the biological condition of these waters before and after the majority of mitigation efforts were completed. The final site management plan is to eventually convert this active treatment system to a more sustainable passive iron treatment system.

Results and Discussion

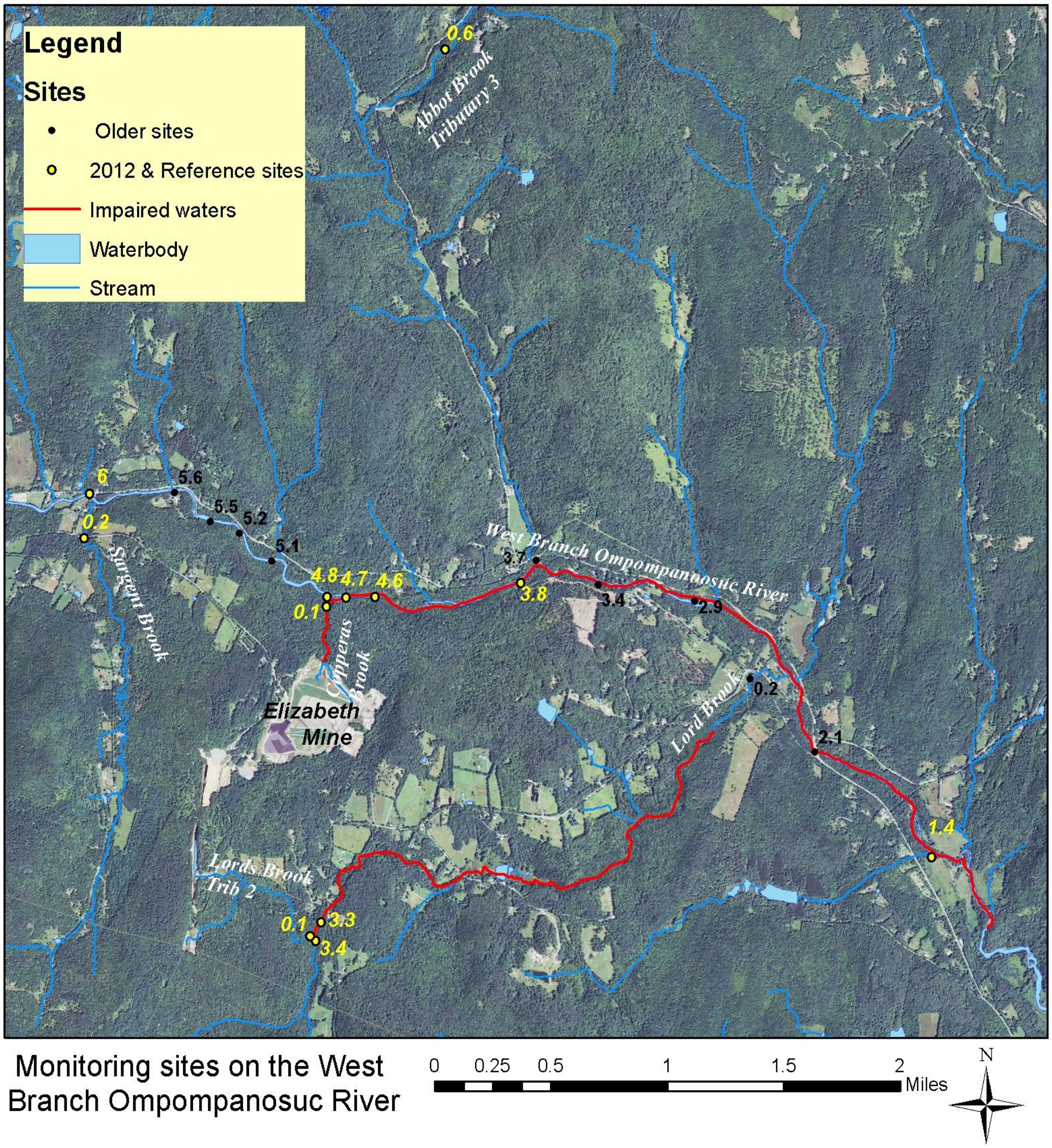
Table 1 describes the stream locations assessed and their relationship to principle sources of mine drainage. Figure 1 shows the location of all monitoring sites in relation to the Elizabeth Mine. For the WBOR the macroinvertebrate stream type and criteria set is Medium High Gradient (MHG). The fish assemblages were evaluated using the Mixed Water Index of Biotic Integrity (MWIBI). For the small tributary streams, the macroinvertebrate Small High Gradient (SHG) criteria were applied, and for fish, the Cold Water Index of Biotic Integrity (CWIBI) was used. All biological indexes are described in VTDEC (2004).

Table 1. Location of stream sites assessed on the West Branch of the Ompompanoosuc River, Copperas and Lords brooks and control streams in the immediate area of the Elizabeth Copper Mine site. Sites (identified by river miles from mouth) appearing in bold were sampled by the VTDEC multiple times between 1986 and 2012. Shaded cells indicate waters within the influence of the mine.

Location	Site (RM)	Miles below mine source	Macroinvert. stream type[1]	Fish IBI[2]	Location
West Branch Ompompanoosuc River	6.0	Above	MHG	MWIBI	local control site - above Tyson Bridge about 50m, below S. Strafford. This site is upstream of all drainage from the Elizabeth Mine site.
	5.6				local control site immediately above private bridge off of Route 132
	5.5				local control site, 100m below private bridge
	5.2				20m below mine air shaft outfall
	5.1				between airshaft outfall and Copperas Brook
	4.8				20m. above Copperas Brook (source of most mine drainage)
	4.7	0.1			50m below Copperas Brook within mixing zone of WBOR and Copperas Brook
	4.6	0.3			200m below Copperas Brook
	3.8	1.0			immediately above Abbott Brook
	1.4	3.7			above Union Village Dam, off Tucker Hill Road on side road (USGS), by Iron Bridge crossing.
Copperas Brook	0.2	Primary source	SHG	CWIBI	immediately upstream from confluence with WBOR
Lords Brook	**3.4**	Above			above ledge chute above the tributary draining the South Cut
	3.3	0.1			immediately upstream from Gove Hill Road
	0.2	3.1			upstream from New Boston Road bridge, below tributary draining the South Mine and south cut.
Abbott Brook Tributary #3	0.6	control			local Control site- adjacent to Miller Pond Road ref. 2012
Sargent Brook	0.2				local Control site- 0.2 miles upstream from confluence with WBOR

Macroinvertebrate stream types - MHG=Medium High Gradient, SHG = Small High Gradient Fish IBI – MWIBI= Mixed Water Index of Biological Integrity, CWIBI = Cold Water Index of Biological Integrity

Figure 1. Locations of biomonitoring sites near the Elizabeth Mine on the West Branch of the Ompompanoosuc River, Lords Brook, Copperas Brook and local control streams Sargent Brook, and Abbot Brook Tributary #3. Lords Brook tributary site was sampled for water chemistry only.



Beginning in 2009 some improvement was observed in the biological integrity of WBOR at locations farthest downstream of the mine and in Lords Brook. In 2012 all locations on the WBOR had recovered to a good-very good condition and Lords Brook was rated excellent for both macroinvertebrate and fish assemblages. The Copperas Brook macroinvertebrate community, while beginning to show improvement in 2012, still fell far short of Class B Vermont Water Quality Standards (VTWQS) for aquatic life use support.

West Branch Ompompanoosuc River - *Upstream from the Elizabeth Mine Site*

Biomonitoring
RM 6.0

This location was sampled as an upstream control site, located below Strafford village. It allows the assessment of the locations below the mine to be compared directly to the biological potential of the watershed immediately upstream. In this way impacts on the community from sites below the mine can be isolated from river-wide impacts and variation and therefore attributed to mine drainage impacts alone. The macroinvertebrate community assessment outcomes and metrics are reported in **Table 2**. The fish community assessments and metrics are presented in **Table 5**

Macroinvertebrate community assessments have consistently met *Good or Very Good to Excellent,* exceeding VTWQS Class B biocriteria all years sampled. In 2012 the community was assessed as *Very Good.* In the two years RM 6.0 was assessed as *Good* (2006 and 2008), the community fingerprint indicated a slight enrichment effect on the community. This fingerprint is very high density, richness and EPT taxa in combination with a slightly elevated Bio Index value and the functional group composition slightly altered from the MHG model. Functional group composition showed an elevation in both the percent collector filterer and scraper individuals. This is likely due to a greater availability of particulates and associated nutrients from the upper watershed compared to a forested reference watershed. The high abundance, total and EPT, taxa also show that toxicity, and or habitat degradation at this upstream control site is not indicated as a stress on the aquatic life.

Fish community assessments for all but one year have also met Class B biocriteria varying between *Very Good* and *Excellent* with MWIBI values between 39 and 41 on four of the five collections. The MWIBI has a range of 9 (Poor) to 45 (Excellent). In 2008 the community was only assessed as *Fair* due to very low total fish abundance (**Table 5)**. Brook trout abundance has consistently been low at this site, and no brown trout have been collected after a single fish was recorded in 1987. All five to six species collected since then are native. The community was dominated in all years by blacknose and longnose dace, and slimy sculpin which are tolerant, intermediately tolerant, and intolerant species respectively. Longnose sucker, an intolerant species, was present during all five samplings in lower abundances **(Appendix 3)**.

Sites RM 5.6, 5.2, 5.1:
Each one of these sites was sampled once for macroinvertebrates between 1986 and 2000 as part of various earlier assessments by EPA and VTDEC. All sites were assessed as *Very Good* or *Very Good to Excellent* in biological integrity. Site 5.6 is a control for the mine as a whole, while sites 5.2 and 5.1 were sampled to evaluate the effect of the mine air shaft outfall only on the river which was located upstream from the confluence with Copperas Brook. The assessments all showed no impact on the macroinvertebrate community from the mine shaft, with the community fingerprint essentially the same as that found at RM 6.0.

Fish were sampled at RM 5.6 and 5.1 in 2001. The MWIBI at RM 5.6 was 39 (*Very Good*), and from RM 5.1 - 35 (*Good*). The communities were similar in composition but the total density was lower at RM 5.1. All six species collected at both sites are native. The community at both sites was dominated by blacknose and longnose dace, and slimy sculpin. Longnose sucker, another intolerant species was present in low numbers at both sites.

Site RM 4.8:

This site was sampled in 2012 to bracket the potential impact from the primary source- Copperas Brook- as closely as possible. It is located immediately above the confluence of Copperas Brook, and therefore accounts for all other potential "background" watershed and mine drainage impact (mineshaft) on the WBOR.

The macroinvertebrate community was assessed as *Excellent to Very Good.* Community metrics were almost identical to RM 6.0, showing a slight improvement in community integrity and recovery from the slight enrichment effect detected at the upper RM 6.0 site. Community abundance, richness and EPT taxa remain very high at RM 4.8, which indicates that there are no toxic or habitat impacts within this reach immediately above Copperas Brook.

The fish community assessment was also *very good* with an IBI of 41. Brook trout numbers were slightly higher than at RM 6.0 but were still lower than expected. All six fish species collected are native. The community at the site was dominated by blacknose dace, and slimy sculpin. Longnose sucker, another intolerant species, was also present in the sample.

West Branch Ompompanoosuc River

Downstream from the Elizabeth Mine Site

Biomonitoring

<u>RM 4.7</u>

This reach represents the mixing zone of Copperas Brook into the WBOR. All water quality data were collected here about 60m below Copperas Brook. At this point about 60% of WBOR flows on the Copperas Brook side of the island that splits the river. The remaining WBOR flow rejoins the main channel just below RM 4.7.

Four water quality samples were collected under base flow conditions from April through September in 2012. Each metal of concern (copper, iron, zinc, cadmium, and aluminum, and iron) was below its associated Maximum Allowable Concentration (MAC) for Aquatic Life. Iron averaged 0.200 mg/l, and 0.120 mg/l, and the other metals of concern were below detection limits. These data show that toxic levels of metals were not detected within the mixing zone reach at RM 4.7 in 2012**.**

<u>RM 4.6</u>

The macroinvertebrate community at RM 4.6, located about 300 m downstream from the mouth of Copperas Brook, was sampled three times between 1998 and 2012. The community was assessed as *Very Good* in 2012, meeting Class B biocriteria for the first time. The two previous samples showed the community to be in *Poor* condition. The density was very low, as was both total and EPT richness. The community fingerprint indicates toxicity as the primary stressor. The density rebounded from 163 and 32 animals in 1998 and 2000, to over 2,500 in 2012, which was very similar to the density found above Copperas brook at site 4.8. Total richness and EPT taxa from 1998 and 2000 (29 and 14, and 14 and 6 respectively) also increased dramatically to 52 and 32, respectively in 2012. The 2012 total richness and EPT metrics are again similar to that found at site RM 4.8 in 2012. The macroinvertebrate community currently shows no apparent impact from AMD entering the WBOR from Copperas Brook as of 2012, and the current operation of the active treatment system over summer months.

The fish community at RM 4.6 was sampled in 2000 and in 2012. As with macroinvertebrates, the fish community here showed a dramatic increase in integrity in the 2012 sample, with density increasing to six times what it was in 2000. The MWIBI rose from 9 to 39 (*Poor* to *Very Good*). While numbers of most fish species increased significantly between the two samples, the increase in numbers of the intolerant slimy sculpin is the best indicator of the improvement in conditions in the WBOR below Copperas Brook. The IBI, while 2 points lower compared to RM 4.8, remained in the *Very Good* range of the index. Both brook trout and slimy sculpin numbers were also very similar to RM 4.8, indicating no toxic effect on these two more sensitive species.

RM 3.8

This location was established to track the mitigation efforts of the Elizabeth mine annually for macroinvertebrates since 2005. This site, also sampled in 1986, 1998 and 2000, was found to be in *Poor* condition every year thru 2008. Abundance, richness and EPT taxa present were all extremely low thru 2008, exhibiting a classic toxic community fingerprint. In 2009 the community improved to *Fair* condition, indicating the first positive improvement due to the mine mitigation efforts. The improved trend continued in 2010 with the macroinvertebrate community assessment of *Good*, and in 2012, the site was found to be in V*ery Good* biological condition. Behind the improvements was an incremental increase in density, richness and EPT taxa. In 2011 no bioassessments were done due to TS Irene which resulted in the complete disruption of the stream channel and bed. The 2012 RM 3.8 the macroinvertebrate metrics were very similar to the two WBOR control sites, RM 4.8 and 6.0, indicating no significant degradation of the macroinvertebrate community attributable to the Elizabeth mine site as of 2012.

The fish community at RM 3.8 prior to 2010 was consistently at very low densities as determined from eight samples taken between 1987 and 2008. As a result, MWIBI scores were consistently 9 (*Poor*). As with macroinvertebrates, extremely low density is usually an indication of some form of toxic impact. The 2010 sample showed a rise in density (Fig 1) over the previous four yearly samples, but still resulted in a MWIBI score of 9. The 2012 sample finally showed a significant increase in density which was enough to elevate the MWIBI from *Poor* to *Very Good* with a score of 39.

Blacknose dace dominated the assemblage at this site over all years sampled, followed by longnose dace and slimy sculpin. Blacknose and longnose dace and brook trout were the only species to be consistently recorded. Slimy sculpin were observed on four of six sampling events, and creek chub and rainbow trout were present on only one occasion each. All species recorded prior to 2010 increased in numbers, especially the intolerant slimy sculpin. These results clearly indicate a significant improvement in the chemical conditions downstream of the mine.

RM 1.4

This reach has also been sampled nearly annually since 2004 for macroinvertebrates throughout mine mitigation activities. The reach exhibited a *Fair* biological condition of the macroinvertebrate community for all years sampled through 2009, with the exception of 2006, when it was found to be in *Poor* condition. Compared to RM 3.8 the reach has always exhibited a slightly better condition with a higher density, total richness and EPT taxa, with the exception of 2009 when only density was higher at RM 1.4. In 2010 however, the site again had higher density, richness and EPT taxa present then RM 3.8 and was assessed as slightly better in biological condition *Very Good*, compared to only good at RM 3.8. In 2011 the site was not sampled due to T. S. Irene. In 2012 the site was again rated *Very Good* for the second year, and was also found to be very similar to the on stream control RM 6.0 in density richness and EPT taxa.

The fish community at RM 1.4 prior to the 2010 sample indicated only a mild impact with MWIBIs ranging from 27-33 and assessments of *Fair* to *Good*. In 2010 and 2012 the community showed some improvement to *Good* with MWIBIs of 35 for both years. The community composition remained fairly consistent through the sampling period. Total densities varied without respect to mine impact mitigation measures that appeared to have resulted in observed improvements at RM 3.8. The assemblage at RM 1.4 was co-dominated by blacknose and longnose dace. In 2009 and 2010 the proportion of intolerant and intermediately intolerant species increased (slimy sculpin, longnose sucker, brook trout and longnose dace), but then decreased in 2012.

Table 2. Macroinvertebrate community assessments and metrics from all locations sampled since 1986 on the West Branch Ompompanoosuc River near the Elizabeth Copper mine site. Shaded sites from RM 4.7 downstream are below the principle source of pollutants from the mine tailings-Copperas Brook. Shaded cells indicate waters within the influence of the mine.

Site (RM)	Date	Assessment	Density	Richness	EPT	PMA-O	Biotic Index	Oligo %	EPT/ EPT&C	PPCS-F
6.0	10/9/1998	Excellent	1492	49.0	26.0	93.0	3.14	0.0	0.89	0.72
	9/30/2000	Very Good	803	49.0	24.7	87.1	3.32	2.9	0.93	0.46
	9/13/2004	Excellent -Very Good	2064	53.0	26.0	78.6	3.36	3.7	0.88	0.50
	9/26/2005	Excellent -Very Good	3640	59.0	31.0	76.1	3.09	0.3	0.79	0.48
	8/31/2006	Good	2110	40.0	19.0	74.2	4.53	0.2	0.84	0.44
	999/11/20077	Excellent-Very Good	2384	54.0	34.5	81.3	2.94	0.0	0.86	0.47
	9/03/2008	Good	1073	55.5	24.5	71.0	4.30	0.4	0.73	0.53
	9/02/2009	Very Good-Good	3422	56.5	30.0	76.0	4.34	0.1	0.91	0.53
	9/01/2010	Excellent -Very Good	4256	75.0	43.5	87.5	3.59	0.7	0.85	0.50
	9/5/2012	Very Good	3062	65.5	31.0	79.8	3.73	0.3	0.91	0.45
5.5	9/30/1986	Very Good	534	35.0	25.5	71.8	2.97	0.0	0.99	0.52
5.2	9/30/2000	Very Good	714	46.0	21.7	82.3	3.70	1.0	0.72	0.46
5.1	9/30/2000	Very Good	611	44.0	24.7	87.9	3.17	5.5	0.86	0.49
4.8	9/6/2012	Excellent -Very Good	3382	65.0	35.0	87.8	3.50	0.7	0.86	0.52
4.7	9/30/2000	Poor	18	6.3	2.7	41.6	4.71	2.0	0.25	0.27
4.6	9/17/1998	Poor	163	29.0	14.0	83.3	4.11	0.6	0.86	0.58
	9/30/2000	Poor	32	16.0	6.3	55.4	3.63	6.9	0.53	0.34
	9/6/2012	Very Good	2538	52.5	31.5	74.9	3.99	0.0	0.87	0.53
3.8	9/30/1986	Poor	25	13.0	9.5	73.7	4.55	0.0	0.90	0.48
	10/9/1998	Poor	109	21.0	15.0	69.0	3.46	0.0	0.99	0.40
	9/30/2000	Poor	117	20.0	9.3	77.4	3.84	2.9	0.84	0.43
	9/26/2005	Poor	60	16.0	9.5	67.3	3.42	0.0	0.95	0.45
	8/31/2006	Poor	74	18.0	7.5	65.4	4.45	1.2	0.56	0.50
	9/11/2007	Poor	16	9.5	3.5	43.1	3.92	0.0	0.59	0.40
	99/03/2008	Poor	111	20.0	9.0	59.0	3.39	0.0	0.93	0.28
	9/02/2009	Fair	188	33.5	14.0	63.0	3.96	0.3	0.59	0.65
	9/01/2010	Good	459	40.0	24.0	56.5	4.00	0.2	0.96	0.41
	9/6/2012	Very Good	2552	54.0	31.5	75.0	3.97	0.1	0.87	0.53
1.4	9/30/2000	Fair	403	38.3	15.0	73.4	5.06	4.1	0.62	0.50
	9/13/2004	Fair	190	32.5	15.0	77.5	4.30	0.5	0.93	0.53
	9/20/2005	Fair	241	35.5	20.0	69.6	4.56	0.0	0.93	0.51
	8/31/2006	Poor	101	23.0	12.0	60.1	4.63	0.0	0.47	0.48
	9/11/2007	Fair	210	37.5	17.5	69.1	3.92	0.2	0.78	0.46
	99/03/2008	Fair	182	30.5	12.0	66.0	3.53	0.2	0.79	0.45
	9/02/2009	Fair	254	30.5	11.5	67.0	4.08	0.5	0.75	0.59
	9/01/2010	Very-good	842	51.0	28.0	69.3	4.45	0.0	0.93	0.54
	9/5/2012	very good	1686	49.5	28.0	90.2	3.90	0.4	0.84	0.61
	Class B MHG criteria		**>300**	**>30**	**>18**	**>45**	**<5.00**	**<12.0**	**>0.45**	**>0.40**
	Class A MHG criteria		**>500**	**>43**	**>24**	**>65**	**<3.50**	**<2**	**>0.65**	**>0.50**

Table 3**.** Fish Community assessments from the West Branch of the Ompompanoosuc River. Shaded sites are downstream from the principle source of pollutants from the mine tailings transported by Copperas Brook. MWIBI range is 9 *(poor)* to 45 *(Excellent)*. Shaded cells indicate waters within the influence of the mine.

Site (river mile)	Date	Assessment	MW IBI	Native Richness	# Native Intoler. Species	# Benthic Insect.	% Creek Chub and white Sucker	% Generalist Feeders	% Insect.	Top Carnivore %	% Anomaly	Density #s/100 m^2
6.0	7/1987	Very good	39	6	3	3	0.0	0.0	98.1	1.9	0.0	18.6
	9/2008	Fair	9	5	3	3	0.0	0.0	97.8	2.2	5.6	5.7
	9/2009	Excellent	41	6	3	3	1.2	1.2	96.4	2.4	0.0	19.9
	9/2010	Very good	39	5	3	3	0.0	0.0	98.6	1.4	0.0	26.6
	9/2012	**Very good**	**39**	**6**	**3**	**3**	**0.5**	**0.5**	**97.0**	**2.5**	**0.0**	**30.9**
5.6	9/2001	Very good	39	6	3	3	0	0	98.7	1.3	0.0	17.4
5.1	9/2001	Good	35	5	3	3	0	0	99.2	0.8	0.0	8.2
4.8	**9/2012**	**Very Good**	**41**	**7**	**3**	**3**	**1.5**	**1.5**	**93.3**	**5.1**	**0.0**	**12.0**
4.6	9/2001	Poor	9	5	2	3	0	0	99.9	0	0.0	3.2
	9/2012	**Very Good**	**39**	**6**	**3**	**3**	**1**	**1**	**99.0**	**0.3**	**0.0**	**19.8**
3.8	7/1987	Poor	9	4	2	2	0.0	0.0	96.0	4.0	0.0	2.5
	10/199	Poor	9	5	2	2	0.0	0.0	66.7	33.3	0.0	1.6
	9/2007	Poor	9	3	1	1	0.0	0.0	95.6	4.4	0.0	2.6
	9/2008	Poor	9	4	1	1	5.3	5.3	84.2	10.5	0.0	1.2
	9/2010	Fair	9	5	3	3	0.0	0.0	96.9	3.1	0.0	5.5
	9/2012	**Very Good**	**39**	**7**	**3**	**3**	**2.4**	**2.4**	**95.6**	**2.0**	**0**	**13.1**
3.4	9/2001	Good	33	5	3	3	0.0	0.0	96.7	3.3	0	15.2
1.4	9/2001	Good	33	7	3	3	0.2	0.4	99.4	0.2	0.0	16.8
	9/2007	Fair	33	5	2	3	0.4	0.4	99.6	0.0	0.0	25.6
	9/2008	Fair	27	4	2	3	0.0	0.0	100.0	0.0	1.1	6.5
	9/2009	Good	33	5	3	3	0.0	0.0	99.4	0.6	0.0	8.6
	9/2010	Good	35	6	3	3	0.8	0.8	97.2	2.0	0.0	23.6
	9/2012	**Good**	**35**	**6**	**2**	**2**	**1.4**	**1.4**	**97.9**	**0.7**	**0**	**12.3**

Habitat

Habitat observations have been recorded at the biomonitoring sites every year concurrent to biological sampling. Selected habitat observations that are known to limit the macroinvertebrate community abundance and richness are presented in **Table 4**. Embeddedness ranged between 10 and less than 50%, or good at both upstream control sites since 2004. The two locations closest to Copperas Brook, RM 4.6 and RM 3.8, have had embeddedness ratings of 50% or more. The embeddedness rating improved from > 62% (fair) at RM 3.8 in 2005-2007 to good (< 50%) from 2008 to 2012. The embeddedness at these sites appeared to be in part due to the coagulating effect of iron on sand and fine gravel and cementing the courser cobble substrate into place. The proportion of sand has generally ranged from 5-10 percent at all locations. Elevated sand is not generally habitat limiting to macroinvertebrates under 15 percent of the total substrate, but in this case it still appears to be exacerbating the embeddedness effect at RM3.8.

A standardized method used to characterize the amount of algae cover of different types was used to semi quantify the amount of iron precipitate cover and thickness in the WBOR. The macro algae index is based on percent cover, and Micro algae index is based on the thickness of the periphyton coating on the coarse substrate materials. These data are presented in Table 4 as a mean weighted cover and thickness index that ranges from 0-10 (see formula in table).

Table 4: Physical habitat (embeddedness and &sand) and, algae/iron observations from sites on the West Branch Ompompanoosuc River near the Elizabeth Copper Mine. The algae cover index is based on observational data during a pebble count. The macro algae index is based on percent cover, and micro algae index is based on the thickness of the coating. From these observations a mean weighted average (range 0-10) is computed for both groups see formula below. Shaded cells indicate waters within the influence of the mine.

Site (RM)	Date	Embeddedness %	Sand %	Macro Algae Cover Index (algae & iron) (0-10)	Micro Algae Thickness Index (algae & iron) (0-10)
6.0	9/13/2004	37.5	10	1.4	1.9
	9/26/2005	37.5	0	0.4	1.3
	8/31/2006	15	4	0.4	1.2
	9/11/2007	15	3	1.5	0.8
	9/03/2008	37.5	5	1.5	1.9
	9/02/2009	35	5	0.8	0.7
	9/1/2010	10	4	3.5	1.2
	9/5/2012	35	10	0.2	1.1
4.8	9/5/2012	40	5	1.1	1.1
4.6	9/5/2012	50	13	0.4	1.5
3.8	9/26/2005	62.5	7	-	5.0
	8/31/2006	62.5	10	7.3	3.7
	9/11/2007	62.5	11	8.3	6.3
	9/03/2008	37.5	6	4.5	1.9
	9/02/2009	45	8	3.0	2.9
	9/1/2010	15	8	0.1	1.5
	9/5/2012	45	**7**	0.1	1.4
1.4	9/13/2004	37.5	0	-	0.6
	9/20/2005	37.5	4	-	3.1
	8/31/2006	62.5	15	8.8	1.6
	9/11/2007	37.5	9	8.2	2.8
	9/03/2008	15	5	2.2	0.2
	9/02/2009	45	4	1.3	3.0

	Date	Embeddedness %	Sand %	Macro Algae Cover Index (algae & iron) (0-10)	Micro Algae Thickick netess Index (algae & iron) (0-10)
	9/1/2010	15	3	0.9	1.9
	9/5/2012	40	**4**	3.3	1.5

Macro and Micro algae observations at site 1.4 and 3.8, and 4.6 on the WBOR includes Iron bactria/precipitate, at other sites it is filamentous algae cover, and bluegreen/diatom thickness. Macro Algae Cover Weighted Average Index = ((0%*0) + (<5%*2) + (5-25%*6) + (>25%*10))/100. Micro Algae Thickness Index= ((0*0)+(1*.5)+(2*2)+(3*4)+(4*7)+(5*10))/100 .

The percent cover and thickness of the periphyton (iron and algae) was generally less than 1 for both measures at the control reach RM 6.0 every year. At RM 3.8 both periphyton indices were elevated thru 2007. The macro algae cover index ranged between 7 and 8, and the micro thickness index ranged between 4 and 6. In 2008 and again in 2009 we saw the first significant reduction in both periphyton indices. The macro index ranged from 3 to 4.5 and the micro index from 2 to 3. In 2010 and 2012 both these indices decreased to similar levels seen at the control site- macro index at 0.1 both years and the micro index about 1.5 both years. Figure 2 below illustrates how the periphyton appearance and cover has changed between the pre mitigation years and 2010. The level of periphyton cover and thickness illustrated below and documented from 2004 thru 2007 can be a physical detriment to macroinvertebrate colonization of the substrate. The reduction of iron loading into the WBOR is the most likely reason for the reduction in the cover and thickness of periphyton. The most dramatic decline coincides with the start of the active lime treatment system in 2008.

Figure 2: Periphyton (iron precipitate) cover- pre and post response action at RM 3.8.

WBOR 3.8 in 2004 substrate

WBOR 3.8 in 2010 substrate

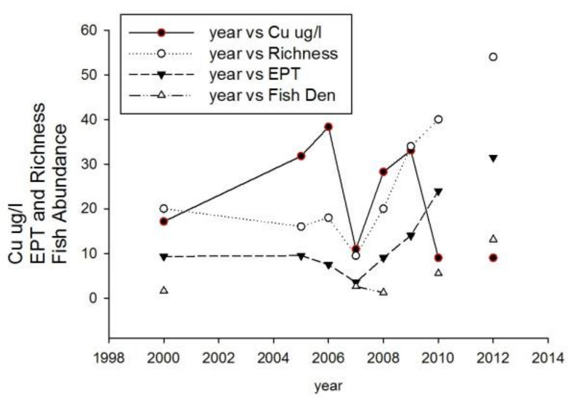
Water Quality

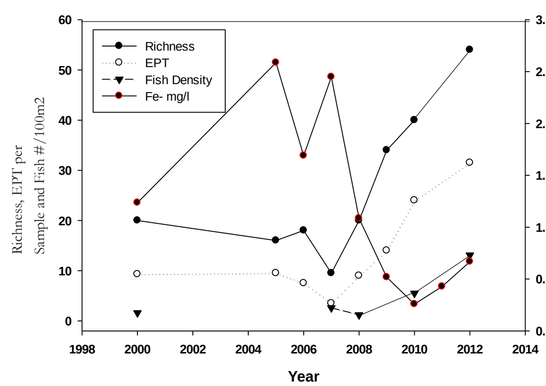
Water quality samples were collected once each year at the time of biomonitoring from 2004 thru 2010 at the biomonitoring sites (**Appendices 4 and 6**). These samples were collected under base flows, and show the WBOR to be alkaline with pH's generally above 8.0 and alkalinity generally between 100 mgl/l, and 136 mg/l. Conductivity ranged from 250-350 µS, with chloride concentrations only slightly elevated from a natural condition ranging from 7 to 17 mg/l. Turbidity was consistently below 1 NTU at the upstream RM 6.0 site. In contrast, even under base flow conditions, the two sites below Copperas brook, RM 3.8 and RM 1.4, had elevated turbidity through 2007. At RM 3.8 turbidity ranged from 37 in 2005 to 12 in 2007, at RM 1.4 turbidity ranged from 6.8 to 3.0 during this time period. From 2008 thru 2010 turbidity values declined dramatically to < 1 at all three locations with exception of RM 3.8 in 2009 when it was 2.3. The elevated turbidity below Copperas Brook was from dissolved iron that gave an orange tint to the water entering from Copperas Brook. Despite this obvious discoloration, iron concentrations (mostly 50 -200 ug/l) were only elevated above the AAC at RM 3.8 in 2007. At RM 3.8 dissolved copper concentrations were below 10 ug/l (the minimum detectible level) for all years except 2009 when it was 30 ug/l.

Because biological improvement was shown in the WBOR in 2010, water quality metals samples were collected more frequently in 2011 and 2012 at several biomonitoring sites (**Appendix 5 and 7)**. In addition water quality sampling was done at three additional locations immediately upstream and downstream from the confluence with Copperas Brook (RM 4.8, upstream, and 4.7 and 4.6 – downstream). These samples showed copper at below 10 ug/l at all locations, on all sampling occasions, even during freshet events when turbidity was elevated. This concentration is below the USEPA Maximum Allowable Concentration (MAC), which is equivalent to acute criteria, and at the threshold of the Average Allowable Concentration (AAC), equivalent to chronic criteria (Vermont Water Quality Standards – Appendix C. Iron only rose above the AAC of 1mg/l during two freshet events, in 2011 and 2012. During these events the upstream control sites RM 6.0 and RM 4.8 were also above the AAC for iron, and turbidity was generally over 10 NTU's.

At RM 3.8 biomonitoring and metals data were collected frequently enough from 2005 thru 2012 to examine the biological condition response to metals concentrations. The improvement in biological condition tracks well with the reduction in metal iron loading from Copperas Brook and resulting iron concentrations recorded at RM 3.8 over time (Figure 3).

Figure 3: Annual mean Copper and Iron concentrations and response of macroinvertebrate species richness and EPT richness and total fish density at site RM 3.8 in the West Branch of the Ompompanoosuc River from 2000 to 2012.





In 2008, and again in 2009, iron concentrations fell dramatically. In 2009, concentrations averaged below the AAC of 1 mg/l for the first time since data has been collected. In 2010 and 2012 the average iron concentrations remained below the AAC level (**Appendices 5-7)**.

Small Tributary Streams

Biomonitoring

Copperas Brook

RM 0.1

This small stream is the direct recipient of most of the copper waste from the Elizabeth Copper Mine site and is considered the principle source of pollutants to the WBOR. This stream was assessed in 2000 for macroinvertebrate and fish community integrity. Both communities were assessed as "*Poor*" (**Table 5 and 6**) with the entire sampled aquatic biota being represented by only four macroinvertebrate individuals. The stream was sampled again in 2012 and was rated as *fair-poor* for macroinvertebrates, with the density increasing from an average of 4, and 3.5 species in 2000, to over 100 animals representing 13 species and 9 EPT taxa. The community was dominated by the taxa *Tipulidae Tipula sp*, a cranefly leaf shredder. As a result the PMA-o and the functional group similarity were also highly dissimilar to the SHG reference condition. A number of single individuals of sensitive taxa however, were collected including the caddis *Dolophilodes*, *Diplectrona sp*, and *Limnophilidae*, as well as the stonefly taxa *Soydinia sp* indicating a lessening of the toxicity at in the stream. No fish were collected in 2012 (Table 6). Because it is suspected that no fish are present upstream of the sampling section located near the mouth, any recolonization of fish species resulting from improved conditions will originate from the WBOR.

Copperas Brook continues to have elevated toxic levels of several metals, including aluminum, cadmium, copper and iron (Appendix 12). Due to a high minimum detectable level in the analytical process during 2012 comparison of Cd levels between the two years cannot be made. During 2011 the two base flow measures showed concentrations of Cd, Cu and Fe to be above AAC for biota. Of the four samples taken during freshet flows, Cd and Cu were over the AAC twice and Fe for all four sampling events. Al was only analyzed during three sampling events (all freshet flows) being above the AAC on one occasion.

Four base flow samplings took place in 2012. Metals over the AAC were Al -once, Cu -twice and Fe -all four times. Concentrations of Cu and Fe however were generally lower in 2012 than in 2011.

Lords Brook

Selected habitat observations are presented in Table 7. Embeddedness and percent sand has never been limiting in Lords Brook. Periphyton cover and thickness has also been low during all sampling years.

RM 3.4

This site was selected as an upstream control for RM 3.3 which was located immediately upstream from the tributary that drained the South Cut. The macroinvertebrate community at this location was sampled in 2000, 2010 and 2012. On all three occasions the streams was assessed as *Excellent* to *Very Good* (**Table 5**), supporting a *very good* quality community. Fish were sampled in 2000 and 2012 (**Table 6**). Only brook trout were present which was not unexpected given the small drainage area of this site. While normally no CWIBI would be scored for a site supporting only a single species, this site was scored for sake of comparison to RM 3.3, which on three of four samples showed blacknose dace as also present prompting the application of the CWIBI there. CWIBI scores for brook trout-only samples are normally 42 - *Excellent,* provided multiple age classes are recorded and density meets the expectation. Both of these conditions were met at RM 3.4.

RM 3.3

As part of the EPA Aquatic BERA in 2000, Lords Brook RM 3.3, located below the confluence with the South Mine Cut drainage was found to be biologically impaired. The macroinvertebrates assessment was *Fair* **(Table 5)** and the fish assemblage assessed as *Poor* (**Table 6**). The macroinvertebrate community was low in density, richness and EPT species, and the fish community was also very low in density, being represented only by one brook trout. In contrast the biota sampled upstream from the South Cut input was in *Excellent* condition. Lords Brook was next assessed in 2007, and 2008. In 2007 the macroinvertebrate community was assessed as *Good* with both density and richness rebounding to a moderate level. In 2008 however it returned to a *Fair* assessment, with densities, and EPT species again very low. The fish community also showed improvement in 2007 and was assessed as *Excellent*. In 2008 however, the fish community also declined in density to very low numbers of brook trout, and blacknose dace, and was assessed as *Fair*. In 2010 and 2012 the macroinvertebrate community was assessed as *Very Good - Good* indicating only a slight change from the SHG reference. The fish samples also indicated no impact with CWIBI scores of 42, as brook trout numbers rebounded from the 2008 dip.

In 2012 copper was found to be above the MAC or AAC criteria on all five occasions sampled (Appendix). Zinc was also elevated above the AAC on three of the five occasions sampled. Water quality data were all collected under base flow conditions and are presented in **Appendix 10.** Lords Brook pH was 7.0 - 7.5, and the alkalinity ranged between 17 and 62 mg/l. Conductivity was also lower than the WBOR ranging between 60 and 150. Chloride was low (below 2mg/l) on all sampling occasions, and was only detectable in the lowest site, RM 0.2 in 2007. Turbidity levels were always less than 1 NTU. Phosphorus and nitrogen values were also low, similar to what would be expected in an unimpacted coldwater stream.

A tributary to Lords Brook that drains the South Cut was sampled once in 2010, and had similar water chemistry for the above parameters with the exception of conductivity, which was considerably high at 214 µS. The increased conductivity was a result of increased calcium and magnesium and not high chloride level which was low. Sulfate was also significantly higher. The tributary also had elevated copper of 22ug/l, which is above the MAC. Iron however was below detection at <50 ug/l. Given the wide range of biological assessments at RM 3.3, it may be that high flow events in this tributary intermittently carry increased levels of copper and iron from the waters in the South Cut causing a reoccurring biological impact at RM 3.3 and perhaps a distance downstream.

Sargent Brook and Abbot Brook tributary (local controls).

In addition to Lords Brook RM 3.4 two other small local tributary streams not influenced by the Elizabeth Mine were sampled. Sargent Brook was sampled in 2000 and again in 2007, and Abbott Brook was sampled in 2012. On all three occasions the macroinvertebrate and fish communty scored excellent (**Table 5 and 6**).
Abundance, richness and EPT taxa present were all well within the SHG stream type reference condition. Curiously, high substrate embeddedness and proportion of sand in Abbott Brook did not limit the biological integrity of the macroinvertebrate population there.

The fish community consisted of brook trout and slimy sculpin in both streams in expected abundances. Along with the upstream control reach on Lords brook these samples verify that local annual hydrologic conditions have not been a factor in the biological integrity of streams in the area. Tropical Storm Irene likely had a scour effect on these streams in 2011; however in 2012 the control streams show a complete recovery from any impact that may have occurred.

Table 5. Macroinvertebrate community assessments and metrics, from Lords Brook, located immediately below the south cut drainage from Elizabeth mine site, Copperas Brook, and a local SHG stream type control Sargent Brook and Abbot Brook Tributary. Metric violations for Class B biocriteria are underlined. Shaded cells indicate waters within the influence of the mine.

Stream	Site (RM)	Date	Assessment	Density	Richness	EPT	PMA-O	BI	Oligo %	Ept /EptC	PPCS-F
Sargent Brook	0.2	9/30/2000	Excellent	418	41.3	20.3	80.7	2.58	0.3	0.86	0.58
		9/10/2007	Excellent	482	43.0	24.0	85.4	2.76	0.3	0.86	0.57
Abbot Brook Trib.	0.6	9/7/2012	Excellent	921	47.0	28.0	69.9	2.31	0.0	0.91	0.52
Copperas Brook	0.1	9/30/2000	Poor	4	3.5	2.5	57.2	1.9	0.0	0.65	0.14
		9/6/2012	Fair-Poor	123	13.0	9.0	38.5	5.20	0.0	0.96	0.20
Lords Brook	3.4	9/30/2000	Excellent	868	46.7	21	81.5	2.95	2.1	0.78	0.58
		8/31/2010	Excellent – Very Good	777	49.5	20.5	72.4	3.14	2.5	0.64	0.47
		9/5/2012	Excellent	1522	48.0	27.0	83.1	2.66	1.2	0.86	0.59
Lords Brook	3.3	9/30/2000	Fair	164	22.3	11.3	71.9	3.26	0.6	0.76	0.49
		9/10/2007	Good	398	42.5	18.0	60.3	2.37	0.0	0.75	0.47
		9/03/2008	Fair	172	33.0	15.5	86.0	3.18	0.0	0.86	0.50
		9/01/2010	Very good	613	38.5	22.0	71.0	2.26	0.0	0.95	0.45
		9/5/2012	Vg-good	901	39.5	25.5	74.0	2.68	0.0	0.82	0.42
	0.2	9/30/2000	Excellent	686	42.3	20.3	75.1	2.99	0.5	0.80	0.52
		9/10/2007	Very good	977	43.0	24.0	78.7	2.72	0.0	0.70	0.43
SHG Class B Criteria				>300	>27	>16	>45	<4.50	<12.0	>0.45	>0.40
SHG Class B-1 Criteria				>400	>31	>19	>55	<3.50	<5	>0.55	>0.45
SHG Class A Criteria				>500	>35	>21	>65	<3.00	<2	>0.65	>0.50

Table 6. Fish Community assessments and species collected from Lord's and Sargent brooks and Abbot Brook Tributary 1. Cold Water index of biotic condition (CWIBI) *range is 9 (Poor) to 45 (Excellent).* Lord's Brook RM 3.4 is immediately upstream of the drainage for the South Mine Cut and RM 3.3 is immediately downstream. Shaded cells indicate waters within the influence of the mine.

Location	Site	Date	*CWIBI* and Assessment	# Intol. Species	% Cold water Species	% Generalist Feeders	Top Carnivore %	Est. Brook Trout age Class Numbers	Density/100m² For all Species Collected		
									Brook Trout	Slimy Sculpin	Blacknose Dace
Copperas Brook	0.1	2000	9 Poor	0	0	0	0	0	0	0	0
		2012	9 Poor	0	0	0	0	0	0	0	0
Lords Brook	3.4	2000	42 Excellent	1	100	0	100	3	10.7	0	0
		2012	42 Excellent	**1**	100	0	100	3	16.1	0	0
	3.3	2000	9 Poor	1	100	0	100	1-2	1.1	0	0
		2007	42 Excellent	1	81	0	81	2	30.2	0	7.3
		2008	29 Fair	1	48	0	48	2	3.1	0	3.3
		2010	42 Excellent	1	81	0	81	2	23.5	0	5.5
		2012	42 Excellent	**1**	**95**	**0**	**85**	**2-3**	**18.3**	**0**	**1.0**
	0.2	2001	45 Excellent	2	100	0	59	-	9.2	6.4	0
		2007	45 Excellent	2	100	0	48	3	9.9	10.9	0
Sargent Brook	0.2	2000	45 Excellent	2	100	0	70.6	-	7.0	2.9	0
Abbot Bk Trib.	0.6	2012	45 Excellent	2	100	0	80.0	3	15.0	3.8	0

Table 7. Physical habitat, algae and iron precipitate observations from small streams near the Elizabeth Mine site from 2007 to 2012. Shaded cells indicate waters within the influence of the mine.

Stream	Site (RM)	Date	Embeddedness %	Sand %	Macro Algae Cover Index (algae & iron) (0 low-10 high)	Micro Algae Thickness Index (algae & iron) (0 low -10 high)
Abbott Br Tributary	0.6	9/7/2012	75	25	0.0	0.2
Sargent Brook	0.2	9/10/2007	62.5	13	0.0	0.0
Lords Brook	3.4	8/31/2010	37.5	4	0.0	0.2
		9/5/2012	15	11	0	0.2
	3.3	9/10/2007	37.5	14	0.0	0.3
		9/03/2008	15	12	0.2	0.4
		8/31/2010	40	5	0.0	0.3
		9/5/2012	25	3	0	0.3
	0.2	9/10/2007	37.5	3	0.0	0.5

Macro and Micro algae observations at site 1.4 and 3.8, and 4.6 on the WBOR includes Iron bactria/precipitate, at other sites it is filamentous algae cover, and blue-green/diatom thickness. Macro Algae Cover Weighted Average Index = ((0%*0) + (<5%*2) + (5-25%*6) + (>25%*10))/100. Micro Algae Thickness Index= ((0*0)+(1*.5)+(2*2)+(3*4)+(4*7)+(5*10))/100 .

SUMMARY and RECOMMENDATIONS

As of this writing, the WBOR, and Lords Brook fully support the Aquatic Life Use as defined by the Vermont Class B Water Quality Standards and described in the implementation of the Biocriteria Guidance for Wadeable Streams in Vermont 2002. The recovery from impairment to meeting Class B standards in the WBOR is assumed to be a result of the response actions that have taken place at Elizabeth Mine, including the removal of TP-3, diverting groundwater and surface water, covering the piles, and actively treating the discharge from the base of TP-1 late spring through late fall.

At this time, the long term management goal for the Elizabeth mine site is to treat the iron originating from the mine using a passive system. It is recommended that the transition to a passive system not be implemented until ground water flows from the base of TP-1 or concentrations of iron decrease sufficiently to the point where a passive system could be effective over the long term. If the transition to a passive system occurs it will be necessary to continue biological assessments and monitoring of habitat and water quality conditions to verify the long term recovery of the WBOR.

Based on the water quality data, the response actions have also significantly reduced the metal loading into Copperas Brook. It is recommended that over time as ground water flows from the base of TP 1 decrease, that Copperas Brook be reassessed to determine if significant recovery has occurred. The waste rock pile TP-3 was identified as the primary source of copper and zinc metal loading, whereas the discharge from the toe of TP-1 was the primary source of iron loading (Reference EPA fall 2012 Presentation). Since TP-3 was removed, the concentrations of toxic metals in Copperas Brook at its confluence with the WBOR have been reduced by two orders of magnitude. Before TP-3 re-location took place, copper concentrations at this location were typically between 1,000 ug/L and 9,000 ug/L. In 2012, approximately two years since TP-3 was re-located, the copper concentrations were less than 100 ug/L. The trend in pre-treatment iron loading from the toe of TP-3 is also decreasing. For example, the estimated iron loading in 2007 was 800 pounds per day, whereas the estimated iron loading in the fall of 2012 was 165.9 pounds per day (Reference EPA fall 2012 Presentation). Further reduction of iron loading occurs when the temporary treatment system is in operation, which is typically from May through October. Lords Brook has also come into compliance with Class B biocriteria. While the small south cut drainage continues to have elevated copper concentrations.

APPENDICES

Appendix 1. The Percent composition of the major insect orders by site from all years sampled from the West Branch Ompompanoosuc River. Shaded sites from RM 4.7 down are below the principle source of pollutants from the mine tailings Copperas Brook. The 2012 assessments are bolded. Shaded cells indicate waters within the influence of the mine.

Site	Date	Coleoptera	Diptera	Ephemeroptera	Plecoptera	Trichoptera	Oligochaeta	Other
6.0	10/1998	5.1	15.6	34.0	4.8	40.5	0.0	0.0
	9/2000	12.4	12.8	31.1	4.2	36.4	2.9	0.2
	9/2004	17.4	17.4	16.5	4.7	39.3	3.7	1.0
	9/2005	12.0	23.1	15.1	3.2	46.4	0.3	0.0
	8/2006	5.4	31.6	46.4	2.2	13.9	0.2	0.3
	9/2007	10.3	14.7	22.6	4.4	47.8	0.0	0.1
	9/2008	13.7	39.6	28.3	2.6	14.8	0.4	0.5
	9/2009	6.6	29.4	46.4	2.7	14.6	0.1	0.2
	9/2010	8.2	14.6	30.3	2.6	43.4	0.7	0.1
	9/2012	**8.8**	**10.6**	**27.1**	**2.7**	**50.4**	**0.3**	**0.3**
5.5	9/1986	4.6	5.2	25.8	3.0	61.2	0.0	0.2
5.2	9/2000	9.5	28.8	35.3	5.7	19.0	1.0	0.7
5.1	9/2000	7.2	15.5	36.5	3.7	30.1	5.5	1.4
4.8	**9/2012**	**4.5**	**14.7**	**32.7**	**2.6**	**43.9**	**0.7**	**0.9**
4.7	9/2000	1.5	74.6	7.8	0.0	14.1	2.0	0.0
4.6	9/1998	9.8	17.2	46.6	7.4	17.8	0.6	0.6
	9/2000	20.1	39.7	15.7	0.9	14.0	6.9	2.7
	9/2012	**3.0**	**14.2**	**21.6**	**3.0**	**58.1**	**0.0**	**0.0**
3.8	9/1986	1.5	15.5	20.3	2.9	59.8	0.0	0.0
	10/1998	2.8	6.4	18.3	21.1	51.4	0.0	0.0
	9/2000	12.0	20.6	15.8	12.2	29.8	2.9	6.8
	9/2005	8.9	15.3	5.3	18.5	52.0	0.0	0.0
	8/2006	10.0	40.0	5.9	4.2	37.5	1.2	1.2
	9/2007	22.9	39.6	0.0	25.0	10.4	0.0	2.1
	9/2008	6.1	11.9	0.0	22.4	58.4	0.0	1.2
	9/2009	10.6	38.0	0.8	4.0	45.0	0.3	1.3
	9/2010	7.2	6.1	3.4	9.8	72.6	0.2	0.7
	9/2012	**3.0**	**14.1**	**21.5**	**3.0**	**57.8**	**0.1**	**0.5**
3.7	9/1998	1.3	70.0	8.8	8.8	8.8	1.3	1.3
2.9	9/2000	5.0	52.0	5.7	8.6	15.9	7.6	5.1
2.1	9/2000	4.9	32.2	24.5	11.5	23.4	1.0	2.5
1.4	9/1998	1.3	83.3	6.4	2.4	6.2	0.0	0.4
	9/2000	10.0	33.1	19.6	3.1	27.5	4.1	2.7
	9/2004	7.8	10.9	18.9	7.9	50.3	0.5	3.6
	9/2005	11.3	9.6	14.0	7.6	56.0	0.0	1.5
	8/2006	5.0	55.8	6.6	3.9	28.7	0.0	0.0
	9/2007	24.6	18.9	12.5	15.6	25.4	0.2	2.8
	9/2008	21.9	20.7	0.4	13.3	40.1	0.2	3.3
	9/2009	7.7	25.6	2.2	7.0	55.4	0.5	1.6
	9/2010	4.3	10.3	15.4	5.8	63.4	0.0	0.8
	9/2012	**1.4**	**17.2**	**35.4**	**5.1**	**40.3**	**0.4**	**0.3**
	Model median	**6.0**	**18.0**	**34.0**	**8.0**	**33.0**	1.0	<1

Appendix 2. Percent composition of the functional feeding groups by site from all sampling dates from the West Branch Ompompanoosuc River. Shaded sites from RM 4.7 down are below the principle source of pollutants from the mine tailings Copperas Brook. The 2012 assessments are bolded.

Site (RM)	Date	Collector/ Filterer	Collector/ Gatherer	Predator	Scraper	Shredder/ Detritus	Shredder/ Herbivore
6.0	10/1998	39.1	30.8	7.8	10.7	1.1	1.1
	9/2000	20.5	26.4	9.3	43.3	0.3	0.1
	9/2004	40.5	22.5	10.1	24.4	0.2	0.2
	9/2005	45.8	23.4	7.1	22.2	0.5	0.2
	8/2006	32.0	46.4	5.0	8.8	0.1	0.0
	9/2007	48.4	24.1	6.5	17.5	0.4	0.1
	9/2008	33.3	26.3	7.2	22.2	0.1	4.2
	9/2009	34.7	35.6	6.3	9.2	0.3	0.2
	9/2010	43.5	25.8	3.8	25.3	0.4	0.6
	9/2012	**48.1**	**20.5**	**4.6**	**25.5**	**0.3**	**0.5**
5.5	9/1986	37.3	15.8	7.0	37.9	0.3	1.1
5.2	9/2000	16.8	40.3	12.2	29.1	0.2	0.1
5.1	9/2000	18.8	36.5	8.1	35.1	0.1	0.4
4.8	**9/2012**	**36.5**	**29.5**	**4.7**	**26.7**	**1.0**	**0.3**
4.7	9/2000	13.7	75.5	7.8	1.5	0.0	0.0
4.6	9/1998	19.6	44.8	9.2	14.7	1.8	0.0
	9/2000	5.4	47.3	16.8	28.8	0.0	0.0
	9/2012	**55.8**	**23.1**	**4.6**	**13.2**	**0.2**	**1.6**
3.8	9/1986	55.0	23.2	9.2	4.4	3.3	4.8
	10/1998	47.7	7.3	28.4	15.6	0.9	0.0
	9/2000	26.4	20.1	28.3	24.6	0.3	0.0
	9/2005	49.2	6.4	30.2	11.3	2.2	0.0
	8/2006	36.3	30.3	7.0	15.0	0.5	10.9
	9/2007	10.4	22.9	29.2	22.9	12.5	0.0
	9/2008	58.4	5.3	29.3	6.1	0.4	0.0
	9/2009	42.3	27.5	15.8	10.9	0.8	2.7
	9/2010	71.1	4.2	13.7	10.1	0.3	0.2
	9/2012	**55.5**	**23.1**	**4.7**	**13.1**	**0.2**	**1.6**
3.7	9/1998	3.8	63.8	23.8	1.3	0.0	2.5
2.9	9/2000	14.2	60.5	17.3	7.4	0.1	0.0
2.1	9/2000	25.0	37.6	17.4	18.4	0.8	0.8
1.4	9/1998	6.2	77.5	5.8	1.7	1.1	3.4
	9/2000	28.4	37.2	8.1	20.2	0.4	5.5
	9/2004	48.7	13.5	15.5	13.8	0.8	3.6
	9/2005	54.4	9.1	12.6	20.7	0.4	1.3
	8/2006	29.6	37.9	6.4	9.3	0.0	16.4
	9/2007	30.0	15.2	22.1	31.6	1.1	0.0
	9/2008	39.2	17.2	19.5	23.2	0.6	0.0
	9/2009	54.8	21.7	11.1	7.9	1.4	2.4
	9/2010	62.0	18.8	8.9	8.8	0.1	1.0
	9/2012	**42.8**	**31.8**	**8.3**	**16.0**	**0.2**	**0.5**
	Reference Model	30	32	13	13	4	1

Appendix 3. Fish species collected and density/100m², as calculated by numbers collected from one electrofishing run for the West Branch Ompompanoosuc River by sampling date. RM 4.8 and higher are upstream from the mine the remaining lower sites are downstream from the mine.

	1987	1998	2001	2007	2008	2009	2010	**2012**
RM 6.0								
Blacknose dace	6.1				1.5	4.5	12.3	**17.7**
Longnose dace	6.7				2.3	4.5	7.0	**4.3**
Slimy sculpin	5.3				1.7	9.6	6.7	**7.7**
Brook trout	0.3				0.1	0.5	0.4	**0.8**
Longnose sucker	0.2				0.1	0.6	0.3	**0.3**
Creek chub	0				0	0	0	**0.2**
Brown trout	0.1				0	0	0	**0**
Total	**18.6**				**5.6**	**19.9**	**26.6**	**31.0**
RM 5.6								
Blacknose dace			7.2					
Slimy sculpin			5.2					
Longnose dace			4.6					
Brook trout			0.2					
Longnose sucker			0.2					
Creek chub			0					
Brown trout			0					
Total			**17.4**					
RM 5.1								
Blacknose dace			1.9					
Longnose dace			2.2					
Slimy sculpin			3.8					
Brook trout			0.1					
Longnose sucker			0.2					
Creek chub			0					
Total			**8.2**					
RM 4.8								
Blacknose dace								**5.5**
Longnose dace								**2.2**
Slimy sculpin								**3.2**
Brook trout								**0.6**
Longnose sucker								**0.3**
Creek chub								**0.1**
White sucker								**0.1**
Total								**12.0**
RM 4.6								
Blacknose dace			0.6					**6.6**
Longnose dace			2.3					**9.4**
Slimy sculpin			0.1					**3.5**
Brook trout			0					**0.1**
Longnose sucker			0.2					**0.1**
Creek chub			0.1					**0.1**
Total			**3.2**					**19.8**
RM 3.8								
Blacknose dace	1.7	0.5		0.5	0.5		3.9	**7.3**
Longnose dace	0.4	0.3		2.0	0.5		0.7	**3.1**
Slimy sculpin	0.3	0.2		0	0		0.6	**2.0**
Brook trout	0.1	0.5		0.1	0.1		0.2	**0.3**
Longnose sucker	0	0		0	0		0.1	**0.1**
Creek chub	0	0.1		0	0		0.1	**0.3**
White sucker	0	0		0	0		0	**0.1**
Rainbow trout	0	0		0	0.1		0	**0**
Total	**2.5**	**1.6**		**2.6**	**1.2**		**5.5**	**13.2**

Appendix 3 Continued

	1987	1998	2001	2007	2008	2009	2010	2012
Rm 1.4								
Blacknose dace			12.0	23.6	5.1	5.7	16.2	9.1
Longnose dace			3.6	1.4	1.1	2.1	4.3	2.5
Slimy sculpin			0.4	0.5	0.2	0.7	0.9	0
Brook trout			0	0	0	0.1	0.5	0.1
Longnose sucker			0.7	0.1	0.1	0.1	1.5	0.4
Creek chub			0	0.1	0	0	0.2	0.1
White sucker			0	0	0	0	0	0.1
Total			**16.6**	**25.6**	**6.5**	**8.6**	**23.6**	**12.2**

Appendix 4: General water quality parameters from the West Branch Ompompanoosuc River 2004-2010.

Station	Date	pH	Alkalinity mg/l	Specific Conductance μS	Diss. Cl mg/l	Tot. SO4 mg/l	Diss. Ca mg/l	Turbidity NTU	Diss. P ug/l	Tot. N mg-N/l
WBOR										
6.0*	9/13/2004	7.92	120	274	9	7.94	48.7	0.45	<5	0.19
	9/26/2005	8.19	141	351	17.7	9.3	53.7	0.24	<5	0.19
	8/31/2006	8.27	127	288	8.8	7.30	49.7	0.58	<5	0.26
	9/11/2007	8.15	113	262	7.6	6.09	48.4	0.41	<5	0.20
	9/03/2008	7.90	121	278	11.6	7.29	45.7	0.25	<5	0.19
	9/02/2009	8.13	124	270	7.85	6.44	48.2	0.99	5.5	0.19
	9/01/2010	8.16	136	301	9.66	6.53	53.6	<0.2	9.4	0.15
3.8	9/26/2005	8.25	115	413	17.5	63.7	59.6	37.2	<5	0.14
	8/31/2006	8.21	110	314	9.1	33.6	52.0	13.4	<5	0.13
	9/11/2007	8.06	100	308	7.0	44.2	46.5	12.5	<5	0.15
	9/03/2008	8.09	112	304	12.4	26.1	49.4	0.61	<5	0.15
	9/02/2009	8.42	116	279	8.42	16.6	47.8	2.33	<5	0.15
	9/01/2010	8.79	125	335	9.55	32.5	55.8	**0.65**	7.1	0.12
1.4	9/13/2004	8.68	91.8	241	8.8	19.2	39	2.9	<5	0.11
	9/26/2005	7.72	101	366	17.4	48.8	50.8	5.59	<5	0.14
	8/31/2006	8.30	99.0	282	9.2	26.8	46.0	3.19	<5	0.17
	9/11/2007	8.22	94.6	278	8.5	36.3	47.3	6.85	<5	0.17
	9/03/2008	8.12	104	285	12.9	22.5	44.7	0.49	<5	0.12
	9/02/2009	8.35	101	252	8.0	16.4	42.4	1.06	<5	0.14
	9/01/2010	8.21	118	302	10.0	21.1	48.0	**<0.2**	9.85	0.12

All data collected at time of biological sampling only. T=Total, D=dissolved (filtered). Site RM 6.0 is the upstream control and OR 3.8 is the off stream control. Both total and dissolved measures of nickel, cadmium, lead, chromium, zinc and arsenic were all below their detection levels. For iron, manganese, sodium, potassium, copper, and aluminum both total and dissolved are reported in 2007-10.

Appendix 5: General water quality parameters 2011 and 2012 from all locations on the West Branch Ompompanoosuc River near Elizabeth mine.

Site	Year	Date	Flow Type	Flow Level	Field pH std units	Field Cond µS	Alkalinity Mg/l	Turb NTU	TP ug/l	TN mg/l	SO4 mg/l	Cl mg/l	Color Ptu's
6.0	2011	3/31	Base	Low	8.54	228							
		5/12	freshet	Low									
		6/7	base	mod									
		7/14	freshet	low				1.8					
		8/16	freshet	mod				13.0					
		10/26	freshet	mod	8.12	227		1.2					
	2012	3/6	base	mod	8.38	285		1.7					
		4/13	base	mod	8.13	230		1.02					
		5/4	freshet	mod	7.75	192		17.9					
		6/6	base	mod	8.25	220		2.29					12
		7/3	base	mod	8.45	272		0.67					12
		9/5	base	mod	8.27	295	125.5		11.4	0.1	7.5	9.1	15
		10/16	base	mod	7.60	278		0.73					
4.8	2011	3/31	base	Low	8.69	220							
		5/12	freshet	Low									
		6/7	base	mod									
		7/14	freshet	low				1.8					
		8/16	freshet	mod				12.0					
		10/26	freshet	mod	8.2	207		1.3					
	2012	3/6	base	mod	8.36	298		3.77					
		4/13	base	mod	7.84	230		1.57					
		5/4	freshet	mod	7.81	195		14.1					
		6/6	base	mod	8.28	214		1.62					12
		7/3	base	mod	8.48	245		0.68					15
		9/5	base	mod	8.40	287	119.5	0.47	6.8	< 0.1	9.5	9.5	
4.7	2011	3/31	base	Low	8.57	262							
		7/14	freshet	low				2.3					
		8/16	freshet	mod				22.0					
	2012	4/13	base	mod	8.03	238		1.6					
		6/6	base	mod	8.30	218		1.74					15
		7/3	base	mod	8.53	289		1.05					15
		9/5	base	mod	8.41	300	116.0	0.95	6.7	< 0.1	14.7	9.3	
4.6	2011	3/31	base	Low	8.8	228							
		5/12	freshet	Low									
		6/7	base	mod									
		7/14	freshet	low				1.9					
		8/16	freshet	mod				13.0					
		10/26	freshet	mod	8.18	200		1.8					
	2012	3/6	base	mod	8.15	305		4.83					
		4/13	base	mod	8.18	236		1.27					
		5/4	freshet	mod	7.81	202		13.9					
		6/6	base	mod	8.24	222		2.18					15
		7/3	base	mod	8.41	287		0.86					12
		9/5	base	mod	8.40	309	117.0	1.06	7.0	< 0.1	22.8	9.5	
3.8	2011	3/31	Base	Low	8.9	234							
		5/12	freshet	Low									
		6/7	base	mod									
		7/14	freshet	low				1.7					
		8/16	freshet	mod				17.0					
		10/26	freshet	mod	8.11	214		1.3					
	2012	3/6	base	mod	8.05	322		1.21					
		4/13	freshet	mod	7.96	236		10.6					
		5/4	base	mod	7.62	208		1.92					

		Date	Flow Type	Flow Level	Field pH std units	Field Cond µS/cm	Alkalinity Mg/l	Turb NTU	TP ug/l	TN mg/l	SO4 mg/l	Cl mg/l	Color Ptu's
		6/6	base	mod	8.04	224		1.36					12
		7/3	base	mod	8.44	283		0.8					12
		9/5	base	mod	8.37	309	117.0	0.61	7.2	0.1	21.9	9.1	20
1.4	2011	5/12	freshet	Low									
		6/7	base	mod									
		7/14	freshet	low				2.3					
		8/16	freshet	mod				12.0					
		10/25	freshet	mod	7.94	188		5.3					
	2012	3/6	base	mod	8.15	241		2.03					
		4/13	base	mod	7.28	217		1.53					
		5/4	freshet	mod	6.92	180		6.86					
		6/6	base	mod	8.02	180		1.31					12
		7/3	base	mod	8.33	254		1.03					15
		9/5	base	mod	8.45	295	104	4.24	12.9	0.2	21.5	11.9	17

Appendix 6: Water quality- metals West Branch Ompompanoosuc River 2004-2010, all collected at time of biological sampling only. T=total, D=dissolved (filtered). Site RM 6.0 is the upstream control and OR 3.8 is the off stream control. Both total and dissolved measures of nickel, cadmium, lead, chromium, zinc and arsenic were all below their detection levels. For iron, manganese, sodium, potassium, copper, and aluminum both total and dissolved are reported in 2007-10. Bolded value indicates above ALS CMC criteria. 2012 data are total metals for baseflow (mean of six samples) and/a single freshet flow sample.

Site (RM)	Date	Diss./Total Fe (ug/l)	Diss./Total Mn (ug/l)	Diss./Total Mg (mg/l)	Diss./Total Na (mg/l)	Diss./Total K (mg/l)	Diss./Total Cu ug/l	Diss./Total Al ug/l	Hardness mg/l
WBOR									
6.0	9/13/2004	267/-	16.7/-	2.14/-	6.3/-	2.4/-	<10/-	10/-	128
	9/26/2005	<50/-	15.9/-	2.50/-	10.5/-	3.0/-	<10/-		144
	8/31/2006	<50/-	15.4/-	2.08/-	7.0/-	2.4/-	<10/-		133
	9/11/2007	<50/<50	9.4/15.9	2.06/1.96	6.09/5.68	2.7/2.5	<10/<10	10/22	129
	9/03/2008	<50/<50	16.0/15.8	2.01/2.03	/7.84	/2.4	<10/<10	11/22	130
	9/02/2009	<50/<50	18.5/20.1	2.01/2.02	6.56/6.63	2.26/2.31	<10/<10	-/19.4	129
	9/01/2010	<50	-/21.1	-/2.25	-/8.39	-/2.55	-/<10	-/16.4	143
3.8	9/13/2004	216/-	16.5/-	1.95/-	6.13/-	2/-	<10/-	32/-	85
	9/26/2005	<50/-	94.8/-	5.56/-	10.6/-	3.5/-	<10/-		172
	8/31/2006	<50/-	60.4/-	3.46/-	7.3/-	2.67/-	<10/-		144
	9/11/2007	58.8/**6240**	81.7/110	3.86/4.06	5.40/5.63	2.77/2.92	<10/<10	21/54	132
	9/03/2008	56/147	15.9/14.0	3.01/3.02	8.35/8.23	2.65/.60	<10/<10	70/80	141
	9/02/2009	<50/459	35.2/41.3	2.46/2.49	6.88/7.02	2.39/2.42	<10/**30**	-/149	130
	9/01/2010	-/234	-/15.6	-/3.97	-/8.57	-/2.93	-/<10	/54.3	156
1.4	9/13/2004	265/-	25.0/-	2.49/-	5.8/-	2.3/-	<10/-	48/-	108
	9/26/2005	<50/-	19.0/-	4.55/-	10.5/-	3.2/-	<10/-		146
	8/31/2006	<50/-	13.4/-	3.01/-	7.3/-	2.5/-	<10/-		127
	9/11/2007	<50/**2100**	25.0/38.2	3.61/3.52	8.3/6.42	3.1/2.9	<10/<10	21/54	168
	9/03/2008	<50/75	<5/<5	2.77/2.83	8.62/8.43	2.56/2.52	<10/<10	54/57	123
	9/02/2009	<50/251	14.7/15.1	2.43/2.46	6.74/6.78	2.29/2.28	<10/<10	-/44.8	116
	9/01/2010	-/<50	-/>5	-/3.02	-/8.74	-/2.74	<10	-/30.9	132

Appendix 7. WBOR total metals sampled in 2011 and 2012 at stream locations above and below Copperas Brook. Samples collected March-June 2011 were analyzed at VTDEC, samples collected from July – Oct 2011 analyzed by Test America, all samples collected in 2012 were analyzed by EPA contract lab Weston. MDL's indicated by < sign. Shaded cells indicate waters within the influence of the mine.

RM	Date	Flow Type	Flow Level	Turb NTU	Hard ness	Al ug/L	As ug/L	Ca mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	K mg/L	Mg mg/L	Mn ug/L	Na mg/L	Ni ug/L	Pb ug/L	Zn ug/L
6.0	3/31	base	low		93		<1	35	<1	<5	<10	0.09	1.5	1.6	13.6	4.02	<5	<1	<50
	5/12	freshet	low		83	175	<1	31	<1	<5	<10	0.17	1.5	1.4	18.7	3.43	<5	<1	<50
	6/7	base	mod		100		<1	38	<1	<5	<10	0.05	1.8	1.6	15.8	5.01	<5	<1	<50
	7/14	freshet	low	2	134	95	0.33	50	<2	0.54	<10	0.12	2.5	2.2	34.7	6.66	<20	0.3	2.3
	8/16	freshet	mod	13	98	855	0.88	37	<2	2.3	<10	**1.06**	2.0	1.7	123.0	3.30	<20	1.0	7.1
	10/26	freshet	mod	1	107	99.5	0.28	40	0.06	0.38	<10	0.06	2.0	1.6	22.9	3.55	<20	0.2	1.1
	3/6	base	mod	2	119	750	<10	44	<20	<20	<10	0.68	2.2	2.2	71	5.30	<20	<20	<20
	4/13	base	mod	1	94	<110	<10	35	<20	<20	<10	0.08	1.6	1.6	<20	3.80	<20	<20	<20
	5/4	freshet	mod	18	90	2800	<10	32	<20	<20	<10	**2.60**	2.0	2.4	170	3.10	<20	<20	<20
	6/6	base	mod	2	94	190	<10	35	<20	<20	<10	0.22	1.5	1.7	26	3.80	<20	<20	<20
	7/3	base	mod	1	123	<110	<10	46	<20	<20	<10	0.06	2.3	1.9	23	5.80	<20	<20	<20
	9/5	base	mod		129	<110	<10	48	<20	<20	<10	0.12	2.6	2.1	33	7.10	<20	<20	<20
	10/16	base	mod	1	114	<110	<10	42	<20	<20	<10	0.05	2.0	2.1	<20	5.50	<20	<20	<20
4.8	3/31	base	low		93		<1	35	<1	<5	<10	0.08	1.5	1.7	15.2	4.24	<5	<1	<50
	5/12	freshet	low		82	125	<1	31	<1	<5	<10	0.18	1.5	1.4	19.0	3.74	<5	<1	<50
	6/7	base	mod		100		<1	37	<1	<5	<10	0.07	1.8	1.7	20.7	5.20	<5	<1	<50
	7/14	freshet	low	2	132	111	0.24	49	<2	0.49	<10	0.14	2.5	2.3	34.7	7.26	20	0.3	2.4
	8/16	freshet	mod	12	98	922	0.46	36	<2	1.9	<10	**1.08**	2.0	1.8	132.0	3.27	20	1.0	4.5
	10/26	freshet	mod	1	106	105	2	40	0.06	0.28	<10	0.12	2.0	1.8	23.6	3.65	20	0.1	1.4
	3/6	base	mod	4	114	320	<10	42	<20	<20	<10	0.40	1.9	2.2	40	5.60	<20	<20	<20
	4/13	base	mod	2	94	<110	<10	35	<20	<20	<10	0.14	1.6	1.6	22.0	3.90	<20	<20	<20
	5/4	freshet	mod	14	90	2800	<10	32	<20	<20	<10	**2.40**	2.1	2.4	160.0	3.30	<20	<20	<20
	6/6	base	mod	2	94	180	<10	35	<20	<20	<10	0.22	1.6	1.7	27.0	4.00	<20	<20	<20
	7/3	base	mod	1	121	<110	<10	45	<20	<20	<10	0.11	2.3	2.0	25.0	6.20	<20	<20	<20
	9/5	base	mod	0	122	<110	<10	45	<20	<20	<10	0.13	2.5	2.2	26.0	7.10	<20	<20	<20
4.7	3/31	base	low		94		<1	35	<1	<5	<10	0.32	1.5	1.8	21.6	4.13	<5	<1	<50
	7/14	freshet	low	2	178	111	0.26	63	<2	0.48	<10	0.28	3.3	5.1	55.4	7.19	20	0.3	5.8
	8/16	freshet	mod	22	123	1110	0.26	44	<1	3.4	<10	**1.95**	2.7	3.2	222.0	3.68	6	1.3	79.7
	4/13	base	mod	2	97	120	<10	36	<20	<20	<10	0.24	1.9	1.8	27.0	4.00	<20	<20	<20
	6/6	base	mod	2	97	170	<10	36	<20	<20	<10	0.26	1.6	1.7	28.0	4.00	<20	<20	<20
	7/3	base	mod	1	129	<110	<10	48	<20	<20	<10	0.13	2.6	2.1	28.0	6.10	<20	<20	<20
	9/5	base	mod	1	127	<110	<10	47	<20	<20	<10	0.17	2.7	2.3	32.0	6.80	<20	<20	<20
4.6	3/31	base	low		92		<1	34	<1	<5	<10	0.21	1.5	1.7	17.9	4.18	<5	<1	<50
	5/12	freshet	low		82	115	<1	30	<1	<5	<10	0.16	1.5	1.4	19.7	3.68	<5	<1	<50
	6/7	base	mod		102		<1	38	<1	<5	<10	0.08	1.8	1.8	21.1	5.38	<5	<1	<50

RM	Date	Flow Type	Flow Level	Turb NTU	Hard ness	Al ug/L	As ug/L	Ca mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	K mg/L	Mg mg/L	Mn ug/L	Na mg/L	Ni ug/L	Pb ug/L	Zn ug/L
4.6	7/14	freshet	low	2	136	146	0.27	50	<2	0.61	<10	0.24	2.6	2.7	43.9	7.20	20	0.3	2.4
	8/16	freshet	mod	13	96	971	0.41	36	<2	2	<10	**1.13**	2.0	1.8	136.0	3.37	20	<1	6.0
	10/26	freshet	mod	2	107	109	0.22	40	0.07	0.27	<10	0.13	2.0	1.8	25.8	3.66	20	0.1	1.7
	3/6	base	mod	5	125	260	<10	46	<20	<20	<10	0.94	2.4	2.5	51.0	5.60	<20	<20	<20
	4/13	base	mod	1	95	<110	<10	35	<20	<20	<10	0.22	1.8	1.8	27.0	4.00	<20	<20	<20
	5/4	freshet	mod	14	92	2200	<10	33	<20	<20	<10	**2.00**	1.9	2.3	150	3.40	<20	<20	<20
	6/6	base	mod	2	97	<110	<10	36	<20	<20	<10	0.27	1.6	1.8	27.0	4.00	<20	<20	<20
	7/3	base	mod	1	126	<110	<10	47	<20	<20	<10	0.11	2.5	2.1	24.0	6.20	<20	<20	<20
	9/5	base	mod	1	134	<110	<10	49	<20	<20	<10	0.24	2.6	2.7	39.0	7.10	<20	<20	<20
3.8	3/31	base	low		94		<1	35	<1	<5	<10	0.46	1.6	1.9	25.8	4.29	<5	<1	<50
	5/12	freshet	low		83	95.2	<1	31	<1	<5	<10	0.20	1.6	1.6	19.8	3.79	<5	<1	<50
	6/7	base	mod		104		<1	39	<1	<5	<10	0.09	1.9	2.0	19.7	5.50	<5	<1	<50
	7/14	freshet	low	2	145	93	0.21	53	<2	0.45	<10	0.22	2.8	3.2	31.1	7.47	20	0.3	3.2
	8/16	freshet	mod	17	103	1030	0.43	38	**0.34**	2.1	<10	**1.45**	2.2	2.2	172.0	3.84	2.5	1.0	33.0
	10/26	freshet	mod	1	110	93.9	0.16	41	0.06	0.29	<10	0.15	2.1	2.0	24.7	3.89	20	0.2	1.7
	3/6	base	mod	6	121	360	<10	44	<20	<20	<10	**1.50**	2.3	2.7	60.0	6.30	<20	<20	<20
	4/13	base	mod	1	93	<110	<10	34	<20	<20	<10	0.24	1.9	1.9	25.0	4.10	<20	<20	<20
	5/4	freshet	mod	11	95	2400	<10	34	<20	<20	<10	**2.20**	2.1	2.5	150.0	3.70	<20	<20	<20
	6/6	base	mod	2	97	160	<10	36	<20	<20	<10	0.20	1.7	1.7	25	4.10	<20	<20	<20
	7/3	base	mod	1	124	<110	<10	46	<20	<20	<10	0.16	2.4	2.1	22.0	6.20	<20	<20	<20
	9/5	base	mod	1	138	<110	<10	51	<20	<20	<10	0.21	3.0	2.6	20.0	6.80	<20	<20	<20
	10/16	base	mod	1	119	<110	<10	44	<20	<20	<10	0.16	2.5	2.3	24.0	5.90	<20	<20	<20
1.4	5/12	freshet	low		76	62.1	<1	28	<1	<5	<10	0.88	1.5	1.4	12.6	3.80	<5	<1	<50
	6/7	base	mod		95		<1	35	<1	<5	<10	0.05	1.8	1.8	9.4	5.42	<5	<1	<50
	7/14	freshet	low	2	124	105	0.26	45	<2	0.53	<10	0.19	2.6	2.7	20.7	7.32	20	0.3	2.2
	8/16	freshet	mod	12	90	639	0.37	33	0.19	1.5	<10	**1.00**	2.0	2.0	112.0	3.59	1.5	0.7	22.2
	10/25	freshet	mod	5	98	430	0.3	36	<2	0.94	<10	0.50	2.1	1.9	32.7	3.71	20	0.3	2.3
	3/6	base	mod	2	86	160	<10	31	<20	<20	<10	0.67	1.9	2.1	26.0	5.30	<20	<20	<20
	4/13	base	mod	2	87	<110	<10	32	<20	<20	<10	0.19	1.7	1.7	<20	3.90	<20	<20	<20
	5/4	freshet	mod	7	72	1200	<10	26	<20	<20	<10	**1.20**	1.8	1.8	72.0	3.40	<20	<20	<20
	6/6	base	mod	1	76	<110	<10	28	<20	<20	<10	0.14	1.6	1.5	ND	3.70	<20	<20	<20
	7/3	base	mod	1	110	<110	<10	41	<20	<20	<10	0.12	2.4	1.9	ND	6.30	<20	<20	<20
	9/5	base	mod	4	121	240	<10	44	<20	<20	<10	0.67	2.9	2.7	32.0	8.40	<20	<20	<20

Appendix 8. Percent composition of the major insect orders for SHG tributary streams on all sampling dates. Shaded cells indicate waters within the influence of the mine.

Location	Site (RM)	Date	Coleoptera	Diptera	Ephemeroptera	Plecoptera	Trichoptera	Oligochaeta	Other
Copperas Brook	0.1	9/30/2000	0.0	35.0	0.0	10.0	55.0	0.0	0.0
		9/05/2012	**0.0**	**80.5**	**0.0**	**1.6**	**17.9**	**0.0**	**0.0**
Abbott Brook Trib. 3	0.6	**9/7/2012**	**1.0**	**22.2**	**49.8**	**7.8**	**18.6**	**0.0**	**0.7**
Sargent Brook	0.2	9/30/2000	2.3	21.4	35.5	13.7	26.2	0.3	0.6
		9/10/2007	3.0	28.6	13.6	21.3	31.9	0.3	1.3
Lords Brook	3.4	9/30/2000	8.3	24.8	29.6	12.9	21.2	2.1	1.0
		8/31/2010	21.8	29.3	15.2	8.9	20.8	2.5	1.6
		9/5/2012	**20.7**	**17.5**	**23.5**	**8.3**	**28.3**	**1.2**	**0.5**
	3.3	9/30/2000	1.2	26.0	42.4	10.1	19.0	0.6	0.7
		9/10/2007	2.1	31.5	3.1	7.7	54.7	0.0	1.0
		8/31/2010	3.4	10.2	20.6	8.3	57.2	0.0	0.4
		9/03/2008	6.1	16.3	17.0	22.7	36.1	0.0	1.7
		9/5/2012	**2.6**	**21.4**	**24.4**	**5.4**	**45.5**	**0.0**	**0.8**
	0.2	9/30/2000	1.4	23.7	41.8	20.5	11.7	0.5	0.4
		9/10/2007	0.9	34.7	20.3	33.0	10.0	0.0	1.1
SHG Reference Model			**8.0**	**19.0**	**23.0**	**21.0**	**28.0**	**0.5**	**0.5**

Appendix 9: Percent composition of macroinvertebrate functional feeding groups for SHG tributary streams on all sampling dates. Shaded cells indicate waters within the influence of the mine.

Location	Site (RM)	Date	Collector-Gatherer	Collector-Filterer	Predator	Shredder-Detritivore	Shredder-Herbivore	Scraper
Copperas Brook	0.1	9/30/2000	0.0	10.0	20.0	25.0	0.0	10.0
		9/05/2012	**5.7**	**13.8**	**0.8**	**79.7**	**0.0**	**0.0**
Abbott Brook	0.6	**9/7/2012**	**56.7**	**12.4**	**15.0**	**13.0**	**0.0**	**2.6**
Sargent Brook	0.2	9/30/2000	42.8	13.4	23.4	2.9	0.3	16.9
		9/10/2007	17.9	19.6	31.6	10.0	0.0	17.6
Lords Brook	3.4	9/30/2000	39.5	15.1	17.3	4.4	0.2	21.8
		8/31/2010	39.1	7.4	19.6	5.1	0.0	28.4
		9/5/2012	**33.1**	**20.9**	**12.7**	**8.7**	**0.1**	**23.5**
	3.3	9/30/2000	53.5	11.5	17.4	12.8	0.0	4.8
		9/10/2007	20.4	50.0	14.5	11.4	0.0	3.3
		9/03/2008	26.1	29.2	32.9	5.1	0.0	6.7
		8/31/2010	24.6	50.2	13.1	8.1	0.0	4.0
		9/5/2012	**40.0**	**38.8**	**10.5**	**7.4**	**0.0**	**2.9**
	0.2	9/30/2000	61.9	19.0	12.2	2.6	0.9	3.5
		9/10/2007	38.7	31.9	15.3	4.1	0.0	2.6
SHG Reference Median			**31.0**	**18.0**	**19.0**	**15.0**	**1.0**	**12.0**

Appendix 10: Water quality parameters from 2007-2010 from Lords Brook and a tributary that drained the Elizabeth Mine South Cut. T=total, D=dissolved (filtered). In 2008 total metals samples were also collected, and in 2010 only total metals were collected and are reported here as D/T. Both dissolved and total nickel, copper, cadmium, lead, chromium, zinc and arsenic were all below detection levels. Shaded cells indicate waters within the influence of the mine.

Site	Date	pH	Alk mg/l	Specific Conductance µS	DCl mg/l	TSO4 mg/l	DCa mg/l	Turbidity NTU	DP ug-P/l	TN mg-N/l
3.4	8/2010	7.74	23.9	60.3	<2	4.42	8.1	<0.2	11.1	0.14
3.3	9/2007	7.35	17.3	77.6	<2	14.3	8.8	<0.2	<5	0.14
	9/2008	7.56	20.0	76.3	<2	14.7	9.45	<0.2	5.6	0.12
	8/2010	7.68	23.7	82.5	<2	12.9	10.7	<0.2	12.4	0.14
0.2	9/2007	7.64	62.2	152	4.7	5.3	22.0	0.3	<5	0.15
Tributary	8/2010	7.14	11.3	214	<2	75.2	28.5	<0.2	11.3	0.11

Site	Date	D/T Fe ug/l	D/T Mn ug/l	D/T Mg mg/l	DNa mg/l	DK mg/l	D/TCu ug/l	Hardness mg/l	D/T Al ug/l
3.4	8/2010	-/<50	-/<5	-/1.02	1.38	1.33	-/<10	24.3	-/<10
3.3	9/2007	<50/-	<5/	1.34/-	1.36	1.63	<10/-	27.5	<10/-
3.3	9/2008	<50/<50	<5/<5	1.33/1.34	1.38	1.39	<10/<10	28.9	11.0/12.0
3.3	8/2010	-/<50	-/<5	-/1.43	1.45	1.47	-/<10	32.7	-/<10
0.2	9/2007	-/<50	-/<5	-/1.77	4.48	2.41	-/<10	58.3	-/<10
Tributary	8/2010	-/<50	-/<5	-/4.1	1.86	2.58	-/**22.1**	88	-/<10

Appendix 11: Water quality parameters from 2011 and 2012 for local impacted and control streams. Shaded cells indicate waters within the influence of the mine.

Location	RM	Date	Type	Level	Cond µS	pH	Color	Turbidity NTU	TP ug/l	TN mg/l	SO4 mg/l	Cl mg/l	Alk mg/l
Copperas Brook	0.1	3/11	base	Low	809	7.58							
		5/11	freshet	Low	795	7.42							
		611	base	mod									
		7/11	freshet	low				29					
		8/11	freshet	mod				96					
		10/11	freshet	mod	761	7.93		40					
		4/12	base	mod	732	7.44							
		6/12	base	mod	764	7.90	500						
		7/12	base	mod	1392	7.86	175						
		8/12	freshet	mod	1115	7.78							
		9/12	base	mod	1629	7.73	500	43.2	10.7	0.4		11.9	41
Abbott Brook Tributary	0.6	9/12	base	mod	220	8.09	10	< 0.2	5.8	0.2	4.9	15.7	77
Lords Brook Tributary (drains South Cut)	0.1	5/12	freshet	mod	139	7.10	10						
		6/12	base	mod	149	7.40	8						
		7/12	base	mod	182	7.50							
		8/12	freshet	mod	206	7.65							
		9/12	base	mod	219	7.41		< 0.2	6.17	< 0.1	78.5	< 2	16
Lords Brook	3.4	9/12	base	mod	50	7.49	15	0.7	7.3	< 0.1	3.8	< 2	16
	3.3	8/11	freshet	mod				1.5					
		5/12	freshet	mod	55	7.30	15						
		6/12	base	mod	62	7.30	10						
		7/12	base	mod	65	7.57	10						
		8/12	freshet	mod	78	7.73							
		9/12	base	mod	85	7.44	15	0.6	7.3	< 0.1	17.8	< 2	16

Appendix 12: Water Quality Metals 2011-12- Total metals collected at stream locations draining the Elisabeth Copper Mine and Lord Brook 3.4. Shaded cells indicate waters within the influence of the mine

Location	Station	Date	Flow Type	Flow Level	Turb NTU	Hardness mg/l	Al ug/L	As ug/L	Ca mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	K mg/L	Mg mg/L	Mn ug/L	Na mg/L	Ni ug/L	Pb ug/L	Zn ug/L
Copperas	0.1	3/31/11	base	low		329		1	96	1.21	5	**157**	**31.8**	6.35	21.7	956	4.6	9.72	1	107
		5/12/11	freshet	low						1.09	5	**164**	**14.7**			468		5.46	1	
		6/7/11	base	mod		817		1	249	1	5	94.5	**5.35**	13.8	47.5	631	7.84	5	1	56
		7/14/11	freshet	low	29	1646	422	0.43	502	0.77	0.9	84	**6.38**	27.6	95.4	877	14.8	20	0.42	37.7
		8/16/11	freshet	mod	96	448	**7300**	0.54	142	**18.9**	14.1	**173**	**15.6**	9.38	22.6	1990	5	117	3.1	1660
		10/26/11	freshet	mod	40	404	14.1	2	125	0.05	4	< 20	**27.7**	7.72	22.4	10.9	6.39	20	0.1	20
		4/13/12	base	mod		325	180	<10	970	<20	<20	**54**	**11**	6.5	20	660	5.6	<20	<20	22
		6/6/12	base	mod		366	**1400**	<10	1200	<20	<20	**91**	**28**	7.1	16	500	6.4	<20	<20	50
		7/3/12	base	mod		748	130	<10	2600	<20	<20	43	**2.6**	14	24	410	8.7	<20	<20	<20
		9/6/12	base	mod	43.2	894	140	<10	3000	<20	<20	34	**6.8**	19	35	1100	10	<20	<20	<20
Lords Brook Trib 2	0.1	5/4/12	freshet	mod		52	<110	<10	170	<20	<20	**20**	0.08	1.7	2.4	20	1.1	<20	<20	**46**
		6/6/12	base	mod		56	<110	<10	180	<20	<20	**14**	<0.04	1.8	2.7	<20	1.2	<20	<20	**34**
		7/3/12	base	mod		71	<110	<10	230	<20	<20	**13**	<0.04	2.1	3.3	<20	1.5	<20	<20	25
		9/5/12	base	mod	< 0.2	90	<110	<10	290	<20	<20	**11**	<0.04	2.8	4.2	<20	1.7	<20	<20	23
		10/16/12	base	mod		70	<110	<10	220	<20	<20	**13**	<0.04	2.3	3.6	<20	1.4	<20	<20	**41**
Lords Brook	3.4	9/5/12	base	mod	0.74	20	<110	<10	63	<20	<20	<10	0.05	1	0.95	<20	1.3	<20	<20	<20
	3.3	8/16/11	freshet	mod	1.5	30	119	0.25	10	0.07	0.75	**6.9**	0.19	1.29	1.31	24.2	1.01	1.5	0.29	13.5
		5/4/12	freshet	mod		18	<110	<10	59	<20	<20	<10	0.07	ND	0.9	<20	ND	<20	<20	<20
		6/6/12	base	mod		22	<110	<10	72	<20	<20	<10	<0.04	1	1	<20	1	<20	<20	<20
		7/3/12	base	mod		25	<110	<10	83	<20	<20	<10	<0.04	1.4	1.1	<20	1.2	<20	<20	<20
		9/5/12	base	mod	0.64	34	<110	<10	110	<20	<20	<10	<0.04	1.6	1.5	<20	1.4	<20	<20	<20
		10/16/12	base	mod		26	<110	<10	80	<20	<20	<10	<0.04	1.2	1.5	<20	1.2	<20	<20	<20

Metals shown in red are above the MAC or AAC for ALS. Samples collected March-June 2011 were analyzed at VTDEC, samples collected from July – Oct 2011 analyzed by Test America, all samples collected in 2012 were analyzed by EPA contract lab Weston. MDL's indicated by < sign. Hardness is over 100mg/l at all locations based on earlier samplings