APPENDIX D

Seasonal Monitoring in Chamberlain Creek and Cove Creek, 2003 to 2005

SEASONAL MONITORING
OF
CHAMBERLAIN AND COVE CREEKS

PER CAO LIS 03-061
SECTION B.3.

December 9, 2005

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1.0 INTRODUCTION

In June of 2003, the Dresser Industries – Magcobar (DIM)* Mine Site Water Treatment System (WTS) began treatment operations that resulted in the permitted discharge of treated pit lake water into Cove Creek via Chamberlain Creek. The WTS is an Interim Remedial Measure implemented by TRE Management, Inc. and Halliburton Energy Services, Inc. (the Companies) under the July 7, 2000 Administrative Settlement (No. LIS 00126) between the Companies and the Arkansas Department of Environmental Quality (ADEQ).

The WTS discharge occurs under the authority of the National Pollutant Discharge Elimination System (NPDES) Permit No. AR0049794 (Permit). The Permit is subject to certain provisions of a Consent Administrative Order (CAO) No. LIS 03-061 that allows the WTS to discharge higher concentrations of dissolved minerals (sulfate, chloride, Total Dissolved Solids (TDS)). The CAO allows a temporary modification of the NPDES permit discharge limits for these minerals. The CAO also provides that the WTS discharge may occur as a hydrograph controlled release (HCR) resulting in discharges to Chamberlain Creek based on flows present in Cove Creek in order to protect water quality in Cove Creek.

Section B.3 of the CAO requires that the Companies "…undertake water quality and biological monitoring of Chamberlain Creek and Cove Creek over an approximate 24 month period consisting of six seasonal monitoring events, which shall include two spring and two summer and one fall and one winter monitoring event. Such water quality and biological sampling shall be similar to the scope and quality of such monitoring under a Use Attainability Analysis to evaluate the impact of the discharge of the WTS on these creeks."

This document provides a summary of results and conclusions from the seasonal water quality and biological monitoring conducted in Cove Creek and Chamberlain Creek between August 2003 and April 2005. This monitoring meets the requirements of Section B.3. of the CAO. The conclusions regarding the effect of the WTS discharge on Chamberlain and Cove Creeks were developed by evaluating differences among sampling sites and short term trends in

* As named by the US Environmental Protection Agency

water quality and biological communities in the creeks after WTS discharge operations began as well by reviewing WTS effluent quality as monitored under the NPDES permit.

Section 2.0 provides a summary and conclusions based on the seasonal monitoring data. Methods, results and discussion of the results are provided in Sections 3.0, 4.0, and 5.0, respectively.

2.0 CONCLUSIONS

Seasonal monitoring of Cove and Chamberlain Creeks between August 2003 and April 2005 as well as monitoring of the WTS discharge indicated the following:

1. Based on NPDES water quality monitoring data of the WTS discharge, minimal or no toxicity would be expected in Chamberlain Creek and no adverse impacts to Cove Creek would be expected with the HCR operation in place for such discharge.
2. On balance, the WTS operation results in a net positive impact to the downstream waters of Chamberlain and Cove Creeks. While operating within all permitted water quality parameters, the discharge mitigates the impact of other downstream inputs which contribute relatively high levels of acidity and dissolved metals.
3. There are inputs (acidity and dissolved metals) to Chamberlain Creek below the NPDES outfall that adversely affect water quality in Chamberlain Creek. Lower concentrations (after August 2003) of these parameters in Chamberlain Creek are indicated to be due to the influence of the WTS discharge which contributed increased pH and alkalinity to the creek.
4. Stream water quality differences between CHM-0 and CHM-2 indicate that some acidic and/or metals inputs occur downstream of the influence of the DIM site between CHM-2 and CHM-0. These inputs could include surface water or ground water.
5. No fish were present in Chamberlain Creek during the monitoring events and even though this creek does not fully attain its designated fishery use (Ouachita Mountain Ecoregion), benthic invertebrates were present at all stations during each monitoring event. A change in benthic invertebrate community composition in Chamberlain Creek during the monitoring (i.e. increased proportion of EPT individuals) probably indicates overall improvement of water quality in this creek due to the WTS discharge.
6. Fish and benthic invertebrates were present in Cove Creek at all stations during all sampling events. Cove Creek attains its designated fishery use (Ouachita Mountain Ecoregion) although impairment exists immediately below the Chamberlain Creek confluence. There were no significant water quality or biological community changes in Cove Creek upstream or downstream of Chamberlain Creek during the course of this monitoring.

3.0 METHODS

This section describes sampling locations that were established (Subsection 2.1), sampling methods used (Subsections 2.2 and 2.3), and data analyses performed (Subsection 2.4) during the monitoring from August 2003 through April 2005. WTS daily flow data and NPDES monitoring data of the WTS discharge were also obtained and reviewed as part of the study.

3.1 Sampling Stations

Five stream locations were sampled during the study (Figure 3.1). These include the following locations:

1. CHM-2: Chamberlain Creek upstream of Cove Creek at Baroid Road. This station is located a short distance downstream of the DIM Mine site and downstream of the NPDES outfall. Data from CHM-2 include inputs to the creek from the DIM Mine Site.
2. CHM-0: Chamberlain Creek just upstream of Cove/Chamberlain confluence. This station represents conditions in Chamberlain Creek at its mouth. CHM-0 was not originally included in the list of routinely monitored stations and was not sampled on the August 26, 2003 or April 29, 2004 monitoring events.
3. COV-4: Cove Creek upstream of Chamberlain. This station represents conditions in Cove Creek upstream of the Chamberlain Creek confluence.
4. COV-3: Cove Creek below the Chamberlain Creek confluence. This station represents conditions in Cove Creek immediately downstream of the Chamberlain Creek confluence.
5. COV-1: Cove Creek near the United States (US) Highway 270 bridge. This station is located downstream from the Chamberlain/Cove confluence and represents conditions near the mouth of Cove Creek.

Table 3.1 summarizes the sampling schedule beginning in August 2003.

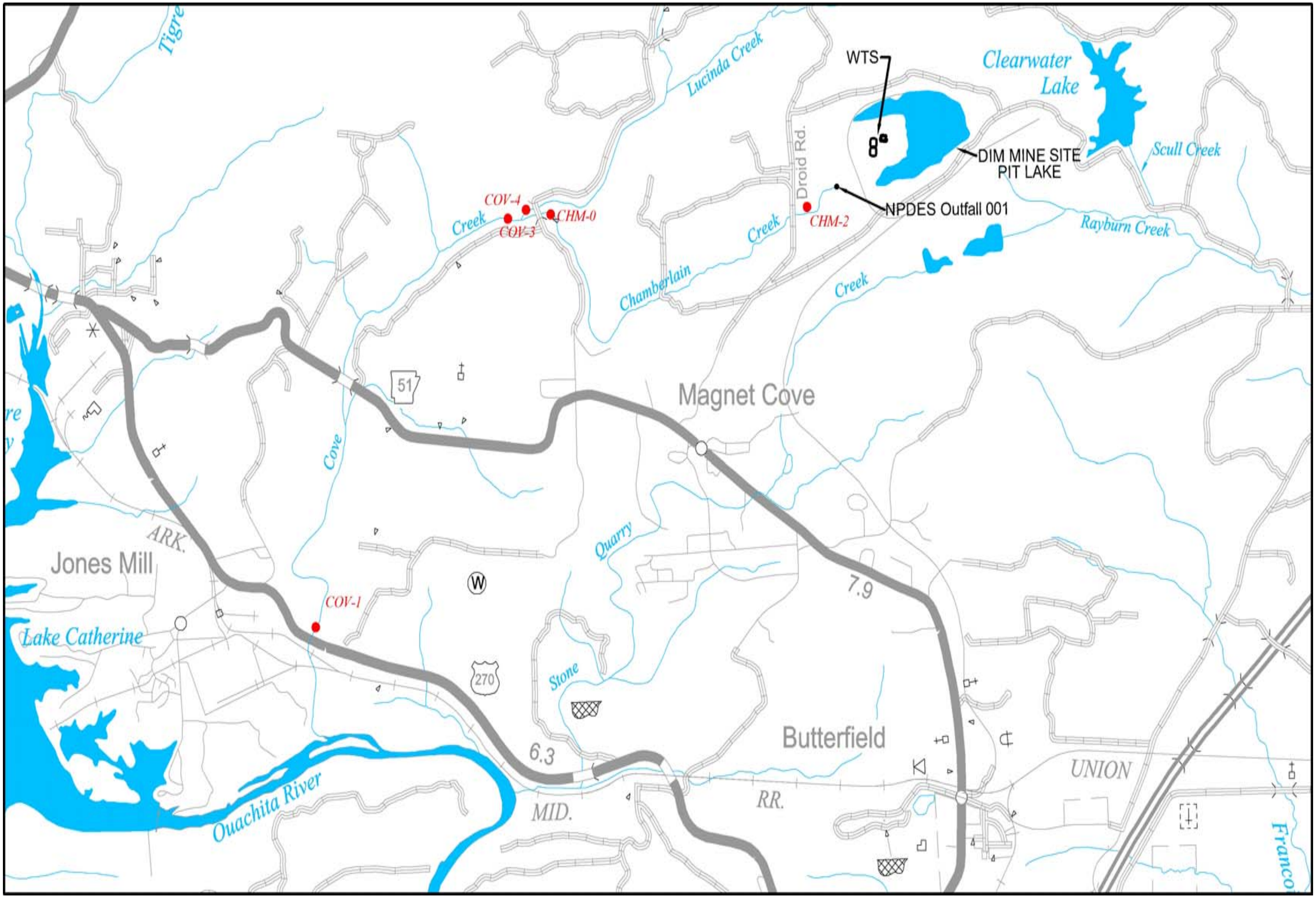


Figure 3.1. Site map and sampling locations.

Table 3.1 Sampling dates and sampled parameters for each date for seasonal monitoring conducted August 2003 through April 2005.

Sampling Location	Sampling Date					
	8/26-27/03	1/14/04	4/27-29/04	8/25-26/04	11/5-11/04	4/27-28/05
COV-1	1, 3, 4	3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
COV-3	1, 2, 3, 4	3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
COV-4	1, 3, 4	3	1, 2, 3	3	1, 3	1, 2, 3
CHM-0	not sampled	3	not sampled	1, 2*, 3	1, 2*, 3	1, 2*, 3
CHM-2	1, 2*, 3, 4	3	1, 2*, 3	1, 2*, 3	1, 2*, 3	1, 2*, 3

1 = Benthic macroinvertebrate communities
2 = Fish communities (semi-quantitative)
2* = Fish communities (qualitative)
3 = Water chemistry, in situ parameters, flow
4 = Habitat assessment

3.2 Habitat and Biological Sampling

Habitat assessments and sampling for benthic macroinvertebrates and fish were based on single habitat Rapid Bioassessment (RBA) procedures (Barbour et al 1999). Benthic sampling consisted of a total of 12 riffle habitat samples collected on each sampling date at each station using a 0.5 m^2 frame kicknet with a 500 u mesh. This procedure sampled approximately 3 m^2 of riffle substrate per site on each biological sampling date.

Semi-quantitative fish sampling was conducted over representative stream reaches (per Barbour et al 1999) using a DC current backpack electroshocker. Qualitative sampling was conducted on selected stream reaches using a seine. Semi-quantitative sampling was intended to assess the species composition and relative abundance of fish communities while qualitative sampling was conducted in order to assess the presence or absence of fish in the selected reaches.

Benthic samples were sorted and identified to the nearest practical taxon, usually genus, by FTN Associates, Ltd (FTN). Fish were identified to species and enumerated upon capture in the field. Flows were measured at each reach, during each sampling event, using a Marsh McBirney flow meter and wading rod per the United States Geological Survey (USGS) (1982) and FTN SOPs. Habitat evaluation was conducted only once during the monitoring period.

3.3 Water Sampling and Analysis

Grab samples and *in situ* measurements were taken from each stream reach during each sampling period indicated in Table 3.1. Grab samples were analyzed for parameters outlined in Table 3.2. Acidity and alkalinity were collected intermittently during the initial sampling periods as indicator parameters until it was determined to add them to the routine parameter list in August 2004. In situ measurements included dissolved oxygen (DO), pH, conductivity, and temperature, and were measured using a Hydrolab Minisonde/Surveyor 4a water quality meter calibrated per manufacturers specifications and FTN SOPs.

Table 3.2. Water chemistry parameters and analytical methods.

Parameter	Analytical Method	Method Detection Limit (mg/L)
Chloride	EPA 300.0	0.2
Hardness	EPA 200.7	1
Sulfate	EPA 300.0	0.2
Alkalinity (as $CaCO_3$)	EPA 310.1	1
Acidity (as $CaCO_3$)	EPA 305.1	5
Total Dissolved Solids	EPA 160.1	10
Beryllium (total recoverable)	EPA 200.8	0.0002
Cadmium (total recoverable)	EPA 200.8	0.0001
Copper (total recoverable)	EPA 200.8	0.003
Nickel (total recoverable)	EPA 200.8	0.002
Selenium (total recoverable)	EPA 200.8	0.003
Zinc (total recoverable)	EPA 200.8	0.0022
Aluminum (total recoverable) *	EPA 200.7	0.040
Beryllium (total recoverable) *	EPA 200.7	0.0003
Cadmium (total recoverable) *	EPA 200.7	0.004
Copper (total recoverable) *	EPA 200.7	0.006
Nickel (total recoverable) *	EPA 200.7	0.010
Selenium (total recoverable) *	EPA 200.7	0.070
Zinc (total recoverable) *	EPA 200.7	0.002

* Method 200.7 was used for total recoverable metals on samples collected after 8/27/03 because the 200.7 method is easier to run and works better with matrices that include solids and some other potential interferences present in this water.

3.4 Data Analysis

Water quality and biological data were summarized and analyzed for Chamberlain and Cove Creek separately. For purposes of summarizing spatial and temporal trends, water quality parameters were placed into groups related to:

- Dissolved oxygen,
- Levels of acidification (pH, acidity, total alkalinity),
- Dissolved minerals (specific conductance, TDS, chloride, sulfate, and hardness), and
- Metals (total recoverable aluminum, beryllium, cadmium, copper, nickel, selenium, and zinc).

Data analysis consisted of visual examination of the graphical plots of the data. No formal or *a posteriori* statistical analyses were performed.

Benthic macroinvertebrate data were analyzed primarily through visual examination of plots of taxa richness (total numbers of taxa) and the % of individuals belonging to the orders ephemeroptera, plecoptera, and trichoptera (EPT). These insect orders are typically considered to be made up of taxa that are, in general, relatively intolerant of degraded water quality. Fish data were analyzed through visual examination of plots of species richness (total number of species).

4.0 RESULTS

4.1 Water Quality

Detailed results of water quality analyses are presented in tabular form in Appendix A and are summarized in Table 4.1 and Figures 4.1 through 4.7.

4.1.1 Water Quality in Chamberlain Creek

Results of water quality sampling and analyses for samples collected from Chamberlain Creek stations CHM-0 and CHM-2 are plotted in Figures 4.1 through 4.4.

Measured flows at CHM-2 are included in the data plots to provide an indication of flow conditions in Chamberlain Creek at the time of sampling. DO concentrations showed differences related to season and were typically higher in CHM-0 than CHM-2 (Figure 4.1). Levels of acidification as indicated by pH, acidity and alkalinity were variable at both stations (Figure 4.1). Dissolved minerals as indicated by specific conductance, chloride, sulfate and hardness were variable at CHM-2 and slightly more variable and lower at CHM-0 (Figure 4.2).

Total recoverable metals at CHM-2 were typically highest in the August 2003 sample and variable thereafter. Total copper, nickel and zinc concentrations ranged as high as 18, 920 and 490 ug/L, respectively. An increase in concentration for some of the total recoverable metals occurred in samples collected at the end of the monitoring period on April 26 and 27, 2005 (Figures 4.3 and 4.4) at a time when low pH levels were measured.

Neither concentrations of total recoverable metals nor levels of acidification appeared to be related to changes in flows. Concentrations of dissolved minerals at CHM-0 were somewhat related to flows (Figure 4.2).

Table 4.1. Summary of water chemistry in samples collected from Cove and Chamberlain Creeks, August 2003 – April 2005.

Parameter Units	COV-1			COV-3			COV-4			CHM-0			CHM-2		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Field pH s.u.	6.9	6.1	7.3	6.1	4.8	6.6	6.7	6.6	6.9	4.5	4.3	4.8	5.1	4.0	6.3
Cond. µmho	538	152	883	567	174	898	67	51	108	1682	1016	2085	2314	2048	2437
Water temp. °C	18.4	11.6	26.2	17.6	10.1	25.4	17.6	10.5	26.7	16.2	9.1	26.0	20.1	11.1	28.9
D.O. mg/L	9.9	7.6	12.7	9.5	7.2	11.3	9.6	7.1	11.3	9.9	7.8	11.3	8.7	6.4	10.4
Acidity mg/L	5.0	5.0	5.0	9.1	5.0	19.0	5.0	5.0	5.0	43.3	9.2	95.0	17.0	5.0	32.0
Alkalinity mg/L	23.0	12.0	52.0	10.5	1.0	33.0	13.1	5.8	26.0	1.0	1.0	1.0	3.6	1.0	12.0
Aluminum µg/L	308	120	540	1880	560	5200	202	120	270	7675	2400	17000	3760	1600	5400
Beryllium µg/L	0.3	0.2	0.3	0.4	0.3	0.7	0.3	0.2	0.3	0.7	0.2	1.3	1.2	0.3	4.8
Cadmium µg/L	3.4	0.1	4.0	3.4	0.2	4.0	3.4	0.1	4.0	4.0	4.0	4.0	3.5	1.2	4.0
Chloride mg/L	11.9	3.0	20.0	12.0	3.0	18.0	2.3	1.8	2.8	37.3	24.0	52.0	55.2	41.0	63.0
Copper µg/L	5.8	4.9	6.0	5.6	3.4	6.0	5.6	3.8	6.0	9.2	6.0	12.0	9.6	6.0	18.0
Hardness mg/L	249	63.0	430	247	66.0	380	23.0	15.0	30.0	867	510	1100	1367	1200	1500
Nickel µg/L	12.1	4.5	20.0	25.8	10.0	73.0	8.7	2.0	10.0	103	43.0	200.0	127	30.0	490
Selenium µg/L	59	3	70	59	3	70	59	3	70	81	70	110	59	3	70
Sulfate mg/L	235	29	420	264	42	440	14	8	21	918	490	1200	1517	1000	2000
TDS mg/L	377	110	660	401	98	640	50	24	84	1423	790	1800	2200	1700	3000
Zinc µg/L	21	14	37	55	21	150	7	3	12	215	91	430	241	51	920

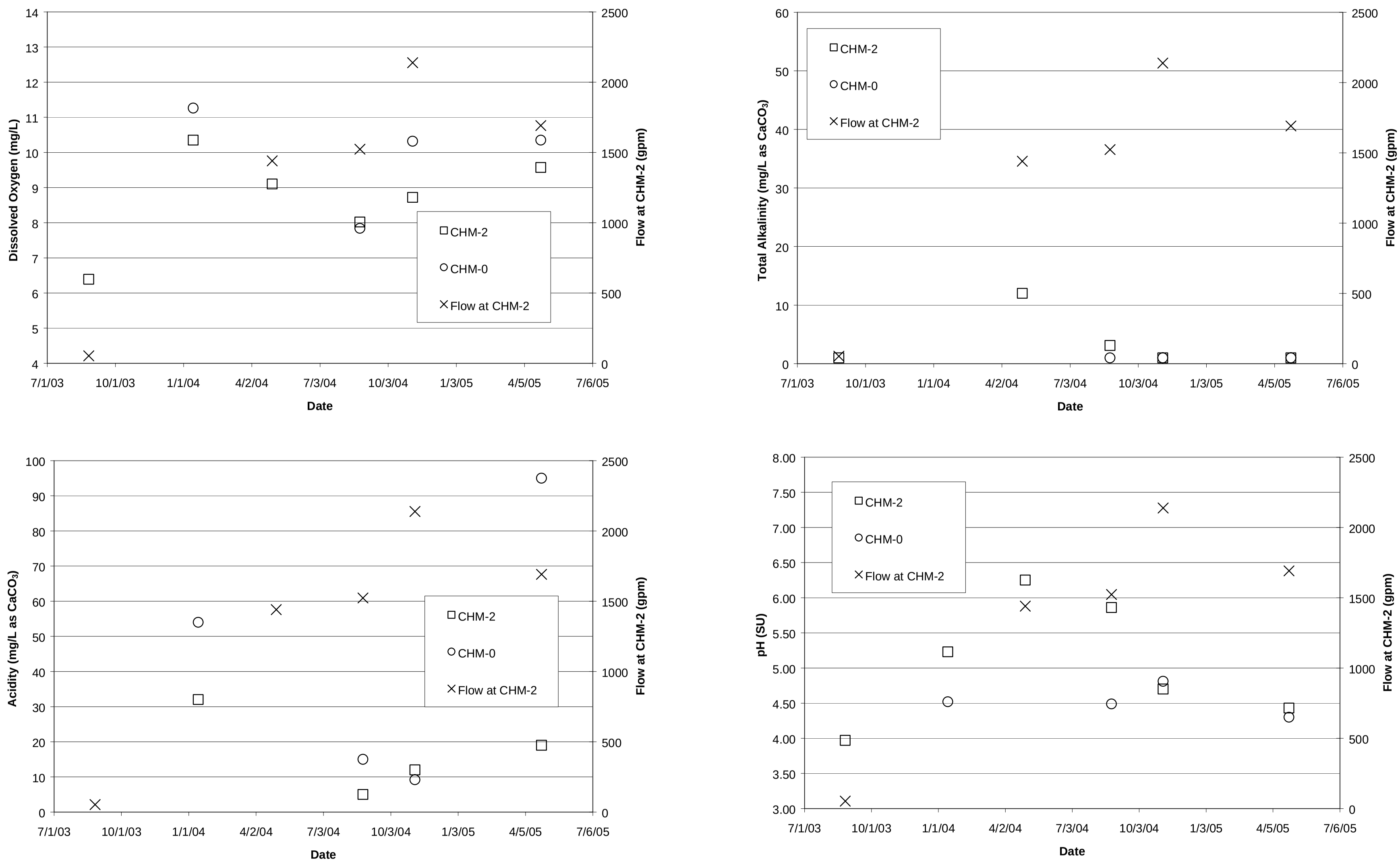


Figure 4.1 Plots of dissolved oxygen, pH, acidity, and total alkalinity in Chamberlain Creek, August 27, 2003 through August 26, 2005

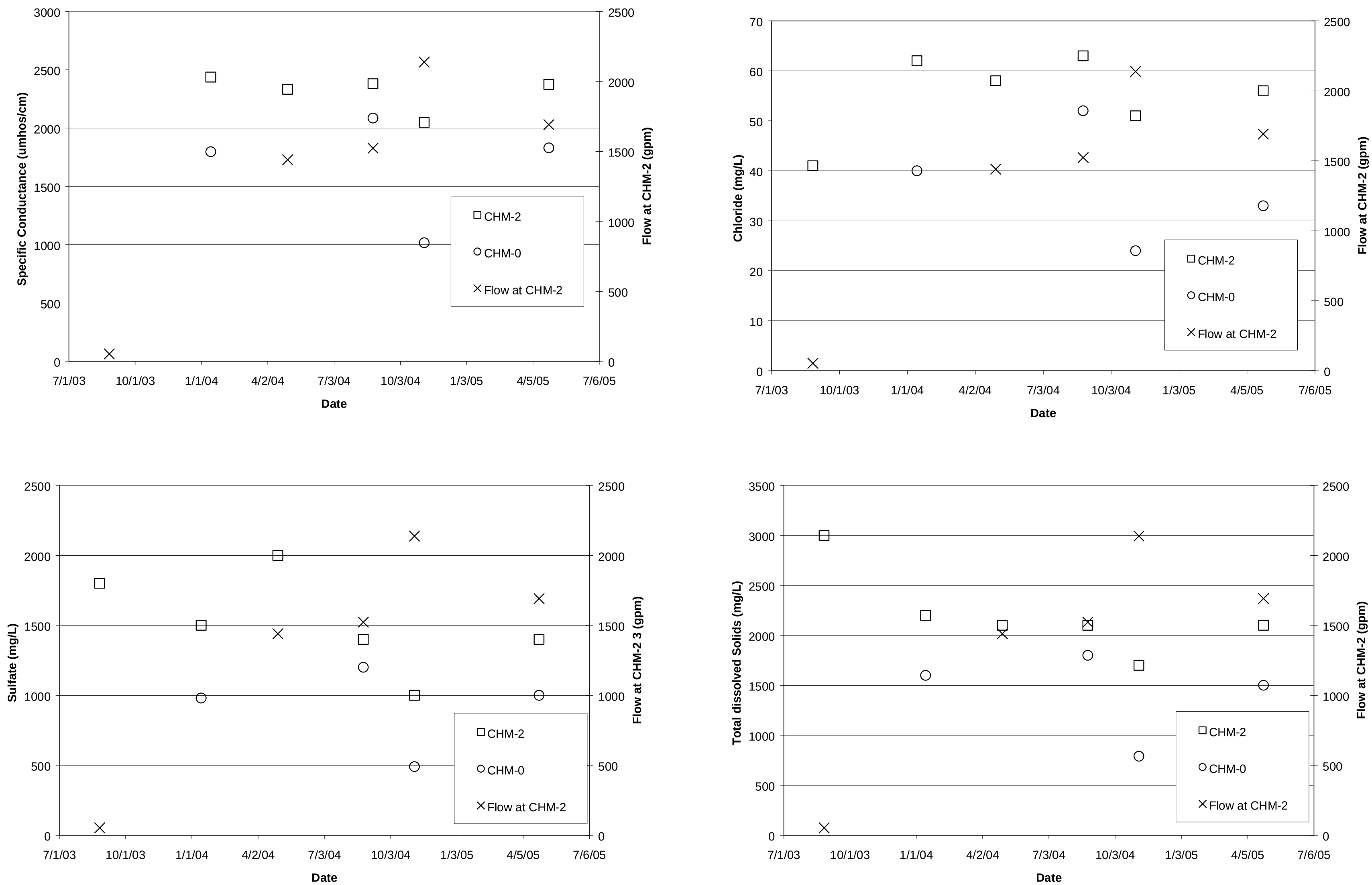


Figure 4.2 Plots of specific conductance, chloride, sulfate and total dissolved solids in Chamberlain Creek, August 27, 2003 through August 26, 2005.

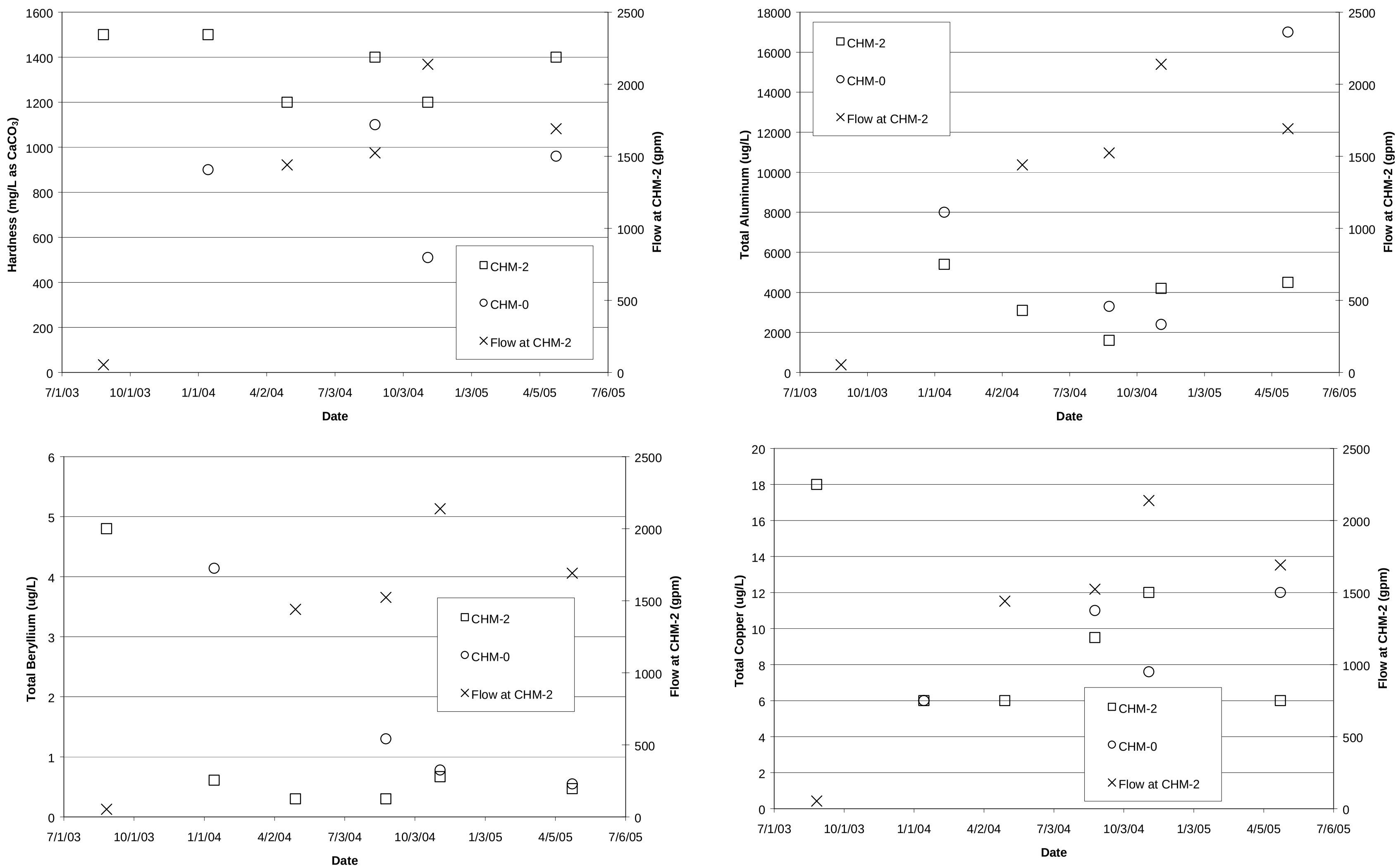


Figure 4.3 Plots of hardness and total recoverable aluminum, beryllium and copper in Chamberlain Creek, August 27, 2003 through August 26, 2005.

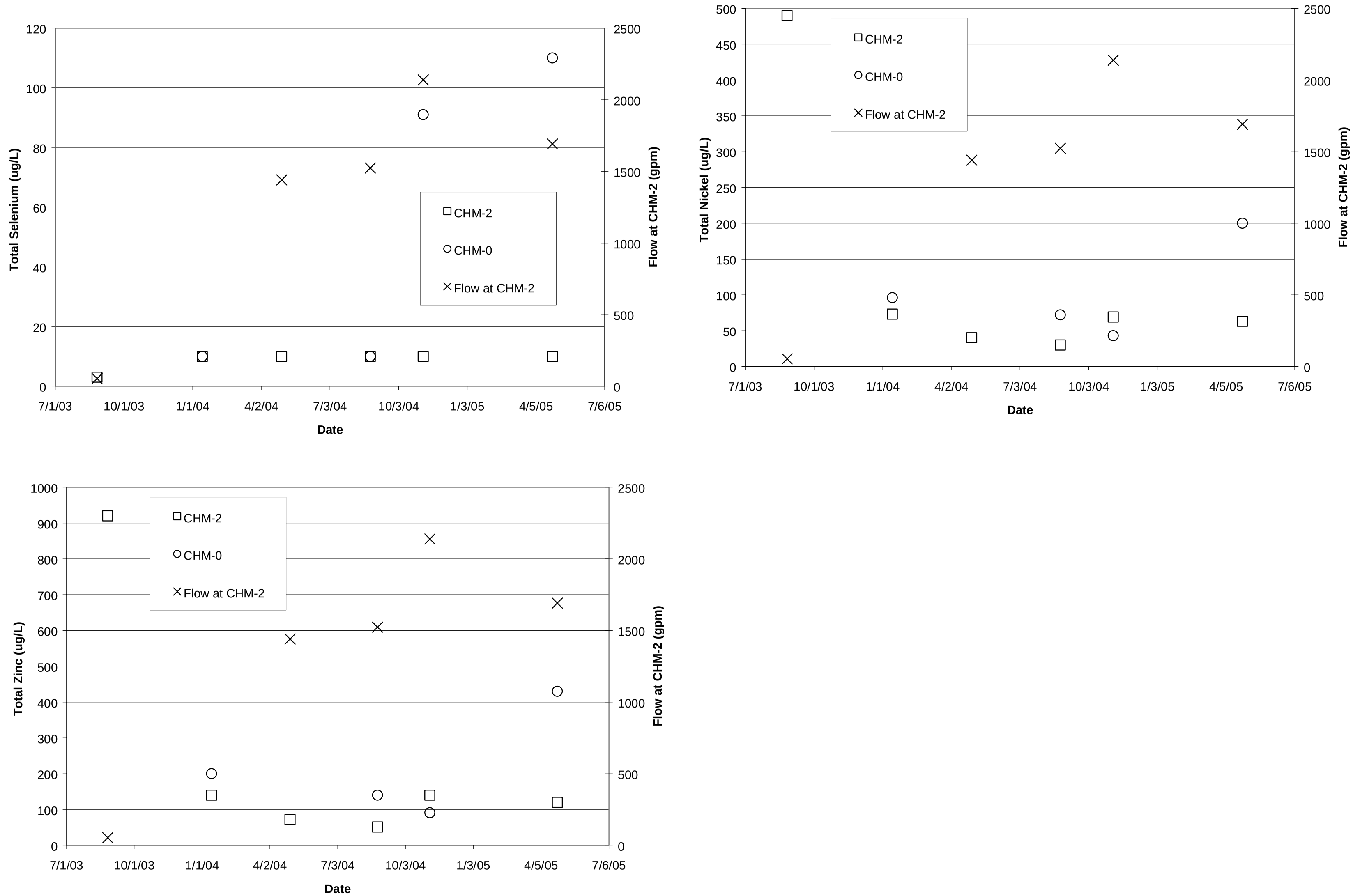


Figure 4.4. Plots of total recoverable selenium, nickel and zinc in Chamberlain Creek, August 27, 2003 through August 26, 2005.

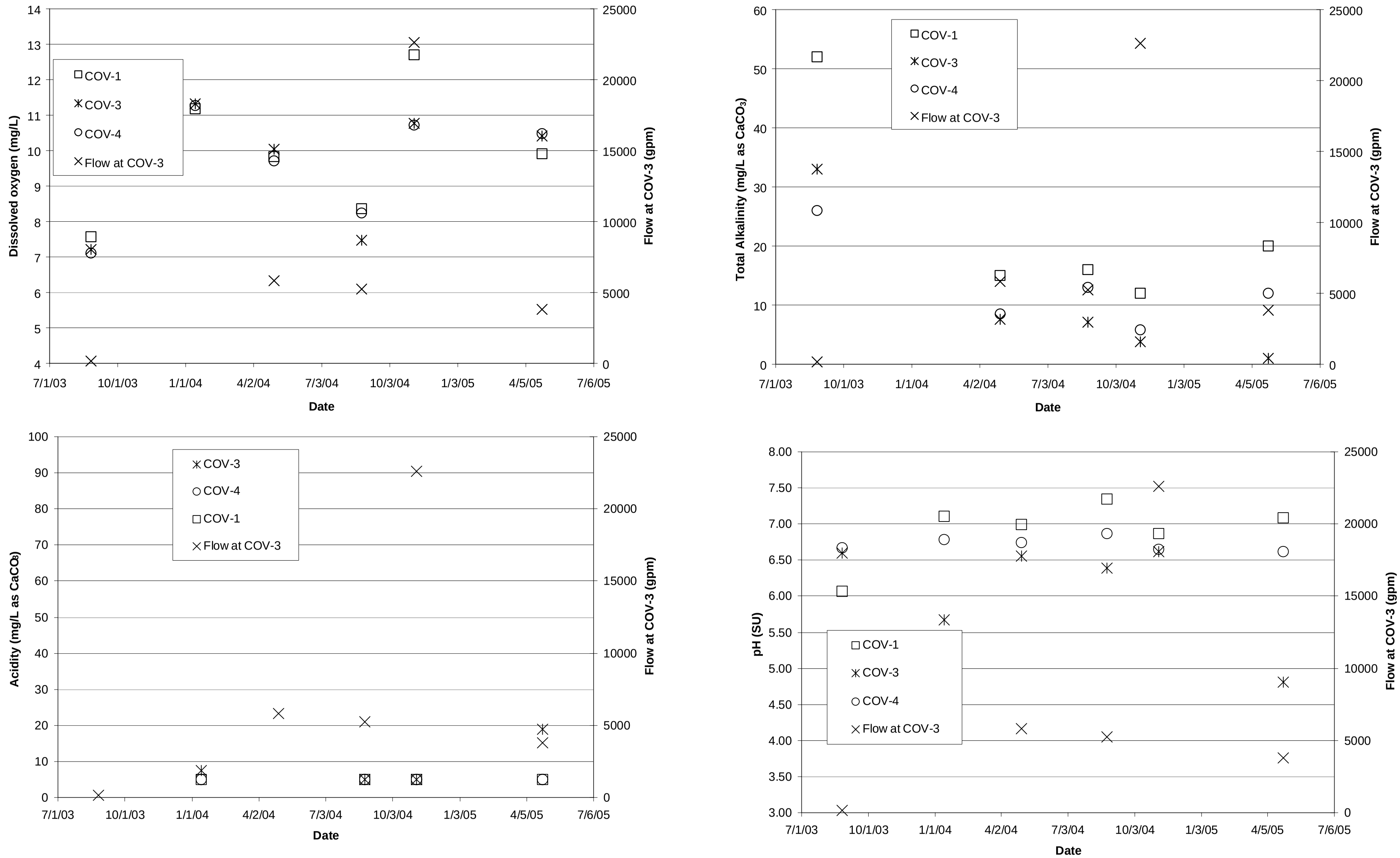


Figure 4.5. Plots of dissolved oxygen, pH, acidity and total alkalinity in Cove Creek, August 27, 2003 through August 26, 2005.

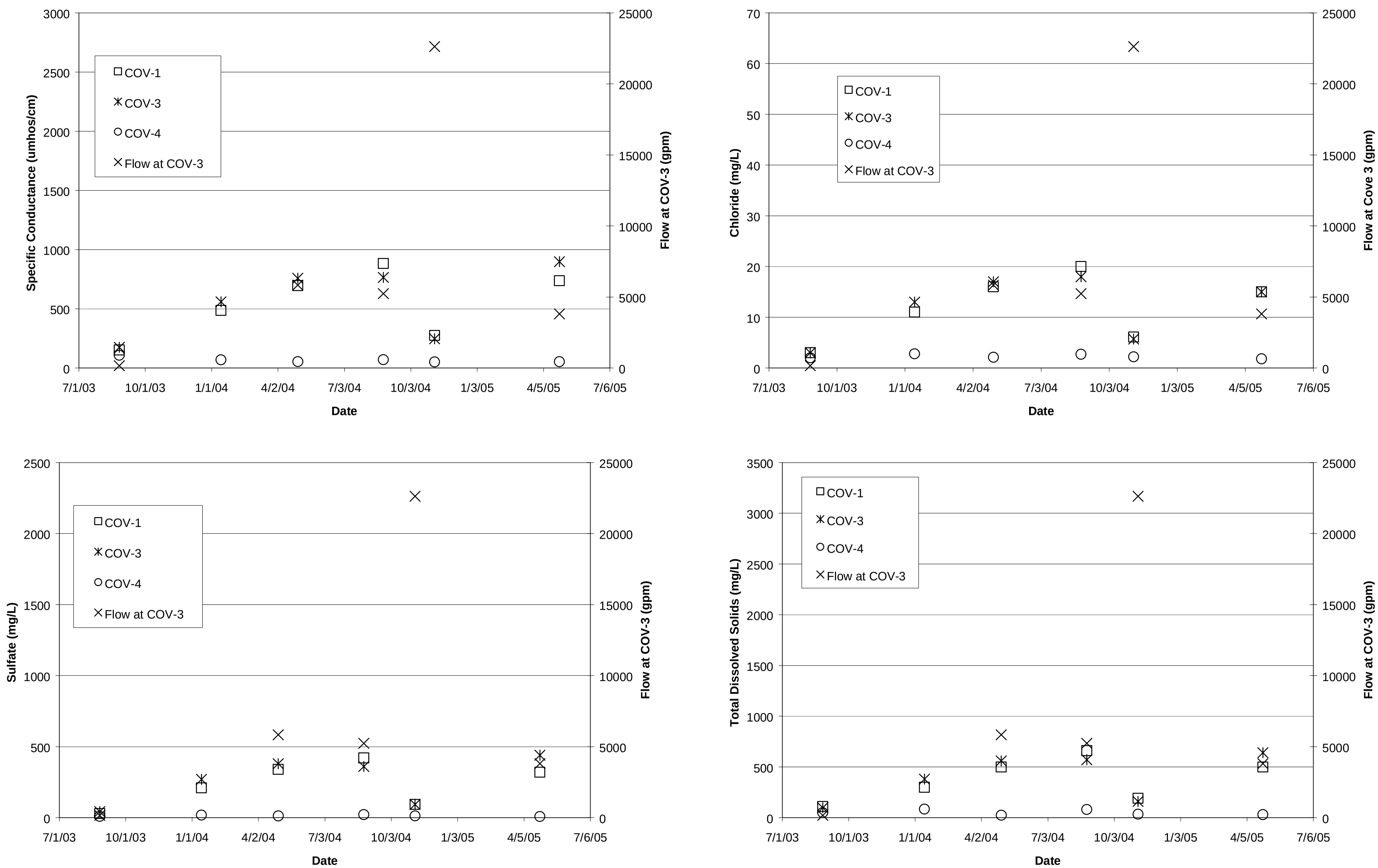


Figure 4.6 Plots of specific conductance, chloride, sulfate and total dissolved solids in Cove Creek, August 27, 2003 through August 26, 2005.

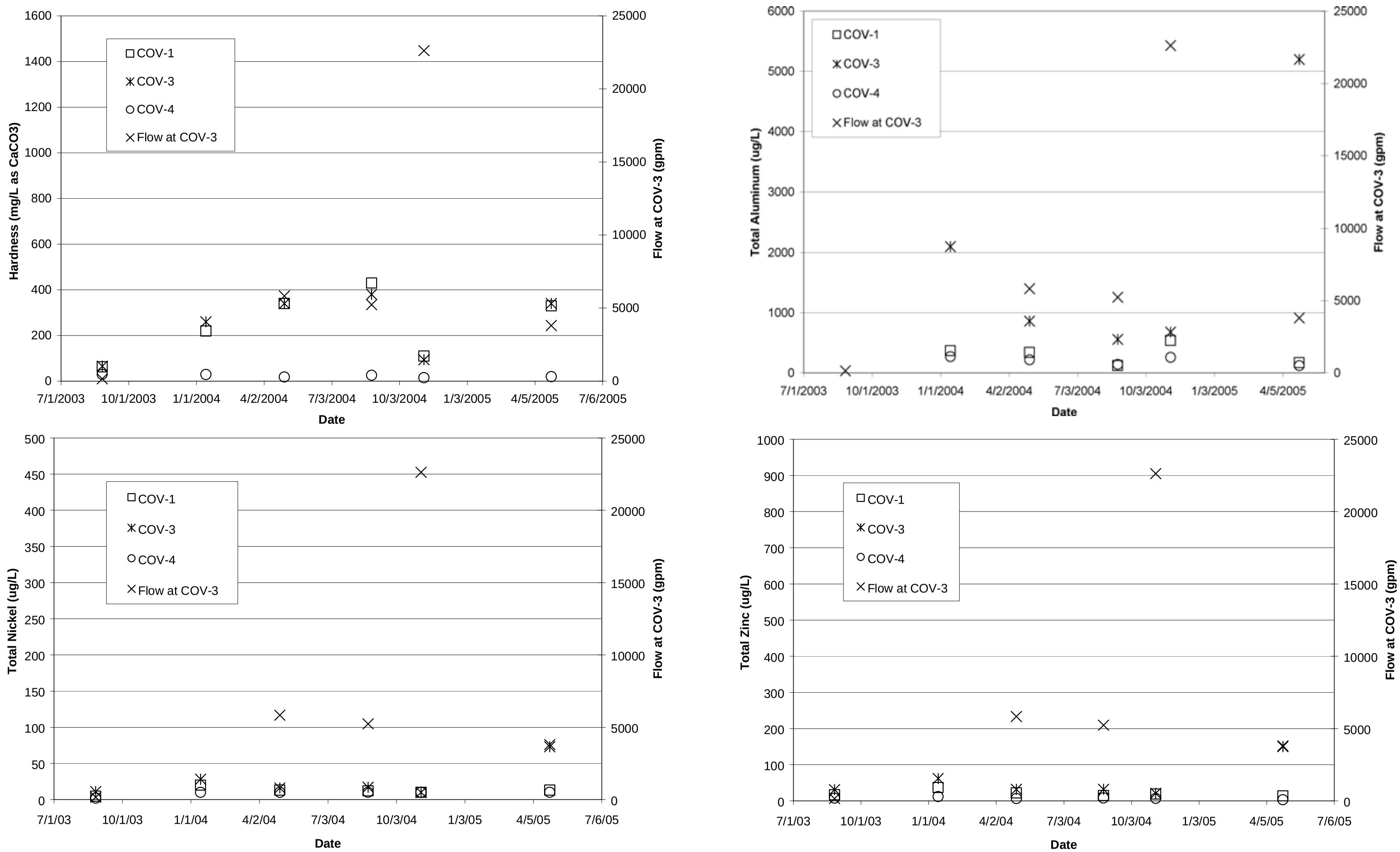


Figure 4.7 Plots of harness and total recoverable aluminum, nickel and zinc in Cove Creek, August 27, 2003 through August 26, 2005.

4.1.2 Water Quality in Cove Creek

Results of water quality sampling and analyses for samples collected from Cove Creek stations COV-1, COV-3 and COV-4 are summarized in Figures 4.5 through 4.7. Plots of beryllium, cadmium and selenium are not provided because these parameters were typically below method detection limits. Measured flows at COV-3 are included in each of the plots to provide an indication of flow conditions in Cove Creek at the time of sampling.

DO concentrations showed seasonal variation and were similar among stations (Figure 4.5). Levels of acidification were low during all monitoring events and showed no clear trends through time. Levels of pH tended to be highest at COV-1 and lowest at COV-3 (Figure 4.5). There were no trends noted at any station in levels of acidification or total recoverable metals.

Mineral concentrations were consistent at COV-4 but increased during the monitoring period at COV-1 and COV-3. Mineral concentrations were highest at COV-3 and lowest at COV-4 (Figure 4.6).

Total recoverable metals' concentrations were similar and low at all stations during the monitoring events. Aluminum and hardness values were higher in samples from the two downstream stations.

4.2 Biological and Habitat Sampling

Results of biological sampling are summarized in Figures 4.8 and 4.9 and provided in detail in Appendix B.

4.2.1 Biological Communities in Chamberlain Creek

Spatial and short-term temporal trends in Chamberlain Creek biological communities are summarized in Table 5.3.

<u>Fish</u>
No fish were captured at CHM-0 or CHM-2 by any sampling method.

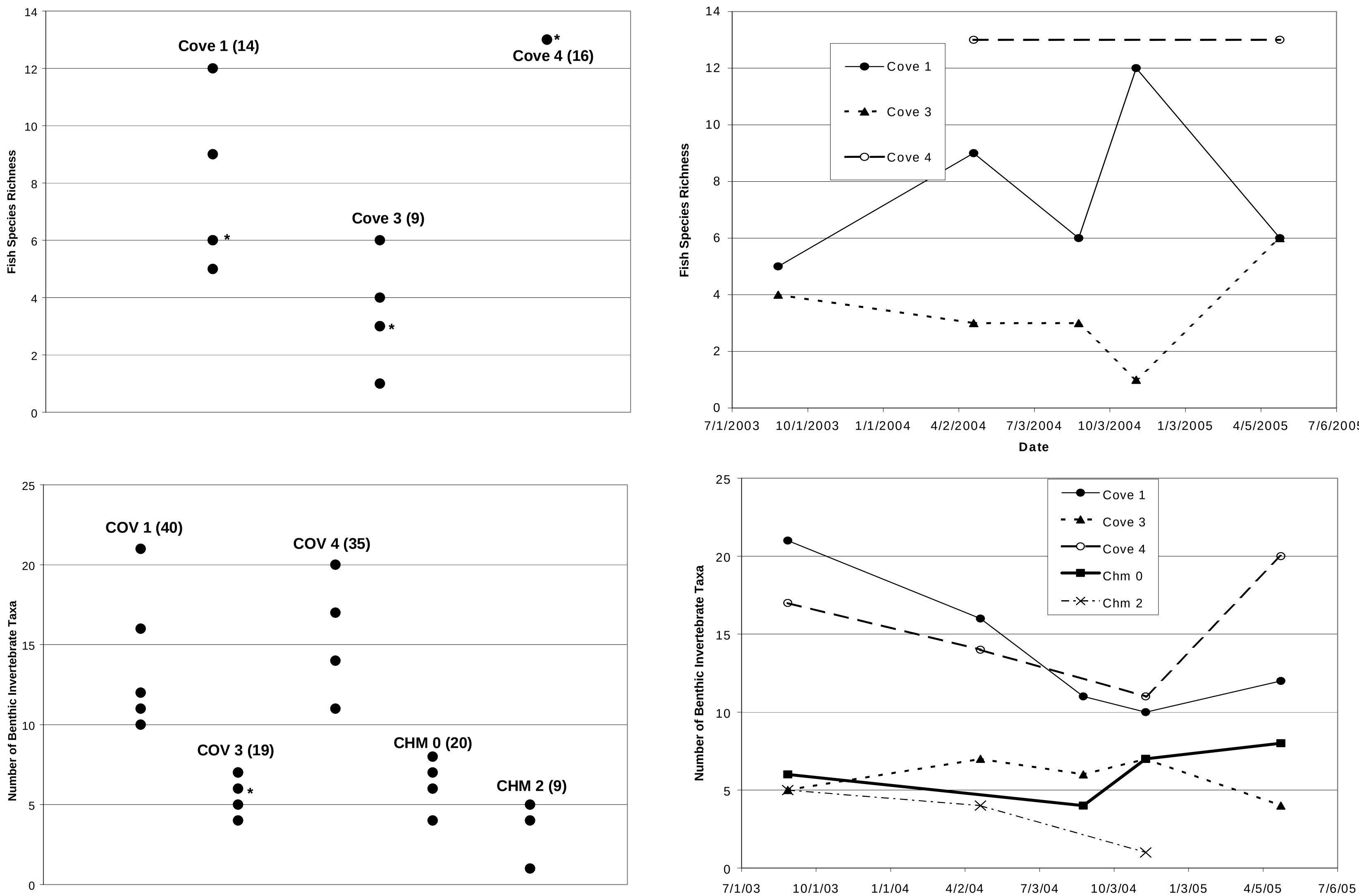
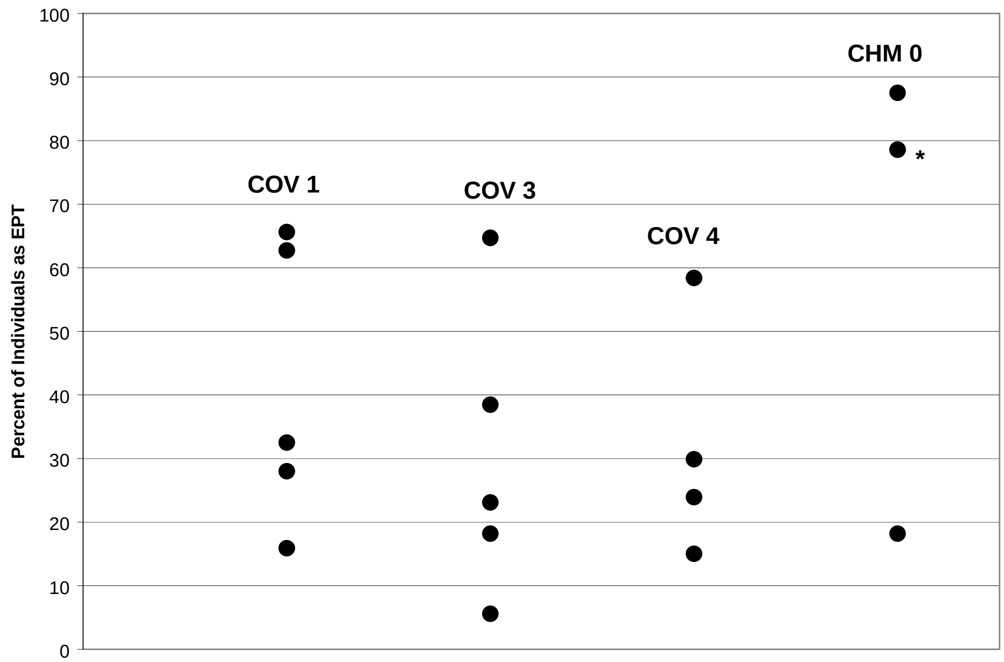


Figure 4.8 Plots of fish species (top figures) and benthic taxa richness (bottom figures) for Cove and Chamberlain Creeks, August 27, 2003 through August 26, 2005. Asterisk beside data point indicates 2 data points with the same value. Values in parenthesis indicate total number of species (taxa) collected across all sampling dates.



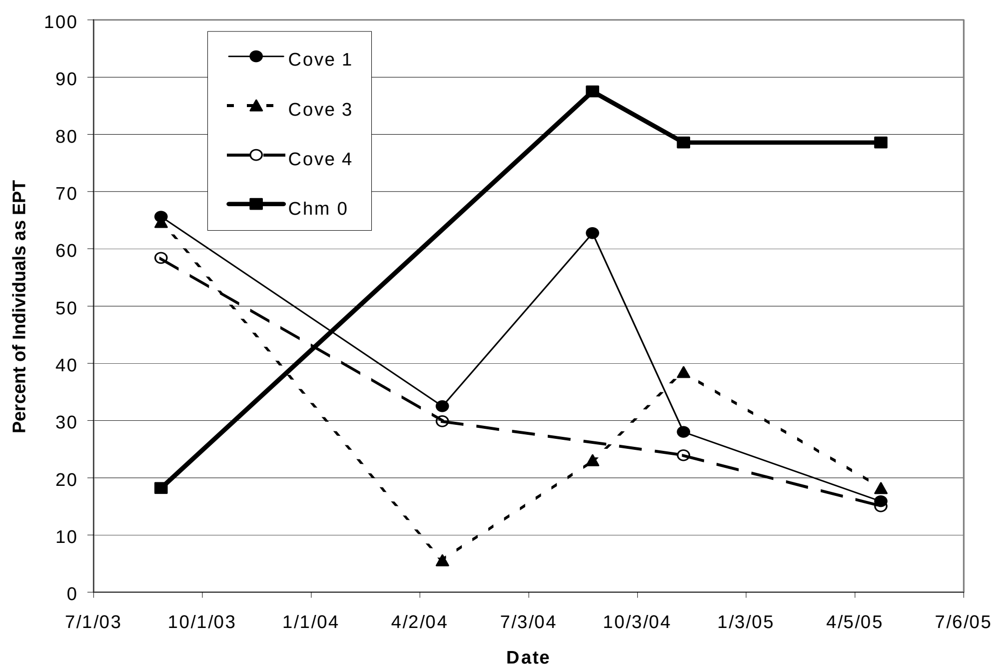


Figure 4.9 Plots of percent of individuals as EPT in Cove and Chamberlain Creeks, August 27, 2003 through August 26, 2005. Asterisk beside data point indicates 2 data points with the same value.

Benthic Macroinvertebrates

Benthic taxa richness (numbers of benthic taxa) summarized in Figure 4.8 indicates that higher numbers of taxa were collected in CHM-0 (a total of 20 taxa across all sampling dates) than in CHM-2 (total of 9 taxa across all sampling dates). A plot of bentic taxa richness vs. sampling date (Figure 4.8) indicates that the CHM-0 taxa richness was relatively constant among sampling dates, while taxa richness appeared to decline at CHM-2.

The percent of individuals as EPT in CHM-0 ranged from 18% to 88% at CHM-0 (Figure 4.9). No EPT taxa were collected at CHM-2. Figure 4.9 indicates that the percent of individuals as EPT increased between sampling dates in 2003 and 2004.

4.2.2 Biological Communities in Cove Creek

Fish

Fish species richness is compared among sampling stations and across sampling dates in Figure 4.8.

The highest fish species richness and total number of species collected across all sampling dates (16) was observed at COV-4. The lowest fish species richness and lowest total number of species collected across all sampling dates (9) was observed at COV-3. Species richness on different sampling dates overlapped between COV-1 and COV-3. Fish species richness across sampling dates showed no short-term trends (Figure 4.8.). However, Figure 4.8 also reflects somewhat greater variability in species counts in COV-1 as compared to other Cove Creek stations.

Benthic Macroinvertebrates

Benthic invertebrate taxa richness is compared among Cove Creek stations in Figure 4.8. COV-1 and COV-4 showed the highest numbers of benthic taxa. COV-1 showed the highest total taxa collected across sampling dates (40). Among Cove Creek stations, the lowest numbers of taxa and the lowest total number of taxa collected across all sampling dates was observed at COV-3.

A plot of invertebrate taxa richness vs. time (Figure 4.8) indicates that COV-3 numbers were relatively constant. Both COV-1 and COV-4 stations showed a decrease in taxa richness from August 2003 to November 2004 followed by an increase in the April 2005 samples.

The percent of total individuals as EPT was relatively constant across Cove Creek stations and decreased slightly during the monitoring period across all stations (Figure 4.9).

4.2.3 Habitat Evaluation

Habitat characteristics are summarized in Table 4.2. Habitat differences among Cove Creek stations were due primarily to differences in substrate characteristics such as embeddedness or characteristics of the riparian zone and vegetative cover. Substrate at COV-3 was distinctly embedded due to the presence of fine precipitate material resulting from the mixing of Cove Creek and Chamberlain Creek a short distance upstream of the sampling reach at COV-3.

Table 4.2 Summary of habitat parameter scores for Cove and Chamberlain Creek stations, August 2003.

Habitat Parameter	COV-1	COV-3	COV-4	CHM-2
Epifaunal substrate/available cover	18	2	18	1
Embeddedness	18	2	18	0
Velocity/depth regime	14	14	17	3
Sediment deposition	18	19	20	1
Channel flow status	13	18	13	7
Channel Alteration	18	20	20	14
Frequency of Riffles or Bends	13	15	18	8
Bank Stability	20	20	20	12
Vegetative Protection	14	18	20	16
Riparian Vegetative Zone Width	12	18	20	20
Total Score	158	146	184	82

4.3 WTS Effluent Data and Daily Flows

Figure 4.10 provides a view of the daily flows measured at the WTS discharge point. These data indicate a period of inconsistent and low maximum daily discharges before the initial sampling dates in August 2003. The second sampling event in January 2004 represents a period after significant WTS discharges had occurred but beginning in March 2004, maximum WTS daily discharges increased and stabilized at consistent levels as allowed by the HCR protocols. WTS NPDES permit monitoring data are summarized in Table 4.3. The results of the chemistry data were within NPDES permit limitations throughout the seasonal sampling.

Table 4.3. Summary of parameter concentrations reported in PCS for AR0049794.

Parameter	Monthly Average Concentration			Median	Number of Violations
	Minimum	Maximum	Average		
Aluminum, Total Recoverable (ug/L)	55	699	262	257	0
Barium, Total Recoverable (ug/L)	8	21	12	11.3	0
Beryllium, Total Recoverable (ug/L)	0	0	0	0	0
Boron, Total (ug/L)	702	1015	834	834	0
Cadmium, Total Recoverable (ug/L)	<2	<2	<2	<2	0
Chloride (mg/L)	51.3	77.9	63.2	63.85	0
Chromium, Total (ug/L)	<20	<20	<20	<20	0
Cobalt, Total Recoverable* (ug/L)	<10	19	7.3	<10	0
Copper, Total Recoverable* (ug/L)	0	<10	0.27	0	0
Iron, Total Recoverable* (ug/L)	<10	66	18.8	14	0
Lead, Total Recoverable (ug/L)	0	0	0	0	0
Manganese, Total Recoverable (ug/L)	96	4586	888	343	0
Nickel, Total Recoverable (ug/L)	0	15	1.96	0	0
pH	6.5	8.9	-	-	0
Selenium, Total Recoverable (ug/L)	0	0	0	0	0
Silver, Total Recoverable (ug/L)	0	0	0	0	0
Sulfate, Total (mg/L)	1200	1518	1324	1339	0
Total Dissolved Solids (mg/L)	2067	2280	2156	2166	0
Vanadium, Total Recoverable (ug/L	<20	<20	<20	<20	0
Zinc, Total Recoverable* (ug/L)	24	94	48	45	0

* Parameter had both detectable and non-detectable concentrations reported. Half the detection limit was used when calculating statistics.

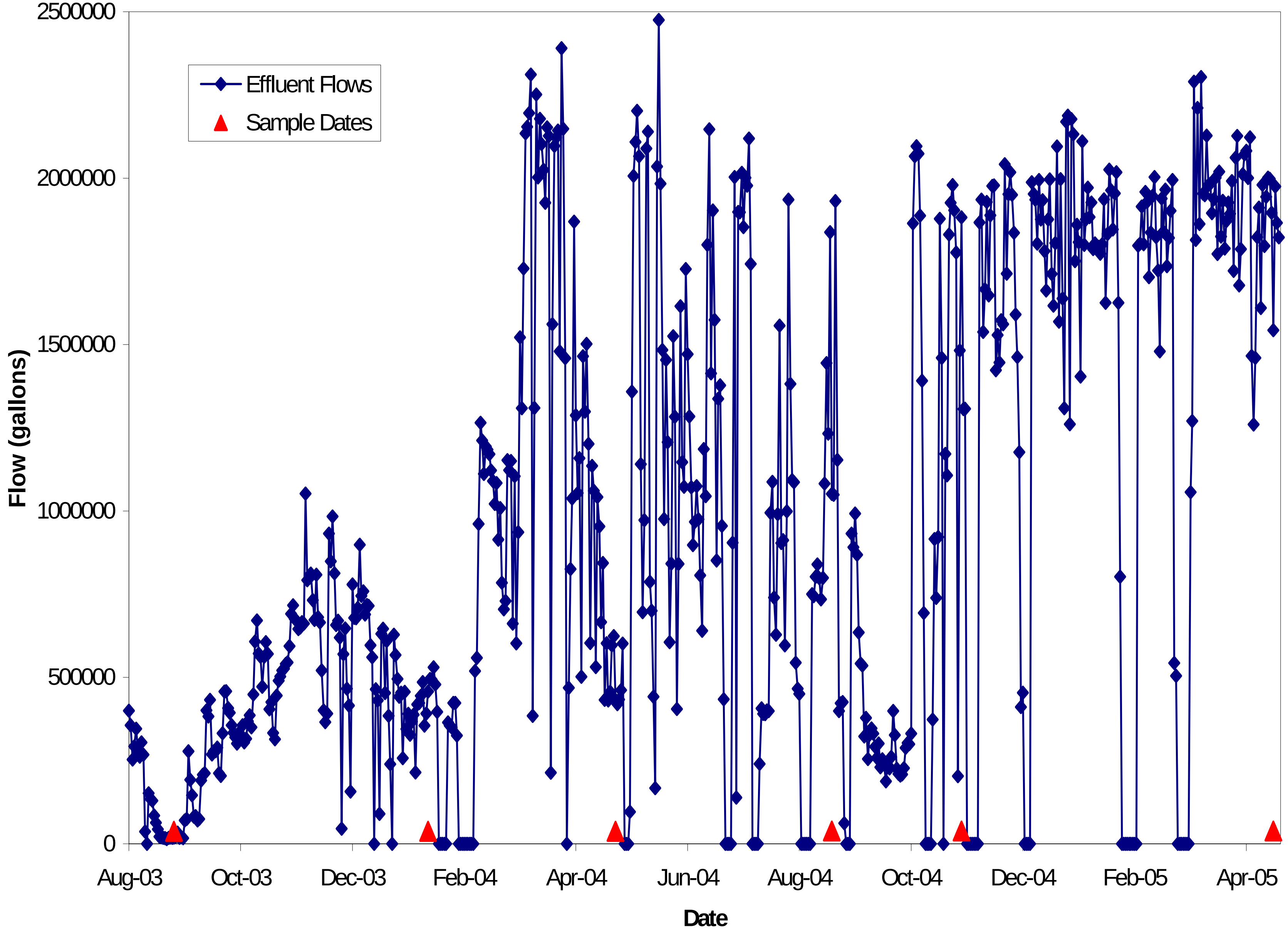


Figure 4.10. WTS daily flows.

5.0 DISCUSSION

5.1 Water Quality of the WTS Effluent

The WTS effluent consistently met NPDES permit limitations with the exception of dissolved minerals concentrations, and therefore, represents a relatively high quality inflow to upper Chamberlain Creek. This inflow mitigates the effects of acidic seepage and dissolved metals inputs to the creek. The overall impact of the WTS discharge on water quality in Chamberlain Creek is positive to the immediate downstream waters, and this positive effect carries through but is much less pronounced to neutral in the downstream reaches of Cover Creek because of the higher volumetric flows.

5.2 Water Quality of the Creeks

5.2.1 Water Quality in Chamberlain Creek

Spatial and short-term temporal trends in Chamberlain Creek water quality are summarized in Table 5.1.

Water quality in Chamberlain Creek showed little evidence of short-term trends relating to dissolved oxygen, the level of acidification, dissolved minerals or total recoverable metals. Chamberlain Creek was more acidic during the Spring 2004 sampling event relative to the other sampling dates, with pH levels near 4.5 at both locations (Figure 4.1).

CHM-0 and CHM-2 data were consistently different for most parameters with water quality at CHM-2 more of a reflection of water quality characteristics of the WTS discharge. In general, pH values were higher and acidity values were lower at CHM-2 due to the influence of the WTS effluent. Differences in water quality between CHM-0 AND CHM-2 reflect additional inputs and/or dilution to Chamberlain Creek downstream of CHM-2.

Table 5.1 Spatial and short-term temporal trends in water quality in Chamberlain Creek between August 2003 and April 2005 (See Figures 4.1 – 4.4).

Parameter Type	**Trend**	
	Short-term Temporal	**Spatial**
Dissolved Oxygen	Seasonal variation; Increase at CHM-2 after August 2003.	CHM-0 $\geq$ CHM-2
Level of acidification (pH, acidity, alkalinity)	Variable, no trend	Level of acidification at CHM-0 $\geq$ CHM-2
Dissolved Minerals (TDS, chloride, sulfate, hardness)	Variable at CHM-0; Less variable at CHM-2	CHM-0 $\leq$ CHM-2
Total Recoverable Metals (aluminum, beryllium, copper, nickel, zinc)	Highest in August 2003, variable thereafter	Variable

Total recoverable metal concentrations were, at times, elevated in Chamberlain Creek and total aluminum, copper, nickel and zinc concentrations ranged as high as 17,000, 18, 490 and 920 ug/L, respectively. Given the metal concentrations sometimes observed and other water quality factors (low pH, elevated TDS) it is likely that toxicity occurs, thereby limiting aquatic life in Chamberlain Creek. Some of the trace metals concentrations (beryllium, copper, zinc and nickel) in CHM-2 were elevated in the August 2003 sample shortly after startup of the WTS and before consistent, HRC regulated WTS discharges had occurred (Figures 4.3 and 4.4). Lower concentrations in Chamberlain Creek for these metals during the remaining monitoring dates are presumed to be due to the influence of the WTS discharge which contributed increased pH and alkalinity to the creek. Figure 4.4 shows the selenium concentrations are consistent throughout the monitoring period at CHM-2 as well as at CHM-0 during the initial sampling events but became elevated near the end of the seasonal monitoring at CHM-0. This would indicate a selenium source to the creek downstream of the DIM site. Therefore, due to the lack of fish and low taxa abundance of benthic invertebrates, Chamberlain Creek does not meet its designated fisher use.

5.2.2 Water Quality in Cove Creek

Spatial and short-term temporal trends in Cove Creek water quality are summarized in Table 5.2. Benthic and fish taxa richness were similar in COV-1 and COV-4 across all sampling periods. COV-4 is upstream of Chamberlain Creek influence and represents an expect Ouachita Mountain Ecoregion fishery. Therefore, Cove Creek upstream and downstream of COV-3 represents an expected Ouachita Mountain Ecoregion fishery.

There was a general increase in minerals concentrations in stations downstream of the Chamberlain Creek confluence as evidenced by increases in specific conductance, chlorides, sulfate and TDS (Figure 4.6). Levels of acidification, were essentially not different between COV-1 and COV-4 and pH values were typically more acidic at COV-4 than at COV-1 which may indicate increasing buffering capacity contributed by the increasing size of the watershed.

Table 5.2 Spatial and short-term temporal trends in water quality in Cove Creek between August 2003 and April 2005 (See Figures 4.5 – 4.7).

Parameter Type	Trend	
	Short-term Temporal	**Spatial**
Dissolved Oxygen	Seasonal	Similar among stations
Level of acidification (pH, acidity, alkalinity)	Levels of acidification slightly higher at beginning of monitoring period	Level of acidification at COV-3 > COV-1 > COV-4
Dissolved Minerals (TDS, chloride, sulfate, hardness)	Constant at COV-4 Increasing to asymptote at COV-1 and COV-3	COV-3 > COV-1 > COV-4
Total Recoverable Metals (aluminum, beryllium, copper, nickel, zinc)	Variable; High values at COV-3 on 4/27/05	COV-3 > COV-1 ≥ COV-4

Reduced pH values at COV-3 on April 26-27, 2005 corresponded to similar reduced pH and elevated metal concentrations at CHM-0 in samples collected at the same time (Figure 4.5).

The data indicate that the Chamberlain Creek inflow affects water quality immediately downstream in Cove Creek (at COV-3) but has little effect on water quality further downstream (COV-1).

5.3 Biological and Habitat Sampling

5.3.1 Biological Communities in Chamberlain Creek

Spatial and short-term temporal trends in Chamberlain Creek biological communities are summarized in Table 5.3.

Chamberlain Creek did not support fish populations during the monitoring period. Lack of fish in Chamberlain creek is most likely due to a combination of low pH, high TDS and metals.

Table 5.3 Spatial and short-term temporal trends in biological communities in Chamberlain Creek between August 2003 and April 2005.

Parameter	Trend	
	Short-term Temporal	Spatial
Fish Species Richness	No fish present	
Benthic Taxa Richness	Constant at CHM-0, Decreasing at CHM-2	CHM-0 > CHM-2
Benthic % EPT	Increasing at CHM-0, No EPT at CHM-2	CHM-0 >> CHM-2

The number of benthic invertebrate taxa at CHM-0 remained constant throughout the monitoring period, indicating relatively constant water quality conditions. However, the community composition at CHM-0 shifted from low to high relative abundance of EPT individuals (Figures 4.8 and 4.9). In the April 2005 samples the proportion of EPT individuals was higher in CHM-0 than at any station including the Cove Creek station upstream of the confluence of Chamberlain and Cove Creeks (Figures 4.8 and 4.9).

The shift in EPT relative abundance at CHM-0 may indicate a slight overall improvement in water quality in Chamberlain Creek. However, as long pH levels remain low and episodes of elevated metal concentrations occur, the aquatic life communities of Chamberlain Creek will remain marginal. The ability of the WTS effluent to improve water quality in Chamberlain Creek (i.e. increase alkalinity and raise pH) is overwhelmed during these high flow conditions and periods of high inflow to the creek.

5.3.2 Biological Communities in Cove Creek

Spatial and short-term temporal trends in Cove Creek biological communities are summarized in Table 5.4.

The lowest numbers of fish species and invertebrate taxa in Cove Creek were observed at COV-3. This result indicates that impairment exists immediately below the Chamberlain Creek confluence. Numbers of benthic invertebrate taxa at COV-3 were comparable to numbers at CHM-0 (Figure 4.8). A general decline and subsequent increase in the numbers of invertebrate taxa was seen at both COV-1 and COV-4 although the increase at COV-1 was less pronounced (Figure 4.8). No definitive conclusion regarding trends in benthic invertebrate communities should be made based on only 2 (or fewer) seasons of data.

Table 5.4 Spatial and short-term temporal trends in biological communities in Cove Creek between August 2003 and April 2005.

Parameter	Trend	
	Short-term Temporal	**Spatial**
Fish Species Richness	None	COV-4 > COV-1 > COV-3
Benthic Taxa Richness	Constant at COV-3; Possible decrease at COV-1	COV-1 = COV-4 > COV-3
Benthic % EPT	General decrease across stations	COV-1 = COV-4 = COV-3

5.3.3 Habitat Evaluation

The habitat evaluation indicated that the lower numbers of fish and benthic macroinvertebrates found at COV-3 corresponds to a lower habitat score at COV-3. The lower habitat score is, in turn, due to substrate embeddedness caused inorganic precipitates formed when water from Chamberlain and Cove Creeks mix.

6.0 LITERATURE CITED

Barbour, M.T., J. Gerritsen, B.D. Snyder, J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental protection agency; Office of Water; Washington, D.C.

USGS. 1982. Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge. Geological Survey Water-Supply Paper 2175.

APPENDIX A

Results of Water Quality Analysis

Table A.1. Water sampling data.

Location	Date	Field pH s.u.	Cond. µmho	Water Temp. °C	DO mg/L	Flow gpm	Acidity mg/L	Alkalinity mg/L	Aluminu m µg/L	Beryllium µg/L	Cadminum µg/L	Chloride µg/L	Copper µg/L	Hardness mg/L	Nickel µg/L	Selenium µg/L	Sulfate mg/L	TDS mg/L	Zinc µg/L
COV 1	8/26/03	6.07	152	24.5	7.57	885	-	52	-	0.2	0.13	3	4.9	63	4.5	3	29	110	17
COV 1	1/14/04	7.11	486.3	11.63	11.18	-	5	-	370	0.3	4	11	6	220	20	70	210	300	37
COV 1	4/29/04	6.99	695.9	16.21	9.83	7590	-	15	340	0.3	4	16	6	340	13	70	340	500	22
COV 1	8/26/04	7.34	882.8	26.2	8.36	4305	5	16	120	0.3	4	20	6	430	12	70	420	660	15
COV 1	11/5/04	6.87	275.4	13.5	12.7	25289	5	12	540	0.3	4	6.1	6	110	10	70	93	190	19
COV 1	4/27/05	7.09	737.7	18.57	9.91	4946	5	20	170	0.3	4	15	6	330	13	70	320	500	14
COV 3	8/26/03	6.60	174	25.4	7.21	157	-	33	-	0.28	0.16	3	3.4	66	11	3	42	98	31
COV 3	1/14/04	5.67	558.7	10.05	11.32	-	7.5	-	2100	0.39	4	13	6	260	28	70	270	380	62
COV 3	4/29/04	6.55	757.5	16.14	10.04	5830	-	7.6	860	0.3	4	17	6	340	16	70	380	560	32
COV 3	8/26/04	6.39	764.8	24.25	7.47	5235	5	7.1	560	0.3	4	18	6	380	17	70	360	570	32
COV 3	11/5/04	6.62	246.7	13.9	10.77	22624	5	3.8	680	0.3	4	5.7	6	94	10	70	93	160	21
COV 3	4/27/05	4.81	897.5	15.97	10.41	3805	19	1	5200	0.73	4	15	6	340	73	70	440	640	150
COV 4	8/26/03	6.67	108	26.7	7.11	373	-	26	-	0.2	0.1	2	3.8	30	2	3	9.7	50	7.5
COV 4	1/14/04	6.78	69	10.47	11.27	-	5	-	270	0.3	4	2.8	6	29	10	70	18	84	12
COV 4	4/29/04	6.74	53.9	15.96	9.71	3920	-	8.5	220	0.3	4	2.1	6	18	10	70	12	24	6.5
COV 4	8/26/04	6.87	70.4	24.78	8.24	1610	5	13	140	0.3	4	2.7	6	26	10	70	21	80	8.2
COV 4	11/5/04	6.65	50.9	14.14	10.72	21596	5	5.8	260	0.3	4	2.2	6	15	10	70	13	34	6.6
COV 4	4/27/05	6.62	52.6	13.34	10.48	1978	5	12	120	0.3	4	1.8	6	20	10	70	7.9	30	3.1
Chm 0	9/3/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chm 0	1/14/04	4.52	1797	9.05	11.26	-	54	-	8000	1.3	4	40	6	900	96	70	980	1600	200
Chm 0	8/26/04	4.49	2085	26.04	7.84	2199	15	1	3300	0.78	4	52	11	1100	72	70	1200	1800	140
Chm 0	11/5/04	4.81	1016	14.67	10.32	3923	9.2	1	2400	0.55	4	24	7.6	510	43	75	490	790	91
Chm 0	4/27/05	4.30	1830	15.21	10.35	1574	95	1	17000	0.21	4	33	12	960	200	110	1000	1500	430
Chm 2	8/26/03	3.97	307	28.9	6.39	53	-	1	-	4.8	1.2	41	18	1500	490	3	1800	3000	920
Chm 2	1/14/04	5.23	2437	11.13	10.35	-	32	-	5400	0.61	4	62	6	1500	73	70	1500	2200	140
Chm 2	4/29/04	6.25	2332	16.53	9.1	1440	-	12	3100	0.3	4	58	6	1200	40	70	2000	2100	72
Chm 2	8/26/04	5.86	2380	27.7	8.02	1523	5	3.1	1600	0.3	4	63	9.5	1400	30	70	1400	2100	51
Chm 2	11/5/04	4.70	2048	17.82	8.72	2138	12	1	4200	0.67	4	51	12	1200	69	70	1000	1700	140
Chm 2	4/27/05	4.43	2374	18.4	9.57	1691	19	1	4500	0.47	4	56	6	1400	63	70	1400	2100	120

APPENDIX B

Results of Biological Sampling

Cove-01

Order	Family	Genus	27-Aug-03 Total organisms	21-Apr-04 Total organisms	26-Aug-04 Total organisms	11-Nov-04 Total organisms	27-Apr-05 Total organisms	
Annelida	Oligochaeta		2	10	3	0	3	1
Coleoptera	Elmidae	*Stenelmis*	23	29	11	0	32	1
Coleoptera	Psephenidae	*Psephenus*	3	1	4	2	0	1
Coleoptera	Gyrinidae	*Dineutus*	0	0	1	0	0	1
Decapoda	Cambaridae		13	42	5	0	19	1
Diptera	Simuliidae		1	0	0	0	0	1
Diptera	Chironomidae		0	3	0	0	5	1
Diptera	Tabanidae	*Tabanus*	0	0	1	0	0	1
Diptera	Tipulidae	*Tipula*	0	0	0	2	2	1
Diptera	Empipidae		0	0	0	0	1	1
Diptera	Ceratopogonidae		0	0	0	0	1	1
Ephemeroptera	Heptageniidae	*Stenacron*	3	0	0	0	0	1
Ephemeroptera	Leptophlebidae		1	0	0	0	0	1
Ephemeroptera	Heptageniidae	*Stenonema*	2	0	0	3	0	1
Ephemeroptera	Caenidae	*Caenis*	0	10	0	0	0	1
Ephemeroptera	Unk*		0	16	2	0	1	0
Ephemeroptera	Baetidae	*Pseudocleon*	0	5	0	0	0	1
Ephemeroptera	Heptageniidae		0	0	2	0	0	0
Ephemeroptera	Ameletidae	*Ameletus*	0	0	0	0	4	1
Hemiptera	Veliidae	*Microvelia*	2	0	0	0	0	1
Hemiptera	Veliidae	*Rhagovelia*	2	0	0	0	0	1
Hemiptera			1	0	0	0	0	1
Homoptera			0	0	3	0	0	1
Hymenoptera			0	1	0	0	0	1
Isopoda			6	0	0	0	0	0
Isopoda	Asellidae	*Lirceus*	0	16	0	84	80	1
Isopoda	Asellidae		0	0	31	0	0	0
Megaloptera	Corydalidae	*Corydalus*	1	3	0	0	0	1
Megaloptera	Corydalidae	*Nigronia*	1	0	1	1	0	1
Megaloptera	Sialidae	*Sialis*	0	1	0	0	0	1
Odonata	Coenagrionidae		0	1	0	0	0	1
Odonata	Gomphidae	*Gomphus*	0	1	0	0	0	1
Odonata	Calopterygidae	*Calopteryx*	0	0	0	1	0	1
Plecoptera	Perlodidae	*Isoperla*	1	0	0	0	0	1
Plecoptera	Chloroperlidae	*Alloperla*	2	0	0	0	0	1
Plecoptera	Nemouridae	*Amphinemerua*	0	3	0	0	1	1
Plecoptera	Perlidae	*Neoperla*	0	3	0	1	1	1
Plecoptera			0	0	8	0	0	0
Trichoptera	Hydroptilidae		1	0	0	0	0	1
Trichoptera	Philopotamidae	*Chimarra*	67	0	21	25	0	1
Trichoptera	Hydropsychidae	*Hydropsyche*	15	0	0	2	0	1
Trichoptera	Hydropsychidae	*Cheumatopsyche*	7	0	19	4	0	1
Trichoptera	Hydropsychidae	*Hydropsyche*	2	15	0	0	20	1
Trichoptera	Hydropsychidae		1	0	1	0	0	0
Trichoptera	Unknown		1	0	0	0	0	0
Trichoptera	Polycentropidae	*Cernotina*	2	0	0	0	0	1
Trichoptera	Hydropsychidae	*Ceratopysyche*	0	0	48	0	0	1
		Count totals	160	160	161	125	170	
		Total Taxa	21	16	11	10	12	40

"= not counted towards Total Taxa"

	27-Aug-03	21-Apr-04	26-Aug-04	11-Nov-04	27-Apr-05
%EPT	66	33	63	28	16
Cove 1	66	33	63	28	16
Cove 3	65	6	23	38	18
Cove 4	58	30		24	15
Chm 0	18		88	79	79
Chm 2	0	0		0	

Cove-03

Order	Family	Genus	26-Aug-03 Total organisms	21-Apr-04 Total organisms	26-Aug-04 Total organisms	11-Nov-04 Total organisms	27-Apr-05 Total organisms	Taxon
Coleoptera	Psephenidae	*Psephenus*	0	1	1	0	2	1
Coleoptera	Elmidae	*Stenelmis*	0	1	0	1	0	1
Decapoda	Cambaridae		4	0	1	1	0	1
Diptera	Tipulidae	*Tipula*	0	7	1	2	7	1
Diptera	Tipulidae		0	1	0	0	0	0
Isopoda	Asellidae	*Lirceus*	0	4	0	1	0	1
Isopoda	Asellidae		0	0	4	0	0	0
Lepidoptera	Pyralidae	*Paraponyx*	1	0	0	0	0	1
Lepioptera	Noctuidae	*Simyra*	0	0	1	0	0	1
Megaloptera	Corydalidae	*Nigronia*	0	2	0	0	0	1
Megaloptera	Corydalidae	*Corydalus*	0	0	1	0	0	1
Odonata	Gomphidae	*Stylogomphus*	1	0	0	0	0	1
Odonata	Gomphidae	*Gomogomph*	0	0	1	0	0	1
Oligochaeta			0	1	0	3	0	1
Plecoptera	Perlidae	*Neoperla*	0	1	0	0	0	1
Plecoptera	Leuctridae	*Zealeuctra*	0	0	0	1	0	1
Trichoptera	Polycentropid	*Polycentropu*	5	0	0	0	0	1
Trichoptera	Philopotamida	*Chimarra*	3	0	0	0	0	1
Trichoptera	Uknown		3	0	0	0	0	0
Trichoptera	Hydropsychidae		0	0	3	0	0	0
Trichoptera	Hydropsychid	*Hydropsyche*	0	0	0	4	0	1
Trichoptera	Helicopsychid	*Helicopsyche*	0	0	0	0	1	1
Trichoptera	Hydropsychid	*Ceumatopsyc*	0	0	0	0	1	1
Totals			17	18	13	13	11	19
		Total Taxa	5	7	6	7	4	19
		%EPT	65	6	23	38	18	

Cove-04

Order	Family	Genus	26-Aug-03 Total organisms	21-Apr-04 Total organism	11-Nov-04 Total organisms	27-Apr-05 Total organism	Taxon
Annelida	Oligochaeta		1	6	2	3	1
Coleoptera	Psephenidae	*Psephenus*	24	25	2	14	1
Coleoptera	Elmidae	*Stenelmis*	8	8	0	25	1
Decapoda	Cambaridae		8	16	1	34	1
Diptera	Tabanidae	*Tabanus*	4	0	0	0	1
Diptera	Culicidae		1	0	0	0	1
Diptera	Tipulidae		0	3	0	0	0
Diptera	Chironomidae		0	2	0	4	1
Diptera	Tipulidae	*Tipula*	0	0	1	2	1
Diptera	Tipulidae	*Hexatoma*	0	0	0	1	1
Diptera	Dixidae		0	0	0	1	1
Diptera	Empipidae		0	0	0	1	1
Ephemeroptera	Uknown		11	2	1	1	0
Ephemeroptera	Heptageniidae	*Stenacron*	8	4	0	0	1
Ephemeroptera	Caenidae	*Caenis*	6	0	0	0	1
Ephemeroptera	Heptageniidae	*Stenonema*	30	6	19	4	1
Ephemeroptera	Heptageniidae		16	0	0	0	0
Ephemeroptera	Ephemeridae	*Ephemera*	1	0	0	0	1
Isopoda			14	0	0	0	0
Isopoda	Asellidae	*Lirceus*	0	54	116	51	1
Lepidoptera	Pyralidae	*Petrophila*	0	1	0	0	1
Megaloptera	Corydalidae	*Nigronia*	2	0	0	0	1
Megaloptera	Corydalidae	*Corydalus*	0	0	2	0	1
Odonata	Gomphidae	*Gomphus*	2	0	0	0	1
Odonata	Coeagrioidae	*Argia*	1	0	0	0	1
Odonata	Calopterygidae	*Calopteryx*	2	0	0	0	1
Plecoptera	Perlidae	*Neoperla*	9	0	0	0	1
Plecoptera	Leuctridae	*Leuctra*	1	0	0	0	1
Plecoptera	Perlidae	*Neoperla*	0	11	10	8	1
Plecoptera	Nemouridae	*Amphinem*	0	1	0	2	1
Plecoptera	Perlidae	*Acroneuria*	0	0	0	1	1
Plecoptera	Capniidae	*Allocapnia*	0	0	0	2	1
Plecoptera*			0	6	0	0	0
Pleoptera	Perlidae	*Agnetina*	0	0	1	2	1
Trichoptera	Uknown		3	1	0	0	0
Trichoptera	Philopotamidae	*Chimarra*	9	2	5	1	1
Trichoptera	Hydropsychidae	*Cheumatop*	0	14	3	0	1
Trichoptera	Glossosomatidae	*Agapetus*	0	2	0	0	1
Trichoptera	Helicopsychidae	*Helicopysc*	0	0	0	1	1
Trichoptera	Polycentropidae	*Cernotina*	0	0	0	1	1
Trichoptera	Hydrophsychidae	*(pupae)*	0	0	0	1	1
Totals			161	164	163	160	
		Total Taxa	17	14	11	20	35
		%EPT	58	30	24	15	

Chamberlain-00

Order	Family	Genus	27-Aug-03 Total organisms	27-Aug-04 Total organisms	11-Nov-04 Total organisms	27-Apr-05 Total organisms	Taxon
Annelida	Oligochaeta		1	0	1	0	1
Coeloptera	Helophoridae	*Helphorus*	1	0	0	0	1
Coleoptera	Gyrinidae	*Gyrinus*	0	1	0	0	1
Coleoptera	Psephenidae	*Psephenus*	0	0	0	2	1
Coleoptera	Gyrinidae	*Dineutus*	0	0	0	1	1
Decapoda	Cambaridae		0	0	0	1	1
Diptera	Chironomidae		5	0	0	0	1
Diptera	Tipulidae	*Tipula*	0	0	9	7	1
Ephemeroptera	Heptageniidae	*Stenonema*	0	0	3	0	1
Hemiptera	Corixidae	*Sigara*	1	0	0	0	1
Isopoda	Assellidae	*Lirceus*	0	0	8	3	1
Megaloptera	Sialidae	*Sialis*	1	0	0	0	1
Megaloptera	Corydalidae	*Nigronia*	0	1	0	1	1
Plecoptera	Leuctridae	*Zealeuctra*	0	0	15	0	1
Plecoptera	Perlidae	*Agnetina*	0	0	0	1	1
Trichoptera	Hydropscyidae		1	0	0	0	0
Trichoptera	Polycentropidae	*Polycentro*	1	0	0	0	1
Trichoptera	Hydropsychidae	*eratopysch*	0	13	0	0	1
Trichoptera	Philopotamidae	*Chimarra*	0	1	1	0	1
Trichoptera	Hydropsychidae	*lydropsyche*	0	0	47	0	1
Trichoptera	Hydropsychidae	*opsyche be*	0	0	0	42	1
Trichoptera	Hydropsychidae	*ydropsyche*	0	0	0	12	0
Totals			11	16	84	70	
		Total Taxa	6	4	7	8	20
		%EPT	18	88	79	79	

Chamberlain 02

			27-Aug-03	21-Apr-04	11-Nov-04
Order	**Family**	**Genus**	**Total organisms**	**Total organisms**	**Total organisms**
Coleoptera	Psephenidae	*Psephenus*	1	0	0
Diptera	Ceratopogonidae	*Bezzia*	8	0	0
Diptera	Chironomidae		5	0	0
Hemiptera	Gerridae	*Aquarius*	0	1	0
Hemiptera	Gerridae	*Aquarius*	0	0	1
Isopoda			1	1	0
Megaloptera	Sialidae	*Sialis*	1	0	0
Odonata	Coenagrionidae		0	1	0
unknown			0	1	0
Totals			16	4	1
		Total taxa	5	4	1