

**West Virginia Water Resources Research Institute
Annual Technical Report
FY 2009**

Introduction

West Virginia Water Research Institute

Introduction

The West Virginia Water Research Institute (WVWRI) addresses the key water resource issues facing policy makers, agency staff and the public. Our research program is guided by the West Virginia Advisory Committee for Water Research. It includes representatives from the following:

\$ West Virginia Department of Natural Resources \$ West Virginia Department of Health & Human Resources
\$ West Virginia Chamber of Commerce \$ West Virginia Coal Association \$ West Virginia Department of
Environmental Protection \$ West Virginia Farm Bureau \$ U.S. Federal Bureau of Investigation \$ U.S.
Geological Survey \$ U.S. Environmental Protection Agency \$ U.S. Department of Energy - National Energy
Technology Laboratory \$ U.S. Army Corps of Engineers - Huntington, WV District \$ West Virginia
University

The Advisory Committee develops the Institute's research priority list, reviews its progress and selects startup projects at its annual meeting. With this direction, the Institute recruits new researchers to study emerging water research issues. Because the Advisory Committee understands future regulatory and economic driving factors, these issues tend to grow in importance and have often led to follow-on funding from their agencies.

Funding Strategy

The Institute receives a grant of roughly \$92,000 annually through the U.S. Geological Survey CWA section 104b program. We use this funding to develop research capabilities in priority areas and to provide service to State agencies, industry and citizen groups. Our strategy relies on using the USGS section 104b funding to develop competitive capabilities that, in turn, translate into successful proposals funded by a broad spectrum of Federal and State agencies.

Our strategy also relies on maintaining a broad cadre of researchers within WVU and other institutions within the state. We also work with faculty from institutions across the country to form competitive research partnerships. As West Virginia University is the State's flagship research institution, its researchers have played the dominant role. Our funding strategy relies on successful competition for Federal dollars while teaming with State agency and industry partners. The latter provide test sites, in-kind support and invaluable background data. The center has 14 full time staff and is adding a new program coordinator this year. The center also supports numerous students (4 within the WVWRI) and more through other departmental projects. All but two positions are supported entirely on grant funds. Roughly two-thirds of the Institute staff is directly engaged in research projects; the remaining handle administration and outreach.

Research Priorities

The following is a list of state research priorities identified by the WV Advisory Committee for Water Research.

Energy production impacts on water resources (oil and gas drilling; hydroelectric; biofuels; etc.); Nutrient reduction/nutrient control/sources of air deposition Mercury (informational fact sheets) Valley fills (viability of fill areas for community uses; protect as a water source; how to handle sewage); Flooding Aquatic ecosystem integrity (anti-degradation, water quality criteria, nutrient/pathogen impacts, headwater stream valuation/mitigation) Water metrics (methods for measuring physical, chemical, biological components, in

situ monitoring, PPCP's, pathogens in drinking water) Uses for mine water discharge (drinking water potential for underground mine pools, irrigation, industrial heating/cooling) Industrial processes and urban sprawl (water budgets, contaminants, flooding, ground-water recharge, storm water applications) Evaluation of water resources (uses)

Future Direction

The following programs of the WVVRI are expected to continue to remain stable and grow modestly into the future:

\$Water Resources Research \$National Mine Land Reclamation Center \$Hydrology Research Center
\$Northern WV Brownfields Assistance Center \$Watershed Assistance Center

Outreach

The WVVRI performs outreach through meetings, workshops, conferences, site visits, web site, newsletters, and publications.

A web site (<http://wvwri.nrcce.wvu.edu>) contains information on all the WVVRI programs and projects. This site is updated on an on-going basis as new information becomes available.

Research Program Introduction

WRI 96 - Experimental Investigation into the Changes in Hydrologic and Environmental Quality Associated with Valley Fills

Basic Information

Title:	WRI 96 - Experimental Investigation into the Changes in Hydrologic and Environmental Quality Associated with Valley Fills
Project Number:	2007WV96B
Start Date:	3/1/2007
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	WV-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Water Quality, Floods
Descriptors:	
Principal Investigators:	Todd Petty, Paul Ziemkiewicz

Publications

There are no publications.

Final Report

May 27, 2010

Project Number: 10008586

State Water Resources Research Institute Program/USGS 104(b) FY 2009 Funds

Principal Investigator:

Tamara Vandivort

Co-Investigator/Task Managers:

Paul Ziemkiewicz

Jingxin Wang

Ronald Smart

Louis McDonald

Jennifer Fulton

James Stiles

J. Todd Petty

Richard Herd

Melissa O'Neal

Tom Brand

Problem and Research Objectives

Mountaintop removal /valley fill mining is a controversial process that may have far-reaching impacts on central Appalachian watersheds. Our project sought to quantify spatial and temporal variation in organic matter processing within Pigeon Creek, an intensively mined sub-watershed of the Tug Fork River in southern West Virginia. Our objectives were to: 1) quantify variation in organic matter retention and decomposition among streams differing in size (drainage area), gradient, and structural complexity; and 2) quantify the effect of valley fills on stream flow, water chemistry, organic matter processing, and benthic invertebrate colonization of detritus packs in 1st order perennial streams. Our study area consisted of 26 sites distributed across a wide range of stream sizes (ephemeral channels to large perennial streams). Four of the small perennial sites were located below large valley fills and were paired to four undisturbed sites. At each site we quantified water temperature (continuous), stream flow (continuous), habitat quality and complexity, water chemistry (seasonal), artificial leaf and stick transport, leaf pack decomposition, and invertebrate colonization. Organic matter decomposition rates were variable, but unrelated to any environmental factors that we measured. Drainage area, channel complexity, and mining had a significant interactive effect on transport distance of leaves and sticks. Sites below valley fills had enhanced flow levels which resulted in higher transport levels. These results add to our understanding of complex interactive effects of mining on stream ecosystem functions and our ability to compensate for lost headwater functions through restoration actions downstream.

Principal Findings and Significance of Findings

Organic Matter Processing Along a Drainage Area Continuum in a Mined Watershed

Results

Structural Complexity

Principle Components Analysis grouped structural complexity measures into 2 axes: Principle Component 1 (PC 1) and Principle Component 2 (PC 2) (Table 1). PC 1 includes measures of: retentive score, number of retentive features per meter, large woody debris per meter, RVHA score, coefficient of variation of depth, and mean distance (meters) to retentive feature. Principle Component 2 includes coefficient of variation of depth and RVHA score.

Transport Distance and Structural Complexity

Basin area is important for organic matter retention; there was a significant positive relationship between basin area and overall transport distance ($R^2 = 0.6625$). Basin area was the best predictor of transport distance for each season (Figure 1). For small and medium perennial sites, the retentive score was the best predictor of dowel transport distance ($R^2 = 0.8374$) and artificial leaf transport distance ($R^2 = 0.9068$) (Tables 2 and 3). PC 1 was correlated with average dowel transport distance and artificial leaf transport distance in medium and large perennial sites (Tables 4 and 5). There was not one good predictor of transport distance for small perennial sites (Tables 6 and 7). However, average dowel transport distance was negatively correlated with number of retentive features per meter (-

0.6185). For ephemeral/intermittent sites, the number of large woody debris ($R^2=0.5880$) and number of retentive features per meter ($R^2=0.6646$) were only moderately good predictors of dowel and leaf transport distance (Tables 8 and 9).

Decomposition , Temperature and Macroinvertebrates

There was no significant relationship between decomposition and basin area ($R^2= 0.0305$, $\text{Prob}>F=0.5177$, $\alpha=0.05$). Also, there was no interaction between season and type ($\text{Prob}>F=0.6478$, $\alpha=0.05$). However, season had a significant effect on decomposition ($R^2= 0.7842$, $\text{Prob}>F=<0.0380$, $\alpha=0.05$); Summer 2008 was significantly different from both Fall 07 and Spring 08 ($\alpha=0.05$, $Q=2.48$). Decomposition was also not affected by any of the habitat variables or conductivity ($\text{Prob}>F=0.6329$, $\alpha=0.05$). Decomposition was not significantly related to % collector gatherers, % predators, % shredders, or % other (Table 10). However, Fall 07 decomposition was related to Fall 07 % other (Correlation= -0.7722). Spring 2008 decomposition was also related to Spring 2008 % other (Correlation= -0.5271). There was not one good predictor of decomposition in this watershed; however, decomposition was slightly negatively correlated with minimum temperature and maximum daily temperature range (Table 10).

Average Temperature was not significantly different across DA type ($\text{Prob}>F=0.2036$, $\alpha=0.05$). CV Temp was not significantly different across DA type ($\text{Prob}>F=0.9953$, $\alpha=0.05$). Mean daily range of temp was not significantly different across type ($\text{Prob}>F=0.3470$, $\alpha=0.05$). Macroinvertebrate abundances were not significantly different across basin area types except for % other ($\text{Prob}>F=0.0253$, $\alpha=0.05$). Ephemeral headwater and large perennial sites were significantly different from intermittent, small perennial, and medium perennial sites.

Discussion

Small streams possessed the highest OM processing power in the watershed; transport is low in ephemeral and intermittent streams. This is consistent with other studies (Minshall et al. 1983; Naiman et al. 1987; Vannote et al. 1980). Stream restoration to recover OM processing function at best will need to focus on small perennial streams rather than larger mainstems (Figure 2). Larger sites exhibited higher and a wider range of transport distances. If headwaters cannot be recovered, it will not make much of a difference to try and restore large perennial sites because not enough organic matter processing power can be gained from them. Small perennial sites exhibited a wider range of habitat conditions to allow room for stream restoration. However, our results also indicate that only moderate gains may be made from restoration efforts in small perennial sites (Figures 3 and 4). Figure 4 shows a slight negative relationship between transport distance and PC 1 score. While transport distance was also negatively correlated with distance to retentive feature, no other structural complexity variables were good predictors in small perennial sites. The loss of the processing power of ephemeral and intermittent sites may be not able to be recovered.

There is some indication that structural complexity influences OM retention in small streams (Figure 4). Mining may have as much of an effect on stream structure than all the residential development in the area. Many streams are pinned against roads and houses and these things have a direct effect on

stream structure. Downstream areas are affected by residential development and many upstream areas are affected by mining. These two interacting factors are hard to separate in a study encompassing the entire watershed. Structural complexity improvements downstream will need to encompass the effects of the residential development on many small perennial sites. These streams have a large range of habitat conditions and many show room for improvement. However, results show that ephemeral and intermittent sites cannot be replaced and a perennial site can never be made into an ephemeral or intermittent site.

There was no direct effect of drainage area on organic matter decomposition in this watershed, however ephemeral and intermittent sites had a wider range of decomposition rates (Figure 5). Temperature and conductivity also did not significantly differ across drainage area either (Figure 6). This could help explain the lack of a significant difference in decomposition rate across drainage area. Also, our “organic matter” was secured into place with rope and rebar. In larger sites, most of the natural organic matter would be flushed out because of higher flows and less structural complexity. Benefield et al. (2000) suggests that downstream locations naturally have fewer resources and therefore leaf packs may attract macroinvertebrates, artificially elevating the decomposition rate. Our values for large streams may only represent potential decomposition.

Organic Matter Processing Downstream of Valley Fills in Headwater Streams

Results

Structural Complexity and Transport Distance

When valley fill and control sites were grouped together, the best predictor of dowel transport distance was coefficient of variation of depth (Table 11). For grouped sites, coefficient of variation of water level was the best predictor of decomposition rate ($R^2= 0.9321$). For valley fill sites alone, coefficient of variation of depth ($R^2= 0.7478$), and large woody debris per meter ($R^2= 0.7820$) were good predictors of dowel and artificial leaf transport distance, respectively. For control sites, coefficient of variation of depth ($R^2= 0.7083$ for dowels; $R^2=0.9315$ for leaves) was the best predictor of transport distance.

Comparisons Between Valley Fill and Control Sites

There was no significant difference between valley fills and non-valley fills in terms of decomposition, however valley fills had a larger range of values (Figure 7). There was also no significant difference between valley fills and non-valley fills in terms of retention, however controls had a larger range of values. Valley fill sites also had a wider range of habitat conditions (Figures 8 and 9). But, there was not a significant difference between control and valley fill sites in terms of retention score and RVHA. Although not statistically significant, water levels below valley fills tended to be less variable than those at control sites (Figure 10).

Discussion

There is an altered flow regime below valley fills: flows below valley fills were more stable than in control sites (Figure 10). Valley fills' sediment ponds and altered geology allow for flows to be more stable and higher than those of control sites. While this did not have a significant effect on dowel transport distances or decomposition, it is possible that flow interacts with other factors that cancel out the effects that flow alone would have on organic matter processing.

Organic matter retention and decomposition rates did not differ between control and valley fill sites. This is contrary to what I predicted. In terms of decomposition, it is possible that valley fill sites are more "sterile". In order for leaves to break down, a leaf needs to first be conditioned by fungi and bacteria, and then macroinvertebrates take over in breaking the leaf down (Webster and Benfield 1986). Fungal and bacterial assemblages were not measured in this study, so there is no way to know if these differed between valley fill and control sites. Streams draining control sites were mostly forested and streams draining valley fills drained a more barren area. Control sites may have much more opportunity for fungal and bacterial colonization than valley fill sites. If leaves in control sites were better colonized then this could potentially cancel out the effect of the higher flows in valley fill sites. In other words, valley fill sites have the potential for higher decomposition rates, but this potential is possibly negated by the fact that these streams drain a relatively sterile landscape.

Transport distances were only measured once every two weeks. This was probably too spaced out for these small, flashy streams. Valley fill sites have a different flow regime and may be moving the dowels in a different way. A flashy control site will push all of the dowels out after a rain even whereas a valley fill site may continuously move dowels for the entire period of time. After two, four, or six weeks the valley fill and control sites have moved the dowels the same distance but in potentially very different ways.

One of our valley fill sites (Big Muncy UNT R1) was positioned above the sediment pond instead of below it. This valley fill was older than the other fills; this fill was approximately 20 years old whereas the others were approximately 10 years old. This site had a much higher coefficient of variation of water level than even our control sites (Table 12). Although no solid conclusions can be drawn from this single sample, the data suggest that sediment ponds do help in controlling the flashiness of the streams draining valley fills.

Although no statistically significant differences could be found between valley fill and control sites, the noticeable difference in flow may indicate that there are underlying, interacting factors that affect organic matter processing in these sites. These subtle effects are difficult to tease apart. Also, headwater streams are inherently highly variable and it is hard to separate the variability due to land use from the inherent variability.

Works Cited

- Benfield, E. F., J. R. Webster, J. J. Hutchens, J. L. Tank, and P. A. Turner. 2000. Organic matter dynamics along a stream-order and elevational gradient in a southern Appalachian stream. *Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie* 27:1341-1345.
- Minshall, G. W., and coauthors. 1983. Interbiome Comparison of Stream Ecosystem Dynamics. *Ecological Monographs* 53(1):2-25.
- Naiman, R. J., J. M. Melillo, M. A. Lock, T. E. Ford, and S. R. Reice. 1987. Longitudinal Patterns of Ecosystem Processes and Community Structure in a Subarctic River Continuum. *Ecology* 68(5):1139-1156.
- Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences* 37(1):130-137.
- Webster, J. R., and E. F. Benfield. 1986. Vascular Plant Breakdown in Freshwater Ecosystems. *Annual Review of Ecology and Systematics* 17(1):567-594.

Publications

Manuscript in preparation.

Awards and Achievements

Information Transfer Program

Presentations given at 2008 Southern Division AFS Spring Meeting , 2008 Mid-Atlantic Regional Water Resources Research Conference, 2009 West Virginia AFS Meeting.

Student Support

Megan Minter, M.S., Eric Merriam, M.S..

Minter, M. 2009. Organic matter processing and opportunities for mitigation in an intensively mined Appalachian watershed. MS Thesis. West Virginia University. 126 pgs.

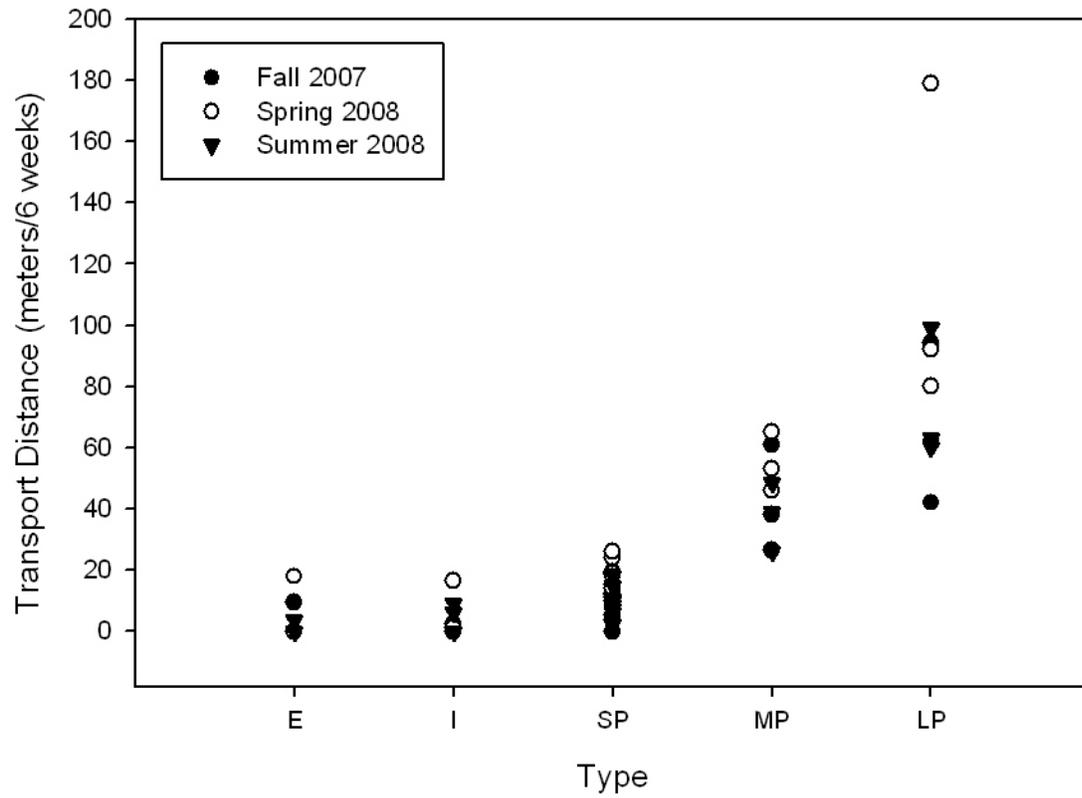


Figure 1: Relationship between seasonal dowel transport distance and drainage area (E=ephemeral, I=intermittent, SP=small perennial, MP=medium perennial, LP=large perennial).

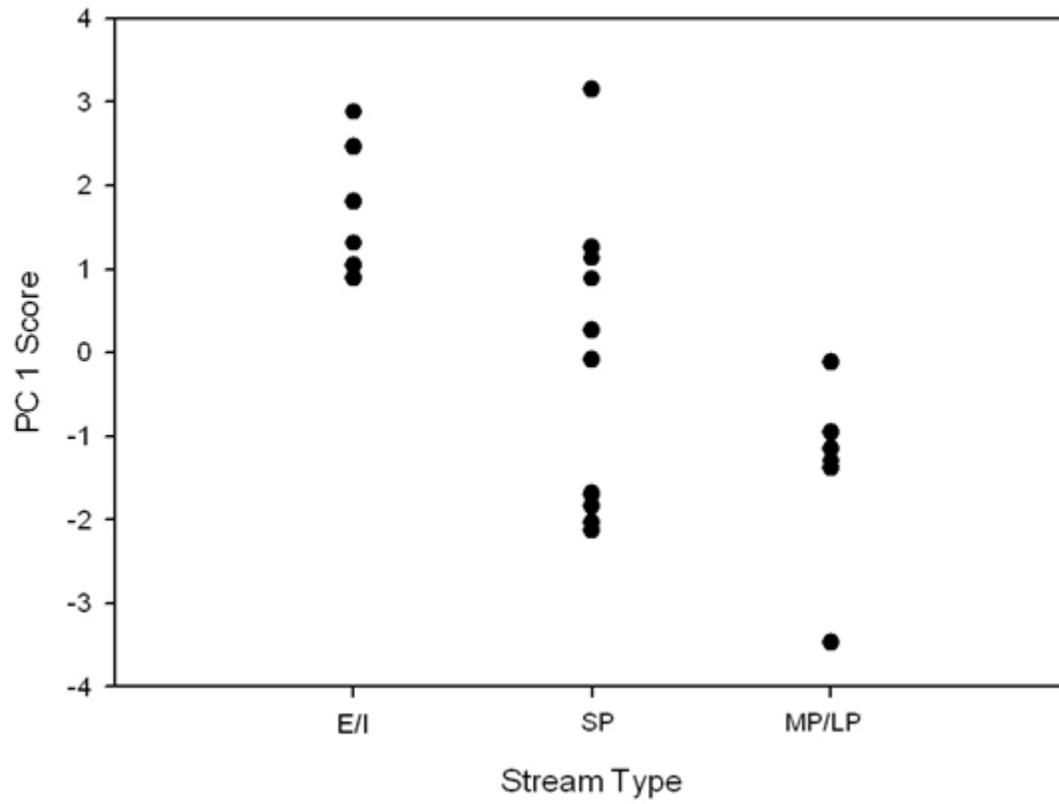


Figure 2: Distribution of Principle Component 1 scores (structural complexity measures) over grouped stream type. The higher the PC 1 score, the more structurally complex the site is.

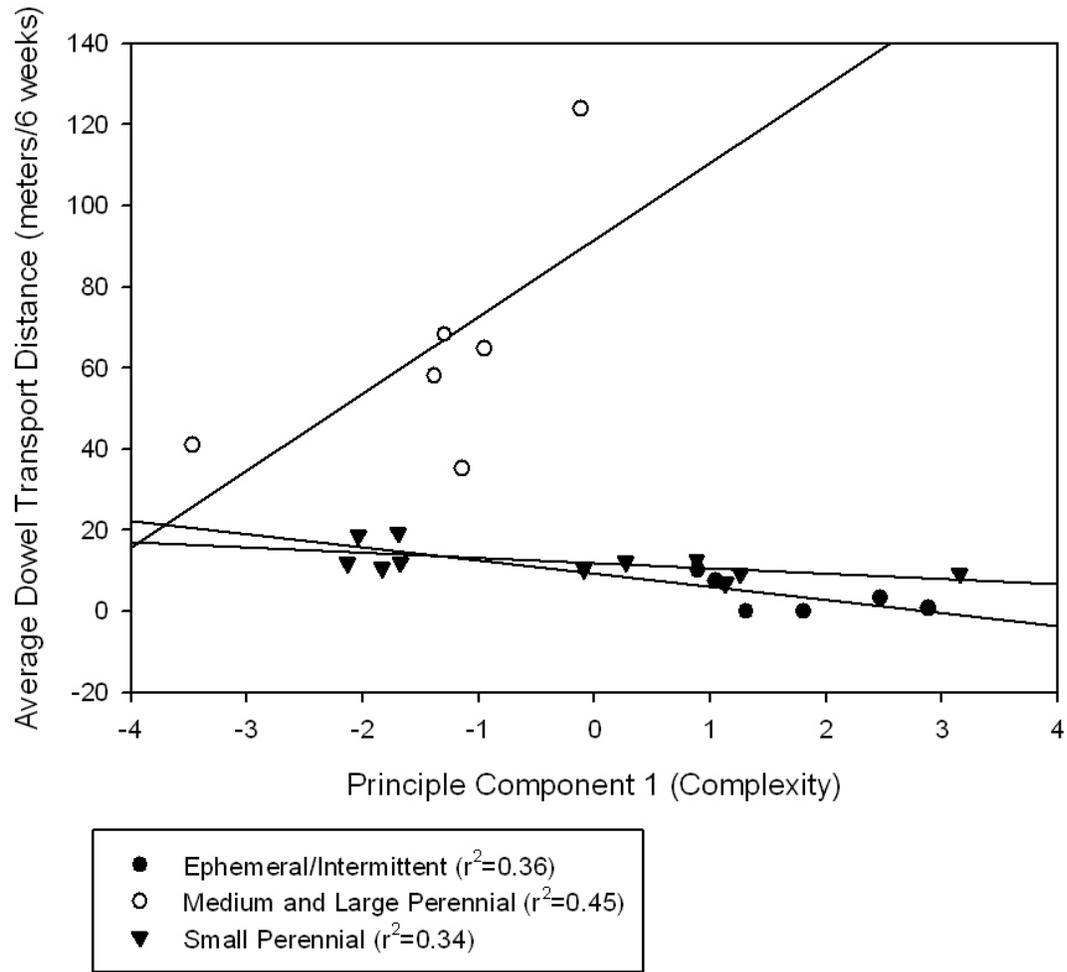


Figure 3: Principle Component 1 Score (complexity measures) and dowel transport distance averaged across all seasons.

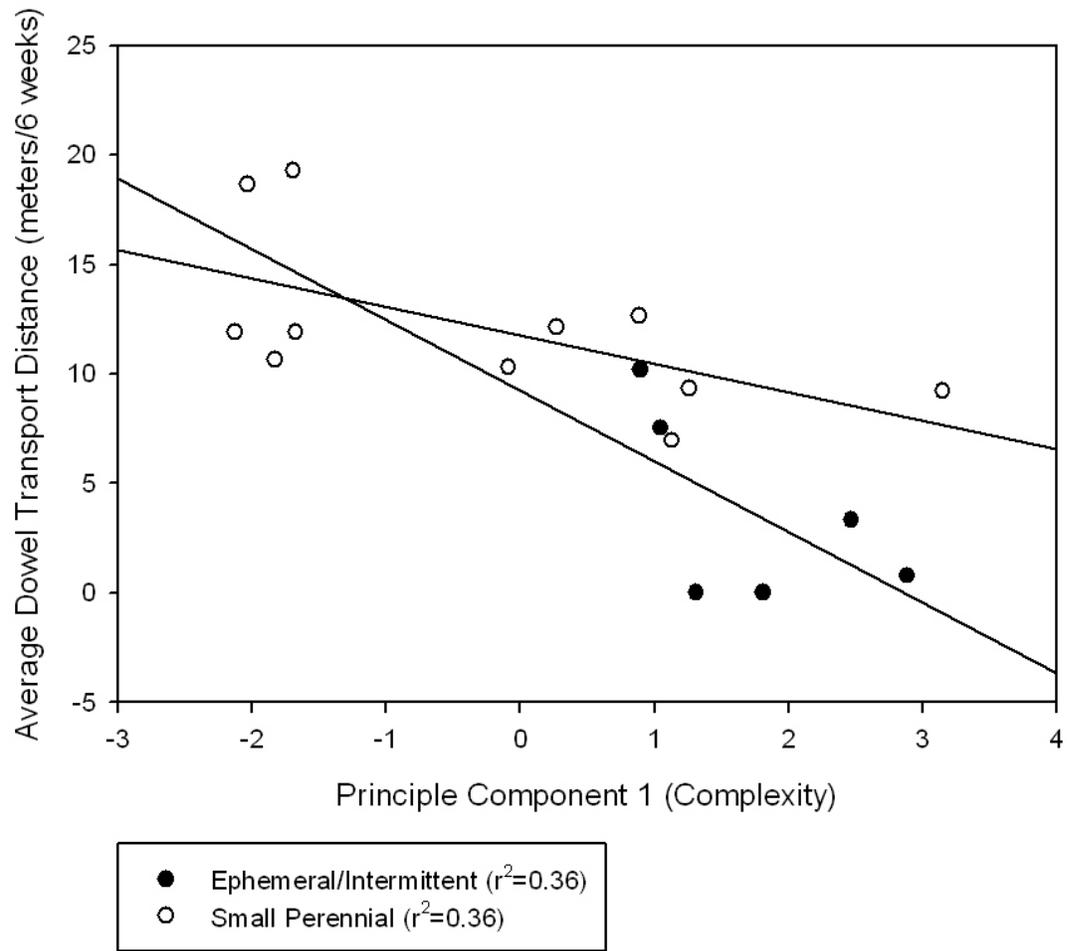


Figure 4: Principle Component 1 Score (complexity measures) and dowel transport distance averaged across all seasons. For Principle Component 1, the higher the score, the more complex the site is. There is a slight negative relationship between PC 1 and average dowel transport distance.

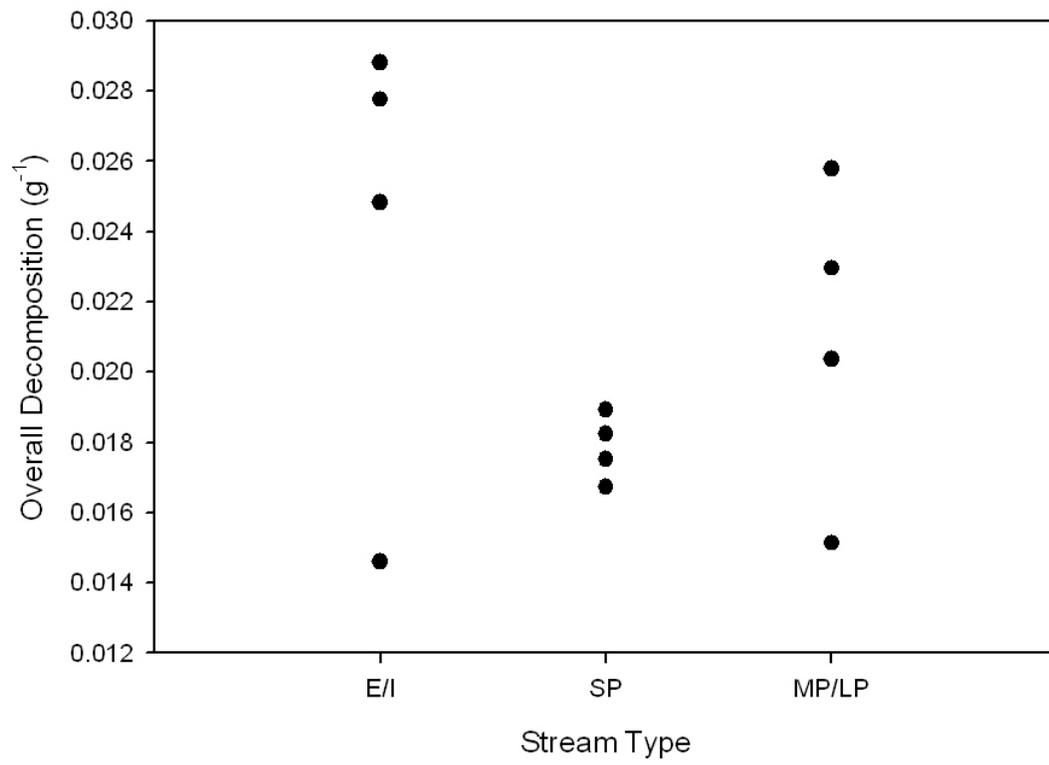


Figure 5: Range of decomposition values across stream types.

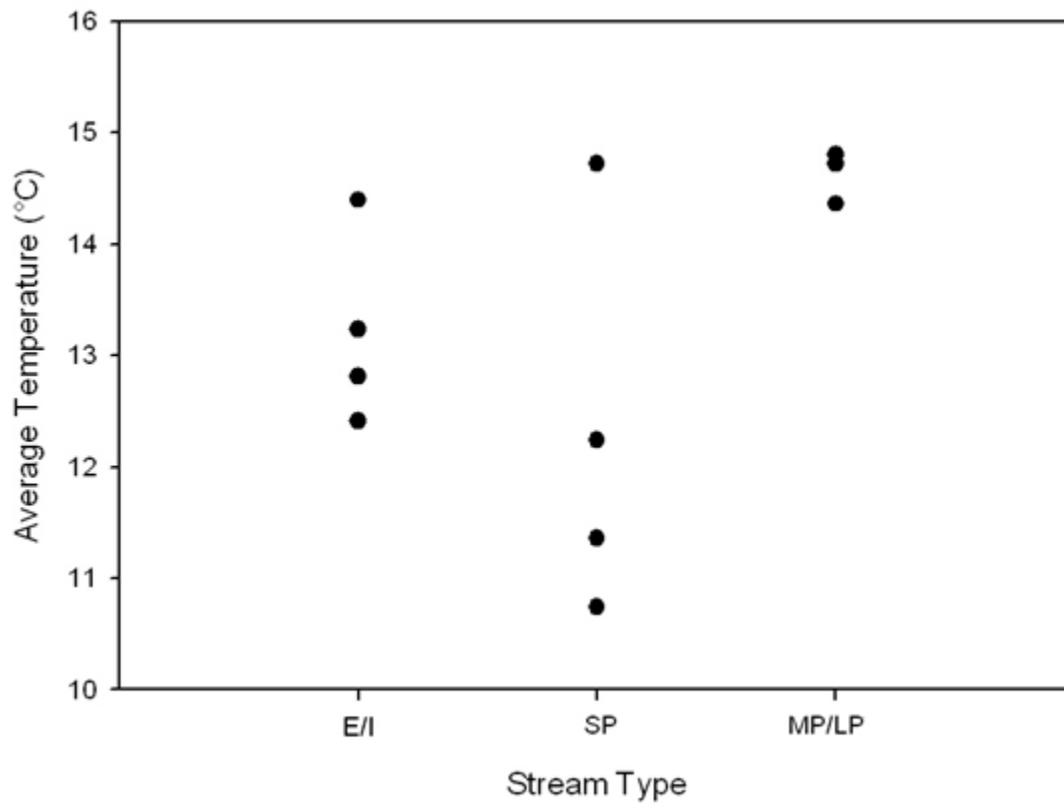


Figure 6: Range of temperature values across stream types.

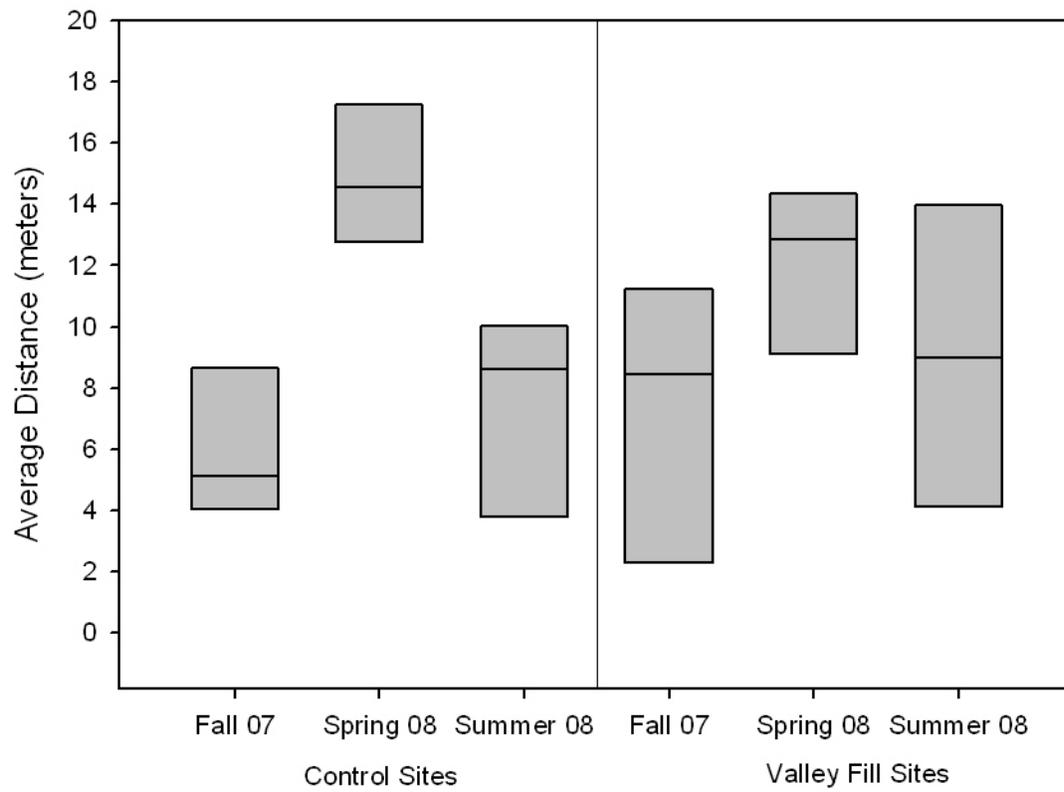


Figure 7: Average dowel transport distance for each season.

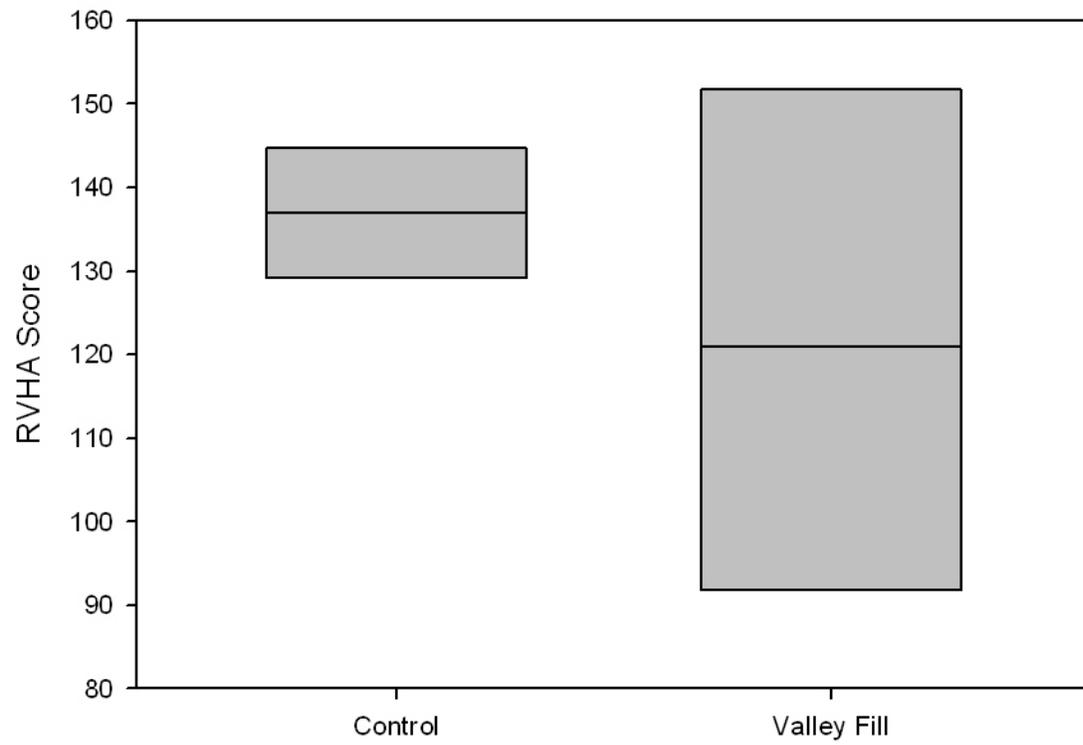


Figure 8: Rapid Visual Habitat Assessment Scores for each stream type.

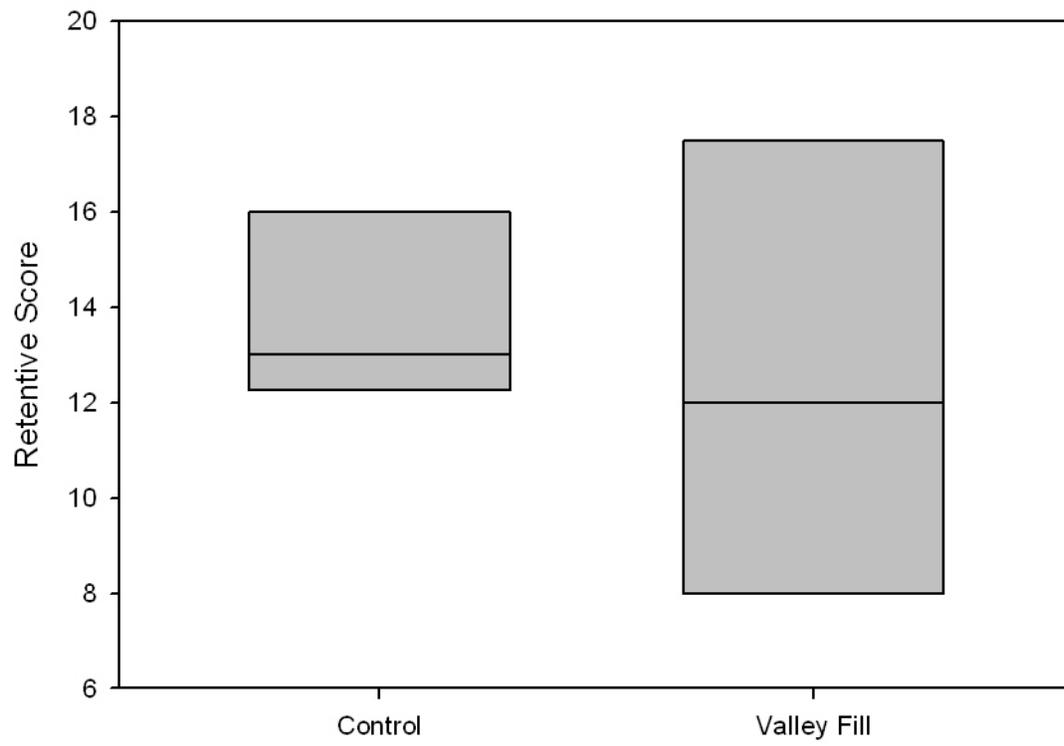


Figure 9: Range of retentive scores for control and valley fill sites.

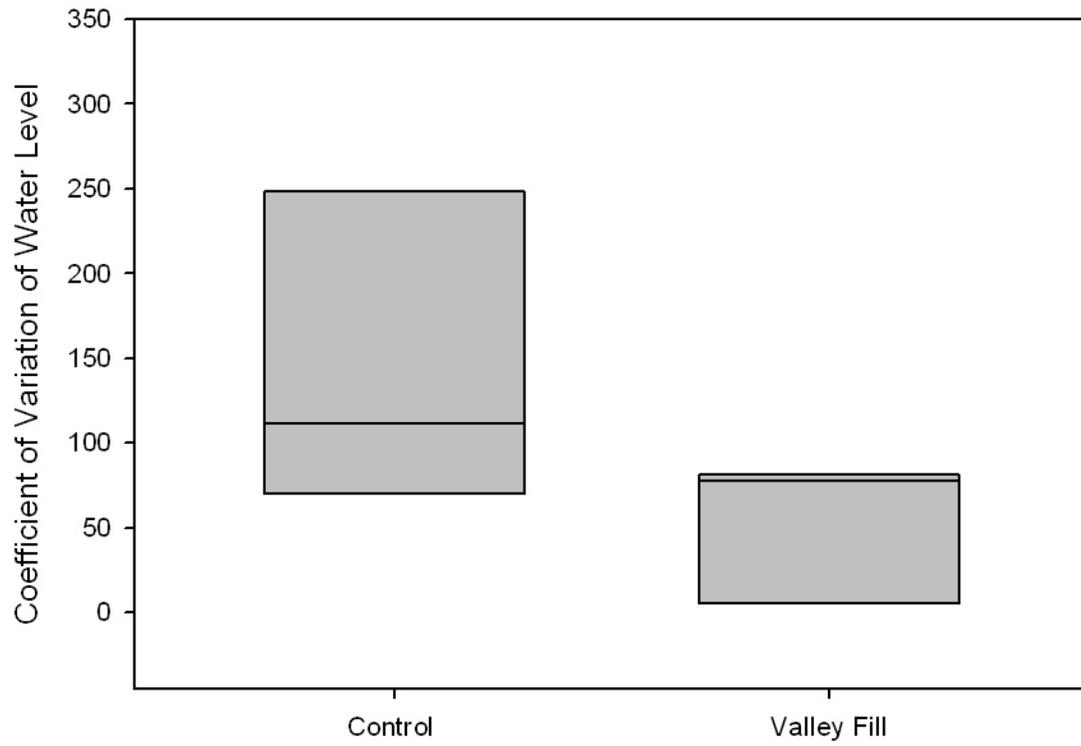


Figure 10: Range of values for the coefficient of variation of water level in control and valley fill sites. Big Muncy UNT R1 was not included in this graph.

Table 1: Principle components analysis results.

	PC 1	PC 2
Eigenvalue	3.34	1.21
Total Variance Explained	55.65	75.77
Total Retentive Score	+0.9140	.
Number of Retentive Features per Meter	+0.8103	.
Large Woody Debris per Meter	+0.7917	.
Rapid Visual Habitat Assessment	+0.7372	-0.5602
Coefficient of Variation of Depth	+0.5135	+0.7946
Mean Distance to Retentive Feature	-0.6426	.

Table 2: Simple Linear Regression models for average dowel transport distance (meters/ 6 weeks) at small and medium perennial sites.

Predictor	n	Corr	P	Estimate	Intercept
Retentive Score	6	0.8374	0.0105	8.54	9.70
RVHA	6	0.1882	0.3902	0.88	-26.49
log (average gradient)	6	0.0529	0.6613	-53.12	66.83
log (large woody debris per meter)	6	0.1548	0.4403	664.98	51.39
Coefficient of Variation of Depth	6	0.0956	0.5510	40.30	0.47
Retentive Features per meter	6	0.0022	0.9300	106.60	63.11
Mean distance to retentive feature (meters)	6	0.1798	0.4020	-0.27	75.37
Principle Component 1	6	0.4473	0.0073	18.97	91.64

Table 3: Simple Linear Regression models for average leaf transport distance (meters/30 mins) at small and medium perennial sites.

Predictor	n	Corr	P	Estimate	Intercept
Retentive Score	6	0.9068	0.0034	8.35	-13.86
RVHA	6	0.0756	0.5980	0.52	-14.20
log (average gradient)	6	0.0786	0.5905	-60.92	42.30
log (large woody debris per meter)	6	0.1429	0.4600	600.66	27.94
Coefficient of Variation of Depth	6	0.1710	0.4150	0.60	9.10
Retentive Features per meter	6	0.1898	0.7199	409.39	32.47
Mean distance to retentive feature (meters)	6	0.0357	0.3878	-0.26	50.25
Principle Component 1	6	0.4476	0.1462	17.84	65.29

Table 4: Correlations between structural complexity variables and average dowel transport distance. Correlation coefficient is listed first followed by the p-value.

Variable	Ephemeral and Intermittent	Small Perennial	Medium and Large Perennial
Coefficient of Variation of Depth (meters)	-0.9642, 0.0358	-0.5952, 0.0534	0.3092, 0.5510
Large Woody Debris per meter	0.7668, 0.0752	-0.5543, 0.0768	0.3934, 0.4403
Mean distance to retentive feature (meters)	0.7168, 0.1090	0.5863, 0.0748	-0.4241, 0.4020
Principle Component 1	-0.6022, 0.2059	-0.6018, 0.0501	0.6688, 0.1464
Retentive Features per meter	-0.6660, 0.1487	-0.6185, 0.0425	0.0467, 0.9300
Retentive Score	-0.0248, 0.9628	-0.5580, 0.0744	0.9151, 0.0105
RVHA Score	-0.1238, 0.8153	-0.3392, 0.3075	0.4338, 0.3902

Table 5: Correlations between structural complexity variables and average leaf transport distance. Correlation coefficient is listed first followed by the p-value.

Variable	Ephemeral and Intermittent	Small Perennial	Medium and Large Perennial
Coefficient of Variation of Depth (meters)	0.7307, 0.0990	-0.5912, 0.0554	0.2749, 0.5980
Large Woody Debris per meter	0.7160, 0.1096	-0.5584, 0.0742	0.3780, 0.4600
Mean distance to retentive feature (meters)	0.2062, 0.6951	0.1819, 0.6149	-0.4357, 0.3878
Principle Component 1	0.1444, 0.7849	-0.4652, 0.1494	0.6690, 0.1462
Retentive Features per meter	-0.6323, 0.1779	-0.5211, 0.1002	0.1890, 0.7199
Retentive Score	-0.8153, 0.0480	-0.4047, 0.2170	0.9522, 0.0034
RVHA Score	-0.9495, 0.0505	-0.2263, 0.5035	0.4136, 0.4150

Table 6: Simple Linear Regression models for average dowel transport distance (meters/6 weeks) at small perennial sites.

Predictor	n	Corr	P	Estimate	Intercept
Retentive Score	11	0.3114	0.0744	-0.38	15.33
RVHA	11	0.1151	0.3075	-0.04	17.11
log (average gradient)	11	0.0052	0.8322	-1.63	12.84
log (large woody debris per meter)	11	0.3072	0.0768	-33.66	14.25
Coefficient of Variation of Depth	11	0.3542	0.0534	-0.11	20.30
Retentive Features per meter	11	0.3825	0.0425	-65.17	14.43
Mean distance to retentive feature (meters)	11	0.3438	0.0748	0.19	8.91
Principle Component 1	11	0.3622	0.0501	-1.29	11.77

Table 7: Simple Linear Regression models for average leaf transport distance (meters/30 mins) at small perennial sites.

Predictor	n	Corr	P	Estimate	Intercept
Retentive Score	11	0.1638	0.2170	-0.12	3.35
RVHA	11	0.0512	0.5035	-0.01	3.80
log (average gradient)	11	0.0851	0.3840	-2.93	3.63
log (large woody debris per meter)	11	0.3118	0.0742	-15.15	3.27
Coefficient of Variation of Depth	11	0.3495	0.0554	-0.05	5.94
Retentive Features per meter	11	0.2716	0.1002	-24.54	3.18
Mean distance to retentive feature (meters)	11	0.0331	0.6149	0.02	1.65
Principle Component 1	11	0.2163	0.1494	-0.45	2.19

Table 8: Simple Linear Regression models for average dowel transport distance at ephemeral/intermittent sites.

Predictor	n	Corr	P	Estimate	Intercept
Retentive Score	6	0.0006	0.9628	-0.05	4.49
RVHA	6	0.0153	0.8150	-0.04	8.07
log (average gradient)	6	0.0485	0.6749	2.96	0.71
log (large woody debris per meter)	6	0.5880	0.0752	178.49	-10.14
Coefficient of Variation of Depth	6	0.9296	0.0358	-0.02	11.59
Retentive Features per meter	6	0.4435	0.1487	-45.97	7.69
Mean distance to retentive feature (meters)	6	0.5137	0.1090	0.53	-1.88
Principle Component 1	6	0.3626	0.2059	-3.23	9.25

Table 9: Simple Linear Regression models for average leaf transport distance (meters/30 mins) at ephemeral/intermittent sites.

Predictor	n	Corr	P	Estimate	Intercept
Retentive Score	6	0.0425	0.6951	0.09	-0.83
RVHA	6	0.0208	0.7849	0.01	-0.42
log (average gradient)	6	0.0023	0.9283	-0.14	0.84
log (large woody debris per meter)	6	0.5539	0.0990	37.09	-2.16
Coefficient of Variation of Depth	6	0.9016	0.0505	-0.00	2.47
Retentive Features per meter	6	0.6646	0.0480	-12.96	1.78
Mean distance to retentive feature (meters)	6	0.5126	0.1096	0.12	-0.50
Principle Component 1	6	0.3998	0.1779	-0.74	1.99

Table 10: Correlations between average decomposition rate (g^{-1}) and water quality and macroinvertebrate data.

Variable	Correlation	Signif Prob
Coefficient of Variation of Temperature	0.0080	0.9803
Maximum Temperature ($^{\circ}\text{C}$)	-0.1387	0.6672
Minimum Temperature ($^{\circ}\text{C}$)	-0.5080	0.0918
Average Temperature ($^{\circ}\text{C}$)	-0.0008	0.9980
Conductivity ($\mu\text{S}/\text{cm}$)	-0.3946	0.2043
Maximum Daily Temperature Coefficient of Variation	-0.0438	0.8924
Maximum Temperature Daily Range ($^{\circ}\text{C}$)	0.5236	0.0806
Mean Daily Temperature Coefficient of Variation ($^{\circ}\text{C}$)	-0.3729	0.2325
Mean Daily Temperature Range ($^{\circ}\text{C}$)	0.4435	0.1487
Overall % collector gatherer	-0.0636	0.8444
Overall % other	0.2664	0.4026
Overall % predator	0.1250	0.6988
Overall % shredders	-0.5038	0.0949

Table 11: Correlations between structural complexity variables as predictors and dowel transport distance (meters/6 weeks). In these correlations, valley fill and control sites were grouped.

Predictor	Corr	n	p-value
Retentive Score	-0.2908	8	0.4847
RVHA	-0.3896	8	0.3401
Average Gradient	-0.2832	8	0.4967
LWD per meter	-0.3598	8	0.3814
Coefficient of Variation of Depth	-0.8262	8	0.0115
Retentive Features per meter	-0.1123	8	0.7911
Mean distance to retentive feature (meters)	0.3526	8	0.3917
Principle Component 1	-0.3504	8	0.3948

Table 12: Correlations between structural complexity variables and dowel transport distance (meters/6 weeks) in control sites.

Predictor	Corr	n	p-value
Retentive Score	-0.0438	4	0.9562
RVHA	-0.1204	4	0.8796
Average Gradient	-0.1353	4	0.8647
LWD per meter	-0.5658	4	0.0334
Coefficient of Variation of Depth	-0.8088	4	0.1912
Retentive Features per meter	-0.0738	4	0.9262
Mean distance to retentive feature (meters)	-0.0337	4	0.9663
Principle Component 1	-0.3506	4	0.6494

WRI 97 - Chemical and Flow Characterization of Mining Impacted Streams Using Continuous Water Quality Monitoring and Watershed Modeling

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WRI-97

Final Report

April 1, 2007 - February 28, 2010

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Abstract

Although metal dynamics in mining impacted streams often respond to temporal changes, efforts to characterize stream water chemistry typically rely upon discrete samples which may not adequately represent the true constituent load of the stream. Our primary objective was to identify continuously monitored parameters that can be used as surrogates for variables of interest in AMD impaired systems in order to estimate constituent concentrations continuously. This continuous water quality data can then be used to examine spatial and temporal variability of water chemistry. We installed a continuous water quality monitoring system at four sites in a mining impacted watershed, and measured a series of parameters continuously while analyzing water chemistry once a month at each site. We found that 76 - 93% of the variation in most water quality parameters could be explained by specific conductance alone, allowing us to use conductance as a surrogate for laboratory-analyzed parameters. In general, North Fork water was circumneutral, while the Middle Fork, South Fork, and lower Greens Run were highly acidic. Acid load in the North Fork was an order of magnitude lower than the other streams. Most of the iron load in the North Fork comes from the three sources that have been identified, but the majority of the acid load is coming from an unknown source. In the other streams, roughly 60 – 70% of the acid, iron, and aluminum loads can be attributed to the known AMD sources. Acidity and sulfates were consistently high in all streams except North Fork. Spikes in manganese and other parameters were seen in spring in the acidic streams. Specific conductance was generally lower during periods of high flows, and rose sharply during summer dry periods. In all streams, dissolved oxygen levels climbed throughout the fall and winter, and dropped sharply in late spring, summer, and early fall. Diel patterns of pH and DO tended to follow the inverse of temperature, with peaks in the morning with lowest temperatures. Estimated iron and aluminum concentrations were lowest in mid-afternoon and highest in the middle of the night, possibly due to temperature impacts on iron oxidation. The results of this study show a clear need to take timing into account when designing field studies in AMD systems, as metal concentrations may vary throughout the day and peak at night.

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Executive Summary

Although metal dynamics in mining impacted streams often respond to temporal changes, efforts to characterize stream water chemistry typically rely upon discrete samples which may not adequately represent the true constituent load of the stream. Sensor technology is not yet available to measure many of the parameters of interest in AMD systems, so our primary objective in this project was to identify continuously monitored parameters that can be used as surrogates for variables of interest in AMD impaired systems in order to estimate constituent concentrations continuously. This continuous water quality data can then be used to examine spatial and temporal variability of water chemistry. We also used our sampled data to assess the ability of a mass balance approach to predict stream water chemistry. We installed a continuous water quality monitoring system at four sites in a mining impacted watershed, and measured a series of parameters continuously while analyzing water chemistry once a month at each site.

The North Fork water was circumneutral, while the other streams were acidic. Mean specific conductance, acidity, sulfates, calcium, iron, and aluminum concentrations were highest in the Middle Fork. Mean pH was lowest in the South Fork. Average magnesium and manganese concentrations were highest in lower Greens Run.

We analyzed relationships between continuous data and laboratory-analyzed samples in order to provide a continuous estimation of chemical concentrations and loads in the watershed. We found that 76 - 93% of the variation in most water quality parameters could be explained by specific conductance alone. Acidity, sulfates, aluminum, iron, calcium, and magnesium had the strongest relationship with specific conductance.

Using regression equations, concentrations of parameters such as acidity and iron were calculated for each instantaneous sonde reading. Flow was estimated using a USGS gage on a nearby stream, and correcting for size using a ratio. Chemical load was then calculated using the estimated instantaneous chemical concentrations and stream flow estimations. Acid load peaked in December 2007 in all streams except North Fork, which reached highest loadings in May and August. Acid load in North Fork was an order of magnitude lower than the other streams. Iron load followed a similar pattern, peaking in December in all tributaries except North Fork. Iron load in North Fork peaked in June and August, and was substantially lower than the other streams. Aluminum load peaked in December in each stream.

Temporal variability was analyzed by season and by day. We identified patterns both in laboratory-analyzed samples and continuously monitored data. Acidity and sulfates were consistently high in all streams except North Fork. Spikes in manganese and other parameters were seen in spring. Chemical concentrations in acidic streams tended to be extremely variable over the course of the year. Specific conductance was generally lower during periods of high flows, and rose sharply during summer dry periods. Dissolved oxygen levels climbed throughout the fall and winter, and dropped sharply in late spring, summer, and early fall. The pH levels stayed fairly constant, without much seasonal variation, only increasing with higher flows. Diel patterns of pH and DO tended to

follow the inverse of temperature, with peaks in the morning with lowest temperatures. During the fall, specific conductance tended to reach a low point around noon each day, and in other months tended to more broadly follow temperature and pH patterns. We used regression equations based on specific conductance measurements to predict continuous iron and aluminum concentrations for these time periods. We found that concentrations for both parameters were lowest in mid-afternoon and highest in the middle of the night, possibly due to temperature impacts on iron oxidation.

We compiled existing water quality data for all known mine discharges in the Greens Run watershed. Loadings from each discharge were incorporated into a mass balance model in order to predict chemical loadings at each monitoring station in the watershed. These predictions were then compared to the average measured loadings in order to identify the amount of uncertainty. We found that in the North Fork, most of the iron load comes from the three sources that have been identified, but the majority of the acid load is coming from an unknown source. In the other streams, roughly 60 – 70% of the acid, iron, and aluminum loads can be attributed to the known AMD sources.

Introduction

Efforts to characterize stream water chemistry typically rely upon discrete samples collected over relatively large time intervals. Many important episodic flushing and peak loading events are not captured by these traditional water chemistry sampling protocols. Furthermore, dissolved metal dynamics in mining impacted streams often respond to seasonal and climatic changes (Petty and Barker 2004), and can fluctuate dramatically within a 24 hour period (Nimick et al. 2003). Discrete samples therefore may not adequately represent the true constituent load of the stream, particularly in mining impacted systems (Fytas and Hadjigeorgiou 1995).

In order to gain a better understanding of water chemistry dynamics in acid mine drainage (AMD) impacted systems, water chemistry data will have to be collected at significantly smaller time intervals. Advances in instrumentation now allow for nearly continuous monitoring of many water quality parameters. Although sensor technology is not yet available to continuously measure many chemical constituents that may be of concern in these systems, regression models can be used to estimate chemical constituent concentrations and loads from the continuously measured parameters and discrete analytical samples (Christensen et al. 2000). A continuous estimation of chemical concentration will provide a more accurate representation of water chemistry variability in mining impacted systems. Improvement in the accuracy of chemical loading estimates will enable more effective design of AMD treatment systems, and may provide an important tool for TMDL development (Rasmussen et al. 2003).

Continuous monitoring and regression analysis have been used extensively to estimate constituent concentrations in Kansas watersheds (Christensen 2001; Christensen et al. 2000). The parameters of concern in these watersheds included alkalinity, fecal coliform bacteria, total suspended solids, sulfates, nitrates, and phosphorus. These parameters of concern were estimated using pH, specific conductance, temperature, dissolved oxygen, and turbidity data measured hourly with a YSI sonde. The U.S. Geological Survey reported that continuous data collection in these watersheds enabled the identification of important seasonal trends, and provided a more accurate representation of actual chemical loads being transported downstream (Christensen et al. 2000; Rasmussen et al. 2003).

Watershed models tend to generalize stream water chemistry conditions. A mass balance approach applies loading rates from various points within a watershed to characterize general stream water quality conditions downstream. Loadings from known mine discharges can be incorporated into the model, producing an estimate of average chemical concentrations in a given stream. Comparison of measured water chemistry loads to the chemical concentrations predicted by mass balance will enable us to evaluate the predictive ability of this particular type of model, and will allow us to place an error bound on the model predictions. We had proposed to use the Watershed Characteristic and Modeling System (WCMS) (Strager et al. 2004), but feel that mass balance is more appropriate for this task. Although WCMS is able to use land use characteristics to

model downstream water chemistry, the models do not include parameters important in AMD systems such as iron or aluminum.

The objectives of the project were to:

- 1) Identify continuously monitored parameters or combinations of parameters that can be used as surrogates for variables of interest in AMD impaired systems, such as acidity, iron, and aluminum, and perform regression analysis to estimate constituent concentrations continuously
- 2) Use continuous water quality data to examine spatial and temporal variability of water chemistry in a mining impacted watershed
- 3) Assess the ability of a modeling approach to predict stream water chemistry based on known AMD discharges

These objectives were accomplished through the completion of three tasks:

Task 1 – We installed a continuous water quality monitoring system at four sites in a mining impacted watershed. The instrumentation recorded pH, conductivity, temperature, and water level hourly. We measured stream discharge and analyze water chemistry once a month at each site.

Task 2– We analyzed relationships between continuous data and laboratory-analyzed samples in order to provide a continuous estimation of chemical concentrations and loads in the watershed. This continuous data was used to examine temporal and spatial variability in water chemistry throughout the watershed.

Task 3 – We compiled existing water quality data for all known mine discharges in the study watershed. Loadings from each discharge were incorporated into the mass balance model in order to predict chemical loadings at each monitoring station in the watershed.

Experimental Methods

Background

Greens Run, located in Preston County, WV is a major source of acidity to the lower Cheat River. The watershed drains approximately 11.5 square miles and has 14.9 miles of impaired stream miles. Greens Run has three major tributaries, the North Fork, the Middle Fork, and the South Fork, all of which are heavily impacted by AMD. The three forks contain five recognized abandoned mine sites, as well as one bond forfeited site. The pH of Greens Run below the confluence of these forks is generally less than 3.5.

Greens Run was chosen for this project because of the high degree of water chemistry variability observed in the watershed.

Reclamation efforts in the watershed have involved the installation of a doser on the bond forfeiture site by the West Virginia Department of Environmental Protection (WVDEP), as well as two passive treatment installations completed through a cooperative effort with the Friends of the Cheat, the WVDEP, and the National Mine Land Reclamation Center at the West Virginia Water Research Institute (WVWRI). These treatment projects on the Middle Fork and the North Fork help reduce acidity entering Greens Run.

Field Methodology

In July 2007, WVWRI installed continuous water quality monitoring systems at the mouth of all forks and below the confluence of the forks, for a total of four monitoring stations (Figure 1). Each monitoring station was comprised of a Eureka Manta multi-parameter sonde with pH, specific conductance, temperature, dissolved oxygen, and depth sensors (Figure 2). These units have an accuracy of $\pm 0.10^\circ \text{C}$, $\pm 0.2 \text{ mg/L DO}$, $\pm 1\%$ of reading for conductivity, and ± 0.2 units for pH, and 0.2% of range for depth. Similar multi-parameter sondes have been used extensively in water quality research, and their continuous monitoring and logging capabilities are used by many state and federal water quality monitoring programs (Atkinson and Mabe 2006; Christensen 2001; Christensen et al. 2000; Hall and Wazniak 2004). Each sonde was secured to a bridge structure at the site (Figure 3), and was situated at a depth slightly lower than the lowest point in the stream channel. The sondes were programmed to collect data every two hours, and data was downloaded on a WVWRI laptop computer every month (Figure 4). Probes were cleaned and calibrated monthly (Figure 5).

WVWRI staff collected water samples and measured stream discharge at each monitoring station once per month (Figure 6). Monthly sampling intervals have been found to effectively capture the broad range of temporal and spatial variability of water quality parameters in mining impacted systems (Petty and Barker 2004). The water samples were analyzed by the analytical lab at the National Research Center for Coal and Energy. Chilled grab samples were analyzed for alkalinity, acidity, and sulfates. Filtered ($0.45 \mu\text{m}$), acidified samples were analyzed for dissolved iron, aluminum, calcium, magnesium, and manganese concentrations. Discharge was calculated at each site using an area-velocity technique, by measuring depth and average current velocity (at 60% depth) with a digital Marsh-McBirney flow meter in ten equal cells in a cross-section of the stream.

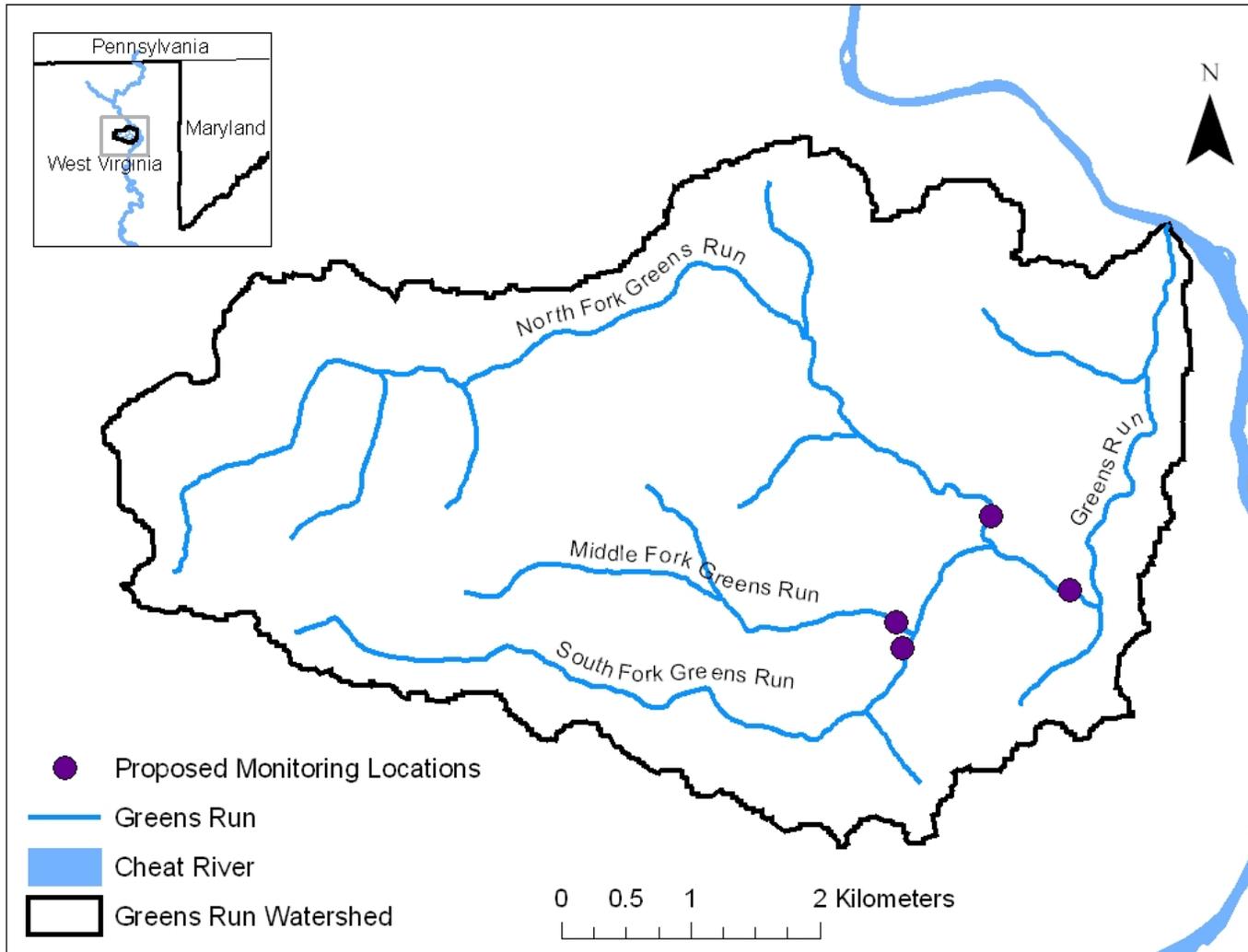


Figure 1. Location of continuous monitoring stations in the Greens Run watershed



Figure 2. Top and sensor view of the Eureka multi-parameter sonde



Figure 3. Continuous monitoring station on the Middle Fork of Greens Run



Figure 4. Graduate research assistant Ben Mack downloading data from a Eureka sonde on lower Greens Run



Figure 5. Graduate research assistant Joseph Kamalesh calibrating a Eureka sonde on South Fork Greens Run



Figure 6. Undergraduate research assistant Mary Beth Tajc sampling the North Fork of Greens Run

Data Analysis

Using SAS version 9.1 software, we input both the continuously measured sonde data and the water quality data resulting from laboratory analysis of the water samples. Data were square root transformed when necessary to approximate normality, and pH was converted to H⁺ concentration. We performed a stepwise multiple regression to examine relationships between sonde measurements (daily mean pH, conductivity, temperature, dissolved oxygen, and depth) and the discretely measured water chemistry data in order to produce equations that can be used to estimate chemical concentrations from the sonde data. An alpha level of 0.15 was used to determine which variables to include in the model, whereas overall model significance was judged at an alpha level of 0.05.

We had proposed to use monthly discharge calculations to create stage-discharge rating curves, which would enable estimation of continuous stream flow at each site from the continuous water level data. Malfunctions with the depth sensors led to a lack of quality depth data, and reliable rating curves could not be created. Discharges for Greens Run were therefore created using discharge data from a USGS gage on a comparable watershed. Although there are no stream gages within or directly downstream from the Greens Run watershed, daily discharge data were pulled from Big Sandy Creek (USGS gage 03070500), a larger stream that flows into the Cheat River nine miles downstream from Greens Run. Greens Run is approximately 5% the size of Big Sandy Creek, by basin area. Discharge in Big Sandy Creek was compared to field-measured flows at the four Greens Run sampling stations on 12 occasions throughout the year, and proportions were calculated. The proportions for each stream were applied to the daily Big Sandy Creek flows in order to estimate discharge at the Greens Run sampling stations.

Concentrations of parameters such as acidity and iron were calculated for each instantaneous sonde reading, using the regression equations produced by our multiple regression analysis. Chemical load was then calculated using the estimated instantaneous chemical concentrations and stream flow estimations.

Water quality data for all known mine discharges in the Greens Run watershed were compiled into a GIS database. We used mean annual chemical loadings from each known discharge to predict chemical loadings at each monitoring station in the watershed. These predictions were then compared to the average measured loadings in order to identify the amount of uncertainty when using this approach in Greens Run.

Results and Discussion

Water Quality

Continuous sonde data collection was conducted for one year, from October 2007 – October 2008 (Table 1). We sampled each stream monthly, for a total of 13 sampling events. At each visit, we collected water samples for analysis and measured stream

discharge (Table 2). Malfunctions in the mainstem Greens Run sonde resulted in only three complete points for the site.

The North Fork water was circumneutral, and generally had low specific conductance and a small amount of alkalinity. Mean specific conductance, acidity, sulfates, calcium, iron, and aluminum concentrations were highest in the Middle Fork. Mean pH was lowest in the South Fork. Average magnesium and manganese concentrations were highest in lower Greens Run. Dissolved oxygen and temperature were relatively constant among sites.

Table 1. Mean sonde water quality measurements

Site	pH	Temp (°C)	SC (µS/cm)	DO (mg/l)
North Fork	7.04	11.00	197.55	9.73
Middle Fork	3.46	11.23	1209.33	8.98
South Fork	2.79	12.34	981.17	8.24
Greens Run	3.65	11.14	784.66	8.98

Table 2. Mean water quality parameters. Flow is expressed in GPM and all concentration measurements are expressed in mg/L

Site	Flow	Acidity	Alk.	SO4	Mg	Ca	Fe	Al	Mn
North Fork	5451.90	57.28	28.10	41.86	6.80	27.15	7.47	10.89	1.22
Middle Fork	2324.54	394.87	0.01	578.38	18.32	69.48	40.26	22.25	2.13
South Fork	2329.71	319.90	0.00	393.23	12.48	46.54	36.35	16.65	2.42
Greens Run	13148.28	208.05	0.00	288.65	61.73	37.94	15.91	9.82	2.50

Regression Analysis

Continuous monitoring data paired with regression models makes it possible to predict concentrations and loadings of parameters that are typically only sampled discretely (Rasmussen et al. 2003). We conducted stepwise multiple regressions that included temperature, dissolved oxygen, specific conductance, pH, and depth as independent variables, and only specific conductance met the criteria to be included in the resulting models. Other studies have also shown strong correlations between specific conductance and AMD-related water chemistry parameters (Christensen 2001; Nimick et al. 2003).

We found that 76 - 93% of the variation in most water quality parameters could be explained by specific conductance alone. Acidity (Figure 7), sulfate, (Figure 8), magnesium (Figure 9), calcium (Figure 10), iron (Figure 11), and aluminum (Figure 12) had R^2 values above 0.75. Alkalinity was generally not present at most sites, and was therefore not included in the regression analysis. The regression model created to predict manganese concentrations included conductance as well, but the R^2 value was too low to have much predictive value ($R^2 = 0.63$, $P < 0.0001$).

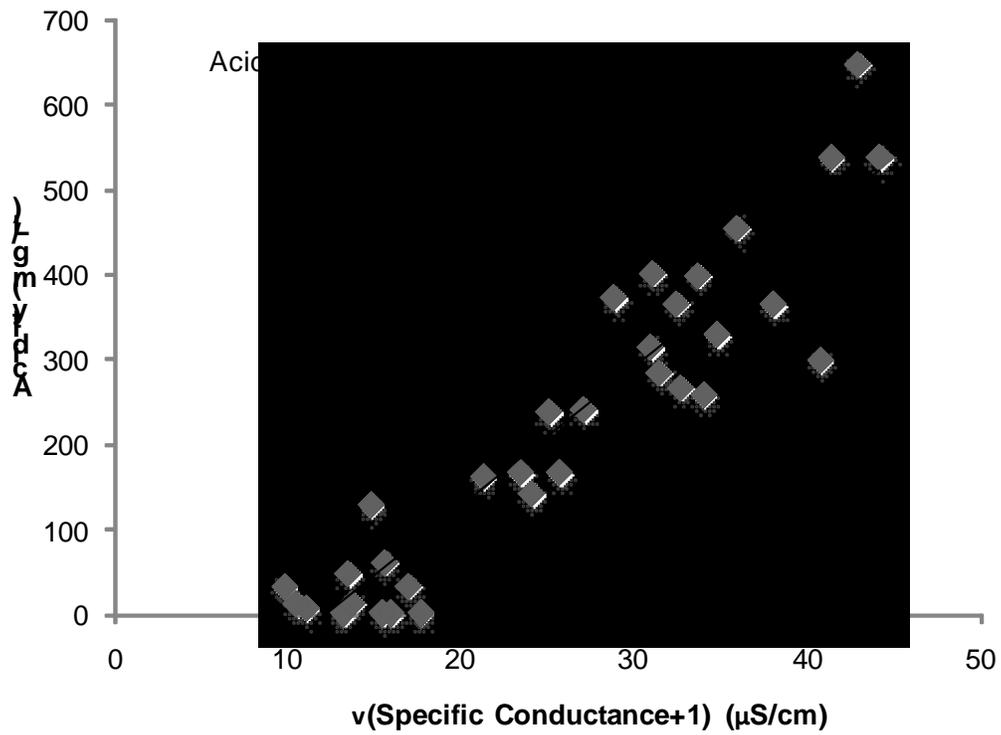


Figure 7. Relationship between acidity and transformed specific conductance data

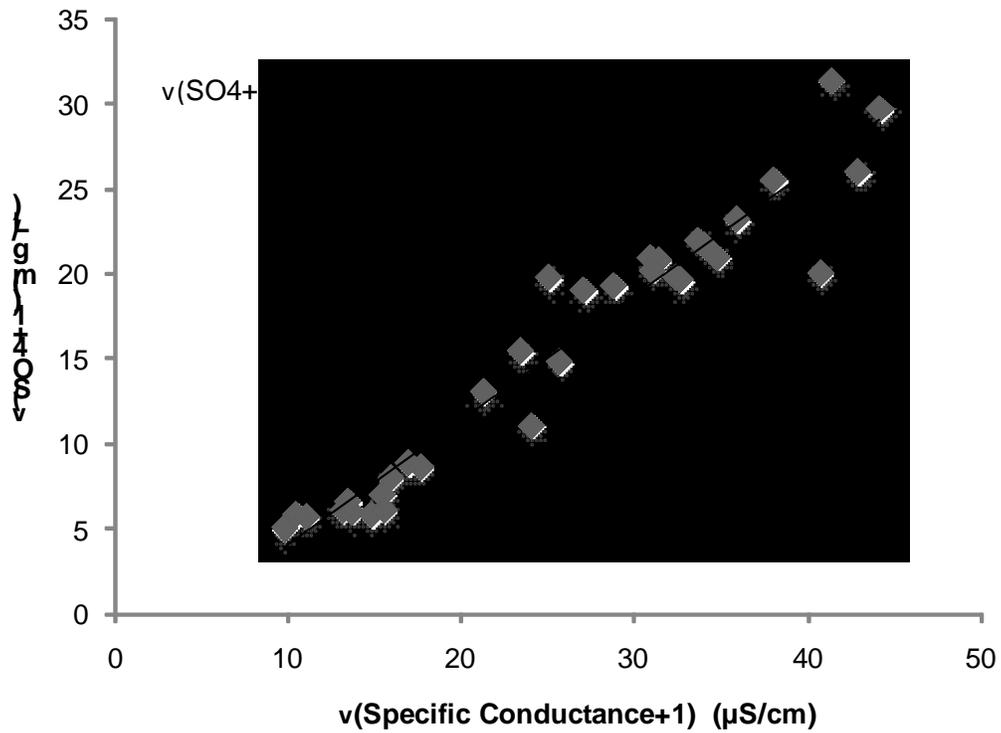


Figure 8. Relationship between transformed sulfate and specific conductance data

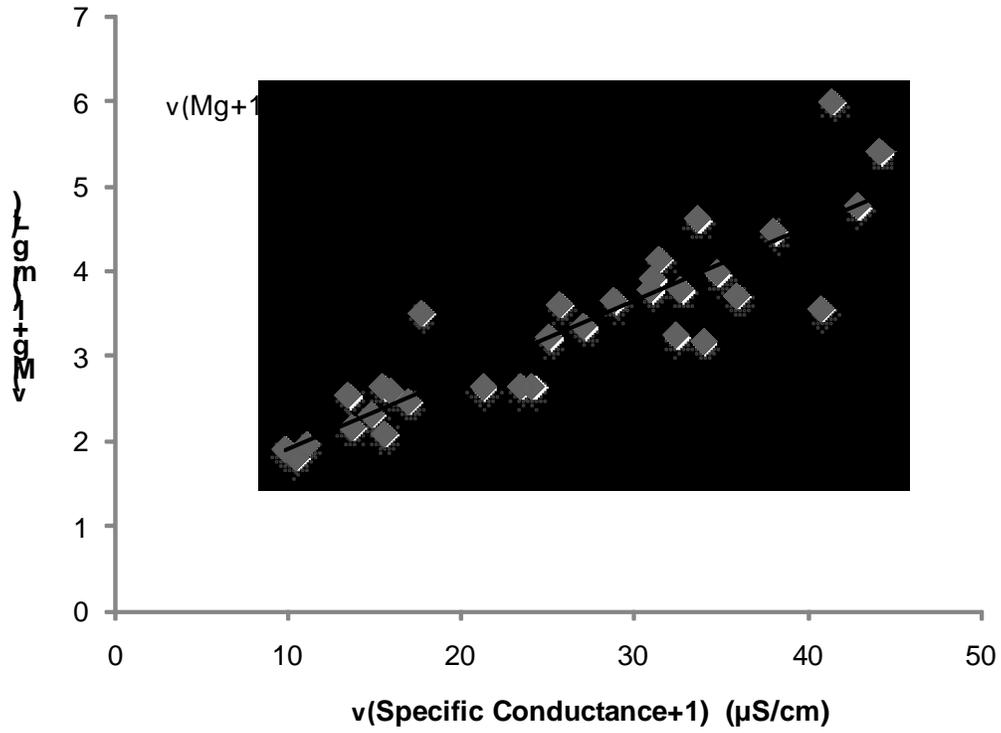


Figure 9. Relationship between transformed magnesium and specific conductance data

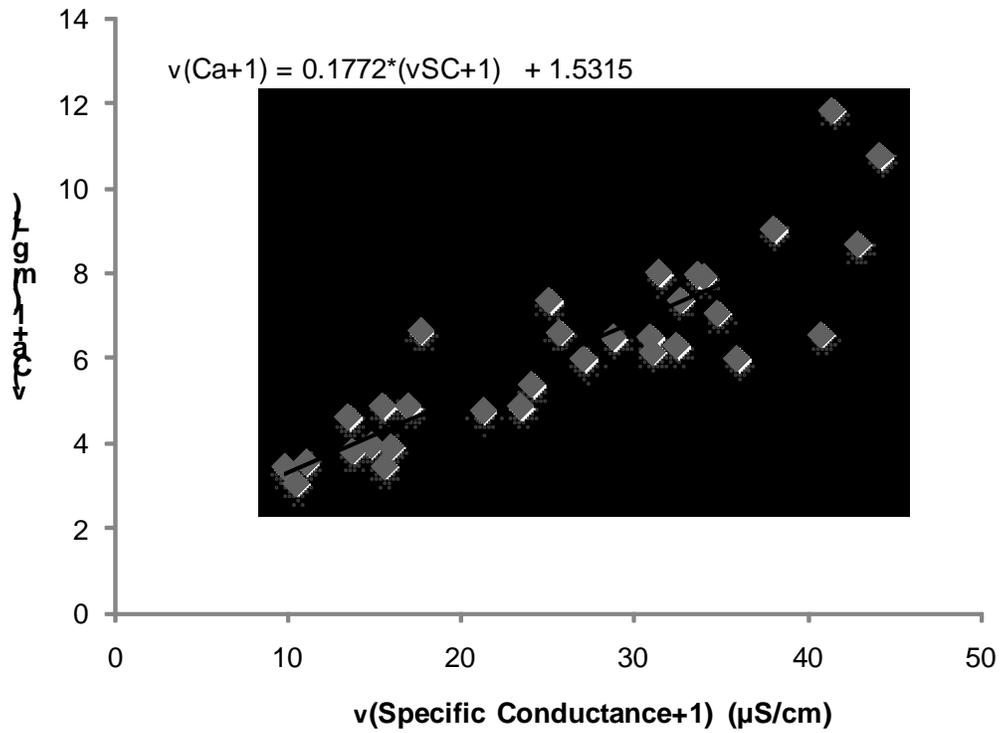


Figure 10. Relationship between transformed calcium and specific conductance data

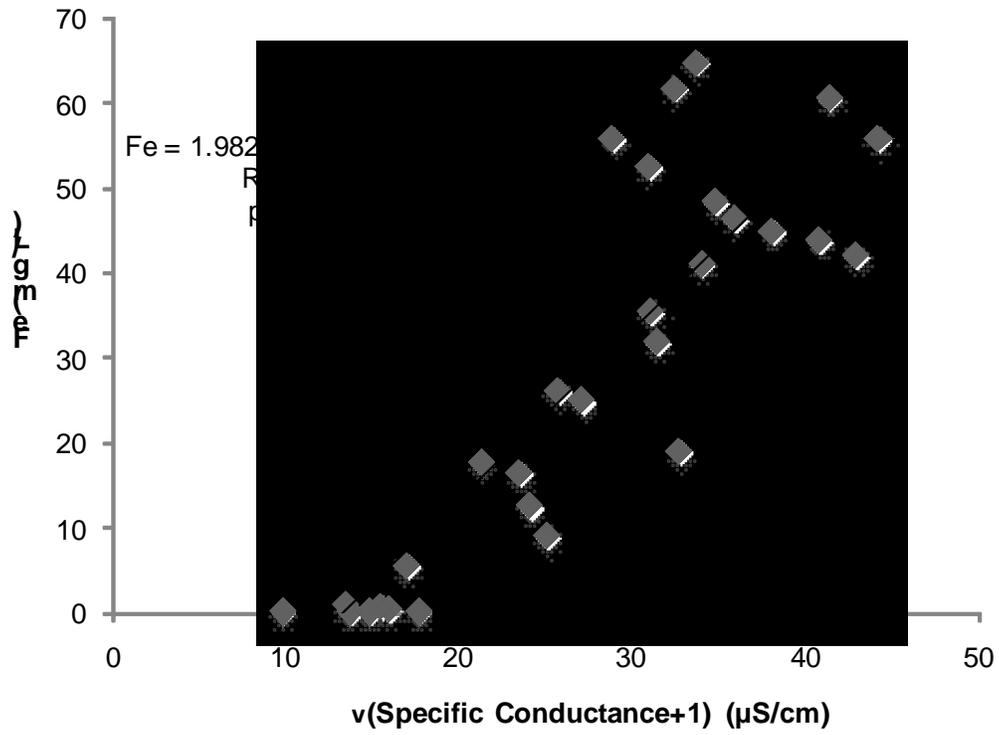


Figure 11. Relationship between iron and transformed specific conductance data

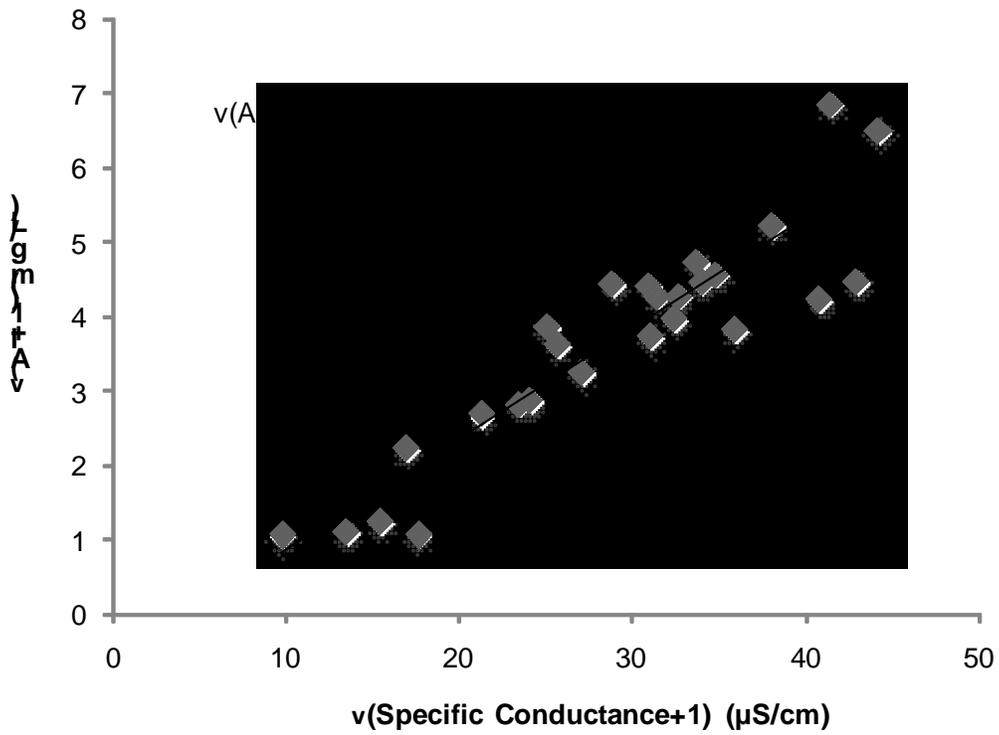


Figure 12. Relationship between transformed aluminum and specific conductance data

Chemical Loading

Several studies have shown the utility of estimating water chemistry concentrations and loadings using surrogate parameters that can be measured continuously. Many of these studies were conducted in the Midwest, and were designed to model parameters of concern in agricultural watersheds such as herbicides, suspended solids, and fecal coliform bacteria (Christensen 2001; Christensen et al. 2000; Rasmussen et al. 2003). To date, work of this type has been very limited in watersheds impacted by AMD.

In this study, concentrations of acidity, iron, and aluminum were calculated for each instantaneous sonde reading using the regression equations produced by our multiple regression analysis. Any negative calculations were converted to zero. Loading of each constituent was then calculated using the estimated instantaneous chemical concentrations and stream flow estimations.

Discharges for Greens Run were created using discharge data from a USGS gage on a comparable watershed. Discharge in Big Sandy Creek was compared to field-measured flows at the four Greens Run sampling stations on 12 occasions throughout the year, and proportions were calculated. Flows in lower Greens Run averaged 5% those of Big Sandy, while flows in the forks of Greens Run averaged between 1.6 – 2.6% of flows in Big Sandy Creek. These proportions correspond to the difference in basin area size between the watersheds. The proportions for each stream were applied to the daily Big Sandy Creek flows in order to estimate discharge at the Greens Run sampling stations.

Discharge in lower Greens Run peaked on December 13, 2007, with another smaller high water event in late January and early February 2008 (Figure 13). The sonde in lower Greens Run failed after February 2008, so discharge was not estimated past this time. Discharge in the Middle Fork (Figure 14), North Fork (Figure 15), and South Fork (Figure 16) also peaked on December 13, with several smaller peaks in January, March, June, and July 2008.

Acid load peaked in December 2007 with the high flow event in lower Greens (Figure 17), Middle Fork (Figure 18), and South Fork (Figure 20). The North Fork reached highest loadings in May and August (Figure 19). Acid load in North Fork was an order of magnitude lower than the other streams. Iron load followed a similar pattern, peaking in December in lower Greens (Figure 21), Middle Fork (Figure 22), and South Fork (Figure 24). Iron load in North Fork peaked in June and August, and was substantially lower than the other streams (Figure 23). Aluminum load peaked in December in lower Greens Run (Figure 25), and in the Middle Fork peaked in December with lower peaks in March, June, and July (Figure 26). In North Fork, aluminum load peaked in December, January, June, and August (Figure 27), and South Fork peaked in December with lower peaks in May and August (Figure 28). Loading was not calculated for manganese because the R^2 between specific conductance and manganese was extremely low, therefore loading values created using this relationship would not be accurate.

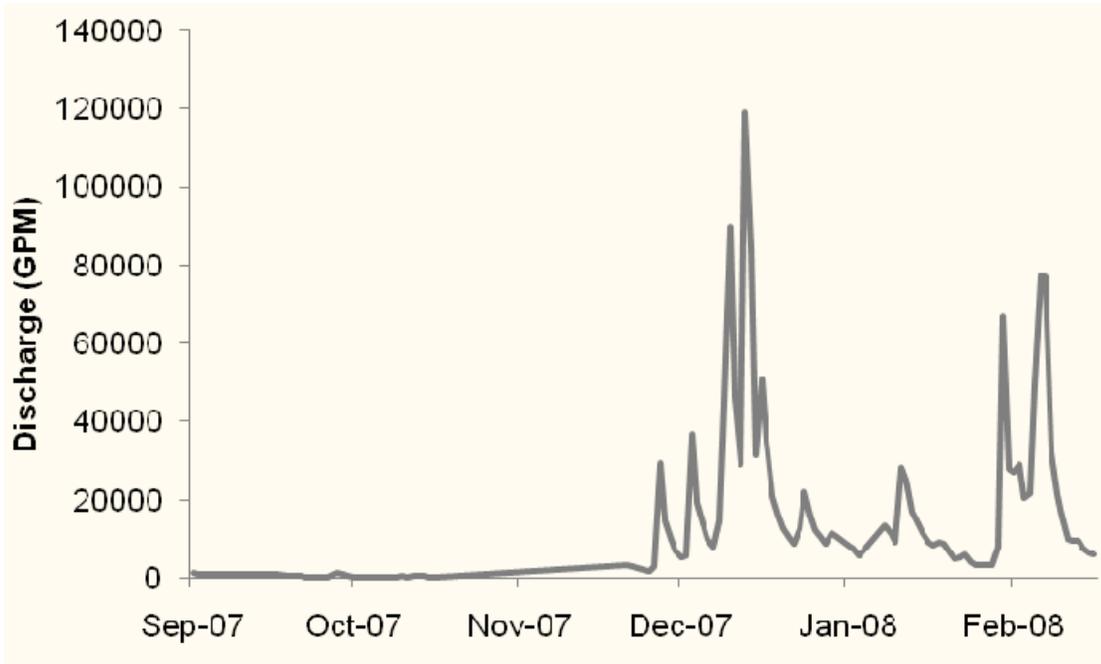


Figure 13. Estimated discharge in lower Greens Run, shown in gallons per minute

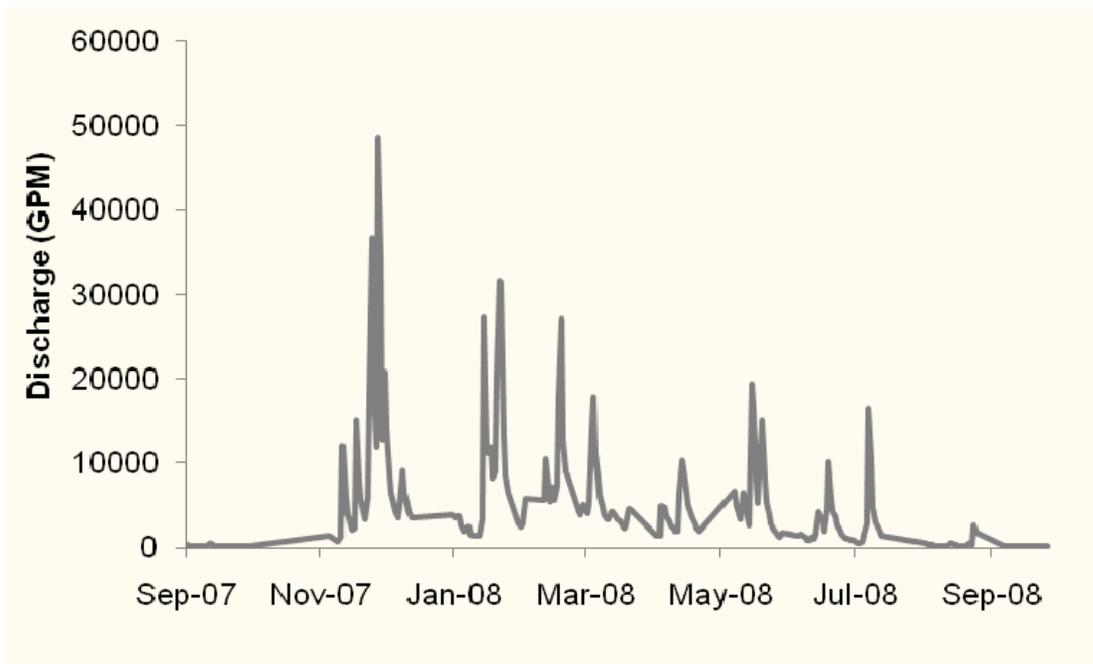


Figure 14. Estimated discharge in Middle Fork Greens Run, shown in gallons per minute

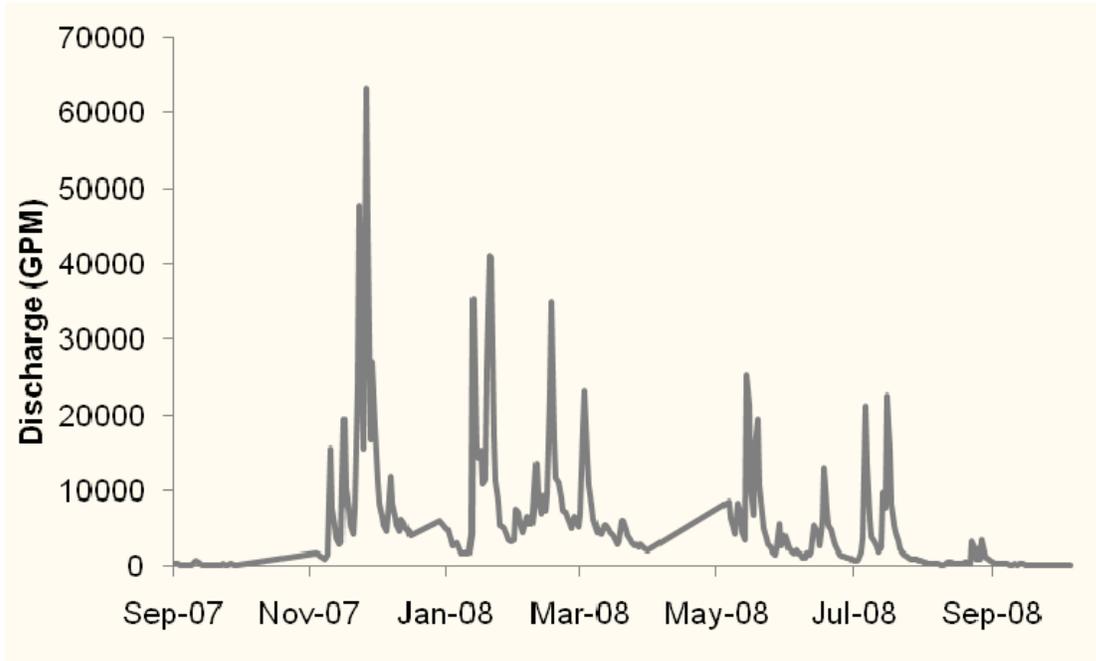


Figure 15. Estimated discharge in North Fork Greens Run, shown in gallons per minute

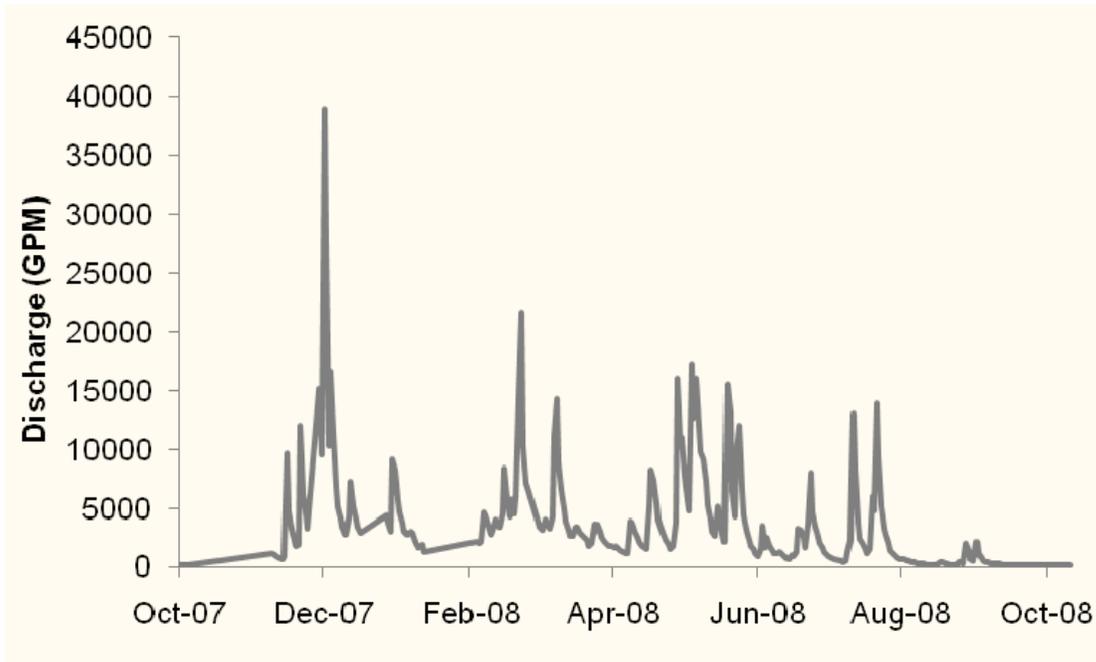


Figure 16. Estimated discharge in South Fork Greens Run, shown in gallons per minute

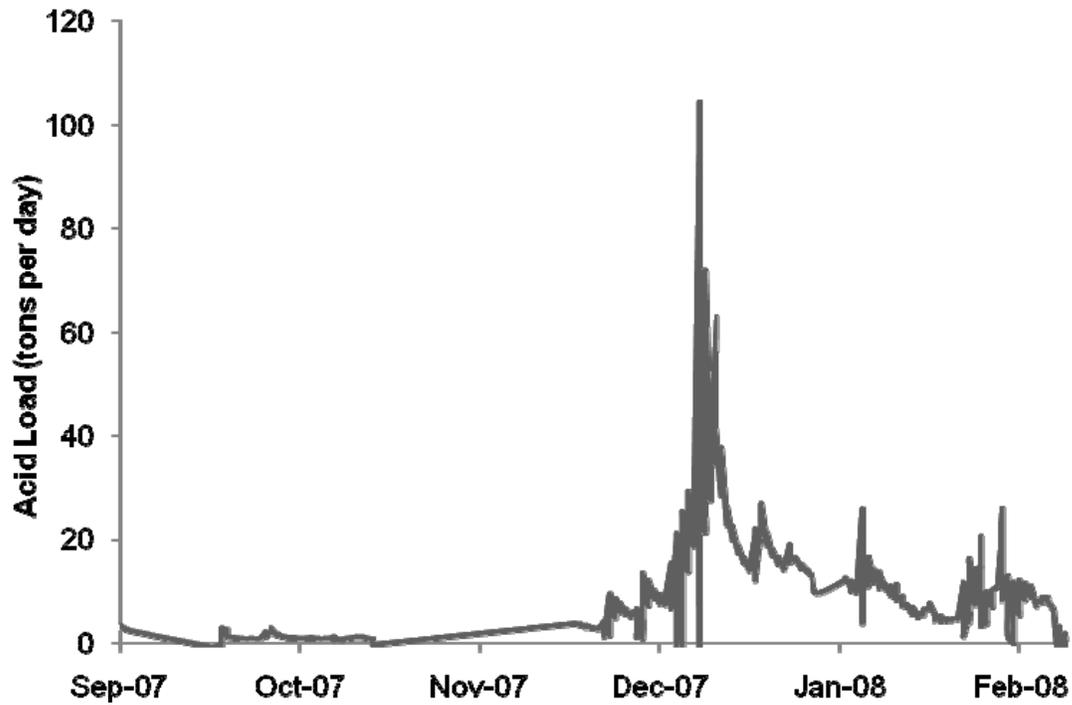


Figure 17. Acid load in lower Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

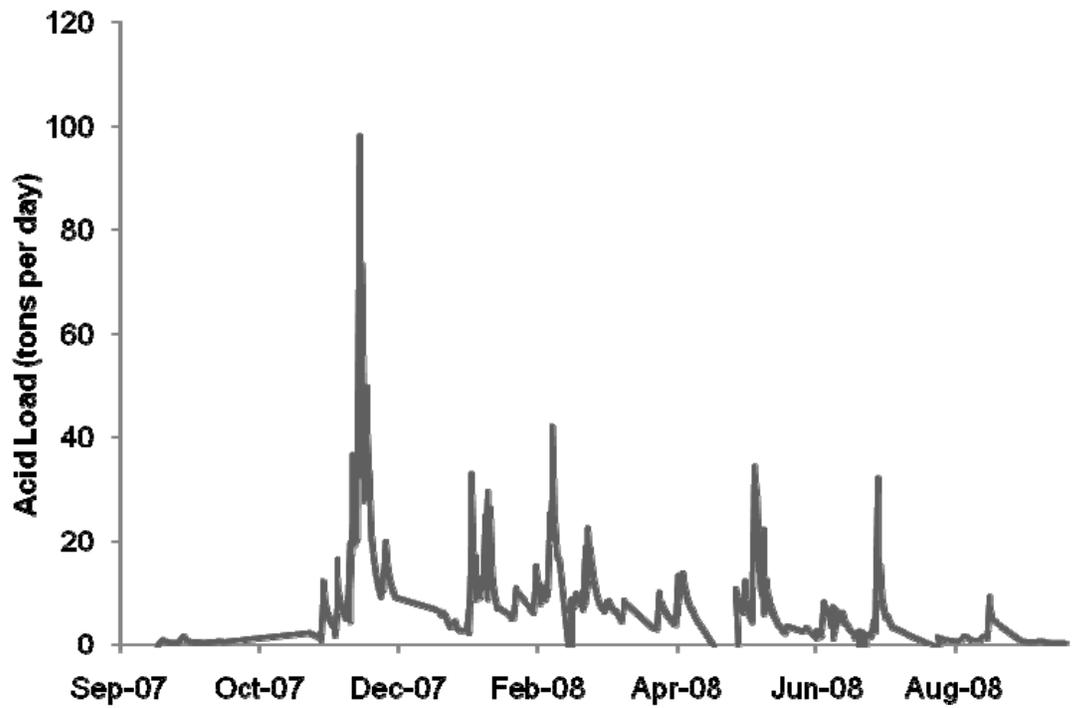


Figure 18. Acid load in Middle Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance

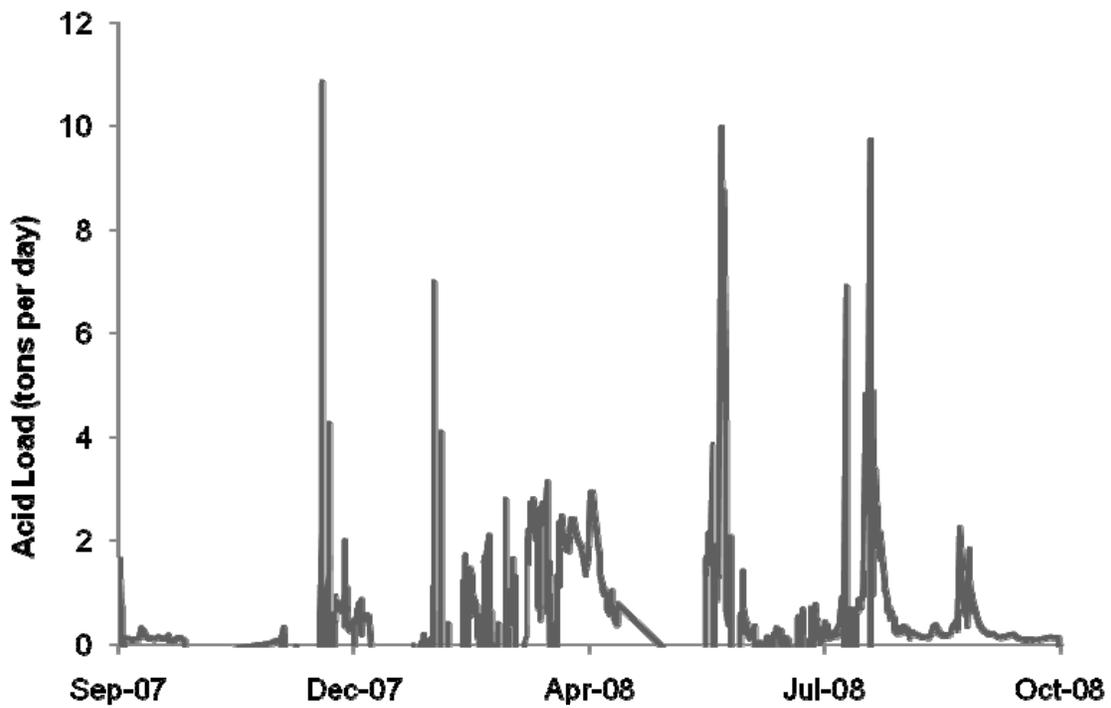


Figure 19. Acid load in North Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements (note change in vertical axis scaling)

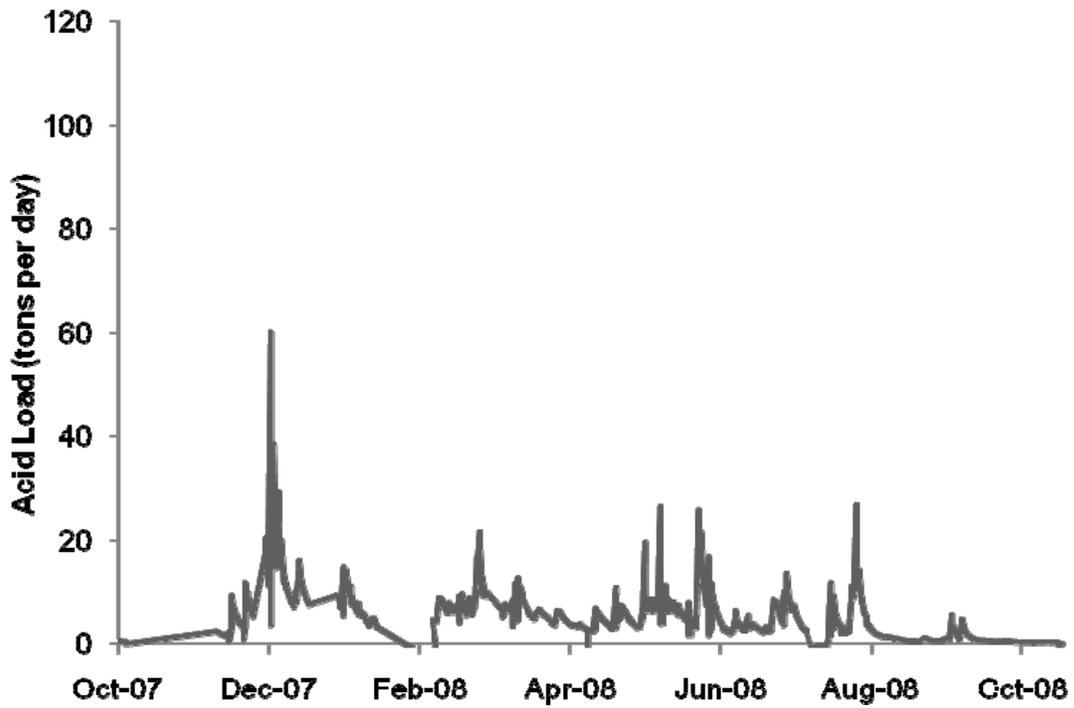


Figure 20. Acid load in South Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

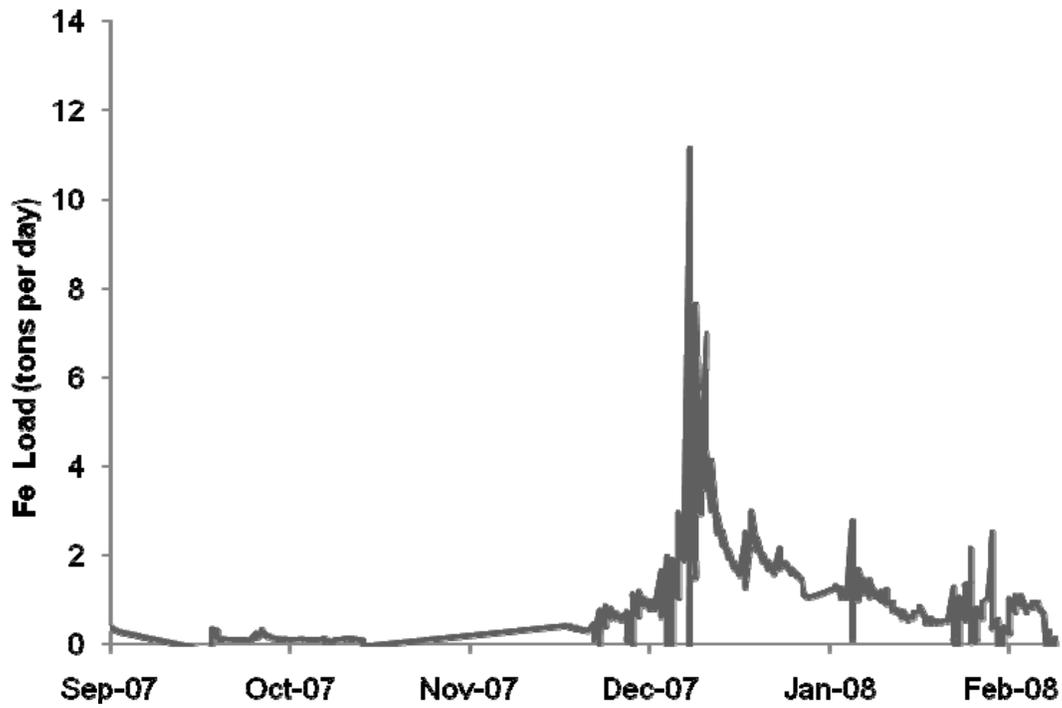


Figure 21. Iron load in lower Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

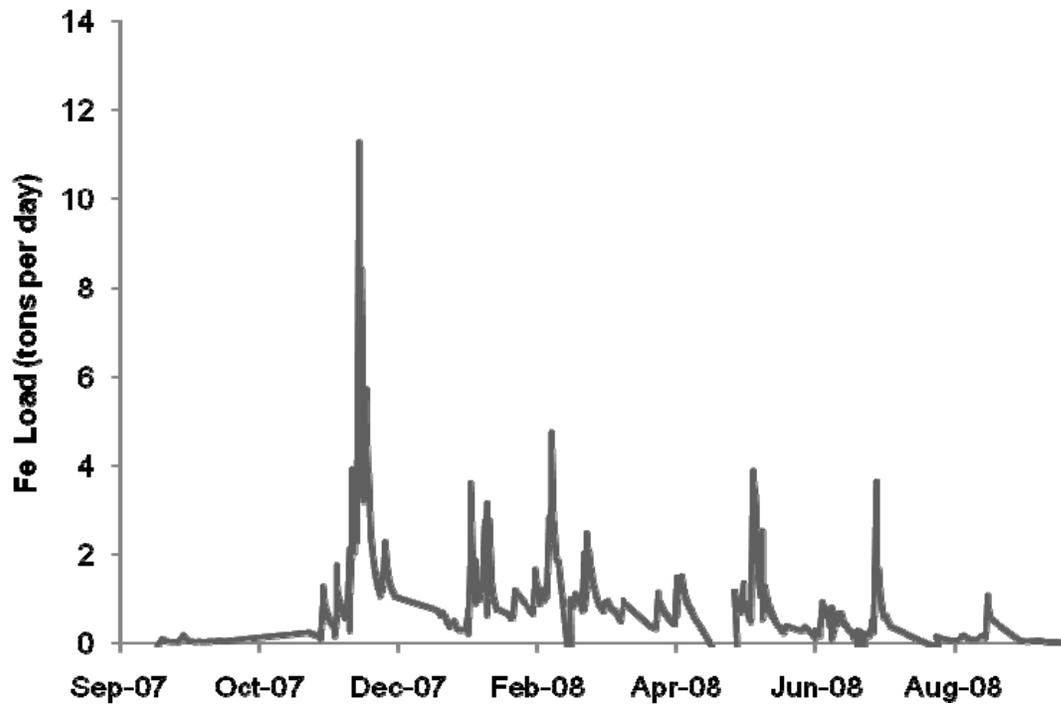


Figure 22. Iron load in Middle Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

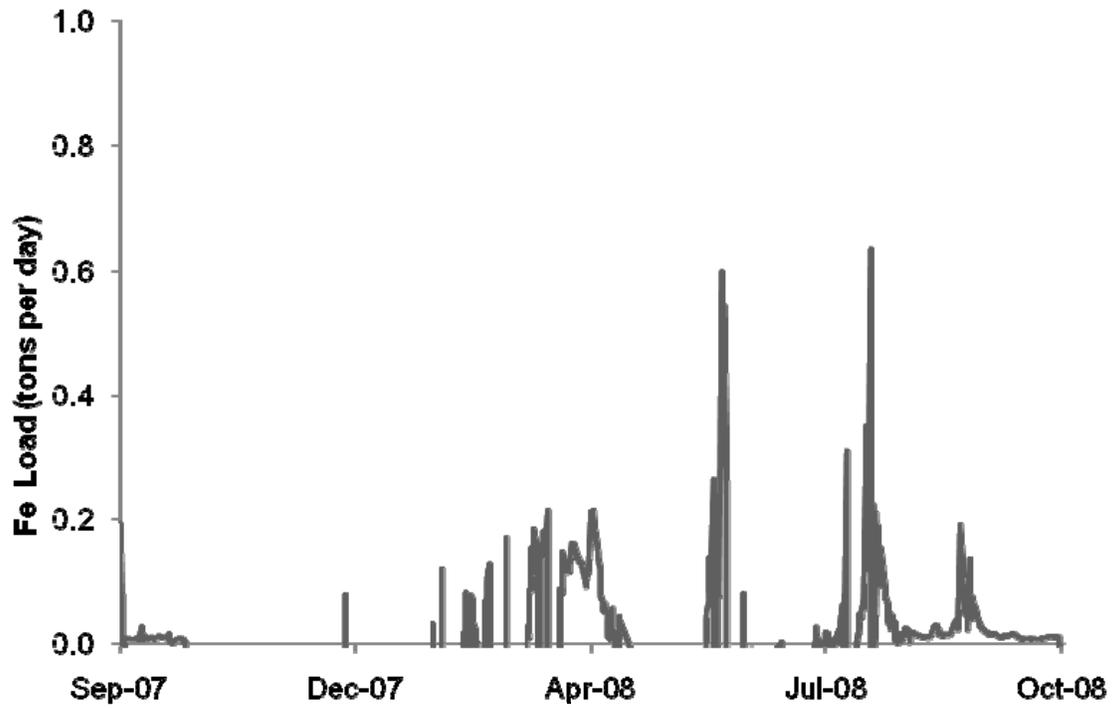


Figure 23. Iron load in North Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements (note change in vertical axis scaling)

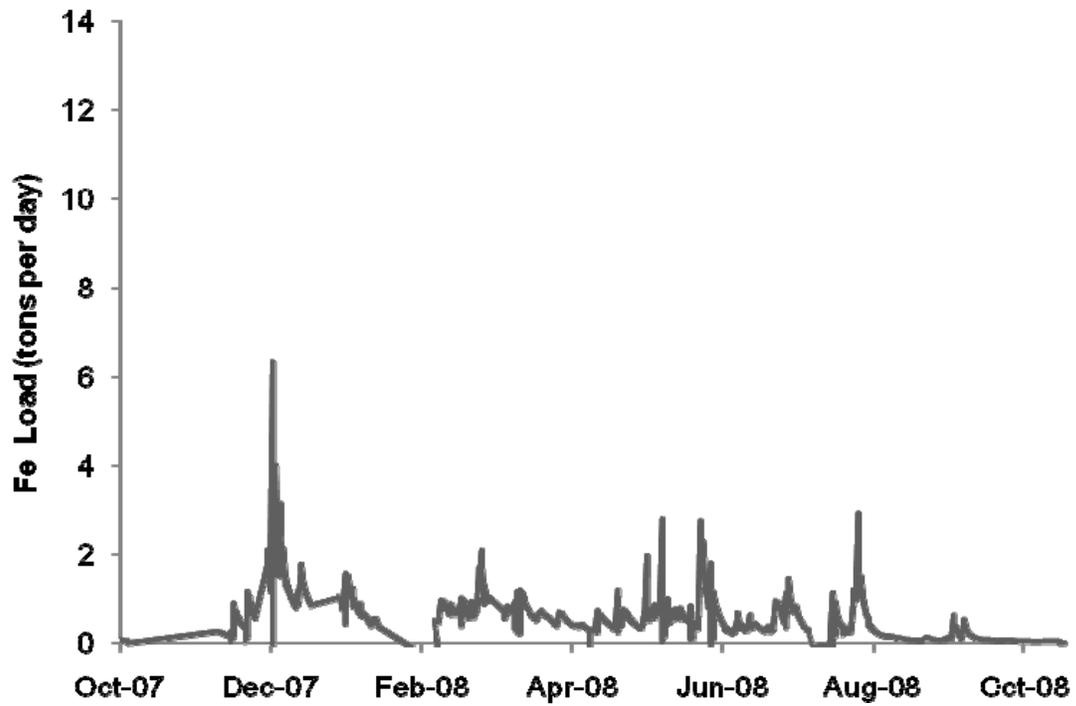


Figure 24. Iron load in South Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

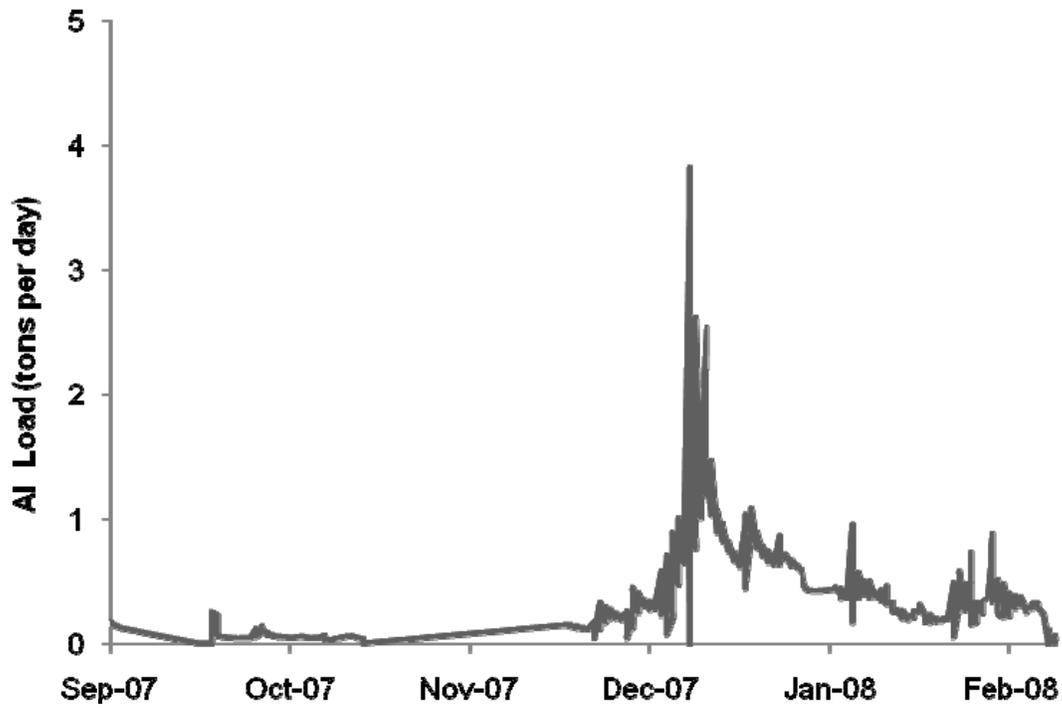


Figure 25. Aluminum load in lower Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

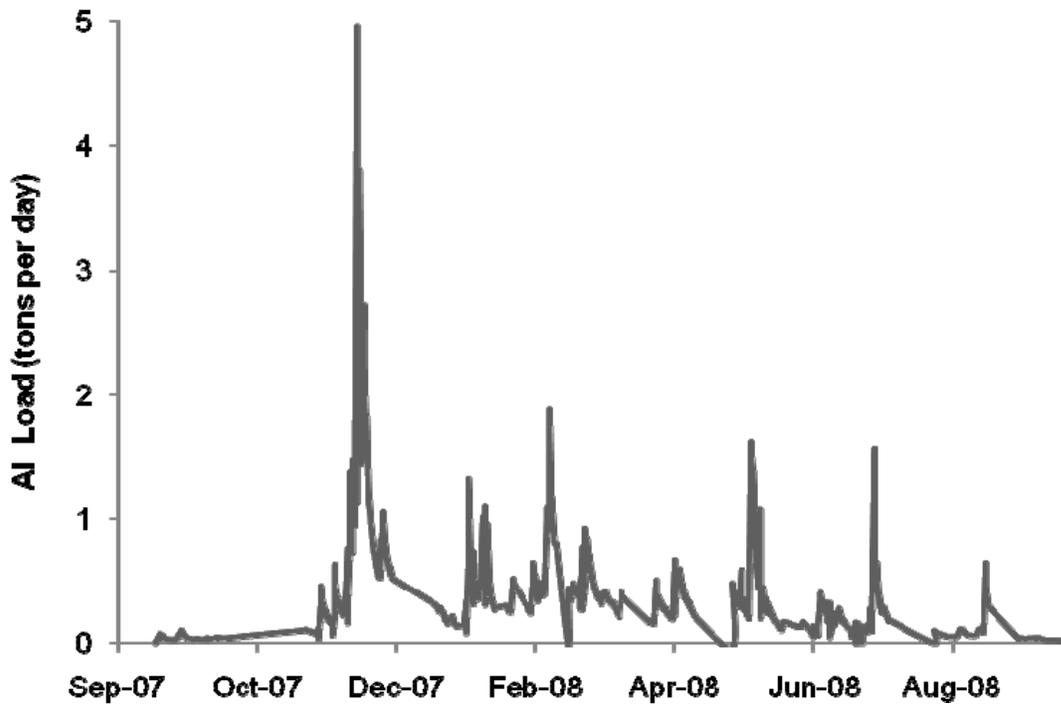


Figure 26. Aluminum load in Middle Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

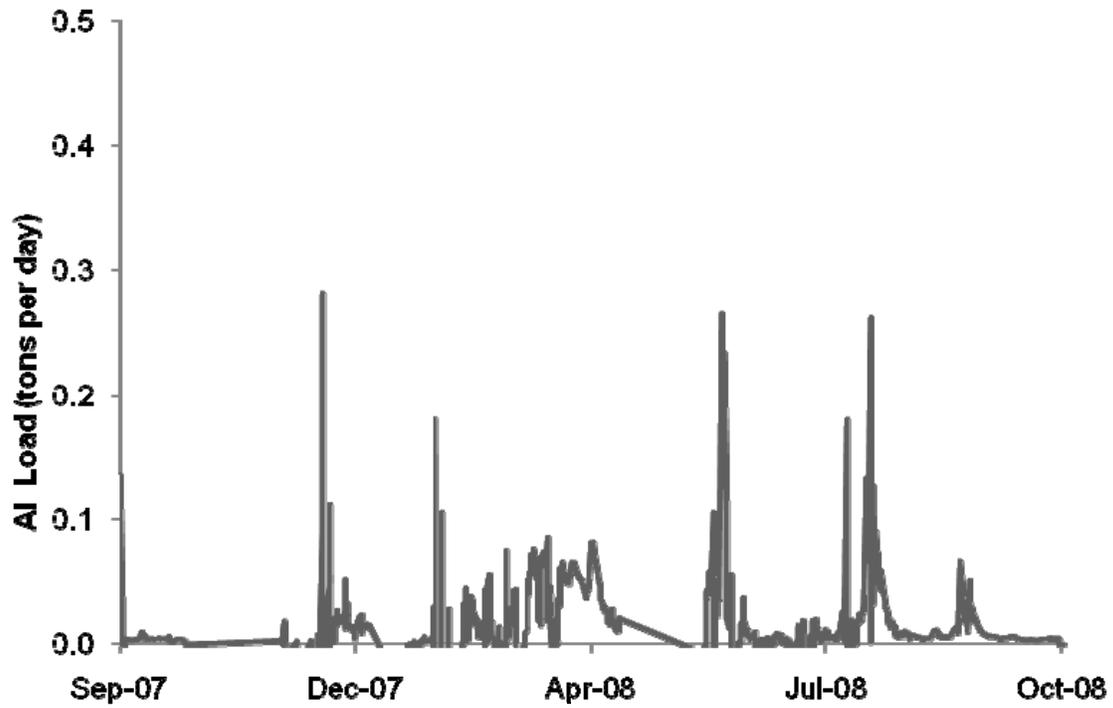


Figure 27. Aluminum load in North Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements (note change in vertical axis scaling)

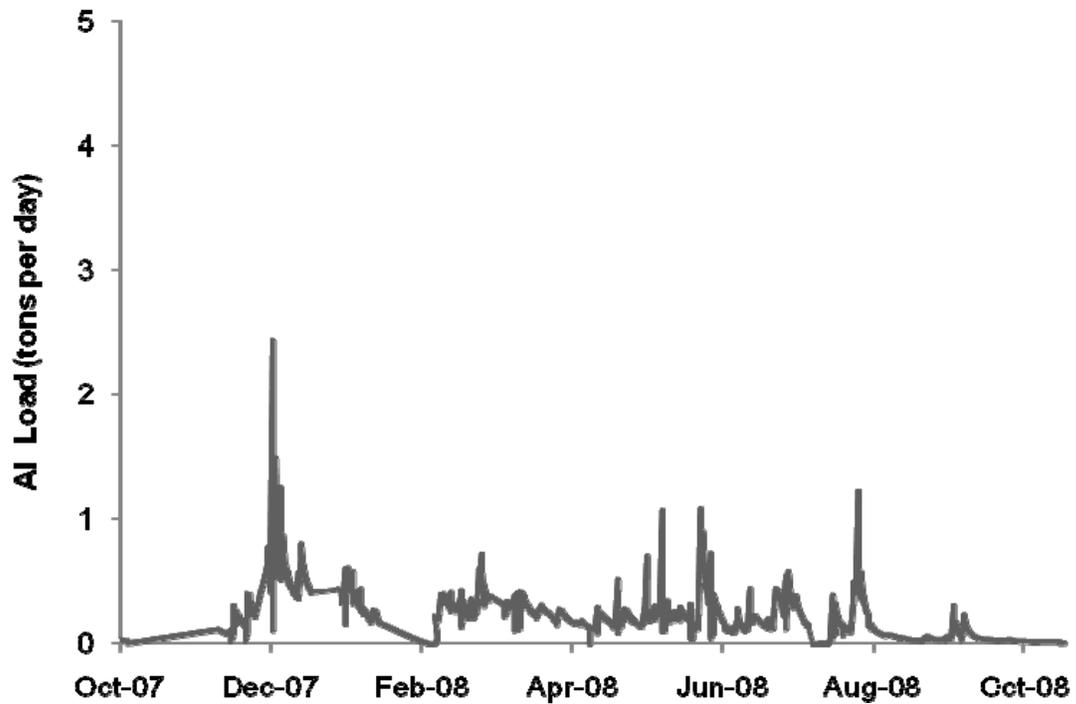


Figure 28. Aluminum load in South Fork Greens Run (shown in tons per day), predicted using instantaneous specific conductance measurements

Temporal Variability

Seasonal Variation – Laboratory Data

Acidity and sulfates were consistently high in the Middle Fork, which only had a brief period of alkalinity in spring (Figure 29). There was a spike in all chemical parameters during fall 2007 and late summer/early fall 2008. Other parameters, including magnesium, calcium, aluminum, and particularly iron were also elevated in February 2008 (Figure 30).

Alkalinity was higher in the North Fork, which had a small spike in acidity during mid-winter (Figure 31). A pattern of elevated chemical parameters in late summer and fall was seen in this stream, as well as a large spike in manganese in April 2008 (Figure 32).

Alkalinity was not present in the South Fork. Acidity and sulfates were consistently high, dropping only in winter 2007 and spring 2008 (Figure 33). Chemical parameters were extremely variable in this stream, and the large spike in manganese during the April sampling event was also seen here (Figure 34).

In lower Greens Run, acidity and sulfate levels were similar to the Middle and South Forks, and increased in fall 2008 (Figure 35). Similar to the South Fork, the chemical concentrations were extremely variable in this stream, with large spikes in spring and fall 2008 (Figure 36).

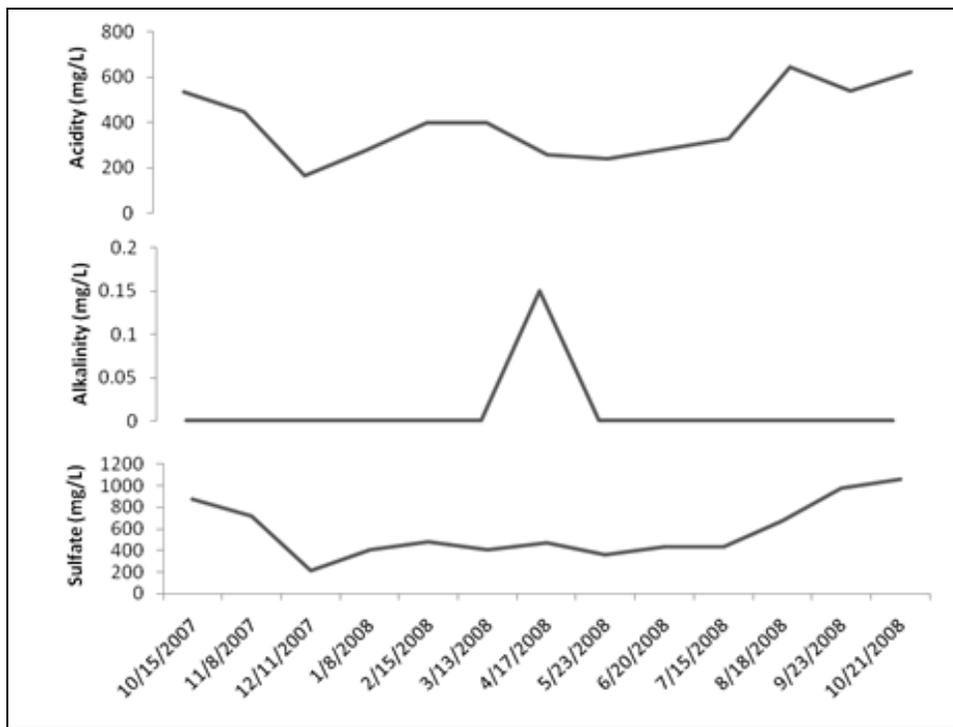


Figure 29. Monthly grab sample data from water sampling conducted on Middle Fork Greens Run

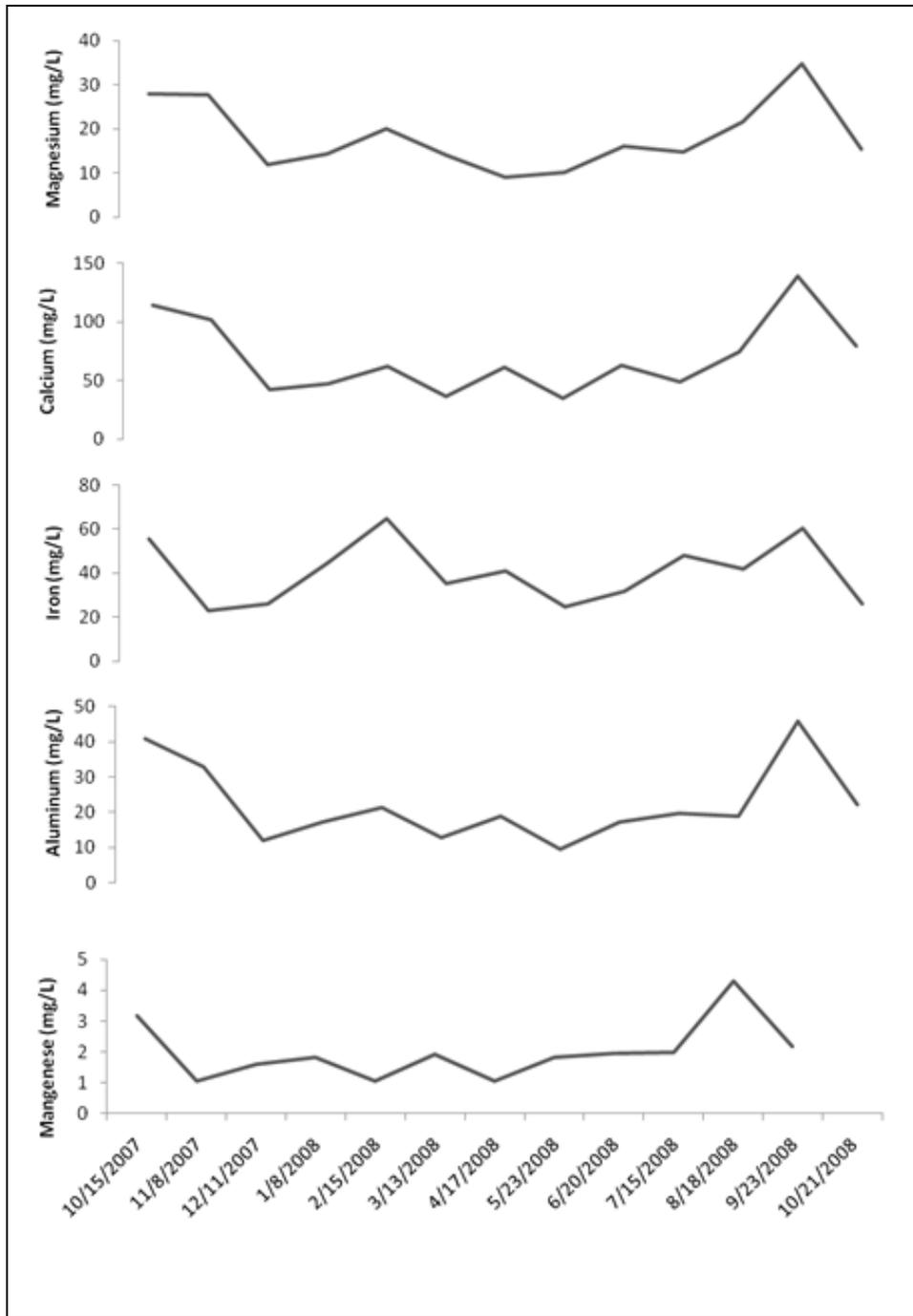


Figure 30. Monthly chemistry data from water sampling conducted on Middle Fork Greens Run

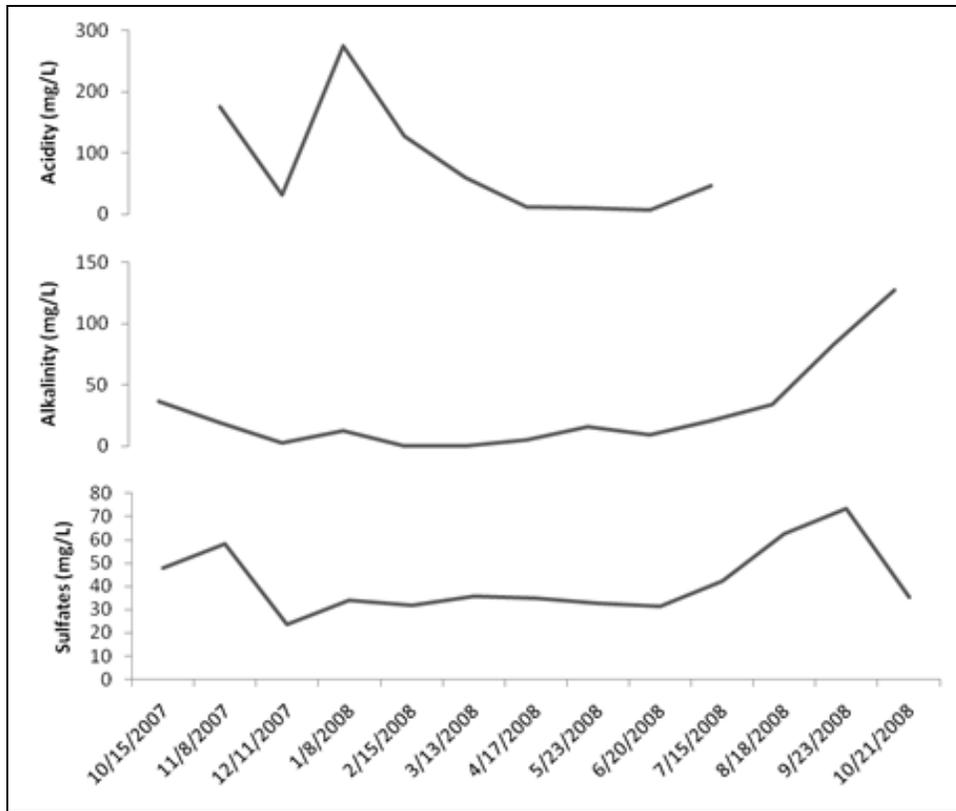


Figure 31. Monthly grab sample data from water sampling conducted on North Fork Greens Run

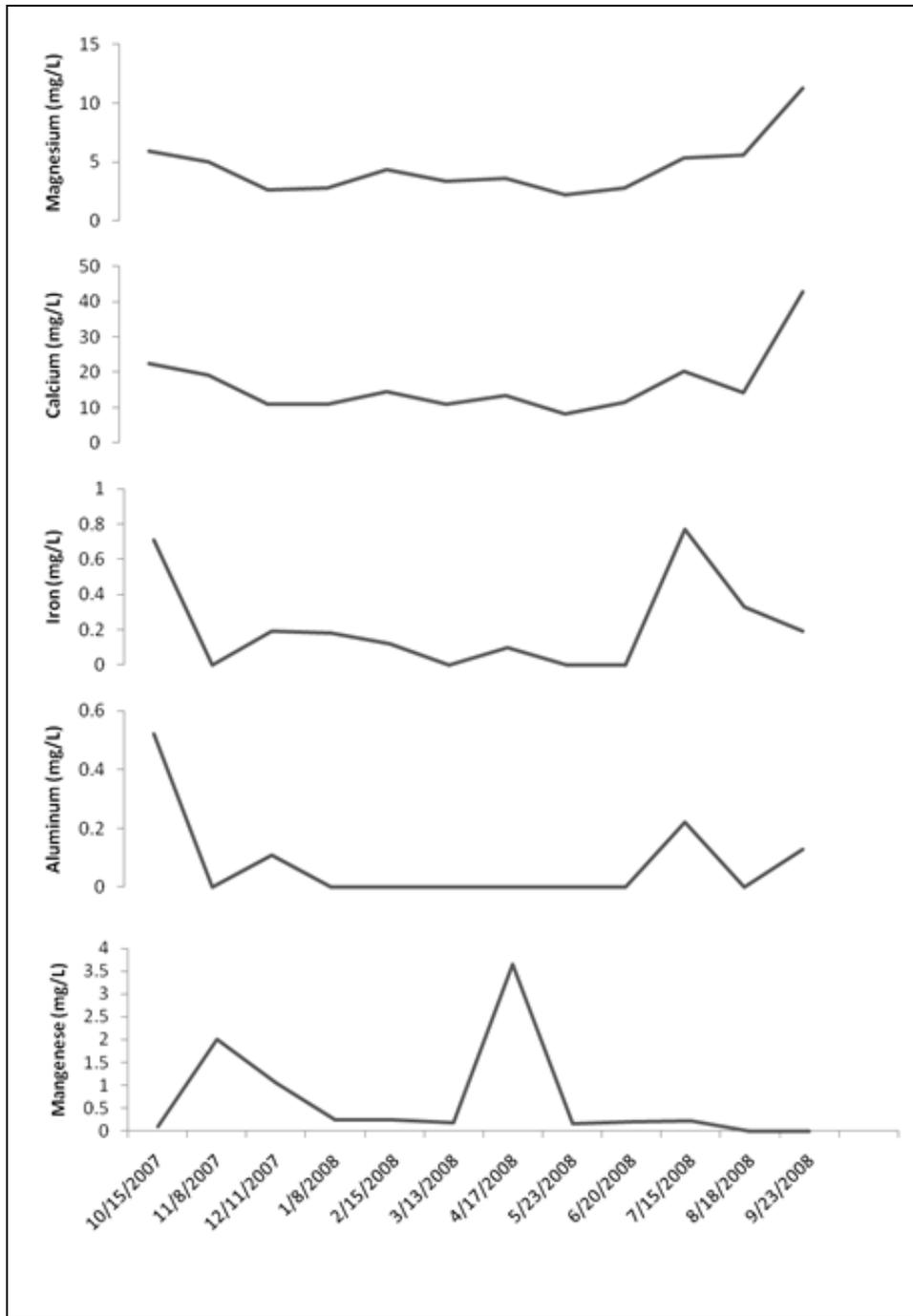


Figure 32. Monthly chemistry data from water sampling conducted on North Fork Greens Run

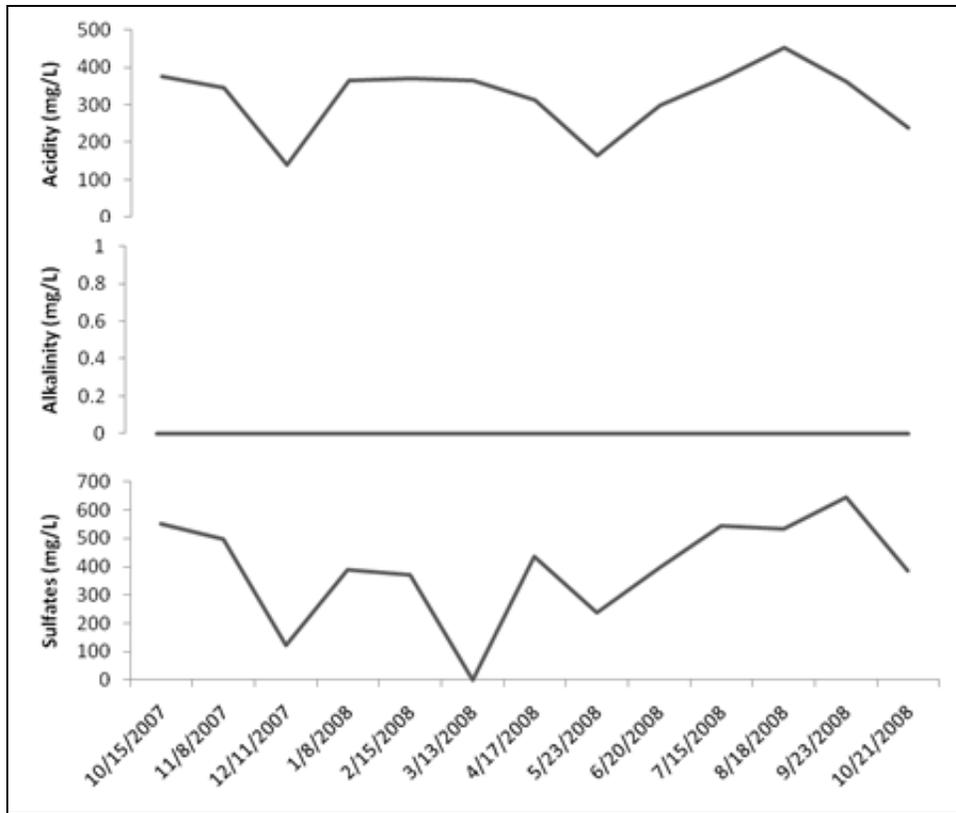


Figure 33. Monthly grab sample data from water sampling conducted on South Fork Greens Run

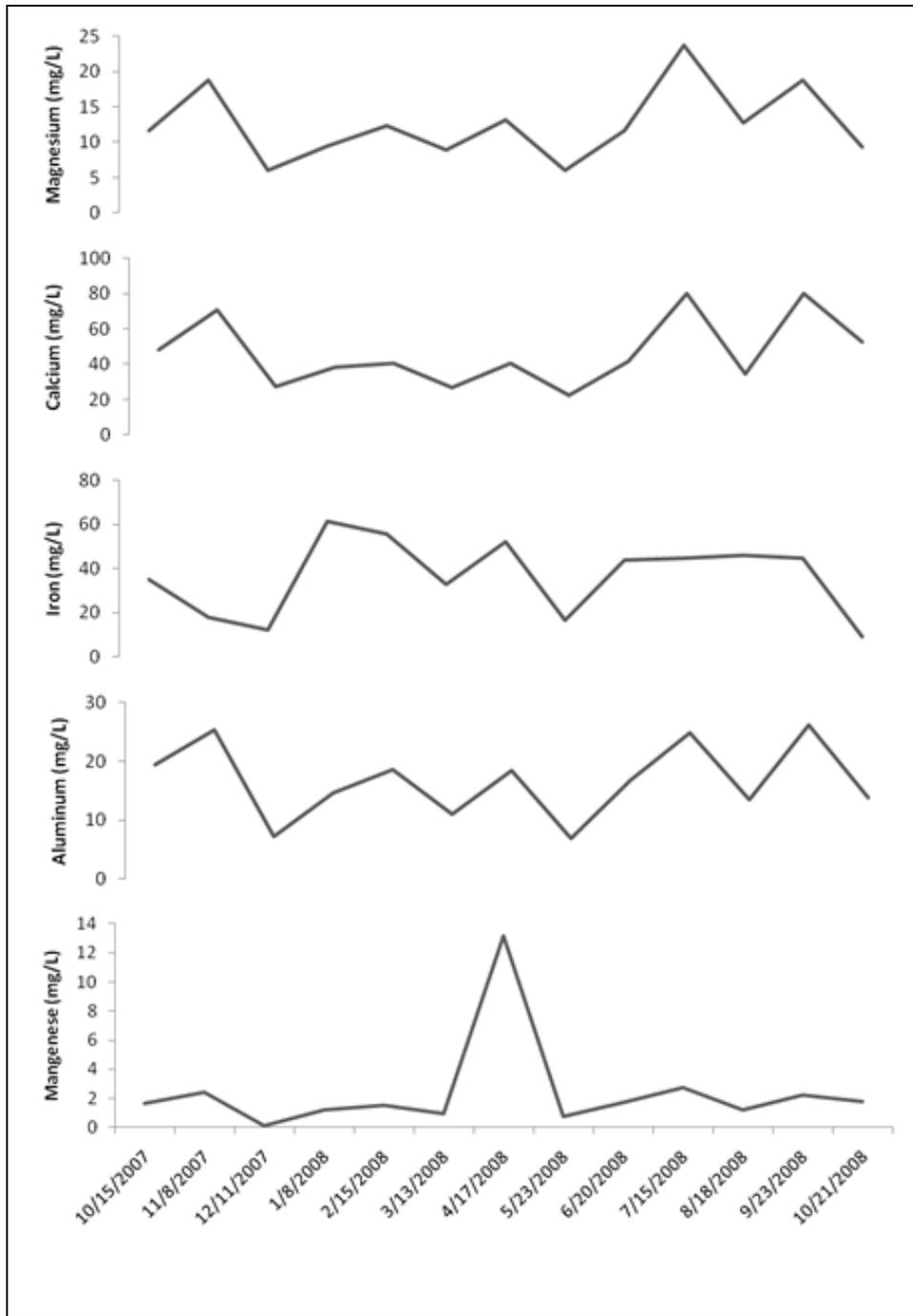


Figure 34. Monthly chemistry data from water sampling conducted on South Fork Greens Run

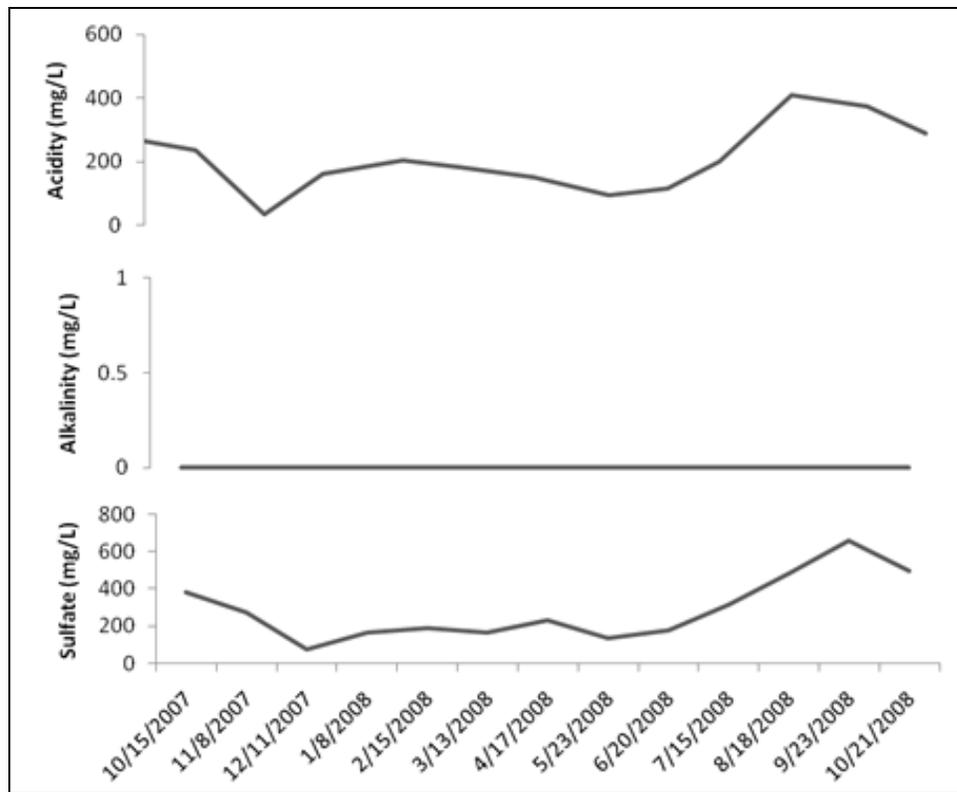


Figure 35. Monthly grab sample data from water sampling conducted on lower Greens Run

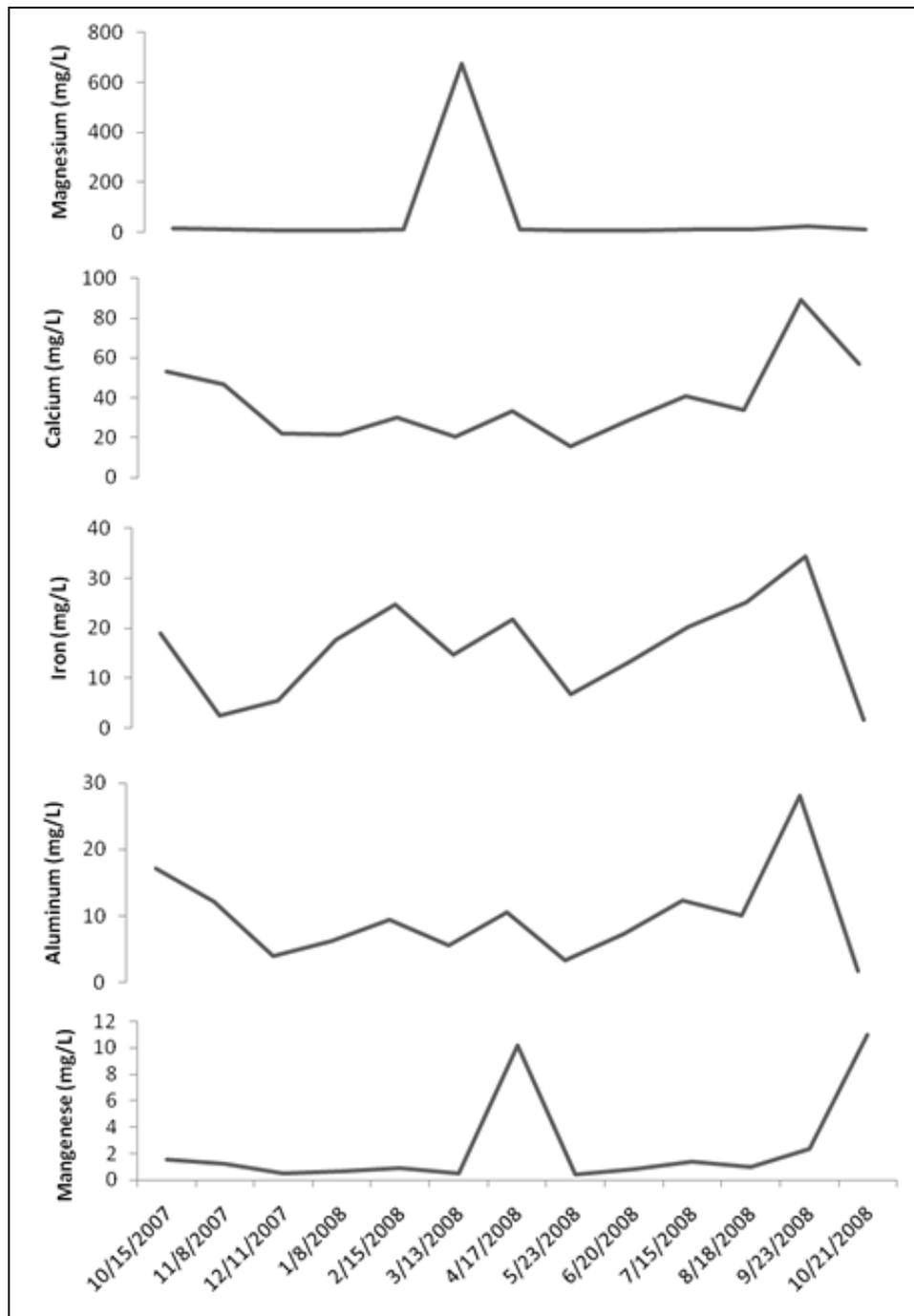


Figure 36. Monthly chemistry data from water sampling conducted on lower Greens Run

Seasonal Variation – Continuous Data

Temperature followed the expected pattern at most sites, peaking in early fall 2007 and mid-summer 2007 (Figure 37, Figure 41, Figure 45, and Figure 49). In the South Fork, a sharp spike to 55 degrees in late fall 2007 indicated an error with the sensor, and this outlier was removed from the graph.

Specific conductance was generally lower during periods of high flows, and rose sharply during summer dry periods (Figure 38, Figure 42, Figure 46, and Figure 50). The moderating effect of precipitation on specific conductance was also seen in a continuous monitoring study in Lake Texoma (Atkinson and Mabe 2006).

Dissolved oxygen levels climbed throughout the fall and winter, and dropped sharply in late spring, summer, and early fall (Figure 39, Figure 47, and Figure 51). In the Middle Fork, the pattern holds true, but an unusual drop during winter may indicate icing issues (Figure 43).

The pH levels stayed fairly constant, without much seasonal variation (Figure 40, Figure 44, Figure 48, and Figure 52). In the more acidic streams such as Middle Fork, South Fork, and lower Greens, pH increased with higher flows.

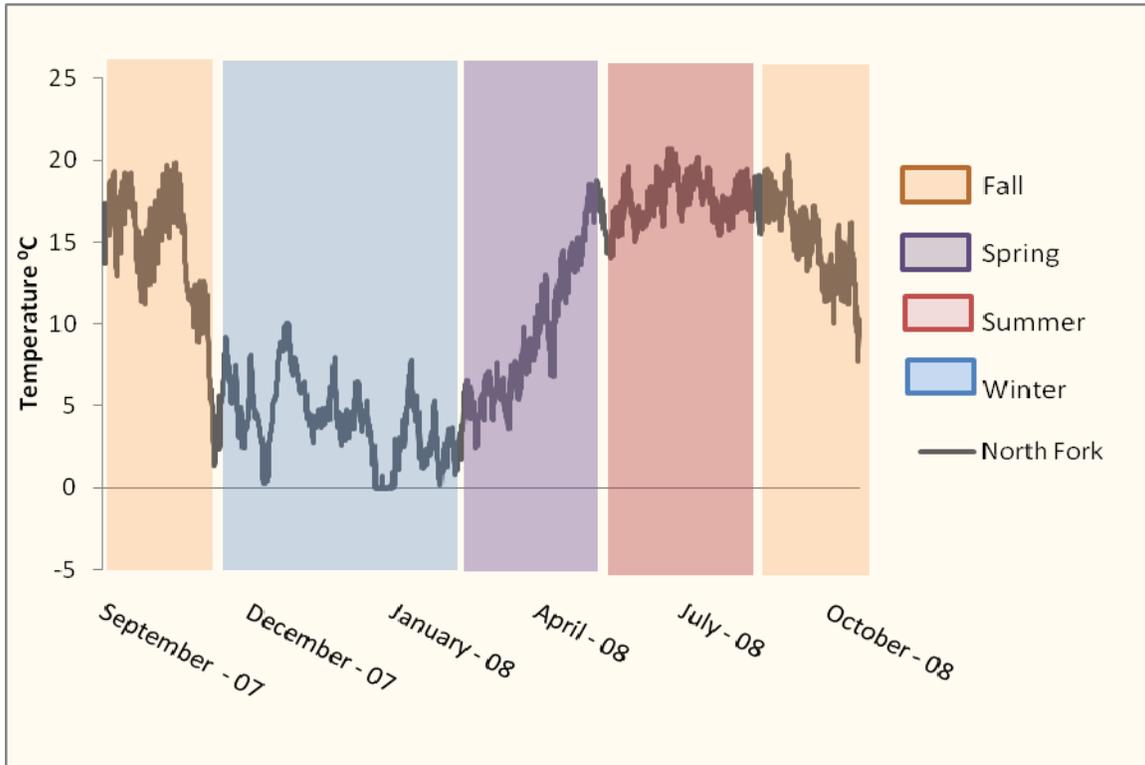


Figure 37. Seasonal temperature from continuous monitoring on North Fork Greens Run

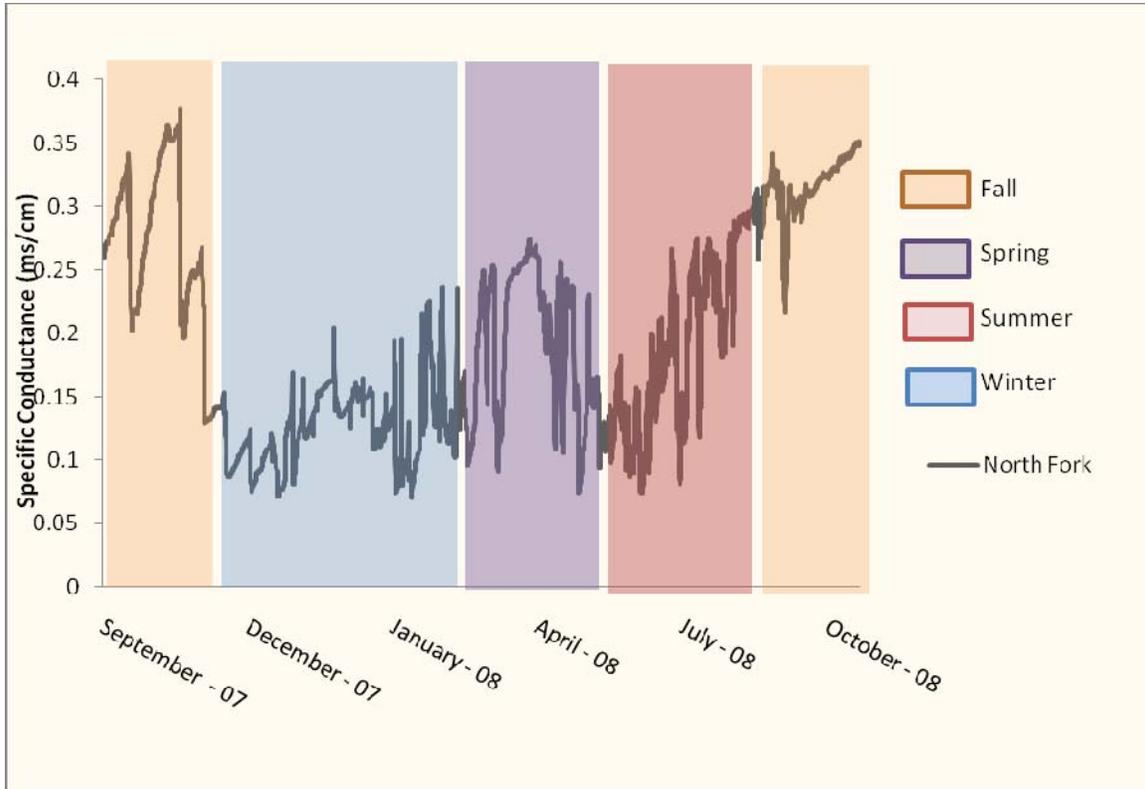


Figure 38. Seasonal specific conductance from continuous monitoring on North Fork Greens Run

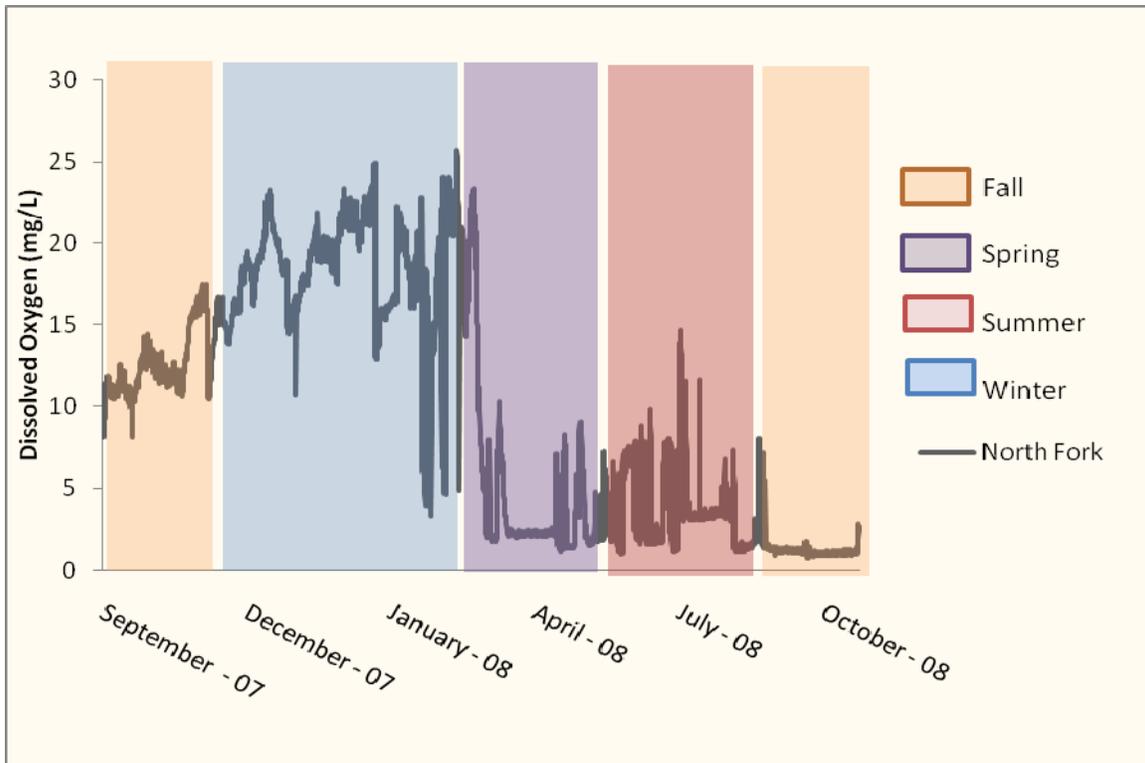


Figure 39. Seasonal dissolved oxygen from continuous monitoring on North Fork Greens Run

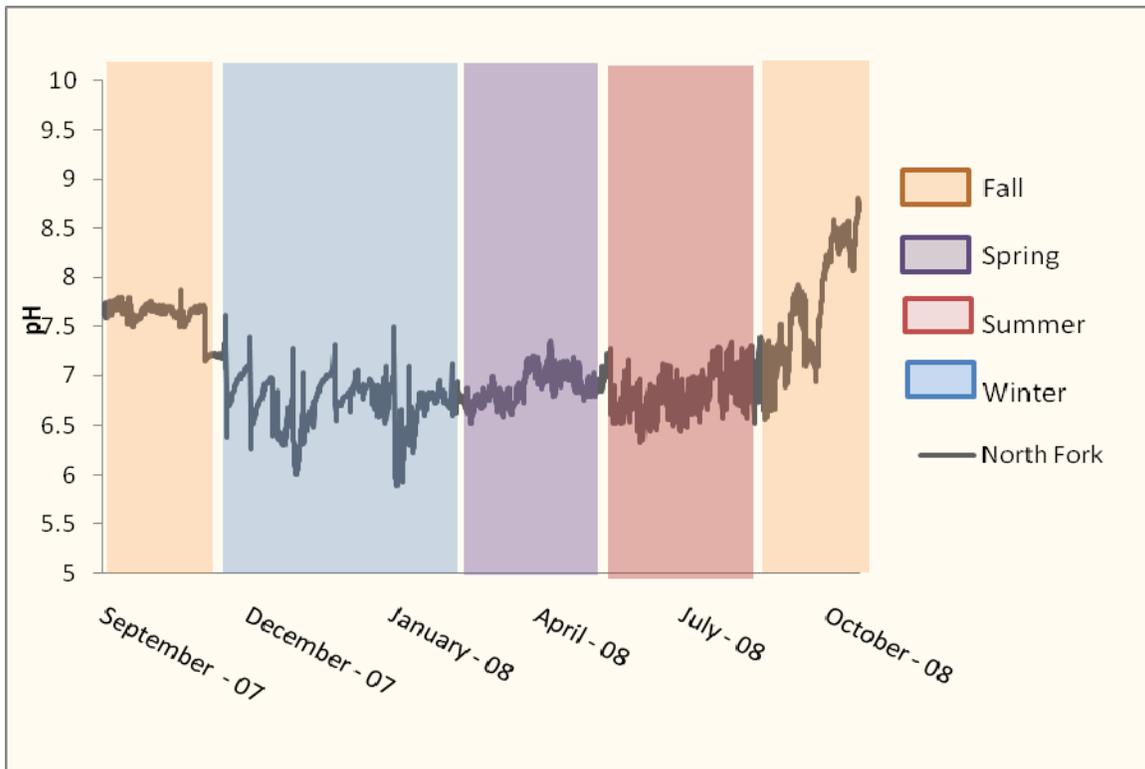


Figure 40. Seasonal pH from continuous monitoring on North Fork Greens Run

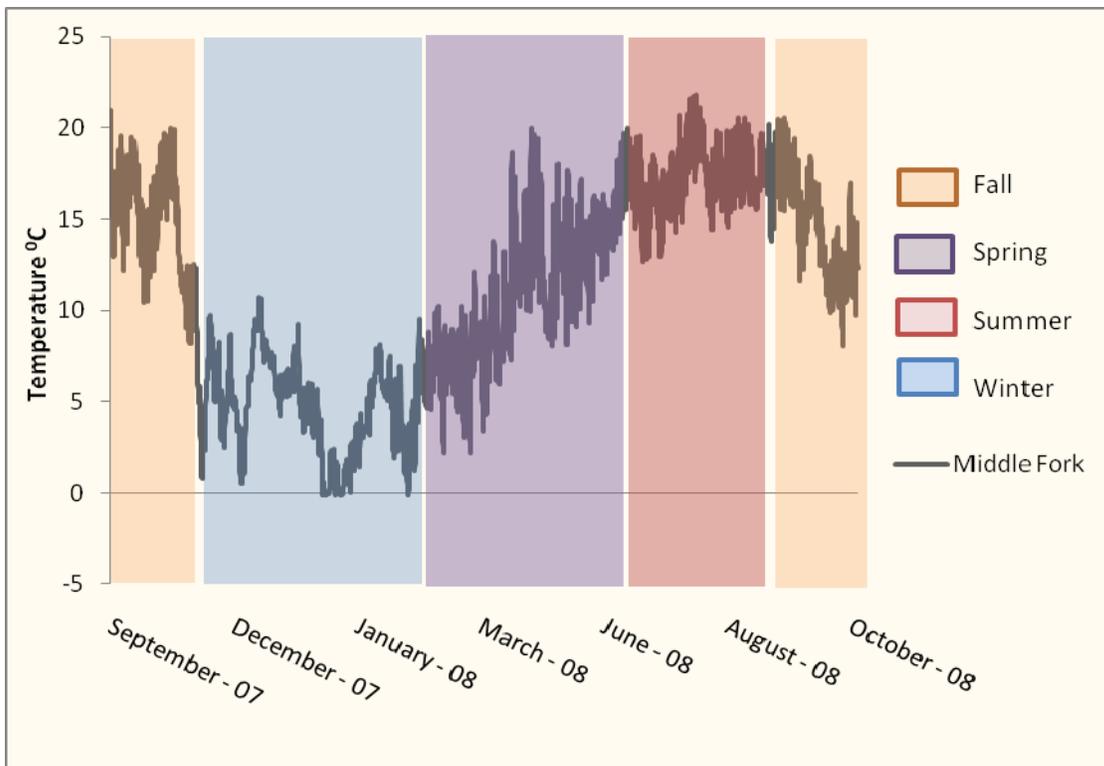


Figure 41. Seasonal temperature from continuous monitoring on Middle Fork Greens Run

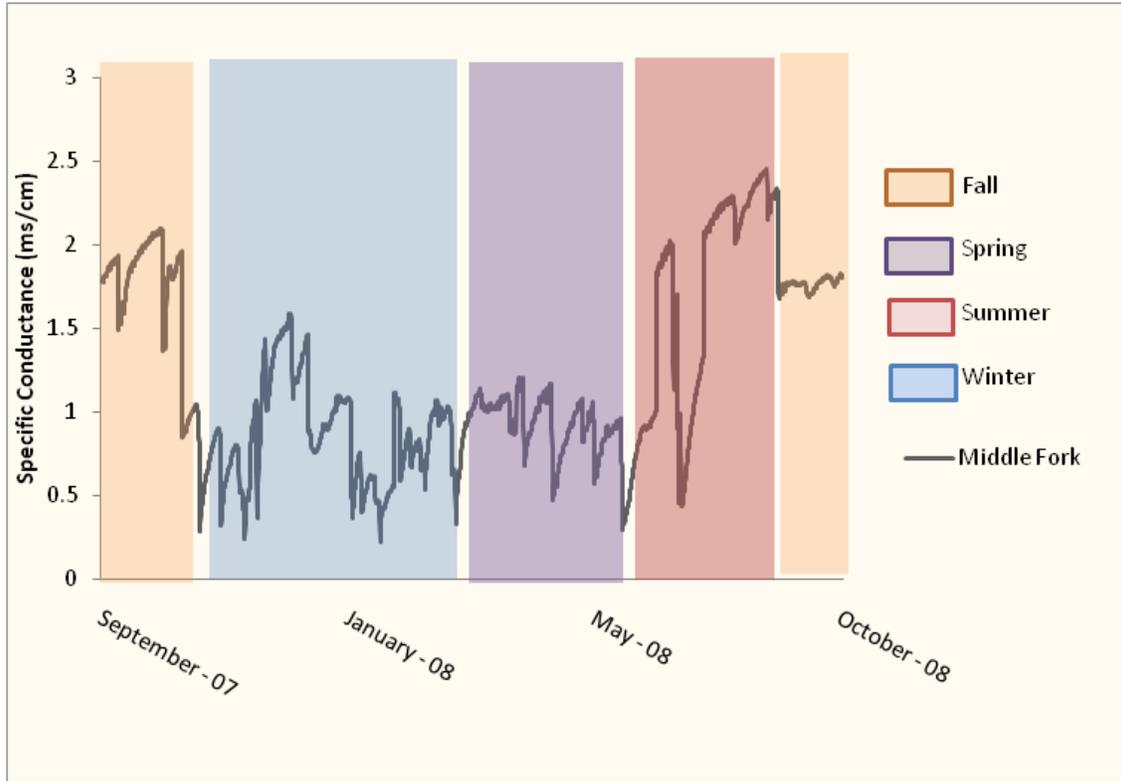


Figure 42. Seasonal specific conductance from continuous monitoring device on Middle Fork Greens Run

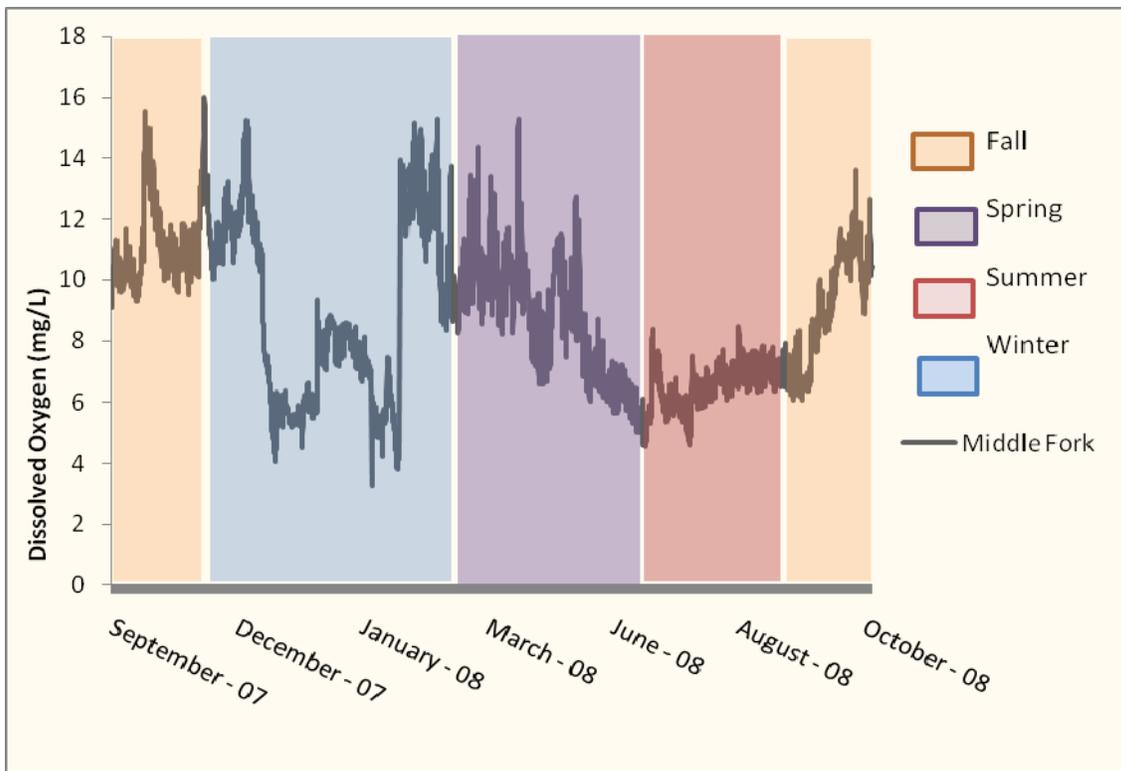


Figure 43. Seasonal dissolved oxygen from continuous monitoring on Middle Fork Greens Run

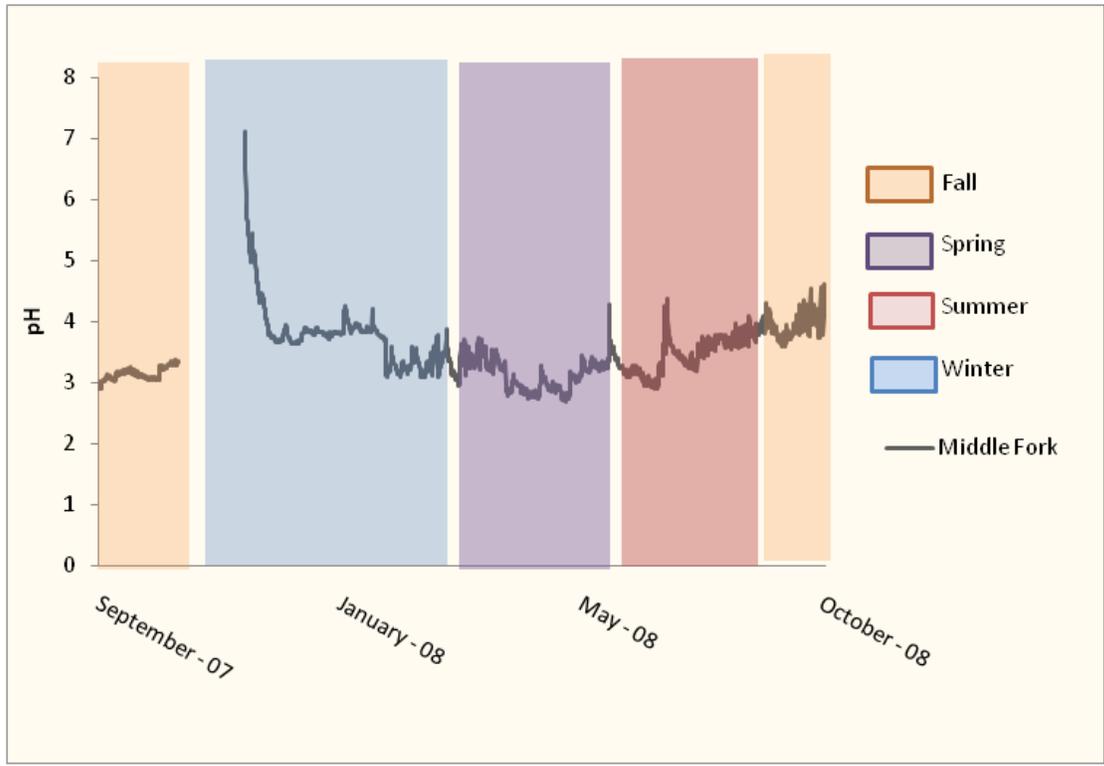


Figure 44. Seasonal pH from continuous monitoring on Middle Fork Greens Run

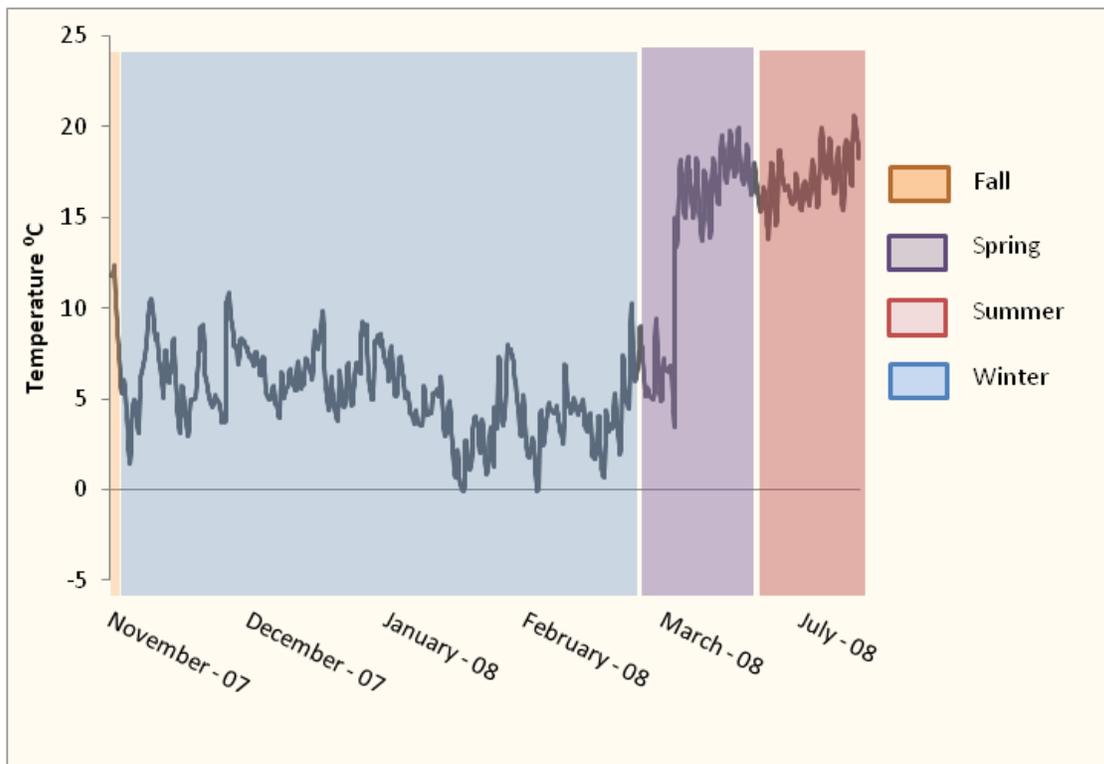


Figure 45. Seasonal temperature from continuous monitoring on South Fork Greens Run

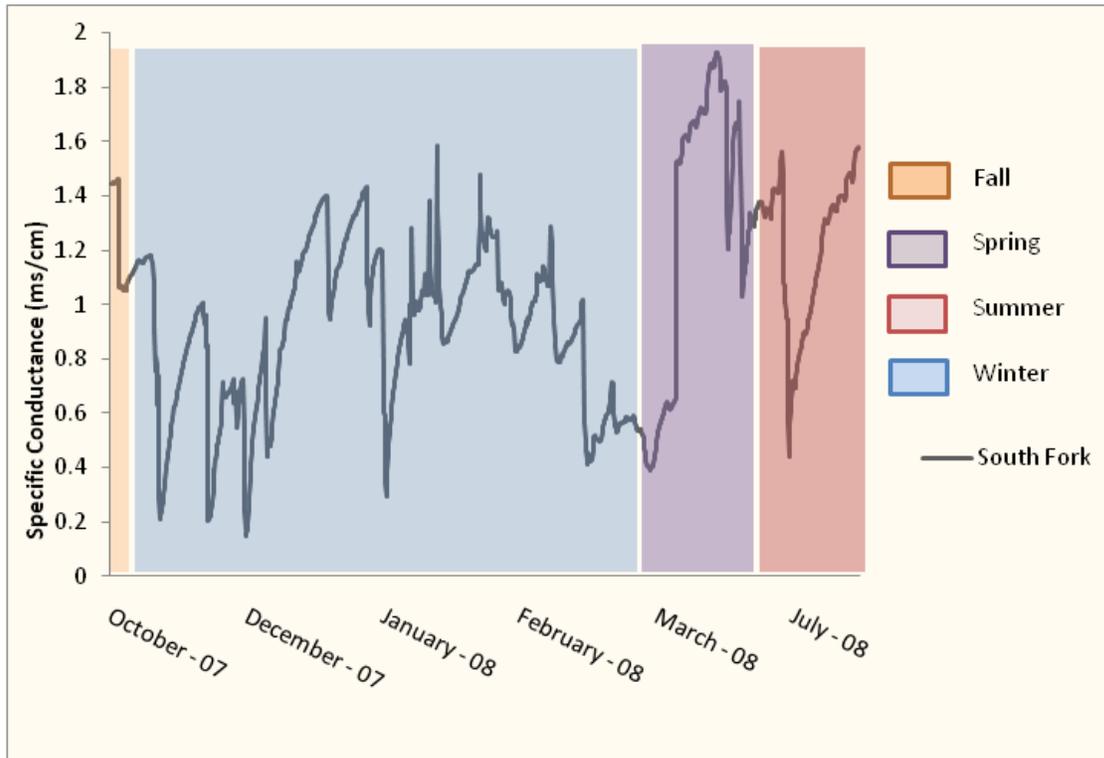


Figure 46. Seasonal specific conductance from continuous monitoring on South Fork Greens Run

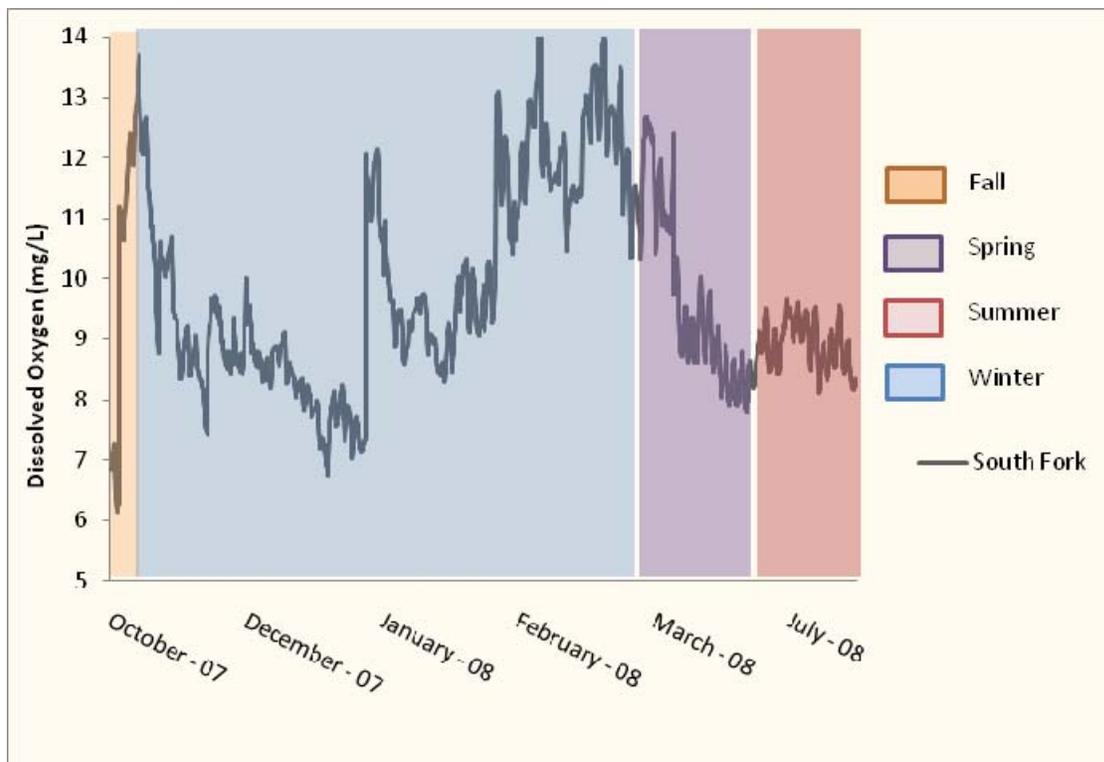


Figure 47. Seasonal dissolved oxygen from continuous monitoring on South Fork Greens Run

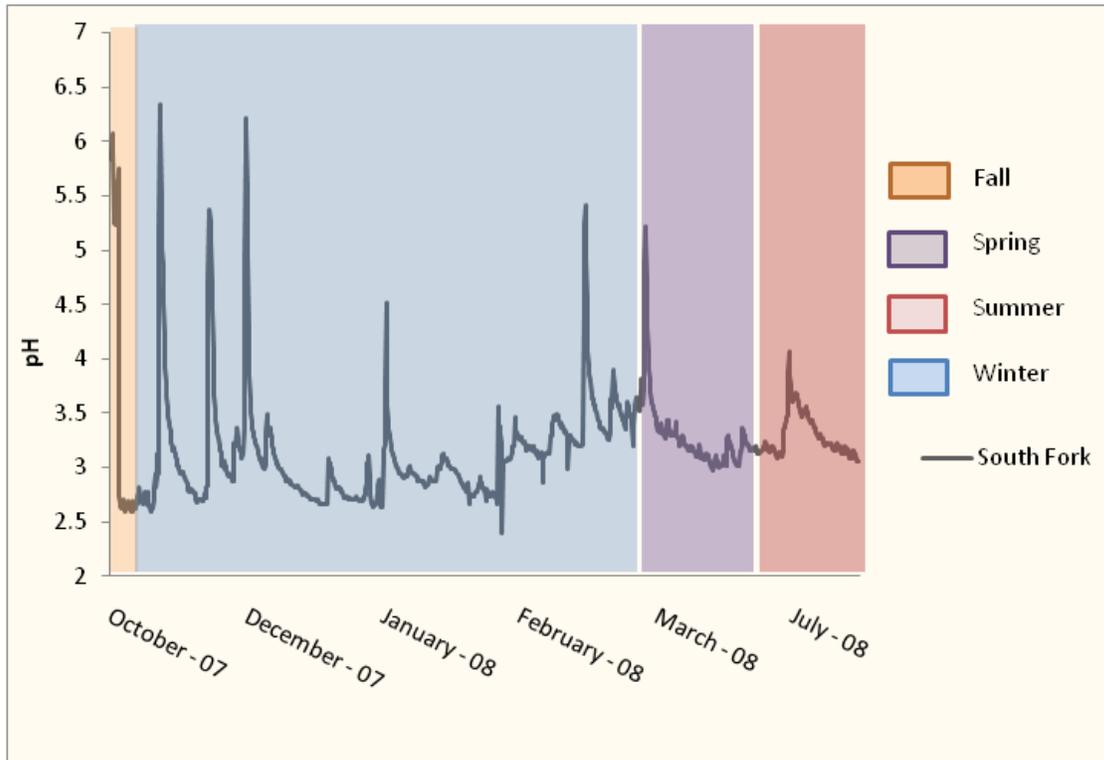


Figure 48. Seasonal pH from continuous monitoring on South Fork Greens Run

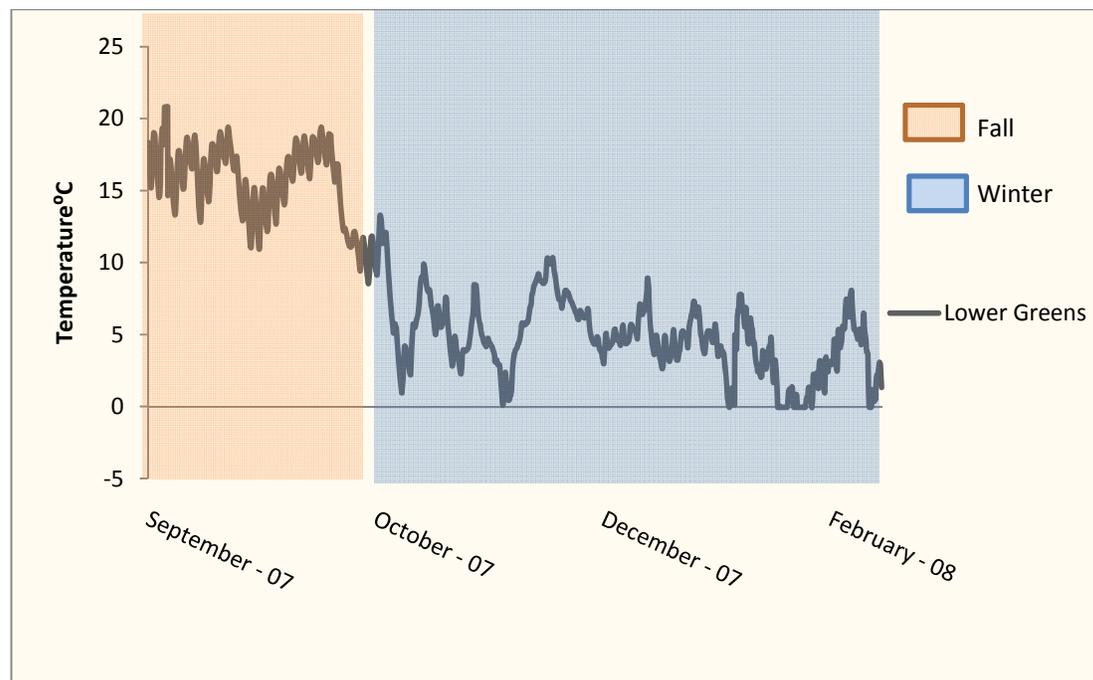


Figure 49. Seasonal temperature from continuous monitoring device on lower Greens Run

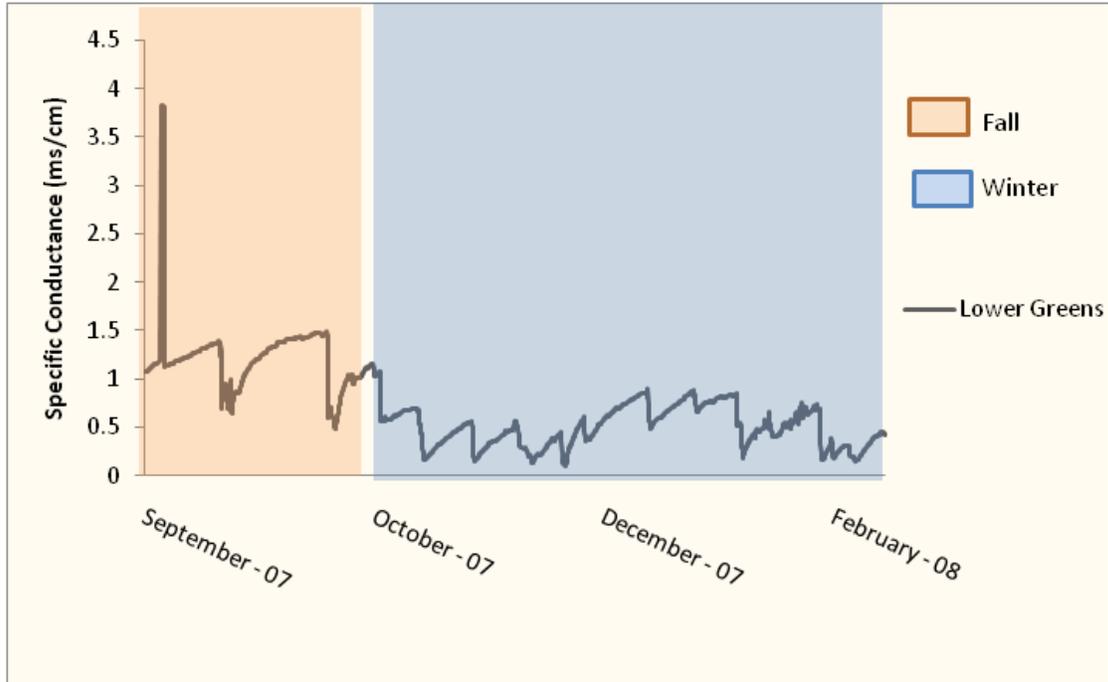


Figure 50. Seasonal specific conductance from continuous monitoring device on lower Greens Run

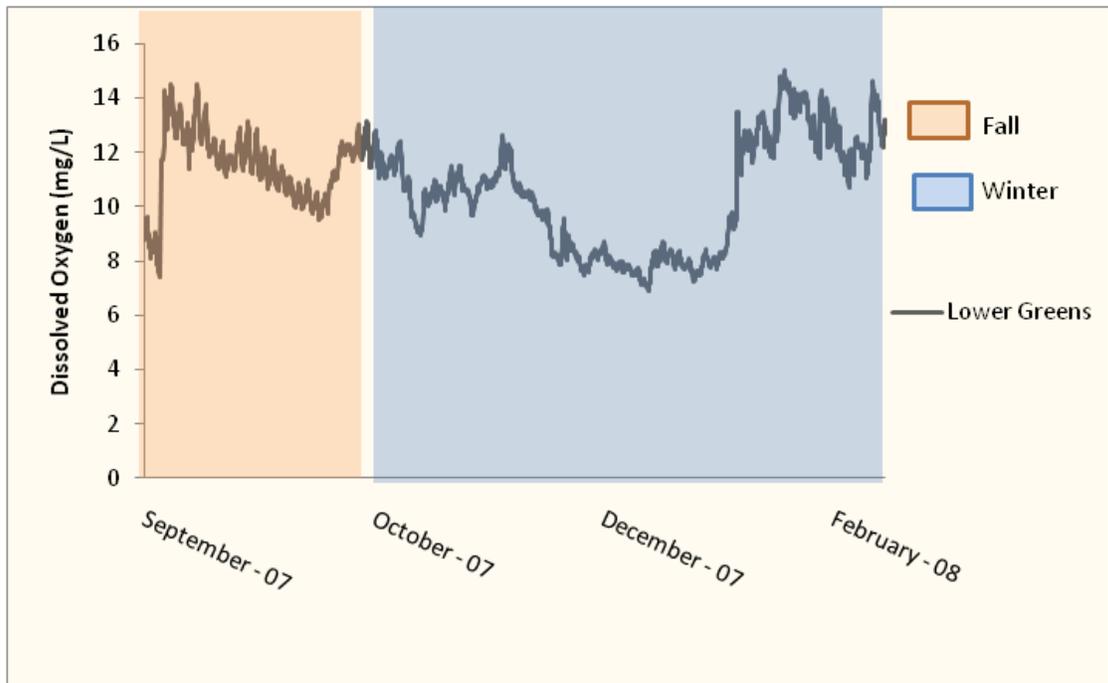


Figure 51. Seasonal dissolved oxygen from continuous monitoring on lower Greens Run

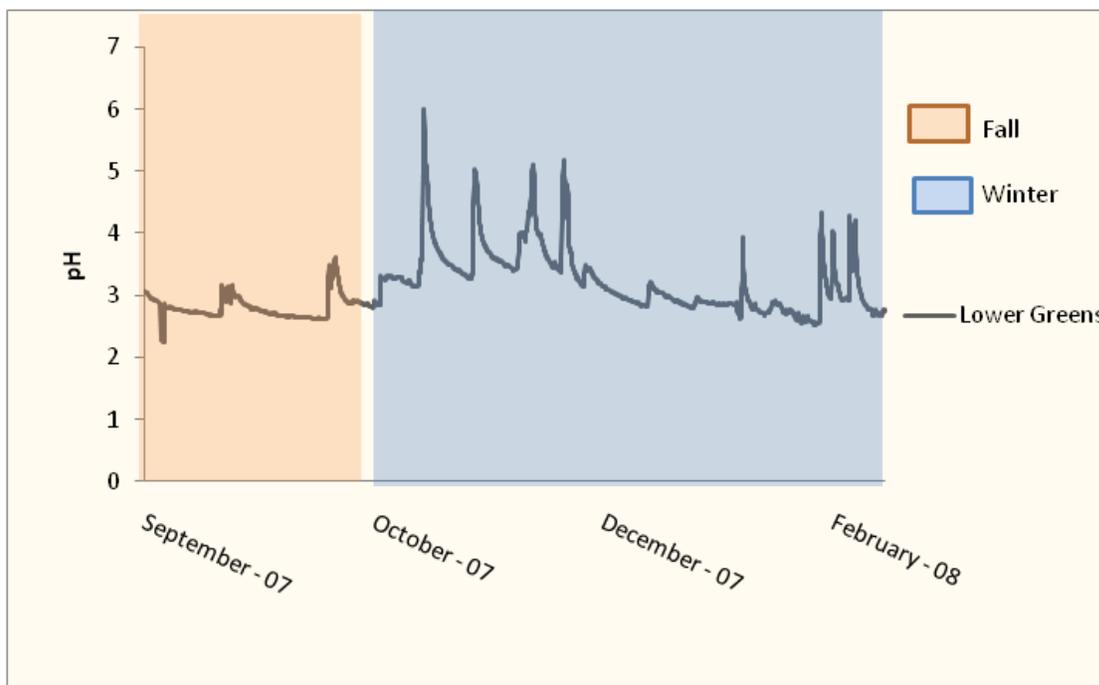


Figure 52. Seasonal pH from continuous monitoring on lower Greens Run

Diel Variation

Diel patterns of pH and DO tended to follow the inverse of temperature, with peaks in the morning with lowest temperatures. Generally, diel cycles driven by photosynthesis tend to involve higher pH and DO in mid-afternoon when temperatures are warmest (Fuller and Davis 1989; Nimick et al. 2003). The cycles observed in the Greens Run watershed do not appear to be photosynthesis-driven, as pH and DO tend to follow the inverse of temperature. The AMD impacts in the Greens Run watershed have largely precluded the growth of lotic plant life, therefore photosynthesis impacts would not be expected to have a significant impact on the daily water chemistry cycles. Rather, it appears that DO may be responding to temperature, as oxygen becomes less soluble in water when temperatures increase. This pattern was also seen in less productive streams in the Coeur d’Alene watershed (Nimick et al. 2003). It is unclear what is causing the cycling of pH, although metal hydrolysis was suggested as a possible mechanism in a study of an AMD impaired wetland/stream system in West Virginia (Smilley 2007).

In the Middle Fork, specific conductance tended to reach a low point around noon and a high point late at night, which is similar to patterns seen in other watersheds (Nimick et al. 2003). During some months, conductance tended to more broadly follow temperature and pH patterns (Figure 53, Figure 54, Figure 55, and Figure 56). In the South Fork, very little daily variation was seen in specific conductance, but a more general inverse relationship with pH is seen (Figure 57, Figure 58, and Figure 59). In the North Fork, patterns do not appear to be as cyclical in winter months (Figure 60 and Figure 61). The relationship between pH and specific conductance was more apparent in lower Greens Run (Figure 62, Figure 63, and Figure 64).

We used regression equations based on specific conductance measurements to predict continuous iron and aluminum concentrations for September in the Middle Fork and June in the South Fork, because diel patterns for specific conductance were most apparent during these time periods. Possible explanations for diel cycling include variable source input, diel streamflow cycles, oxidation/reduction of manganese, iron photoreduction, biological absorption, precipitation/dissolution, and adsorption.

We found that concentrations for both parameters were lowest in mid-afternoon and highest at night (Figure 65 and Figure 66). Diel cycling of dissolved iron has also been documented in other small AMD impacted streams and wetlands (McKnight et al. 1988; Sullivan et al. 1998; Vesper and Smilley 2010). There are several possible mechanisms for this cycling. The process is often controlled by daytime photoreduction of hydrous ferric oxides. However, this process should result in an increase in dissolved iron during the day and a decrease at night (McKnight et al. 1988). Our estimations of dissolved iron suggest that iron concentrations are highest in the middle of the night. This pattern of iron cycling has been observed in a study of an AMD impacted wetland in West Virginia (Smilley and Vesper 2007). In addition, trace metal concentrations in the Coeur d'Alene River in Idaho also increased during the night, and reached a low point during mid-afternoon (Nimick et al. 2003). Both sets of researchers concluded that the diel cycles were most likely due to temperature and/or pH-driven sorption, which explains the opposite cycling of cations and anions. These reactions are temperature and/or pH-dependent; cation adsorption should increase when pH or temperature increases, therefore cation concentrations would be lowest mid-day. This may explain the general association in the Greens Run watershed between pH/temperature and specific conductance, iron, and aluminum.

Another possibility is that temperature is impacting iron oxidation. At night, temperature decreases and the Fe^{2+} oxidation rate decreases, therefore more soluble iron is left in solution. Iron is then removed via mineral precipitation when the temperatures increase and the Fe^{2+} oxidation rate increases. The net effect is for the total dissolved Fe concentration to increase inversely with temperature (Vesper and Smilley 2010).

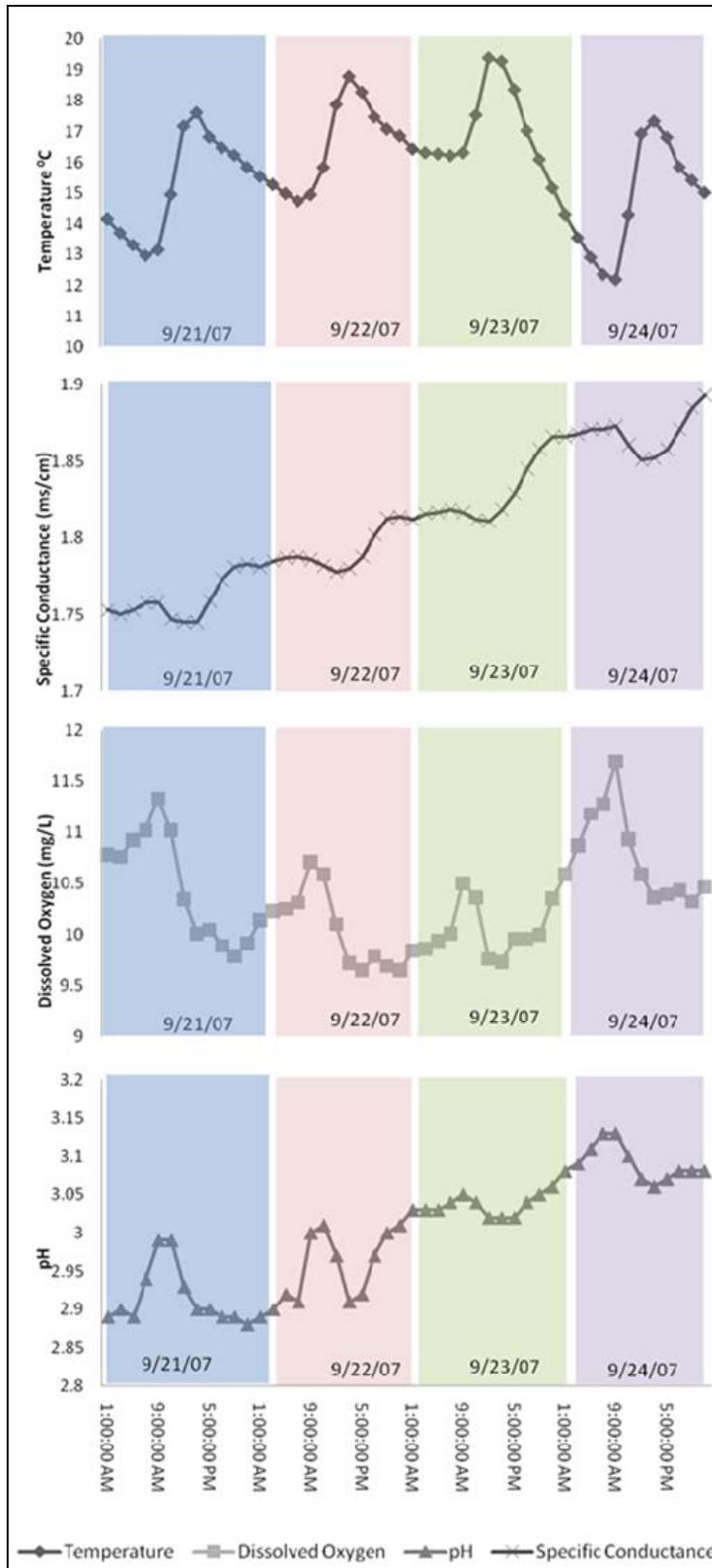


Figure 53. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from September 21-24, 2007 on Middle Fork Greens Run

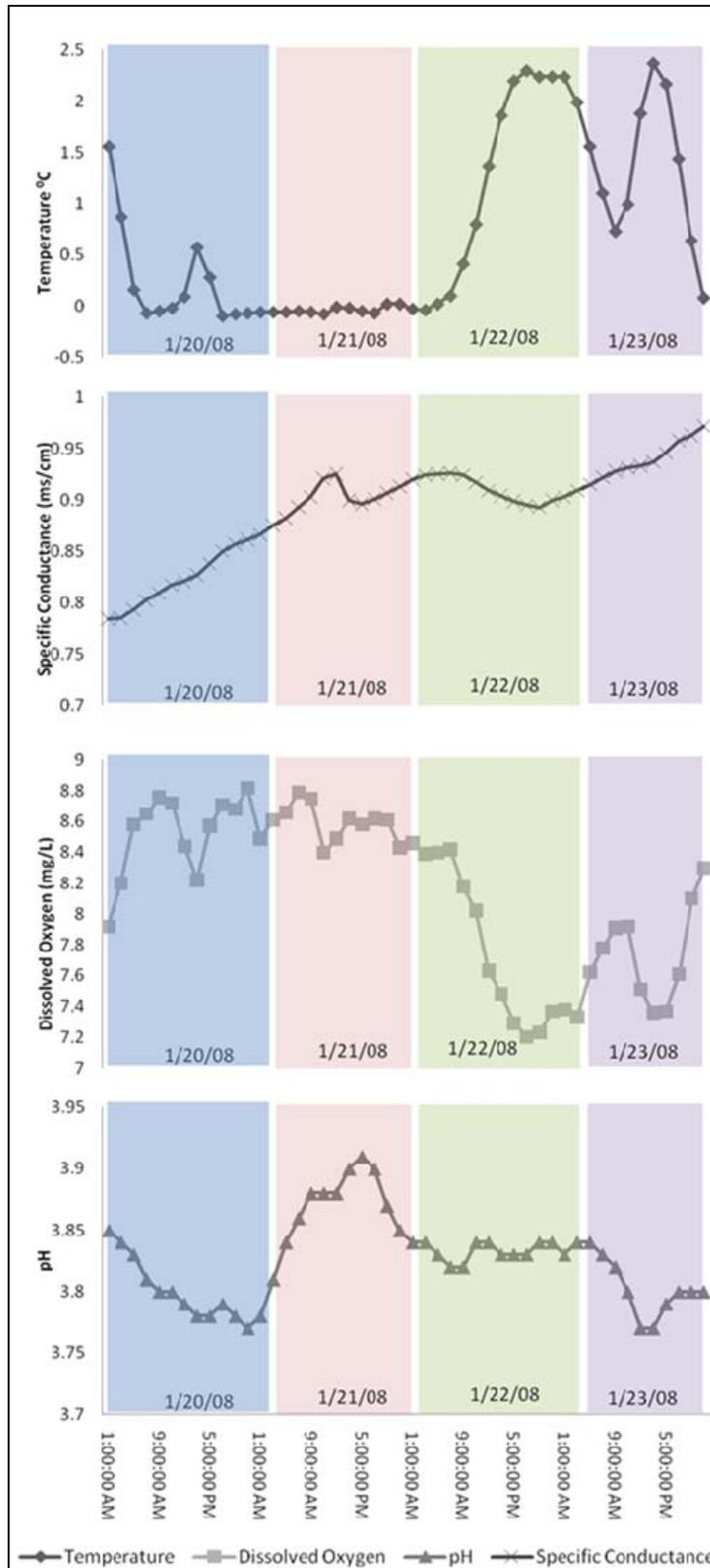


Figure 54. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from January 20-23, 2008 on Middle Fork Greens Run

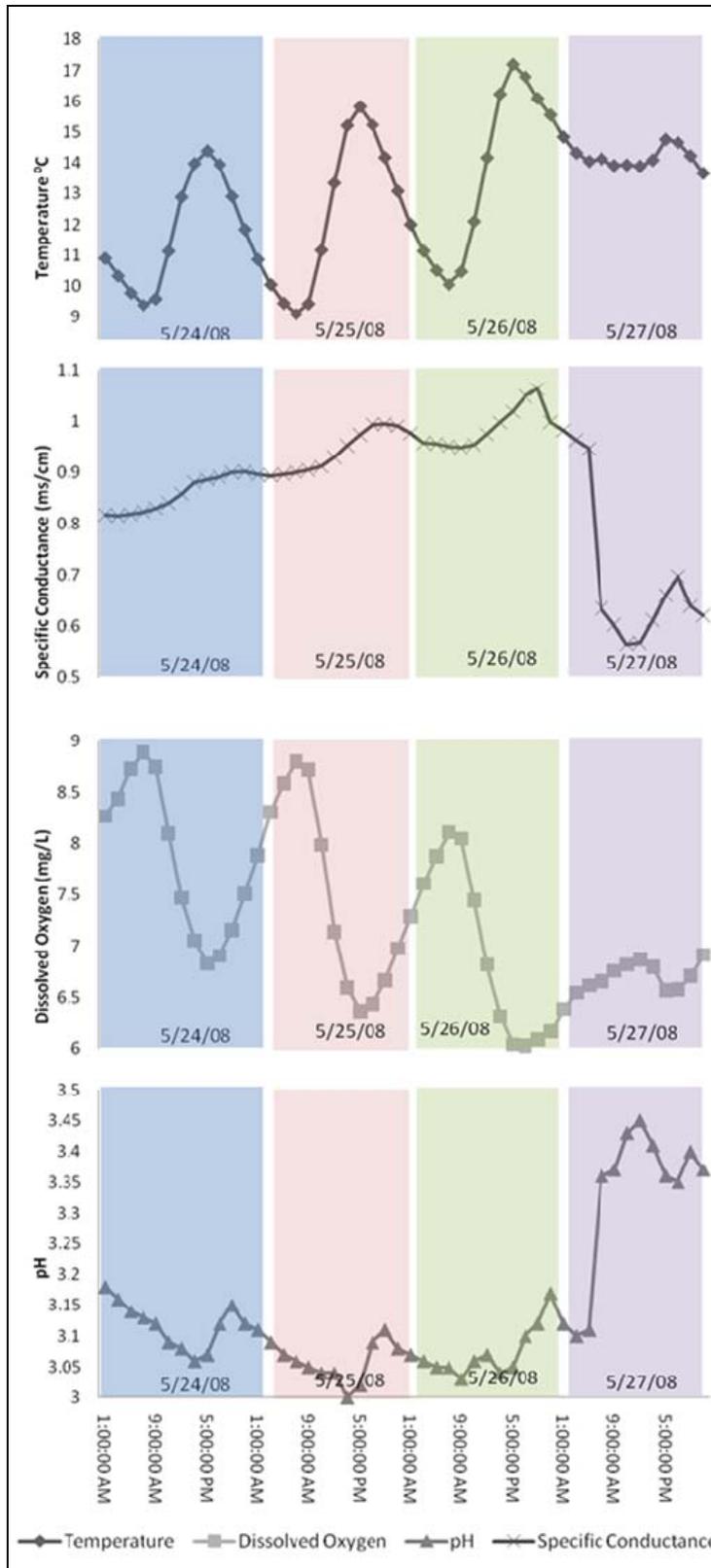


Figure 55. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from May 24-27, 2008 on Middle Fork Greens Run

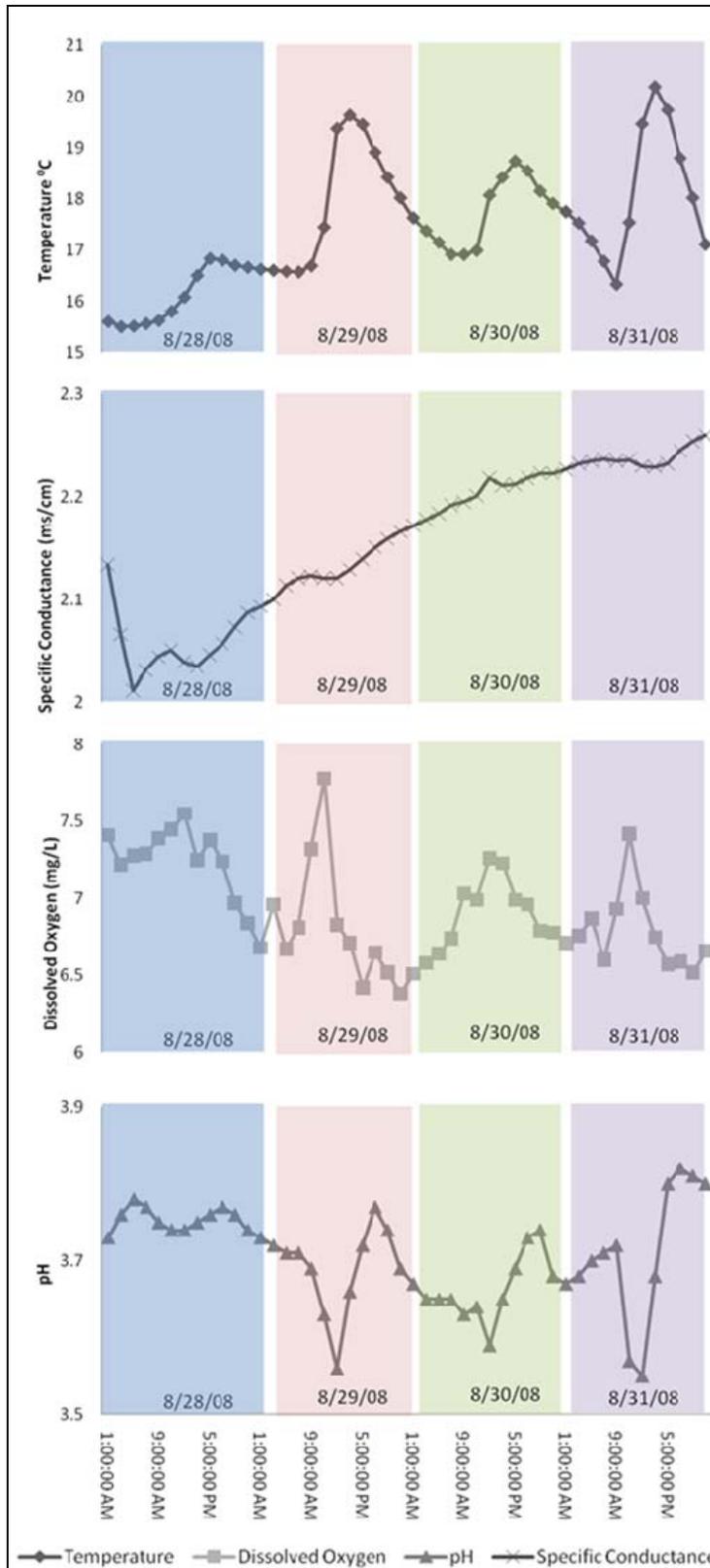


Figure 56. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from August 28-31, 2008 on Middle Fork Greens Run

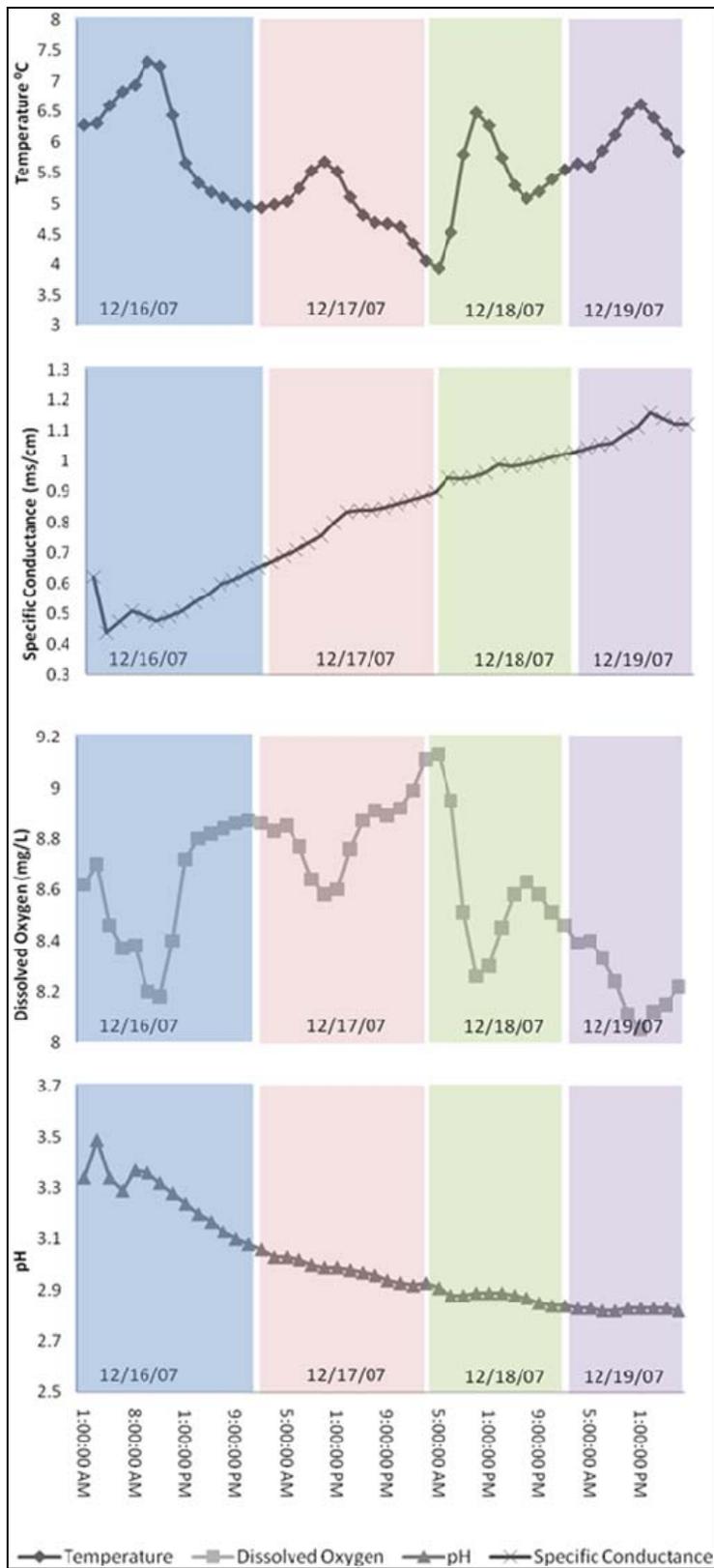


Figure 57. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from December 16-19, 2007 on South Fork Greens Run

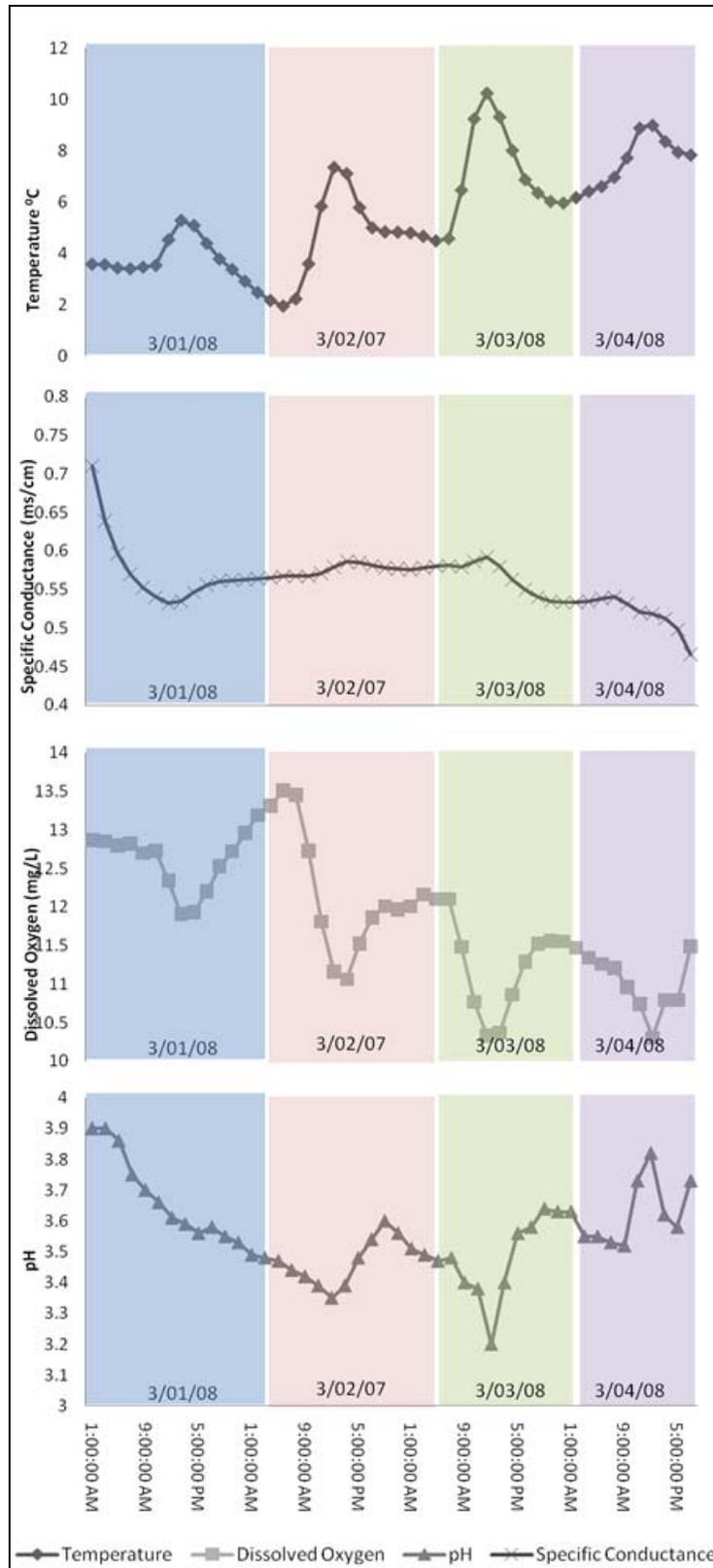


Figure 58. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from March 1-4, 2008 on South Fork Greens Run

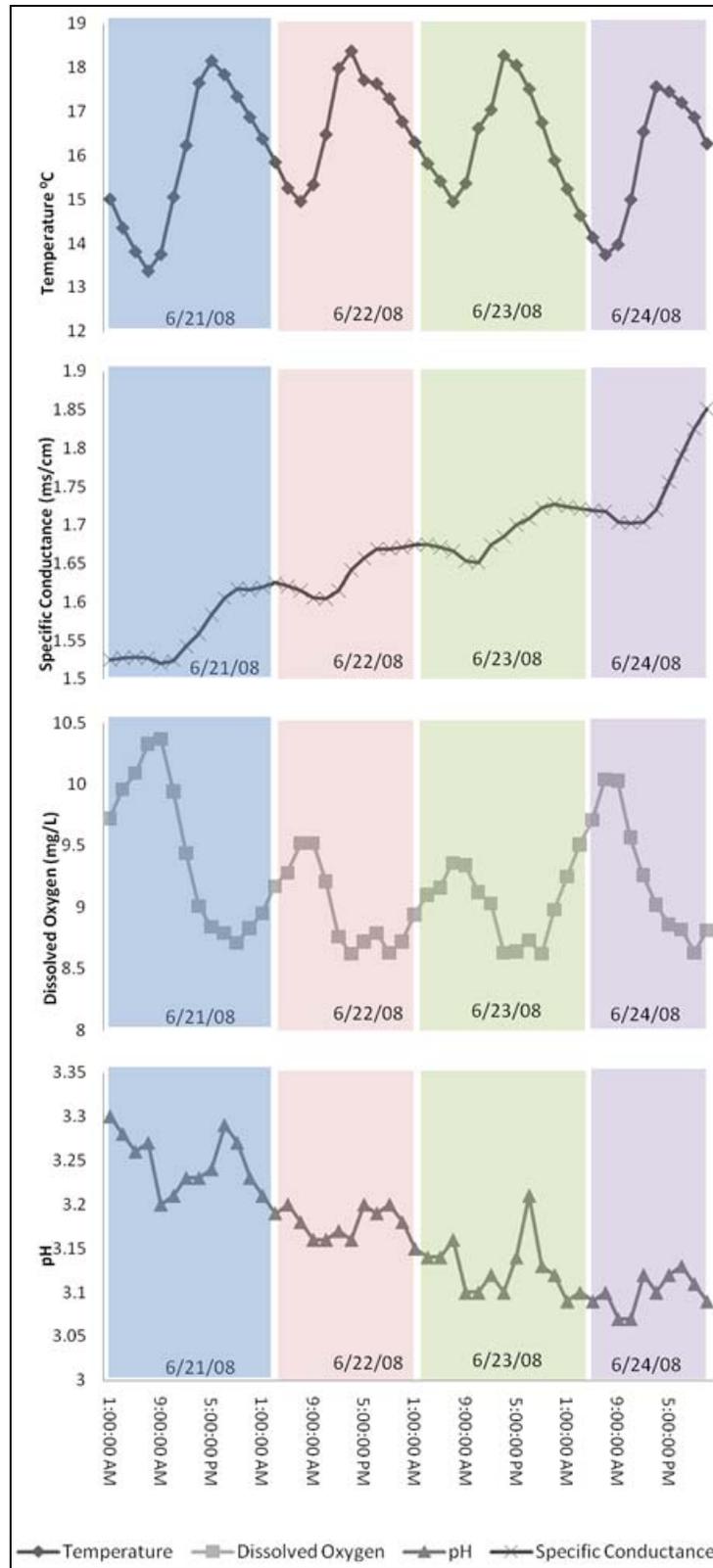


Figure 59. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from June 21-24, 2008 on South Fork Greens Run

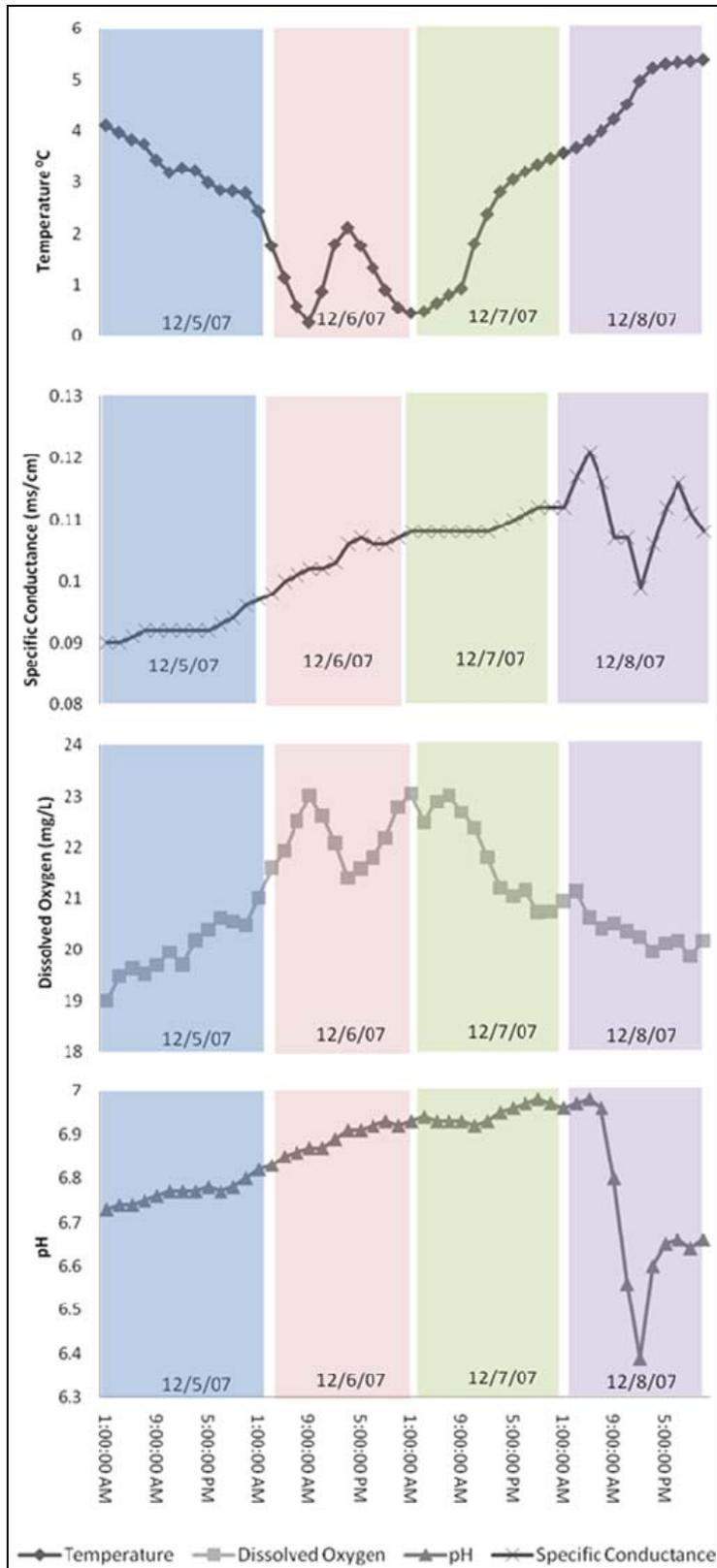


Figure 60. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from December 5-8, 2007 on North Fork Greens Run

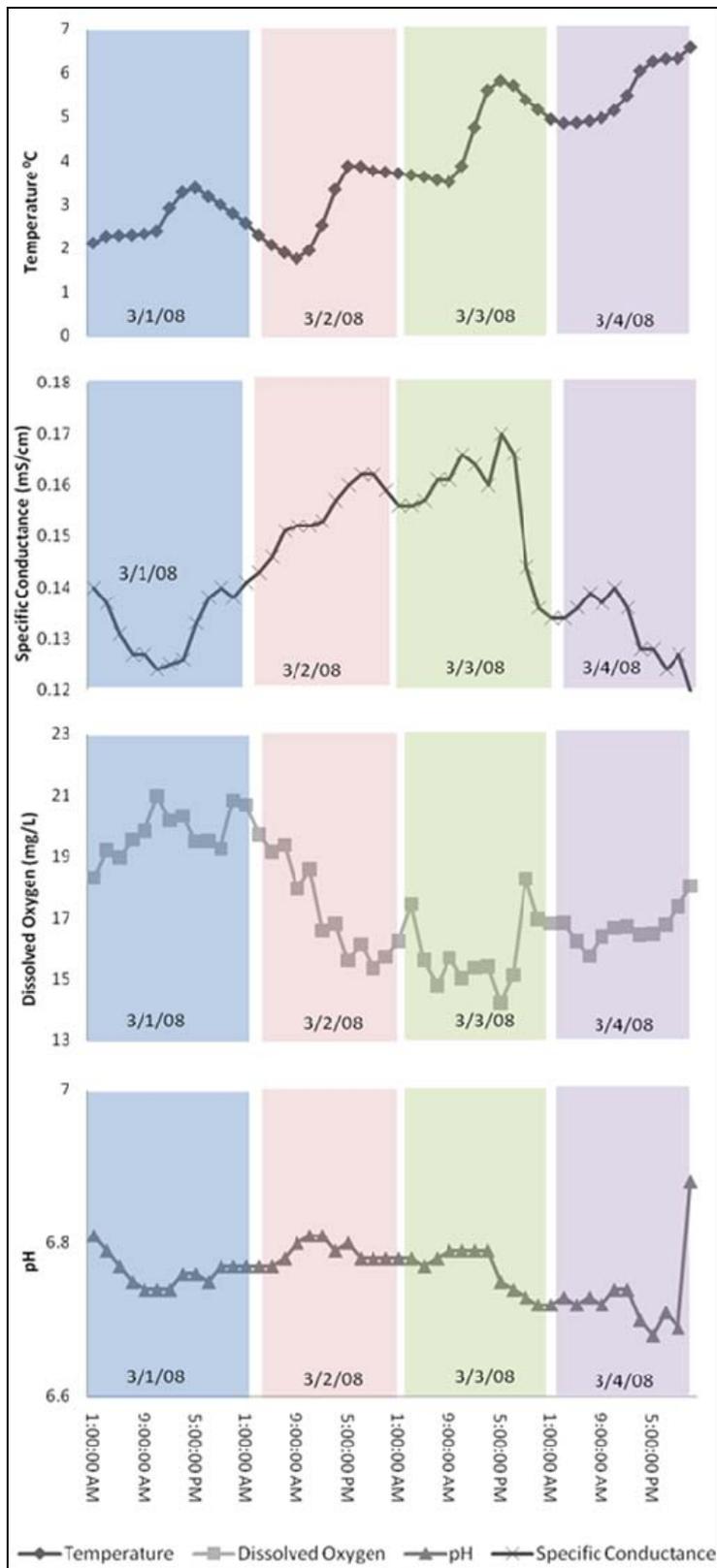


Figure 61. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from March 1-4, 2008 on North Fork Greens Run

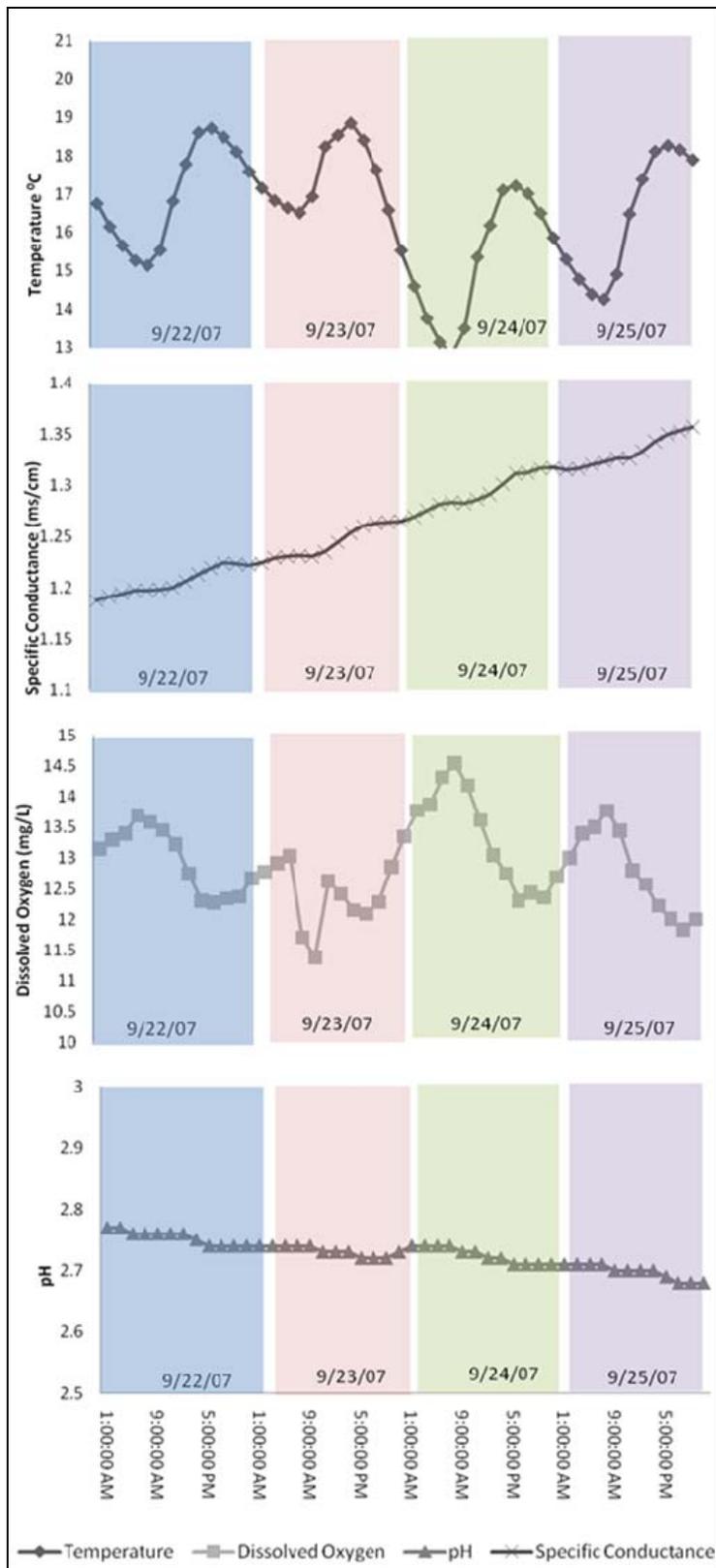


Figure 62. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from September 22-25, 2007 on lower Greens Run

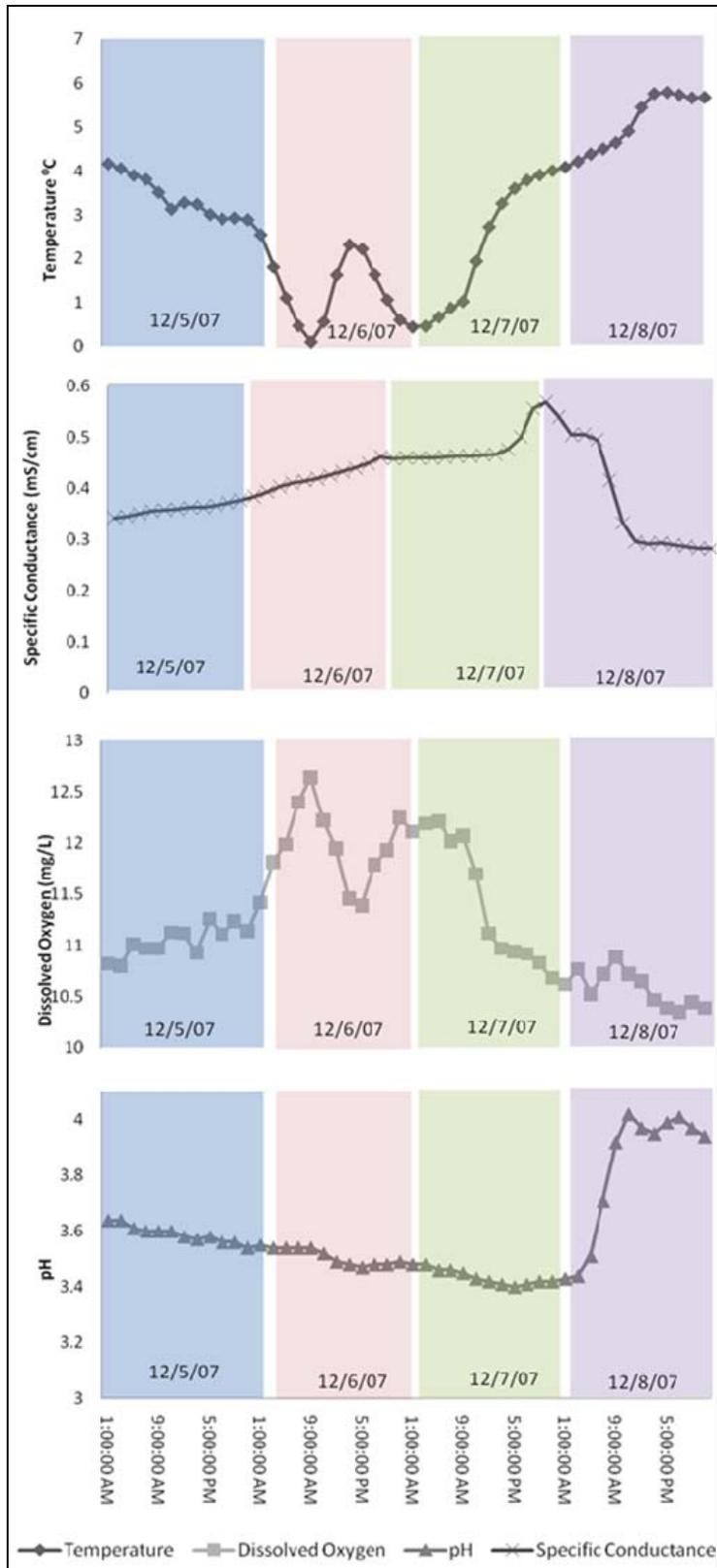


Figure 63. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from December 5-8, 2007 on lower Greens Run

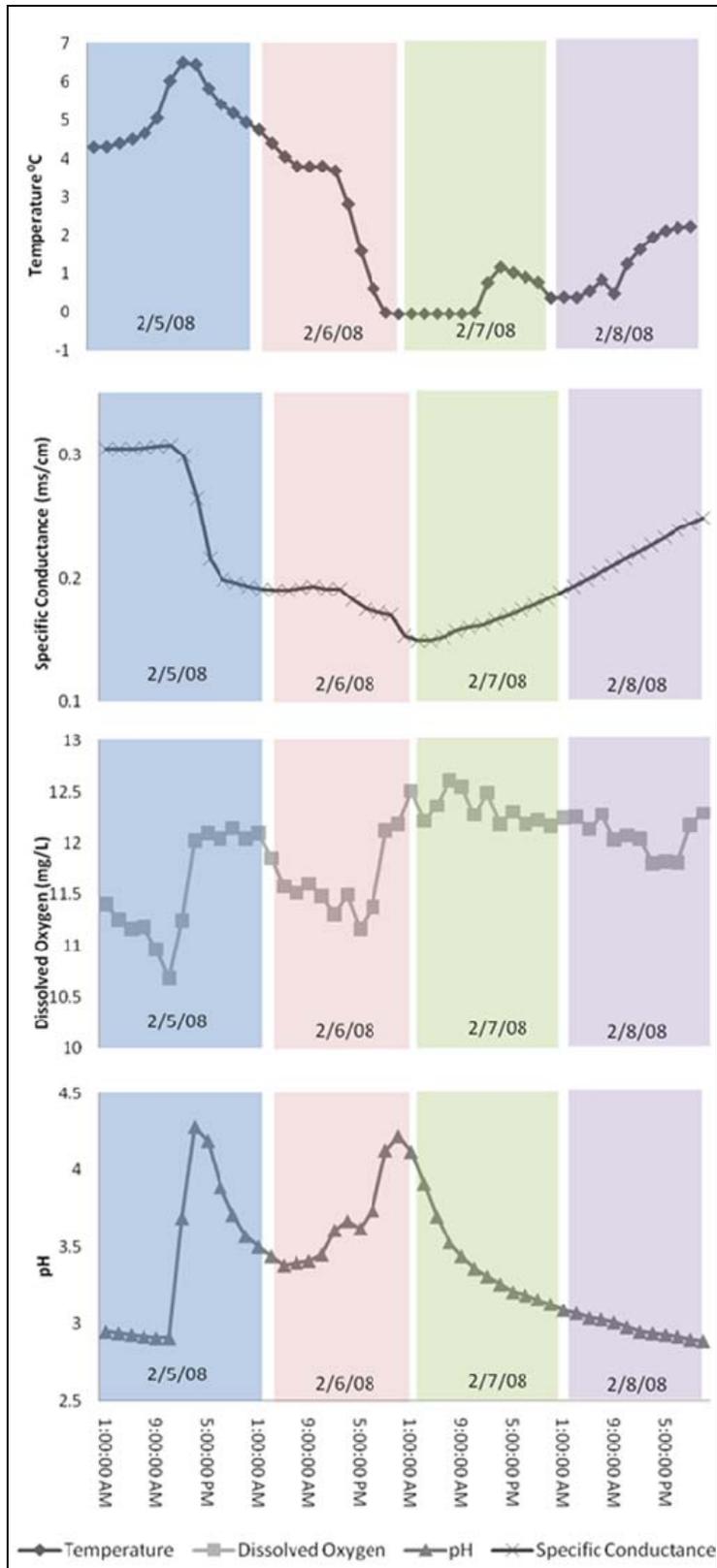


Figure 64. Diel patterns of dissolved oxygen, pH, temperature, and specific conductance from February 5-8, 2008 on lower Greens Run

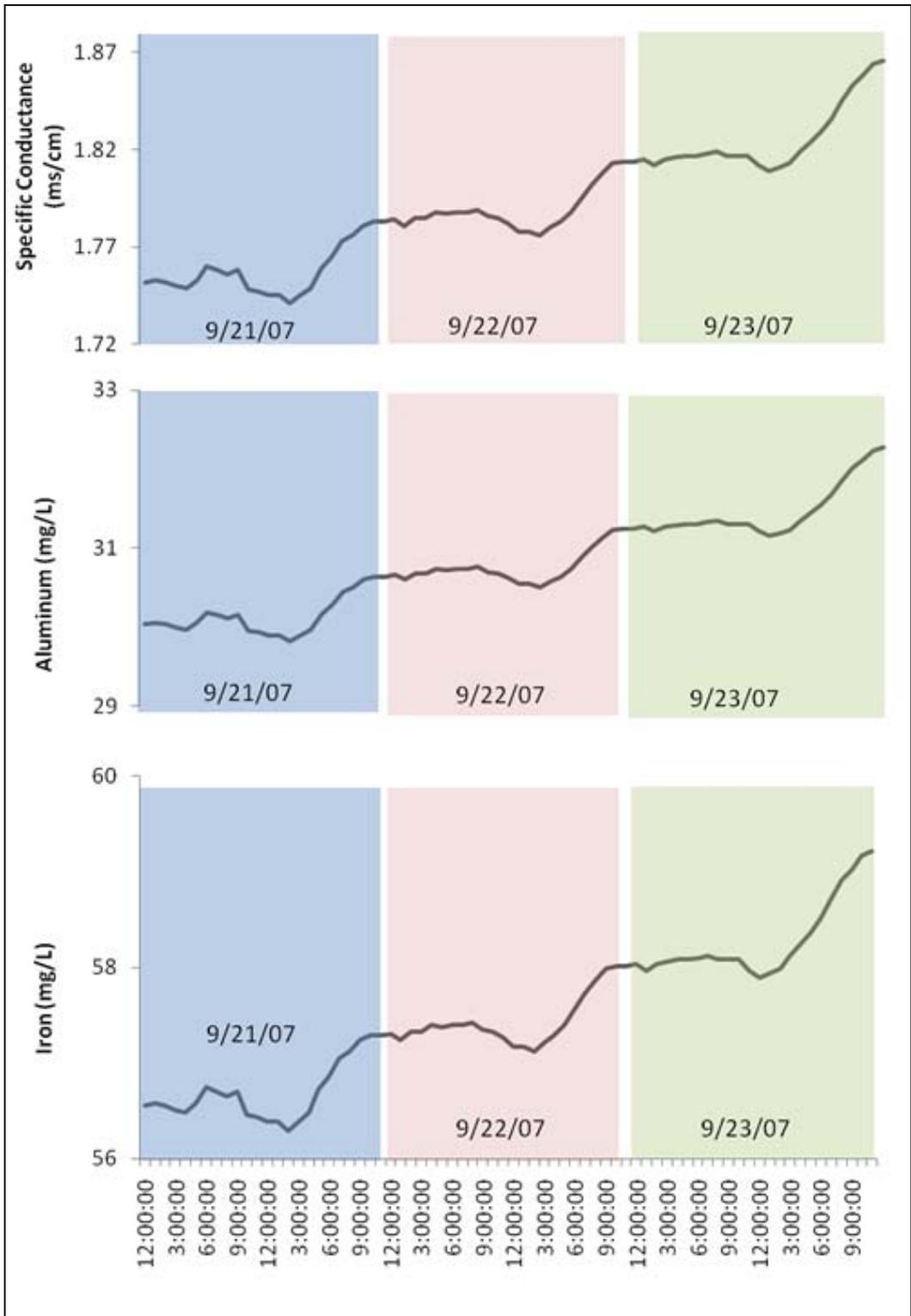


Figure 65. Diel patterns of iron and aluminum from September 21-24, 2007 on Middle Fork Greens Run

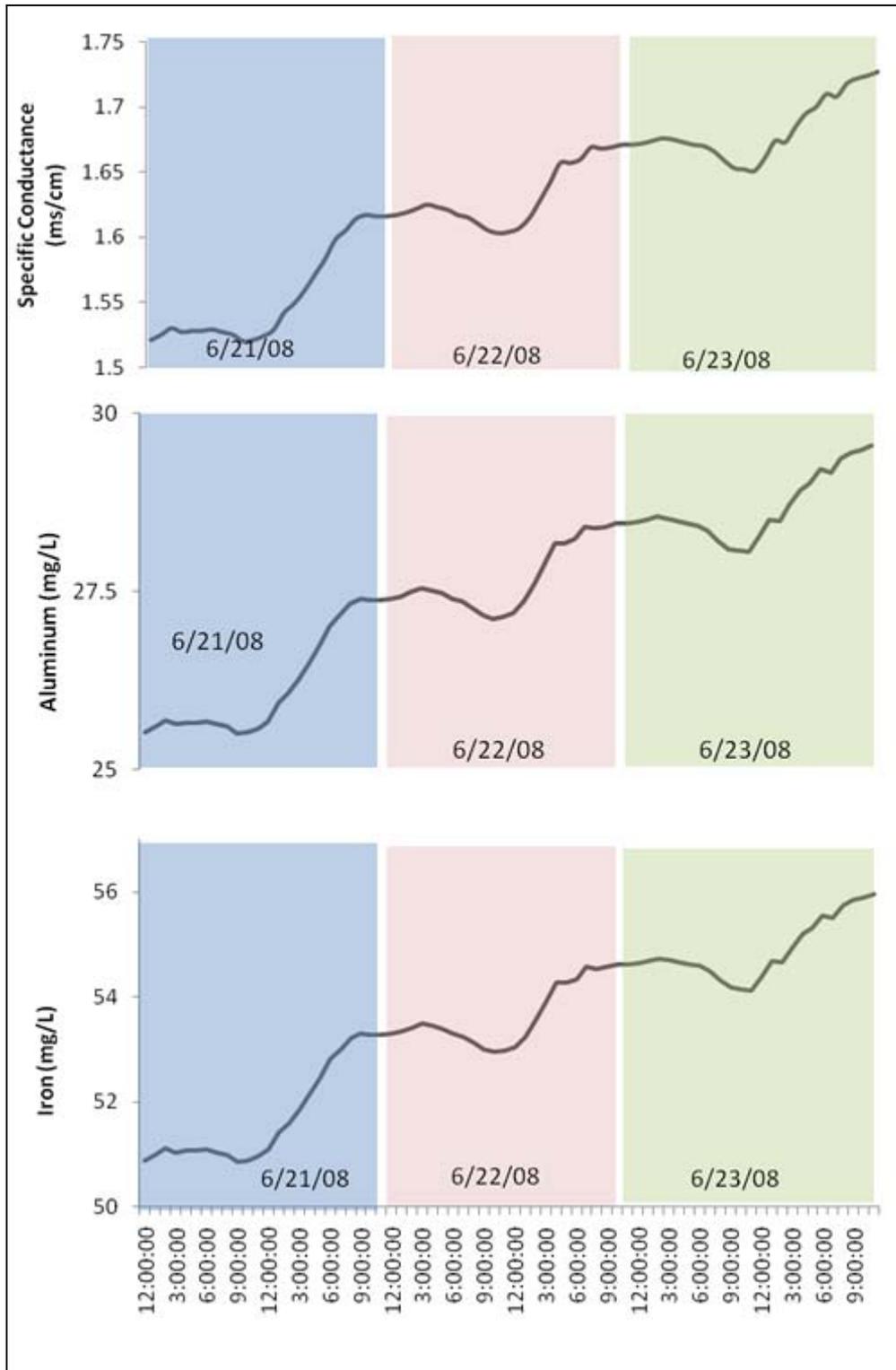


Figure 66. Diel patterns of iron and aluminum from June 21-24, 2008 on South Fork Greens Run

Mass Balance

We used known chemical loadings from each discharge in the Greens Run watershed (Figure 67) to predict chemical loadings at each monitoring station. Acid load, iron load, and aluminum load were calculated from chemical and flow data collected by staff from WRI from 2001 to 2006, the Friends of the Cheat (a local watershed group) from 2005 to 2008, and the West Virginia Department of Environmental Protection in from 2000 to 2007. The average loading for each parameter was summed in each stream to gain a predicted loading for each sampling station. These predictions were then compared to the measured loadings in order to identify the amount of chemical loading that was unaccounted for in the mass balance approach (Table 3).

We found that in the North Fork, most of the iron load comes from the three sources that have been identified, but the majority of the acid load is coming from an unknown source. Approximately 66% of the acid load and 72% of the Al load in the Middle Fork can be attributed to three sources. In the South Fork, five sources have been identified, and these contribute 63 - 65% of the acid, iron, and aluminum load in the stream.

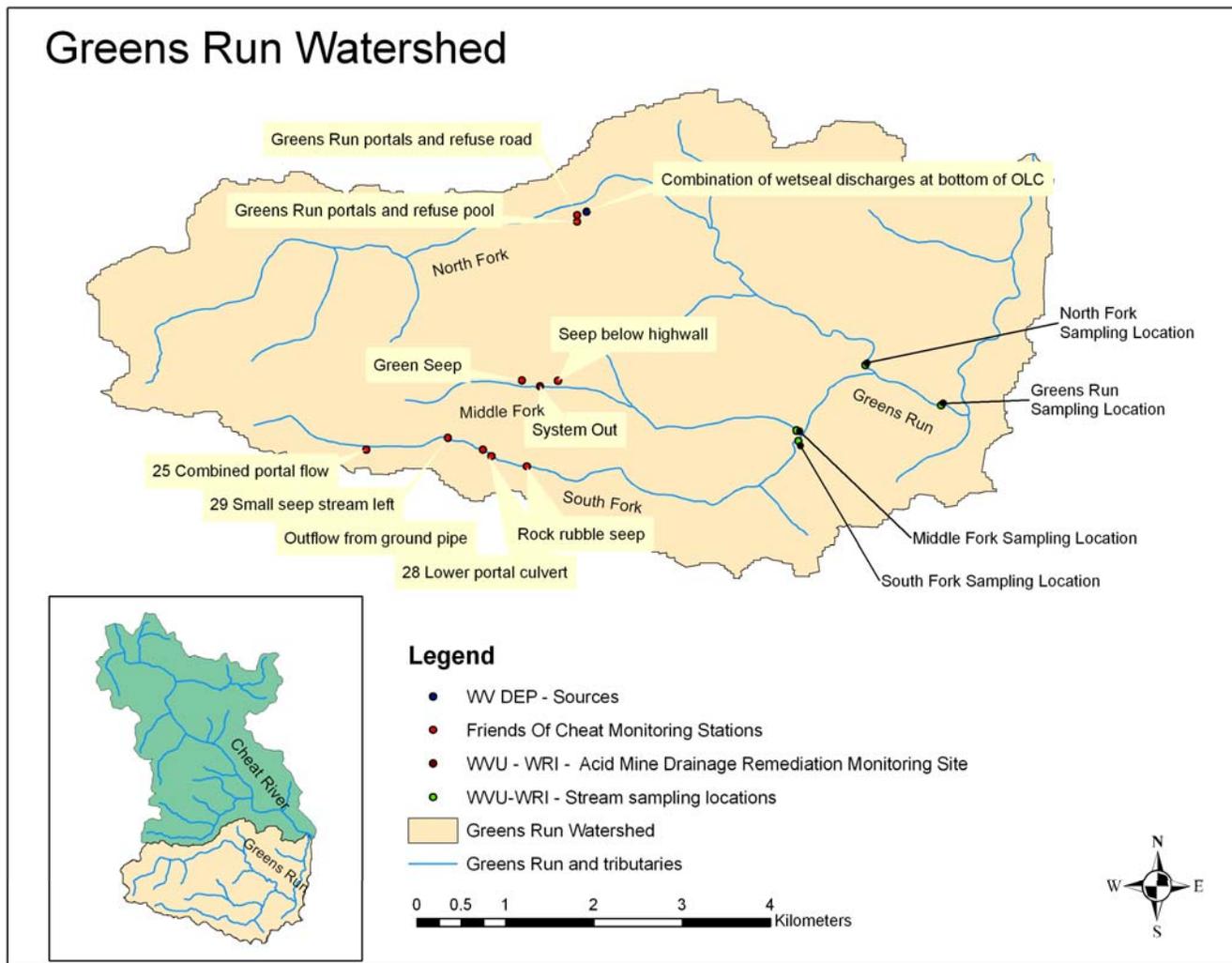


Figure 67. AMD source locations in the Greens Run watershed

Table 3. Measured and calculated chemical loads in tons/year

Stream	Source Name, Number of Samples	Acid Load (tons/year)			Fe Load (tons/year)			Al Load (tons/year)		
		Source Loads	Measured Load	% Un-identified	Source Loads	Measured Load	% Un-identified	Source Loads	Measured Load	% Un-identified
North Fork	GR Portals (1)	9.27			1.65			0.61		
	Collapsed portal (1)	9.26			0.01			0.00		
	Wetseal discharges (13)	7.71			1.07			0.45		
	MASS BALANCE	26.24	1212.58	97.84	2.73	2.57	-5.92	1.06	2.00	46.79
Middle Fork	System Out (9)	656.81			145.16			41.25		
	Green Seep (5)	62.20			9.89			4.91		
	Seep below Highwall (5)	147.69			23.81			4.09		
	MASS BALANCE	866.70	1303.54	33.51	178.86	160.37	-11.53	50.24	69.68	27.90
South Fork	Combined Portal Flow (20)	10.41			0.09			0.20		
	Small Seep (18)	6.80			0.22			0.25		
	Outflow from ground (6)	17.60			1.34			0.66		
	Lower Portal (19)	277.21			26.40			14.30		
	Rock Rubble Seep (1)	178.75			27.79			7.54		
MASS BALANCE	490.77	1402.79	65.01	55.85	151.69	63.18	22.94	66.37	65.43	
Greens	MASS BALANCE	1505.16	3137.05	52.02	258.52	427.39	39.51	77.27	235.69	67.22

Conclusions

Although water chemistry in mining impacted streams is often extremely variable, efforts to characterize stream water chemistry typically rely upon discrete samples which may not adequately represent the true constituent load of the stream. The most important outcome of this project is the ability to produce continuous concentration estimations for parameters of concern in AMD systems and to identify daily and seasonal variation in these parameters that may affect sampling accuracy. The continuous data generated in this study will greatly enhance our understanding of water chemistry dynamics in acid mine drainage systems. With more reliable flow estimates, we will be able to produce more accurate estimates of constituent loads, which would be particularly important when designing TMDLs and AMD treatment systems.

In order to understand where the different constituents of AMD were coming from in the watershed, we incorporated loadings from each mining discharge in the watershed into a mass balance model. We were able to estimate chemical loadings at each monitoring station in the watershed, which were then compared to the average measured loadings in order to identify the amount of uncertainty. In general, we found that at least 60% of the acid, iron, and aluminum loads can be attributed to the known AMD sources. By developing an understanding of the limitations of mass balance, we are enabling greater utility of this approach for predicting benefits of future restoration actions in this watershed.

We found that most of the variation in most water quality parameters could be explained by specific conductance. Specific conductance has been found to be a primary surrogate in other studies of this type, although these projects have focused on agricultural impacts and have therefore not attempted to predict common AMD parameters such as iron and aluminum.

Using regression equations, we calculated concentrations of parameters such as acidity and iron for each instantaneous sonde reading. This allowed us to calculate a daily loading for each constituent, and also to identify temporal patterns in chemical data. Acid, iron, and aluminum loads peaked with high flows in December 2007 in all streams except North Fork, which reached highest loadings in May/June and August. Acid load in North Fork was an order of magnitude lower than the other streams. Acidity and sulfates were consistently high in all streams except North Fork.

Spikes in manganese and other parameters were seen in spring. Chemical concentrations in acidic streams tended to be extremely variable over the course of the year. Specific conductance was generally lower during periods of high flows, and rose sharply during summer dry periods. Dissolved oxygen levels climbed throughout the fall and winter, and dropped sharply in late spring, summer, and early fall. The pH levels stayed fairly constant, without much seasonal variation, only increasing with higher flows.

Diel patterns of pH and DO tended to follow the inverse of temperature, with peaks in the morning with lowest temperatures. Generally, pH cycles driven by photosynthesis tend to involve highest pH in mid-afternoon (Fuller and Davis 1989; Nimick et al. 2003). The cycles observed in the Greens Run watershed do not appear to be photosynthesis-driven, but may instead be driven by temperature and metal hydrolysis.

During the fall, specific conductance tended to reach a low point around noon each day, and in other months tended to more broadly follow temperature and pH patterns. We used regression equations based on specific conductance measurements to predict continuous iron and aluminum concentrations for these time periods. We found that concentrations for both parameters were lowest in mid-afternoon and highest in the middle of the night, which is similar to patterns in trace metals observed in other studies of metal cycling. Possible mechanisms for this cycling are daytime photoreduction of hydrous ferric oxides, temperature and/or pH-driven sorption, or temperature impacts on iron oxidation. Researchers in similar systems have concluded that temperature impacts on iron oxidation are the most likely cause, because this causes iron concentration to vary inversely with temperature.

It is clear that diel cycling should be taken into consideration when planning field sampling studies, particularly during time periods where temperature will vary considerably over the course of the day. By sampling a stream at different times on different days, some variation should be automatically assumed due to diel fluctuations in metal concentrations. In addition, samples taken during the daytime may underestimate concentrations of AMD metals, as they may peak at night.

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Publications

No publications associated with the project are available at this time.

Information Transfer Program

No publications associated with the project are available at this time. A manuscript will be developed for peer review from this work.

Student Support

Graduate students and undergraduate students have been utilized in the installation of the monitoring equipment, monthly data downloading and water sampling, as well as current and historic data compilation. This has provided these students and young professionals with knowledge of the design and maintenance of an automatic data logging system, field experience in water chemistry sampling procedures, and GIS/database experience.

Graduate Students

Joseph Kamalesh, M.S. in Civil and Environmental Engineering, 2008

Ben Mack, M.S. in Plant and Soil Sciences, 2008

Undergraduate Students

Mary Beth Tajc, B.S. in Chemistry, 2008

Melissa O'Neal, B.S. in Fish and Wildlife, expected 2011

Eric Baker, B.S. in Civil and Environmental Engineering, 2010

Category	Number of students supported with 104b base grant	\$ Value of students supported with 104b base grant	Number of students supported with matching funds	\$ Value of student support with matching funds	Total number of students supported	Total \$ value of student support
Undergraduate	3	\$6,301.26	0	0	3	\$6,301.26
Masters	2	\$479.57	0	0	2	\$479.57
Ph.D.	0	-	-	-	-	-
Post-Doc	0	-	-	-	-	-
Total	4	\$6,780.83	0	0	5	\$6,780.83

Notable Achievements and Awards

No awards associated with the project are available at this time.

(WRI-117) Controlling Phosphate in Agricultural Field Leachate Using Mine Drainage Treatment Ferrihydrite

Basic Information

Title:	(WRI-117) Controlling Phosphate in Agricultural Field Leachate Using Mine Drainage Treatment Ferrihydrite
Project Number:	2009WV122B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Hydrology
Descriptors:	None
Principal Investigators:	Paul Ziemkiewicz, Richard Herd, Melissa J. O'Neal

Publications

There are no publications.

WRI 117: Acid Mine Drainage Treatment Residuals (AMD-TR) to Reduce Soil Test Available Phosphorus in Poultry Litter

**Annual Report
March 1, 2009 – February 28, 2010**

by

Richard Herd, West Virginia Water Resources Institute

**Louis. M. McDonald, Ph.D. Assoc. Prof. Division of Plant & Soil Sciences, Davis
College of Agriculture, Natural Resources and Design**

Melissa O’Neal, West Virginia Water Resources Institute

submitted

May 24, 2010

UGS Project Number 2009WV122B

Abstract

Phosphorus (P) contamination of surface waters is a major environmental problem associated with the disposal and use of animal wastes. When animal wastes are continuously applied to fields to meet crop nitrogen needs, soil test phosphorus levels eventually exceed plant removal rates and soil P buildup occurs. High levels of soil test P have been associated with surface water P contamination. The metal oxides produced from the treatment of acid mine drainage (AMD) have significant P sorption capacity. The original purpose of this project was to test six AMD treatment residuals for their P sorption capacity, determine the soil loading rate for one of these residuals that would reduce soil test P concentrations, and conduct a two year field demonstration. During year one, baseline water quality data was collected from the tile drain of a field that had received a known amount of poultry litter. After six months of sampling, no P was detected in the drainage water. Because there could be no P reduction from the application of AMD treatment residuals, it was decided that the objective should be changed to determine the potential for AMD treatment residuals as a poultry litter

amendment to reduce available P in the litter. This could potentially allow litter to be applied on a crop nitrogen need without the negative consequence of soil P buildup.

Introduction

Clay minerals, especially kaolinite, and iron and aluminum oxyhydroxides have the ability to adsorb P from soil solutions. Stable inner sphere complexes are formed because of the high affinity that phosphate has for exchanging surface ligands. Metal oxides have been used in the past to reduce phosphorus loss from non-point sources. Application of water treatment residuals (WTR) to fields has been used to reduce P bioavailability and runoff potential. AMD treatment technologies produce iron and aluminum oxides that have the ability to adsorb P. The potential for AMD –TR to adsorb P from animal manures, could convert what is now a liability (AMD-TR disposal) into an opportunity (P-management technology).

Objective

1. Determine the feasibility of adding AMD-TRs to reduce soil test extractable P.
 - a. Determine the P sorption capacity of AMD-TRs from six different AMD sources.
 - b. Quantify the relationship between final poultry litter STP and the quantity of AMD-TR added.

Materials and Methods

Six AMD-TRs were collected, dried, ground and sieved from currently operation AMD treatment facilities. Inorganic P sorption isotherms were determined for each. Total elemental concentrations were determined after Microwave-Assisted, Nitric Acid Digestion by ICP-OES. Water samples from the tile drain outlet were collected six times between 28 May 2009 and 21 September 2009.

Results

All sludges were alkaline in pH and contained between 9.3 and 94 g kg⁻¹ Fe and between 28 and 88 mg kg⁻¹ P (Table 1). The high pH and concentrations of Ca suggest the presence of unreacted lime.

Table 1. Sludge pH and elemental analysis.

Sample	pH	Fe	Al	Mn	Mg	Ca	P
		----- g kg ⁻¹ -----					mg kg ⁻¹
EM-32	8.3	71	31	2.9	2	49	88
S-10-81	8.4	14	40	7.8	26	78	37
U-2024-87	9.4	55	20	2.2	7.1	81	28
S-26-85	9.2	14	14	15	62	68	61
237-76	8.2	9.3	48	13	50	21	82
34-81	8.0	94	41	22	25	34	70

Sample U-2024-87 had the largest P sorption maxima of approximately 70g P / kg sludge (Figure 1a). All other samples had P sorption maxima of less than 30 g kg⁻¹ (Figures 1a and 1b). Sample U-2024-87 had the highest Ca content (Table 1) which could indicate that unreacted lime was the sorbent or that Ca-phosphates had precipitated.

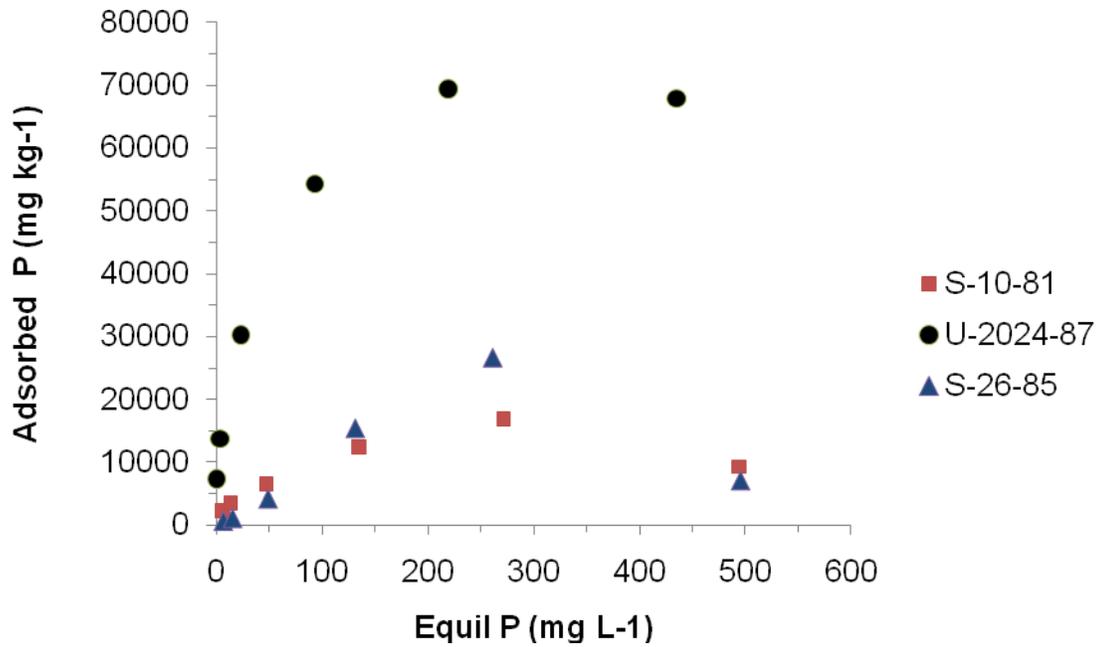


Figure 1a. Phosphorus sorption isotherm for three AMD sludges.

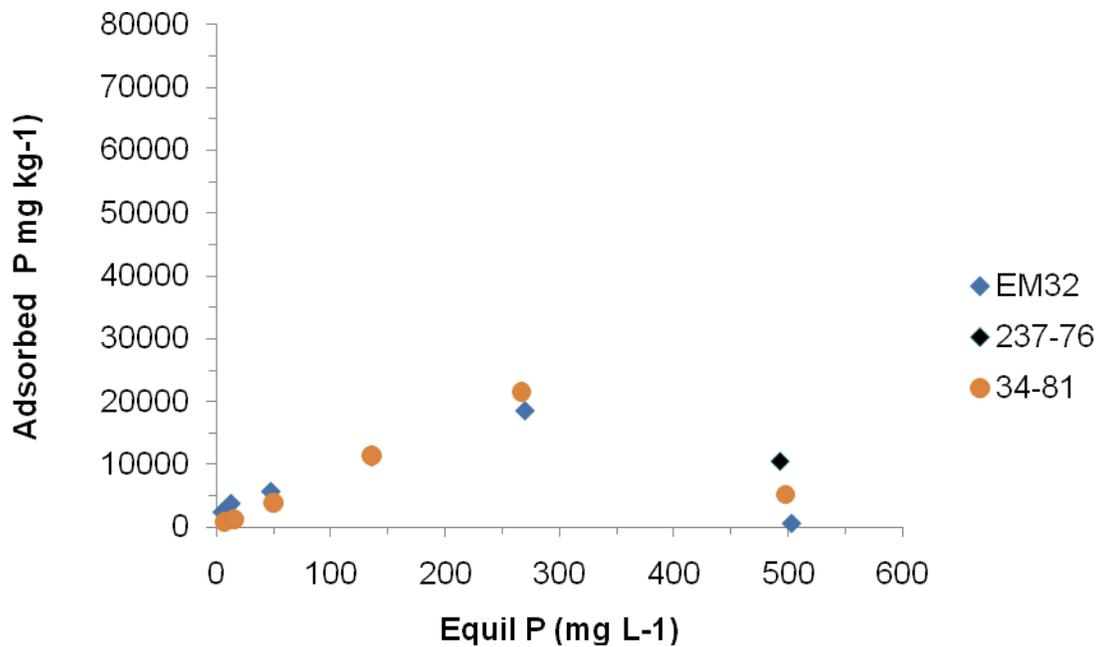


Figure 1b. Phosphorus sorption isotherm for three AMD sludges.

Phosphorus concentrations in the tile drainage were all low, most below detection limit (Table 2).

Table 2. Phosphorus concentrations from tile drained field in 2009

Sampling Date	Total P	Dissolved P	Orthophosphate
	----- mg L ⁻¹ -----		
28 May	<0.047	<0.047	na
24 June	<0.047	<0.047	na
30 June*	0.068	na	0.029
17 July	0.06	0.05	na
27 August	<0.047	<0.047	na
21 September	<0.047	<0.047	na

na = not analyzed

* Sample collected and analyzed by State Ag Laboratory

Discussion

Because so little phosphorus was detected in the field drainage, it was decided that field applications of AMD sludge would have no measurable effect on surface water P concentrations. It was further decided that the project goals would change from the potential for AMD sludge as a soil amendment to reduce P concentrations to the potential for AMD sludge to be a litter amendment to reduce available P.

New Objective

The new objective is to:

2. Determine the feasibility of adding AMD-TRs to poultry litter to reduce soil test extractable P.
 - a. Determine the P sorption capacity of AMD-TRs from six different AMD sources.

- b. Quantify the relationship between final poultry litter STP and the quantity of AMD-TR added.

When these parameters have been determined, it will be possible to quickly identify AMD-TRs likely to achieve high phosphorus removal efficiency, and the mass of AMD-TR required to achieve a desired STP level in the treated litter. This information is needed before proceeding to larger-scale field testing.

Materials and Methods

Additional characterization for amorphous and crystalline oxides and X-ray diffraction for the six AMD sludge samples will be determined using standard methods.

Two additional raw poultry litter samples have been acquired (five total) and have been air-dried, ground and sieved. Litter properties to be determined include pH and conductivity, nitrogen and phosphorus.

Three AMD-TRs will be mixed in varying amounts with a constant mass of each litter sample. These mixtures will be moistened to approximately field capacity, and then allowed to dry in a dark plant growth chamber. This cycle will be repeated until there is no change in Mehlich 3 extractable P.

Student Support (to date)

Category	Number of students supported with 104b base grant	\$ Value of students supported with 104b base grant	Number of students supported with matching funds	\$ Value of student support with matching funds	Total number of students supported	Total \$ value of student support
Undergraduate	1	\$582.40	0	0	1	582.40
Masters						
Ph.D.						
Post-Doc						
Total	1	\$582.40	0	0	1	\$582.40

(WRI-119) Development and Presentation of Current Water Quality Data for the Public

Basic Information

Title:	(WRI-119) Development and Presentation of Current Water Quality Data for the Public
Project Number:	2009WV127B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	None
Principal Investigators:	Paul Ziemkiewicz, Melissa J. O'Neal

Publications

There are no publications.

DEVELOPMENT AND PRESENTATION OF CURRENT MONONGAHELA RIVER WATER QUALITY DATA FOR THE PUBLIC

WRI-119
USGS AWARD NUMBER: 2009WV127B

ANNUAL REPORT

REPORTING PERIOD: MARCH 1, 2009 - FEBRUARY 28, 2010

PRINCIPAL INVESTIGATORS:

Paul Ziemkiewicz, Ph.D.

Tamara Vandivort, M.S.

Dave Saville, M.S.

Ben Mack, M.S.

Melissa O'Neal

MAY 28, 2010

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ABSTRACT

The Monongahela River has been impacted by acid mine drainage and episodes of high total dissolved solids (TDS) from flooded underground coal mines and other sources. In year one of this two-year project, the West Virginia Water Research Institute developed a comprehensive water quality monitoring program and reporting mechanism for the Monongahela River. Twelve locations were selected for sampling including 4 sites on the main stem of the Monongahela River and at the mouths of 8 of its largest tributaries. Field parameters have been recorded and samples have been collected every other week and analyzed in the laboratory.

The analytical chemistry program includes a suite of acid mine drainage parameters (acidity, alkalinity, pH, specific conductivity, sulfate, iron, manganese, aluminum, calcium, magnesium) and dissolved metals (aluminum, iron, manganese, calcium, sodium, chloride, bromide, and total suspended solids). The resultant data is regularly placed in a useful and user-friendly manner on a website (www.MonWQ.net) using a Geographic Information System database. The website includes a description of water quality parameters that are being analyzed, basic information on the Monongahela River Watershed, links to relevant websites, and a list of project participants.

The interactive database which has been developed allows users to select date ranges and parameters to create “on the fly” graphs that will graphically display the data for the unique queries. Statistical analysis has been incorporated into an easy to visualize color-coded ranking of TDS loading at the various sampling locations in the watershed.

This project has the support of the West Virginia Advisory Committee for Water Research and stakeholders including the U.S. Geological Survey, U.S. Army Corps of Engineers, WV Department of Environmental Protection, WV Department of Natural Resources, WV Division of Health & Human Resources, West Virginia University Extension Service, industry, and others.

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EXECUTIVE SUMMARY

This project has been designed, and implementation begun, to systematically collect water quality information for the Monongahela River watershed and make it readily accessible to the public in a user-friendly manner via the internet.

Current water quality information can be useful to many users of the Monongahela River. Recreationists such as anglers and boaters can use this data to measure expected fishing success for example. Water conditions are also important to industries while upsets in the quality of the water is important information for regulatory agencies. Nearly one million people get their drinking water from the Monongahela River. The need exists to gather and present current water quality information in a form that is accessible to the public. This information can be used to:

- Assess the quality of the fishery and other recreational opportunities
- Identify upsets in water quality
- Evaluate historic trends
- Provide a framework for other data sources
- Aid in the development of policy and regulations

BACKGROUND

The need for chemical data on the Monongahela River became apparent following episodes of high TDS in the River during the summer and fall of 2008. After initial meetings and discussions with regulatory agencies and stakeholders, including the WV Department of Environmental Protection, U.S. Geological Survey, US Environmental Protection Agency Region 3, US Army Corps of Engineers, and others, this need became even clearer.

A great deal of stream data is, and has been, collected by watershed associations, agencies, municipalities, industry and research organizations. At the beginning of year 1 of this project, an advisory committee was established consisting of WVWRI personnel as well as staff from the various research interests from the Advisory Committee. The Committee met several times and a questionnaire was developed to determine what water chemistry data was available and/or being collected on the Monongahela River and its tributaries. It also asked what parameters needed to be measured. This initial outreach determined that much data was being collected, but it was not measured using compatible techniques or organized into parameters and locations easily included in a monitoring program. To create a database with useful, accurate and current information, it was decided that a standardized, systematic program was necessary.

PROJECT IMPLEMENTATION

A strategic monitoring program for the Monongahela River watershed was developed which was implemented in July, 2009. The program included water quality monitoring and sampling on a bi-weekly basis. Monitoring locations were determined partially based on the availability of

stream flow data at 12 locations in the watershed. These locations included 4 sites on the Monongahela River and at 8 locations at the mouths of its major tributaries. Flow calculations for locations without regularly collected flow information were determined based on nearest USGS gage, or calculated from basin area.

The monitoring program tests the water for five parameters measured in the field including electrical conductivity, oxidation reduction potential, pH, temperature and total dissolved solids. Water samples are collected and analyzed in the laboratory at the National Research Center for Coal and Energy at West Virginia University for aluminum, acidity, alkalinity, bromine, calcium, chlorine, iron, magnesium, manganese, sodium, sulfate, sulfur and total suspended solids.

PUBLIC OUTREACH

An important part of this program is the dissemination of the results of the monitoring program to the public. The principle venue for sharing this information is the project website, www.MonWQ.net. This website uses a GIS database and map. The map makes it easy to view the project area and the “zoom-in” feature allows visitors to identify the monitoring locations as well as other details about the watershed. Map view options include highways, topographic features or aerial imagery.

Website visitors are able to view the resultant data from the monitoring program by entering a query by monitoring location. Graphs are then generated for each of the monitored parameters. Lab analyzed data for the various components of TDS are compiled and depicted in “stacked bar graphs.” These stacked bar graphs are constructed for each monitoring date and depict TDS loading for all monitored locations. The TDS loading graphs are organized on the website by month. There is also a color-coded map feature to display the TDS concentrations at the various monitoring locations. These are depicted by different color and size “dots” at the sample sites.

The project website also includes basic information about the Monongahela River and project details including participants, news items and links to related websites. Detailed descriptions of the measured parameters and a printable fact sheet about the project are included. A slide show on the home page shows images of the sampling locations.

PROJECT IMPORTANCE

Soon after the monitoring program was implemented, a fish kill in September 2009 on Dunkard Creek, a tributary of the Monongahela River, gained much media attention. The WV DEP and PA DEP determined that the fish kill was caused by a toxic bloom of golden algae, *P. parvum*, which flourishes in salty water. Not typically found in the freshwater streams of the Appalachians, it has not been determined how the algae were introduced into Dunkard Creek. Testing done by the WV and PA DEPs has since determined that the algae have also been introduced into other streams in the watershed and states. The water quality data collected by this study has been very helpful in determining sources and concentrations of the pollutants that allowed these exotic algae to flourish.

As coal mining continues in the Monongahela River watershed, and gas well drilling is on the upswing, the water quality of the River is a topic of much concern. Increases in the demand for water, including nearly one million people who get their drinking water from the Monongahela River have further intensified the debate. The fishery in the River has improved over the years and there is a considerable increase in the amount of sport fishing taking place there. Several large fishing tournaments are now taking place on the River increasing the economic impacts from this recreational use. Fishing access to the river has been made easier by a new boat launch and docking facility built on the Morgantown Pool by the WV Division of Natural Resources.

Increases in water usage, recreational usage, and industrial impacts to the river have caused considerable debate about the adequacy of existing water quality regulations. The data generated from this study has provided crucial information to inform many of these concerns. It has provided the accurate and current water quality information necessary to inform the public and to aid regulatory personnel in making sound policy decisions. For example, information provided by this watershed monitoring program was important in drafting the newly proposed water quality regulations by the WV Department of Environmental Protection (WVDEP). Competitors in fishing tournaments on the Mon River in both Pennsylvania and West Virginia use current information about the water quality to gain a competitive edge. These tournaments are important economic contributors and examples of the importance of a clean river for our state's natural resource based tourism economy.

PROJECT CONTINUANCE

Plans for year two of the project include adding several monitoring locations on other significant tributaries. Continuous data loggers will be installed at several locations to better calculate stream flow. The project website will continue to be updated regularly and improvements in data depiction and usefulness will be incorporated. There is also considerable interest in this project so there will be some additional emphasis on the media to help raise awareness of the program and increasing visitation to the project website.

METHODOLOGY

Baseline sampling of the Monongahela River and its tributaries began on July 29, 2009 and is currently ongoing. Samples have been collected by WVWRI staff at 12 different locations every other week from four locations on the Monongahela River and eight locations on major tributaries that enter the Monongahela River (Table 1, Figure 1).

Table 1. Sample location descriptions.

Site ID	Site Name	Site Description	lat	long
WF	West Fork River	Along Enterprise Road just north of the Everson-Monongah Bridge	39 26.928	80 14.675
TV	Tygart Valley River	Right on the boat dock behind Wood's Boat House downstream of the I-79 bridge	39 26.574	80 10.833
M102	Monongahela R. mile 102	Located upstream of the Morgantown Utility Board treatment plant along the rail trail	39 36.622	79 58.238
DE	Decker's Creek	Behind the dog park along the portion of rail trail between Morgantown and Sabraton	39 37.725	79 57.605
M89	Monongahela R. mile 89	Located off the edge of Water St. just south of the new route 88 bridge	39 44.237	79 54.194
CH	Cheat River	Located at the tailrace of the Lake Lynn Lock and Dam just under the public fishing area	39 43.301	79 51.460
DU	Dunkard Creek	Along the north side of the creek at the end of Beal Road	39 45.903	79 57.909
WH	Whitley Creek	Located at the Route 88 bridge near Alicia.	39 51.132	79 55.564
M82	Monongahela R. mile 82	Just under the railroad tracks and straight ahead under the route 21 bridge	39 51.666	79 56.919
TE	Tenmile Creek	On the boat ramp at the Ten Mile Creek County Park in Clarksville, PA.	39 58.681	80 01.043
M23	Monongahela R. mile 23	Located at the north end of the riverfront park boat dock upstream of the route 51 bridge	40 16.401	79 53.291
YO	Youghiogheny River	Right off the boat ramp on the Youghiogheny behind the Sutersville playground	40 14.202	79 48.385

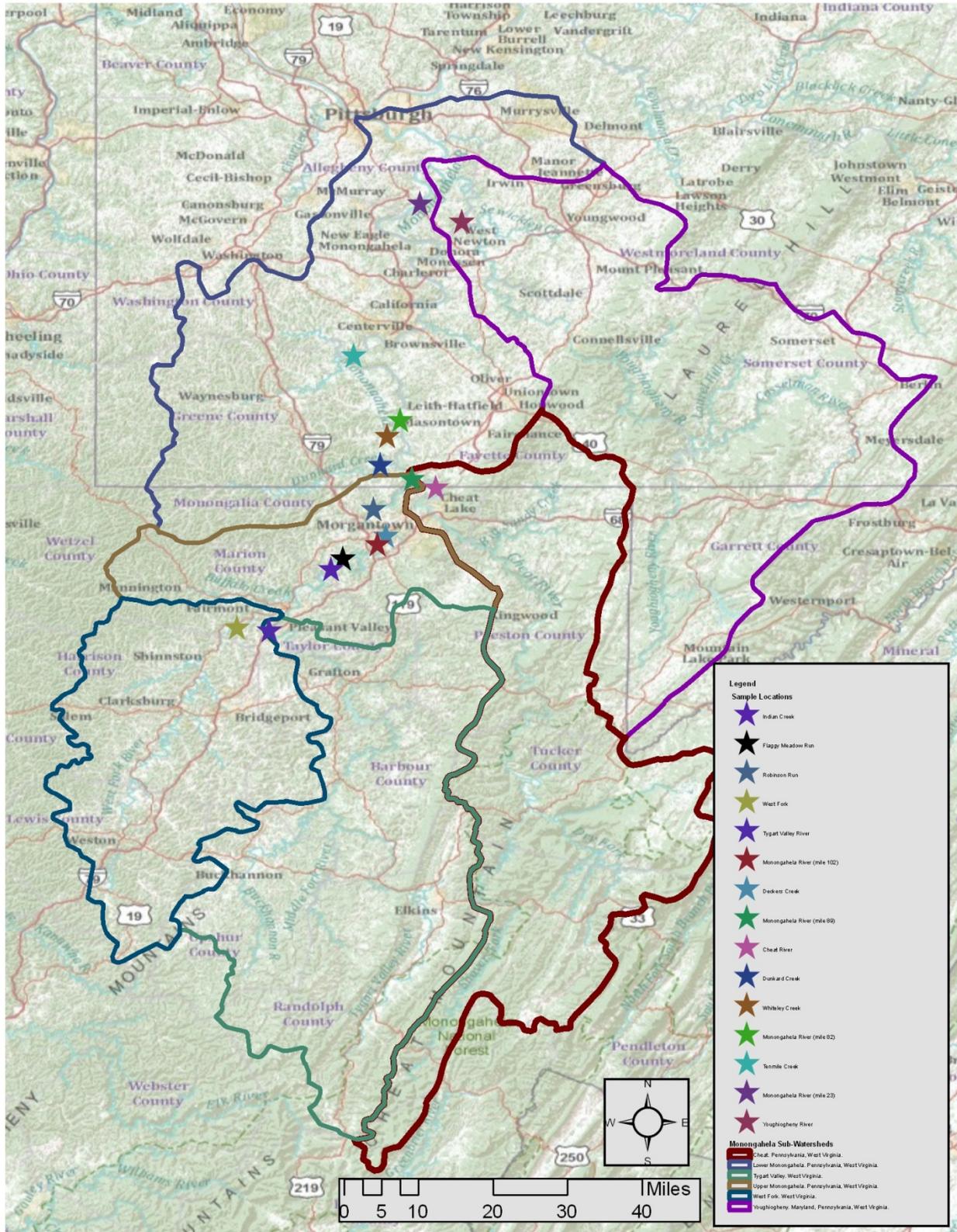


Figure 1. Topographic map of sample locations and sub-watersheds within the study area.

FIELD PARAMETERS

A suite of parameters to incorporate into the monitoring program was determined during early meetings with the project Advisory Committee. Parameters analyzed in the field include: electrical conductivity, Oxidation-Reduction Potential (ORP), pH, temperature, and Total Dissolved Solids (TDS). Flow is also measured for some of the sampling points using the nearest USGS gauges. For those sites that are located on ungauged streams, flow is calculated based on nearest USGS gauge and basin size.

Electrical Conductivity

Electrical conductivity is an indicator of dissolved metals. Some common metals that may be found in surface water include: iron, aluminum, calcium, magnesium, and others. High conductivity levels may be due to several different factors, including: untreated wastewater infiltration, mining, and agricultural runoff. High conductivity concentrations can be damaging to aquatic life because of increased salinity in the stream and possible smothering of the stream bottom (Kentucky Water Watch, 2010a).

For the purposes of this study, the graphical range for conductivity is 0-4,000 us/cm. Detection limits for conductivity are as low as 0 us/cm, with an upper value of 9,999 us/cm. Conductivity is measured in the lab using EPA method 120.1 (American Public Health Association et al., 1998) and in the field with an YSI model 556 multiprobe.

Oxidation-Reduction Potential (ORP)

ORP is the potential of a chemical species to acquire (reduction) or lose (oxidation) electrons. An oxidizing substance, such as chlorine, will have a positive ORP value, while a reducing agent, such as hydrogen sulfide, will have a negative ORP value. High or low ORP values could indicate the presence of large amounts of certain chemical species, such as chlorine or hydrogen sulfide, which may affect aquatic life (Andrews et al., 2004).

For the purposes of this study, the graphical range for conductivity is -50-250 millivolts. There are no upper or lower detection limits for ORP. ORP is measured in the field with an YSI model 556 multiprobe.

pH

Values of pH in surface water outside acceptable ranges can indicate human impacts such as agricultural runoff, mining, or infiltration of untreated wastewater. Low pH is acidic and can cause corrosion of pipes, as well as increased dissolved metals concentrations in surface water. High pH is alkaline and can cause scale buildup in fixtures, bad taste, and reduce the effectiveness of chlorine disinfection, as well as increased metal concentrations in stream sediments (Kentucky Water Watch, 2010b).

For the purposes of this study, the graphical range for pH is 4-10 standard units. Detection limits for pH are between 0 and 14 standard units. pH was measured in the field using a portable YSI 556 multiprobe and was also determined in the lab using EPA method 150.1 (American Public Health Association et al., 1998).

Temperature

Temperature has a large impact on the biological activity of aquatic organisms. All aquatic organisms have a preferred temperature range. If the water temperature gets too far above or below this range, then the biological community becomes stressed and may have difficulty maintaining a stable population (USEPA, 1986)

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic invertebrates or certain fish (USEPA, 1986).

For the purposes of this study, the graphical range for temperature is -30-100 degrees Centigrade. There are no upper or lower detection limits for water temperature. Water temperature was measured in the field with an YSI model 556 multiprobe.

Total Dissolved Solids (TDS)

TDS is a general indicator of overall water quality. It is a measure of inorganic and organic materials dissolved in water. High levels of TDS in surface water may be due to several factors, including: sedimentation, mining, or storm water runoff. Increased TDS may impart a bad odor or taste to drinking water, as well as cause scaling of pipes and corrosion (Kentucky Water Watch, 2010a).

For the purposes of this study, the graphical range for TDS is 0-1000 mg/L. The lower detection limit for TDS is 3.36 mg/L and there is no upper detection limit. TDS was measured in the field with an YSI model 556 multiprobe and in the lab using Standard Method SM-2540C (American Public Health Association et al., 1998).

LABORATORY PARAMETERS

Parameters analyzed in the laboratory include: aluminum (Al), acidity, alkalinity, bromine (Br), calcium (Ca), chlorine (Cl), electrical conductivity, iron (Fe), magnesium (Mg), manganese (Mn), pH, sodium (Na), sulfate (SO₄-2) , sulfur (S), and Total Suspended Solids (TSS).

Aluminum (Al)

Aluminum is the third most common element on Earth. In most forms, aluminum is not very soluble in water. However, low pH waters, such as those associated with mine drainage, may contain large amounts of dissolved aluminum due to dissolution of aluminum-containing minerals within the local geology. When aluminum precipitates within the water column, it is in the form of an aluminum hydroxide. Aluminum hydroxide may be very harmful to aquatic life due to smothering of the stream bed of the water body. Aluminum may also clog the gills of aquatic organisms if the concentration is high enough (Kentucky Water Watch, 2010c).

For the purposes of this study, the graphical range for both dissolved and total aluminum is 0-20 mg/L. The lower detection limit for aluminum is 0.021 mg/L and there is no upper detection limit. Both total and dissolved aluminum is measured in the lab using EPA method 200.7. (American Public Health Association et al., 1998)

Acidity

Low pH values indicate that surface water is acidic. High acidity values in surface water may come from several sources, such as mining and acid precipitation. Acid precipitation may cause the dissolution of aluminum in soils with poor buffering capacity, which in turn causes acidity to increase in surface water when the soil enters the stream as runoff. As acidity increases, dissolved metal concentrations increase, which in turn may cause problems for aquatic life in streams and rivers (Kentucky Water Watch, 2010b).

For the purposes of this study, the graphical range for acidity is 0-1,000 mg/L as CaCO₃. Detection limits for acidity are as low as 2 mg/L, with no upper value. Acidity was measured in the lab using EPA method 305.2 (American Public Health Association et al., 1998).

Alkalinity

High pH values indicate that surface water is alkaline in nature and that the water has a greater neutralization capacity. Alkalinity is made up of the constituents of the water that elevate pH above 4.5 (USEPA, 1986). Typically, a small to moderate amount of alkalinity in water is also important to have for the well-being of the organisms that live in the water body. However, too much alkalinity can be toxic to wildlife. High alkalinity can also cause impacts to humans, including scale buildup in fixtures, bad taste, and reduce the effectiveness of chlorine disinfection. Alkaline water may also impact irrigation if the alkalinity of the water is greater than the alkalinity of the surrounding soil.

For the purposes of this study, the graphical range for alkalinity is 0-1,000 mg/L as CaCO₃. Detection limits for alkalinity are as low as 2 mg/L, with no upper value. Alkalinity was measured in the lab using EPA method 310.1 (American Public Health Association et al., 1998).

Bromine (Br)

Bromine is a chemical element found in the halogen group. At room temperature, it is a reddish-brown liquid that is slightly soluble in water. Dissolved bromine comes from several sources, including surrounding geology, fluids used in gas well drilling, seawater infiltration, and industrial waste (Sollars et al., 1982). Elevated levels of dissolved bromine may interfere with water treatment, as well as pose a possible increased cancer risk to humans and wildlife.

For the purposes of this study, the graphical range for dissolved bromine is 0-5 mg/L. The lower detection limit for bromine is 0.13 mg/L and there is no upper detection limit. Dissolved bromine is measured in the lab using EPA method 300.0 (American Public Health Association et al., 1998).

Calcium (Ca)

Calcium is an element that is found naturally in water due to its abundance in the Earth's crust. Large bodies of surface water, such as rivers, typically contain 1-2 mg/L of calcium. High levels of calcium in surface water mean that the water is hard, which helps aquatic life by buffering the pH of the water and protecting those organisms with gills from direct metal uptake. However, if calcium and hardness are too high, hardening of pipes and staining may occur (Kentucky Water Watch, 2010d).

For the purposes of this study, the graphical range for dissolved calcium is 0-20 mg/L. The lower detection limit for calcium is 0.007 mg/L and there is no upper detection limit. Dissolved calcium is measured in the lab using EPA method 200.7 (American Public Health Association et al., 1998).

Chlorine (Cl)

Chlorine occurs naturally as a green gas. It appears in many different compounds. The most important chlorine compound for many forms of life is NaCl, or salt. Chlorine (as the Cl⁻ ion) is the most abundant dissolved ion in salt water, and is also found in freshwater in much smaller concentrations. Freshwater chlorine is usually derived from chlorine mineral dissolution. Other sources of chlorine in freshwater may include wastewater runoff and breakdown of chlorinated compounds. High amounts of dissolved chlorine can be very harmful to wildlife due to the oxidative properties of chlorine (USEPA, 1986). When chlorine concentrations reach a certain level within the organism, it combines with the water and oxygen to create hydrochloric acid, which destroys animal tissues.

For the purposes of this study, the graphical range for dissolved chlorine is 0-20 mg/L. The lower detection limit for chlorine is 0.10 mg/L and there is no upper detection limit. Dissolved chlorine is measured in the lab using EPA method 300.0 (American Public Health Association et al., 1998).

Iron (Fe)

Iron is the most abundant metal in the Earth's core. It is found in a large range of compounds in either a +2 or +3 oxidation state. It is also very important to humans and other organisms, as it is partially responsible for transporting oxygen through the bloodstream (USEPA, 1986). Iron is easily dissolved in water and can be found naturally occurring in water bodies. High levels of precipitated iron oxides may cause smothering of stream bottoms and plugging of organism's gills.

For the purposes of this study, the graphical range for both dissolved and total iron is 0-20 mg/L. The lower detection limit for iron is 0.013 mg/L and there is no upper detection limit. Both total and dissolved iron is measured in the lab using EPA method 200.7 (American Public Health Association et al., 1998).

Magnesium (Mg)

Magnesium is found in large concentrations in both the Earth's crust and the human body. It is highly soluble in water, and is the third most abundant element in sea water. Concentrations of magnesium in freshwater vary according to surrounding geology. Along with calcium, magnesium concentrations are used to determine water hardness. High concentrations of magnesium cause similar problems to high concentrations of calcium, including staining and hardening of pipes and fixtures (Wilkes University Center for Environmental Quality, Environmental Engineering and Earth Sciences, 2010a).

For the purposes of this study, the graphical range for both dissolved and total magnesium is 0-20 mg/L. The lower detection limit for magnesium is 0.003 mg/L and there is no upper detection

limit. Both total and dissolved magnesium is measured in the lab using EPA method 200.7 (American Public Health Association et al., 1998).

Manganese (Mn)

Manganese is commonly found in soil in its oxide form (pyrolusite) (USEPA, 1986). It is used in the steel making process, and is also an essential nutrient for most organisms. High concentrations of manganese in humans can cause many different health problems, including Parkinson's disease and bronchitis. Manganese is also soluble in water, with large concentrations causing health problems in aquatic life. Manganese can also bioaccumulate through the food chain, causing top predators to have unhealthy levels of manganese in their bodies.

For the purposes of this study, the graphical range for both dissolved and total manganese is 0-20 mg/L. The lower detection limit for manganese is 0.017 mg/L and there is no upper detection limit. Both total and dissolved manganese is measured in the lab using EPA method 200.7 (American Public Health Association et al., 1998).

Sodium (Na)

Sodium is a very common element found in rocks and soils. It is needed for all life forms to aid in the transmission of nerve impulses. It is also highly soluble in water and will react violently with water to form lye and hydrogen gas. Sodium is found naturally in freshwater bodies. Concentrations of sodium vary greatly, and are dependent on the surrounding soil and geology (Kentucky Water Watch, 2010e). Too much sodium can raise the pH level of a water body to the point where it is too high for certain species of aquatic life to survive.

For the purposes of this study, the graphical range for both dissolved and total sodium is 0-5 mg/L. The lower detection limit for sodium is 0.012 mg/L and there is no upper detection limit. Both total and dissolved sodium is measured in the lab using EPA method 200.7 (American Public Health Association et al., 1998).

Sulfate (SO₄ -2)

Sulfate is a salt consisting of one sulfur atom and four oxygen atoms with an oxidation number of -2. Sulfate is naturally occurring in almost all water bodies. It usually comes from oxidation of sulfite ores, dissolution of sulfate minerals, shale, and industrial wastes. High concentrations of dissolved sulfate may give water an unpleasant taste and may be corrosive to plumbing. It may also have health effects including nausea and diarrhea (Kentucky Water Watch, 2010f).

For the purposes of this study, the graphical range for both dissolved and total sulfate is 0-200 mg/L. The lower detection limit for sulfate is 0.15 mg/L, and there is no upper detection limit. Both total and dissolved sulfate is measured in the lab using EPA method 300.0 (American Public Health Association et al., 1998).

Sulfur (S)

Sulfur is a non-metal that is a yellow solid at room temperature. Sulfur is found in many different minerals and is extracted by melting the surrounding rock and collecting the molten sulfur. It may also be produced from hydrogen sulfide. It is a required nutrient for life on Earth and it is an essential building block of cells. It is insoluble in water. However, high concentrations of sulfur-

containing compounds, such as sulfate, may be found in water due to human activities, such as mining. High concentrations of sulfur may cause corrosion of pipes and fixtures, as well as reducing the effectiveness of water used for laundry (Wilkes University Center for Environmental Quality, Environmental Engineering and Earth Sciences, 2010b).

For the purposes of this study, the graphical range for both dissolved and total sulfur is 0-20 mg/L. The lower detection limit for sulfur is 0.05 mg/L, and there is no upper detection limit. Both total and dissolved sulfur is measured in the lab using EPA method 200.7 (American Public Health Association et al., 1998).

Total Suspended Solids (TSS)

TSS, or turbidity, is the measure of the suspended particles in the water column. High levels of turbidity can come from many sources, such as urban runoff, soil erosion, wastewater discharges, agriculture, and removal of riparian zones. Increased levels of turbidity may cause water to darken, which in turn leaves less light for aquatic plants to perform photosynthesis. This in turn decreases the amount of dissolved oxygen being added to the water, which can affect aquatic organisms that are higher on the food chain (USEPA, 1986). Extreme levels of TSS can also clog fish gills.

For the purposes of this study, the graphical range for TSS is 0-250 mg/L. The lower detection limit for TSS is 2.4 mg/L and there is no upper detection limit. TSS was measured in the lab using Standard Method SM-2540D (American Public Health Association et al., 1998).

SAMPLING METHODOLOGY

Three water samples were taken at each sample point: (I) a 250-mL unfiltered sample was taken for general water chemistry (pH, conductivity, total acidity and alkalinity by titration, and sulfate), (II) a 25-mL sample filtered with a 0.45 micrometer Nalgene syringe filter was acidified to pH of <2 with 0.5 ml concentrated nitric acid and used to determine all metal concentrations with the exception of bromine, and (III), a 1 ml sample was filtered with a 0.45 micrometer Nalgene syringe filter for the analysis of bromine.

ANALYSIS

Water quality samples have been collected from each of the twelve site bi-weekly throughout the reporting period and have been submitted to the National Research Center for Coal and Energy (NRCCE) laboratory same day of sampling and have been analyzed according to EPA procedures and methods (Table 2).

Table 2. Mean water quality parameters. Flow (Q) is expressed in cubic feet per second (CFS), specific conductance (EC) in $\mu\text{s}/\text{cm}$, ORP in mv, and all other concentration measurements are expressed in mg/L.

Site	Q	EC	pH	ORP	Alk	Acid	Br	Al	Fe	Mn	S	Cl	Ca	Na	Mg	SO4	TSS	TDS
WF	458.3	695.3	7.1	51.6	82.5	0.0	0.1	0.0	0.2	0.0	92.7	14.0	70.7	47.8	18.3	248.3	10.3	472
TV	823.1	147.5	7.4	43.9	22.6	3.7	0.0	0.0	0.1	0.0	15.4	4.9	16.1	6.3	3.1	28.0	11.9	81
M102	3964.0	384.1	7.4	48.1	42.6	0.2	0.0	0.3	0.4	0.0	49.1	9.3	30.5	32.6	7.3	114.6	40.3	237
DE	56.8	413.5	7.4	39.2	34.7	1.0	0.0	0.0	0.3	0.1	66.0	13.4	56.8	12.9	9.3	162.6	28.4	289.6
M89	4020.8	397.1	7.5	50.8	37.3	0.7	0.0	0.0	0.1	0.0	57.2	10.1	37.0	31.2	8.0	126.5	35.1	250
CH	275.0	118.8	7.5	72.4	15.2	5.0	0.0	0.1	0.1	0.0	13.9	2.9	13.3	3.5	2.7	28.7	10.6	66.7
DU	94.6	4186.3	7.5	17.0	108.9	0.0	0.4	0.1	0.6	0.2	814.1	121.2	221.3	678.8	68.4	2412.8	24.4	3611
WH	59.3	3478.0	7.5	73.4	270.2	0.0	2.0	0.0	0.4	0.0	422.1	243.0	74.0	617.5	38.0	1134.5	12.4	2380
M82	4433.9	401.7	7.3	65.0	33.6	2.4	0.0	0.0	0.2	0.1	59.2	13.9	32.5	44.3	7.9	150.1	21.5	282
TE	47.3	691.8	7.3	64.5	88.9	0.0	0.2	0.1	0.4	0.3	69.8	48.0	48.2	67.9	10.1	172.0	76.5	438
M23	4186.0	426.9	6.5	91.6	44.1	0.6	0.0	0.0	0.2	0.0	50.0	19.8	34.5	37.0	8.5	117.6	18.9	261
YO	2081.0	578.1	7.0	82.5	61.4	1.4	0.1	0.0	0.2	0.1	53.9	66.5	45.7	54.4	11.7	112.1	15.1	352

RESULTS AND DISCUSSION

WATER QUALITY

Healthy, clean, cold tributaries are vital not only in headwaters, but for the overall health and substance of larger watersheds. While this study focuses on the water quality of the Monongahela River, it also provides valuable monitoring of smaller tributaries that ultimately contribute to the health of the entire Monongahela River Watershed. A sub-watershed within the Upper Monongahela River Basin that has received much attention since last fall is Dunkard Creek.

DUNKARD CREEK

During our study period, a devastating fish kill occurred on Dunkard Creek. Sampling for this study had occurred the week prior and week following the initial fish kill. In looking at the Total Dissolved loadings in tons per year (tpy), which is calculated based off of flow discharge (cubic feet per second) and concentration of TDS (mg/L), it is evident that a low flow situation and an increase in high concentrations of TDS led to creating the extremely poor water quality conditions that ultimately led to the fish kill (Figure 2). Between the 25 August 09 and 8 September 10 sampling dates, the TDS concentrations jumped from 3813.21 (mg/L) to 8103.22 (mg/L) while discharge remained around 20 cubic feet per second.

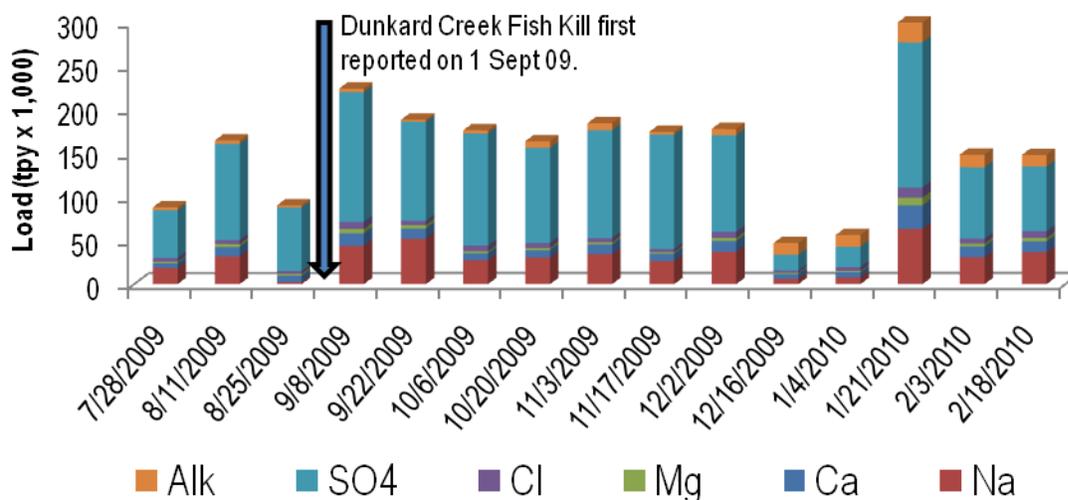


Figure 2. TDS loading on Dunkard Creek throughout study period (July 09-Feb 10).

TDS LOADINGS

TDS loadings are quite useful in realizing the contribution of tributaries to the mainstem of the Monongahela (Mon) River in tons per year. During our study period, Dunkard Creek (DE) which has a drainage area of 229 square miles, was the highest contributor among the watersheds in our study with a basin area smaller than 1500 square miles. Additionally, the dilution effect of the Youghiogheny River is evident when reviewing the averages in tons per year (tpy) between the Mon River at Masontown, PA at river mile 82 (M82) and at Elizabeth, PA on river mile 23 (M23) (Table 3, Figure 3).

Table 3. Mean TDS loadings during July 2009 - February 2010 at project sampling locations. Flow (Q) is expressed in cubic feet per second, and all other concentration measurements are expressed in tpy.

Site	Q	Na	Ca	Mg	Cl	SO4	Alkalinity	TDS
WF	328	10762	16991	4354	4171	67141	24663	128081
TV	757	4125	10138	1957	3481	18302	14131	52135
M102	3971	89794	100651	23089	34988	319356	143628	711506
DE	56	482	1933	319	531	4187	1485	8937
M89	4027	88488	142422	25439	35026	370775	127774	789924
CH	253	782	3009	604	730	6345	3511	14980
DU	90	29468	10541	3193	5565	99472	8040	156279
WH	57	20747	3154	1401	10248	39810	11926	87287
M82	4411	142450	128405	27875	47374	450064	130290	926458
TE	45	2596	1999	417	2004	5962	4255	17232
M23	4109	109406	123020	28541	63432	367201	161436	853037
YO	2564	89010	84488	20516	132155	181909	122546	630625

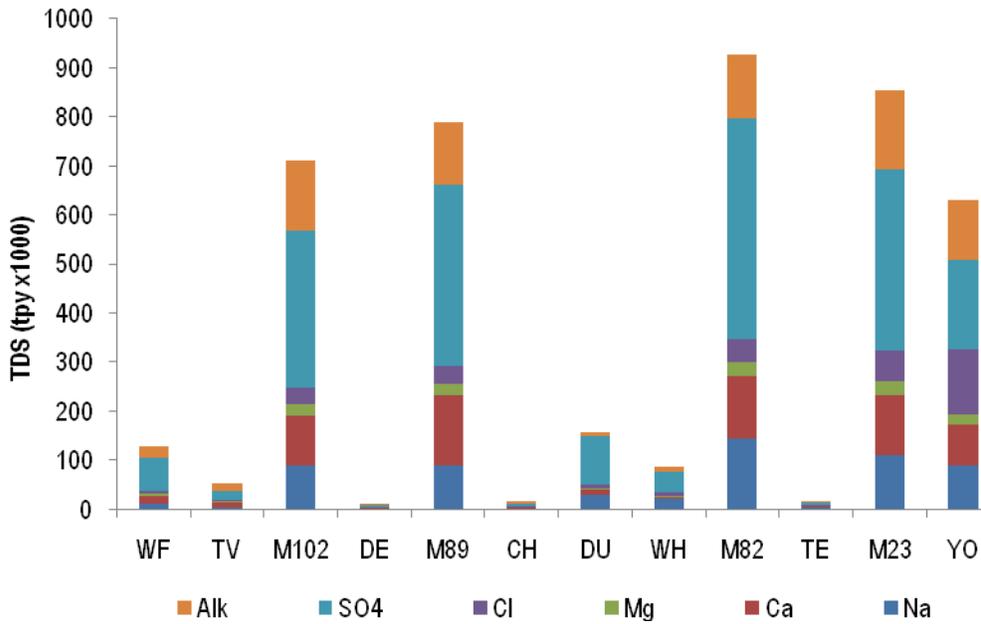


Figure 3. TDS loading (tpy) averages at sampling locations between July 2009 - February 2010.

TDS loadings were determined for each sampling period and provide a snapshot of water quality conditions during that day. Some sampling periods noted quite high TDS loadings throughout the Mon River basin, while other sampling period was relatively low TDS loadings (Figures 4-6).

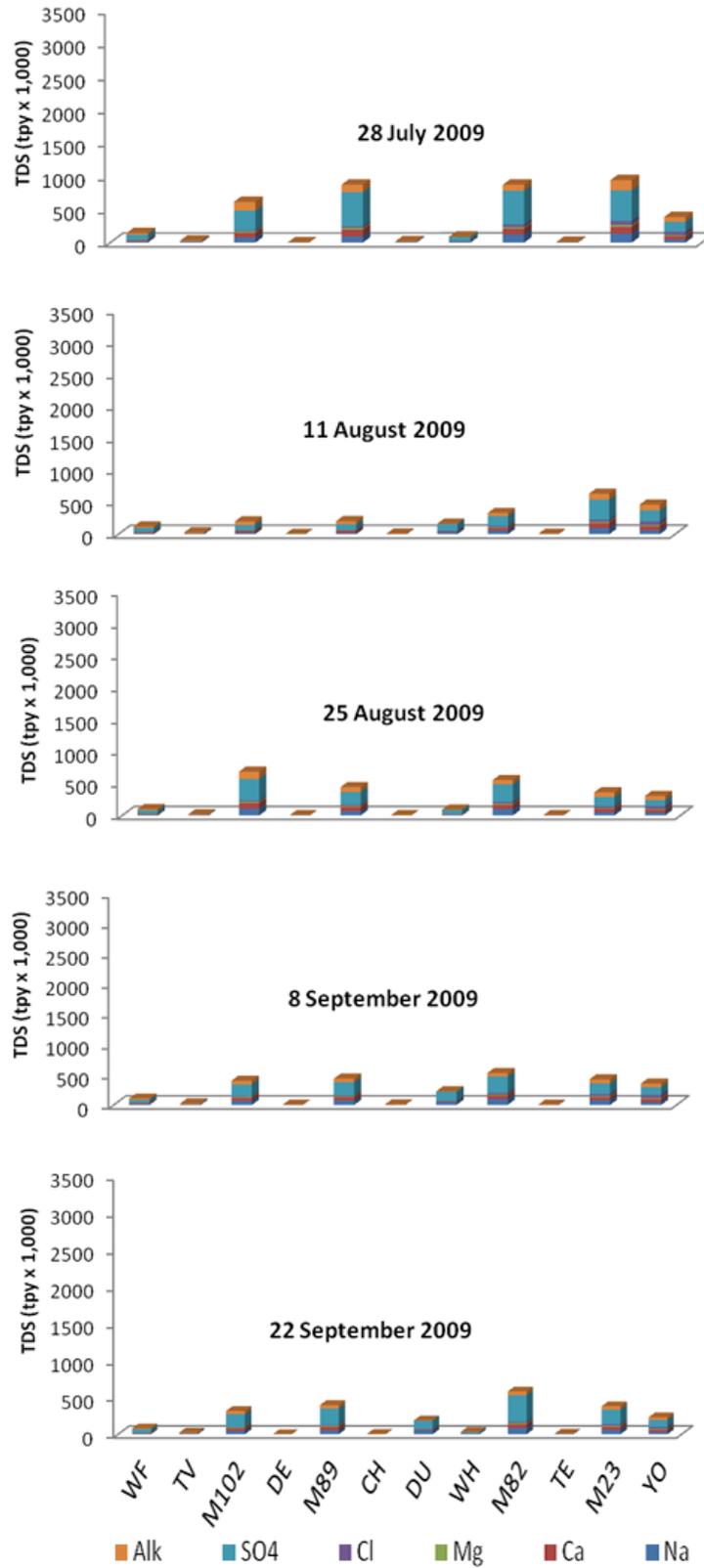


Figure 4. TDS loading (tpy) at sample locations between July - September 2009.

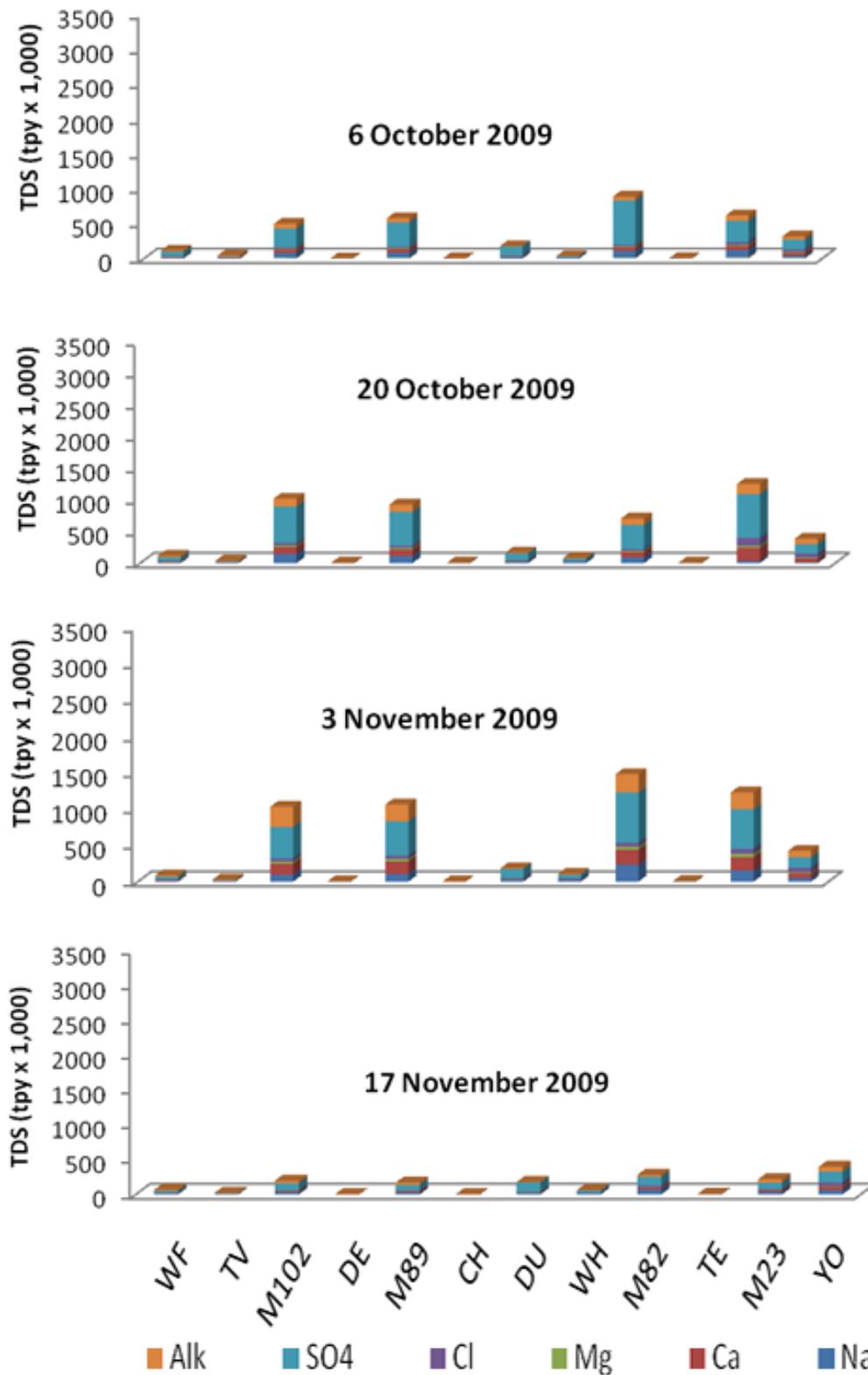


Figure 5. TDS loadings (tpy) at sample locations between October – November, 2009.

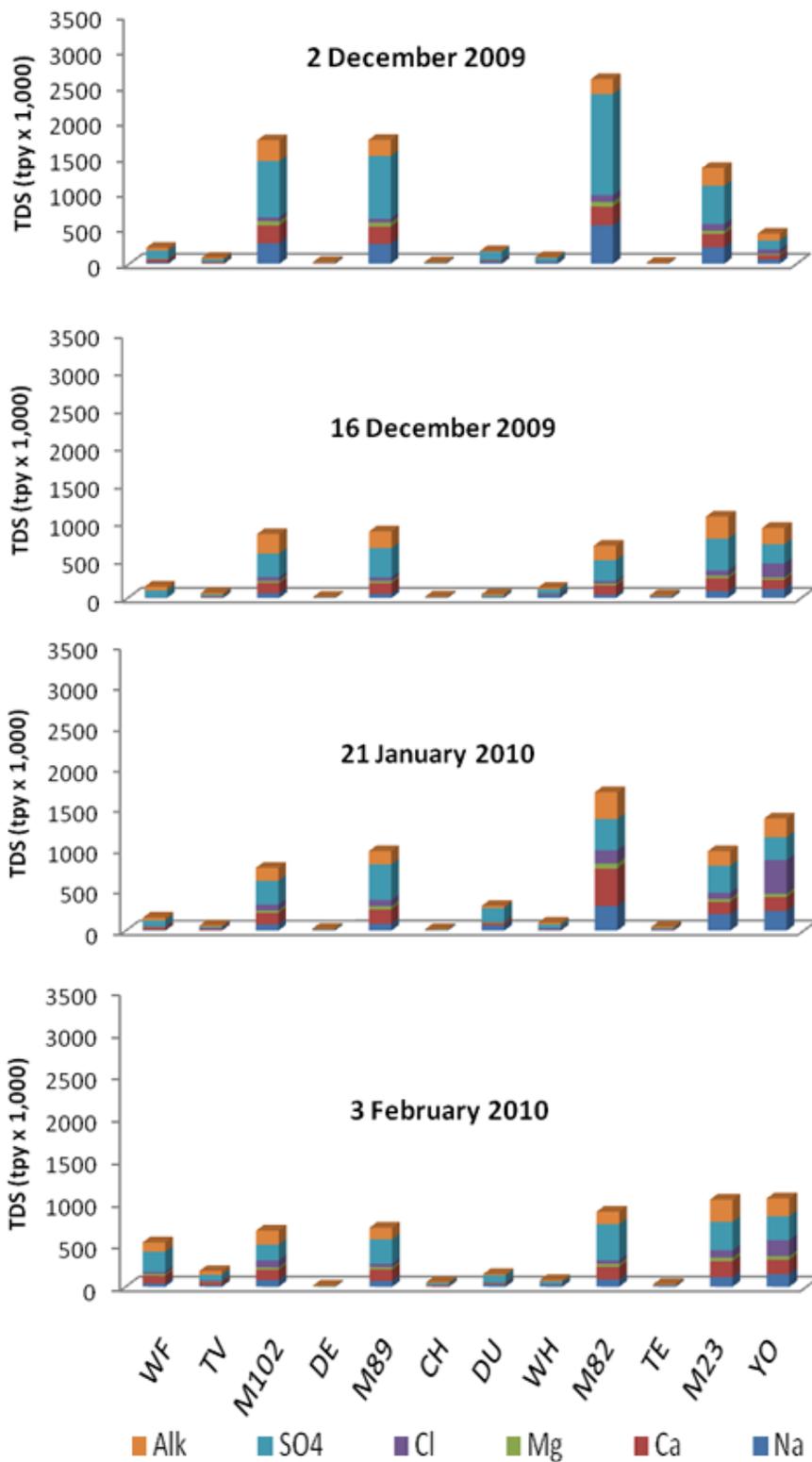


Figure 6. TDS loadings (tpy) at sample locations between October – November, 2009.

TDS VERSUS ELECTRICAL CONDUCTIVITY

As described in the Sample Parameter section of this report, the term TDS describes all solids (usually mineral salts) that are dissolved in water. The TDS and the electrical (interchangeably referred to as specific) conductivity (EC) are in a close connection. The more salts dissolved in the water, the higher is the value of the electric conductivity. EC is relatively easy to determine in the field using instruments such as a YSI multi-probe meter. From this field measurement, TDS can be determined by simply multiplying that EC (ms/cm) by 0.7 to result in an estimate of TDS (mg/L). For this study, we are closely following this relationship to validate our measurements. Not only are we recording EC in the field, but also in the NRCCE laboratory. This provides us with the reassurance that our field equipment is in fact, working properly. Furthermore, after running our calculations in converting EC to TDS, the NRCCE laboratory runs an analytic test to measure TDS (following EPA procedures). In comparing the calculated TDS versus the actual TDS, we are able to report our results with the utmost confidence. Figures 7-9 display the relationship between EC and TDS observed throughout the study between July 09- February 10.

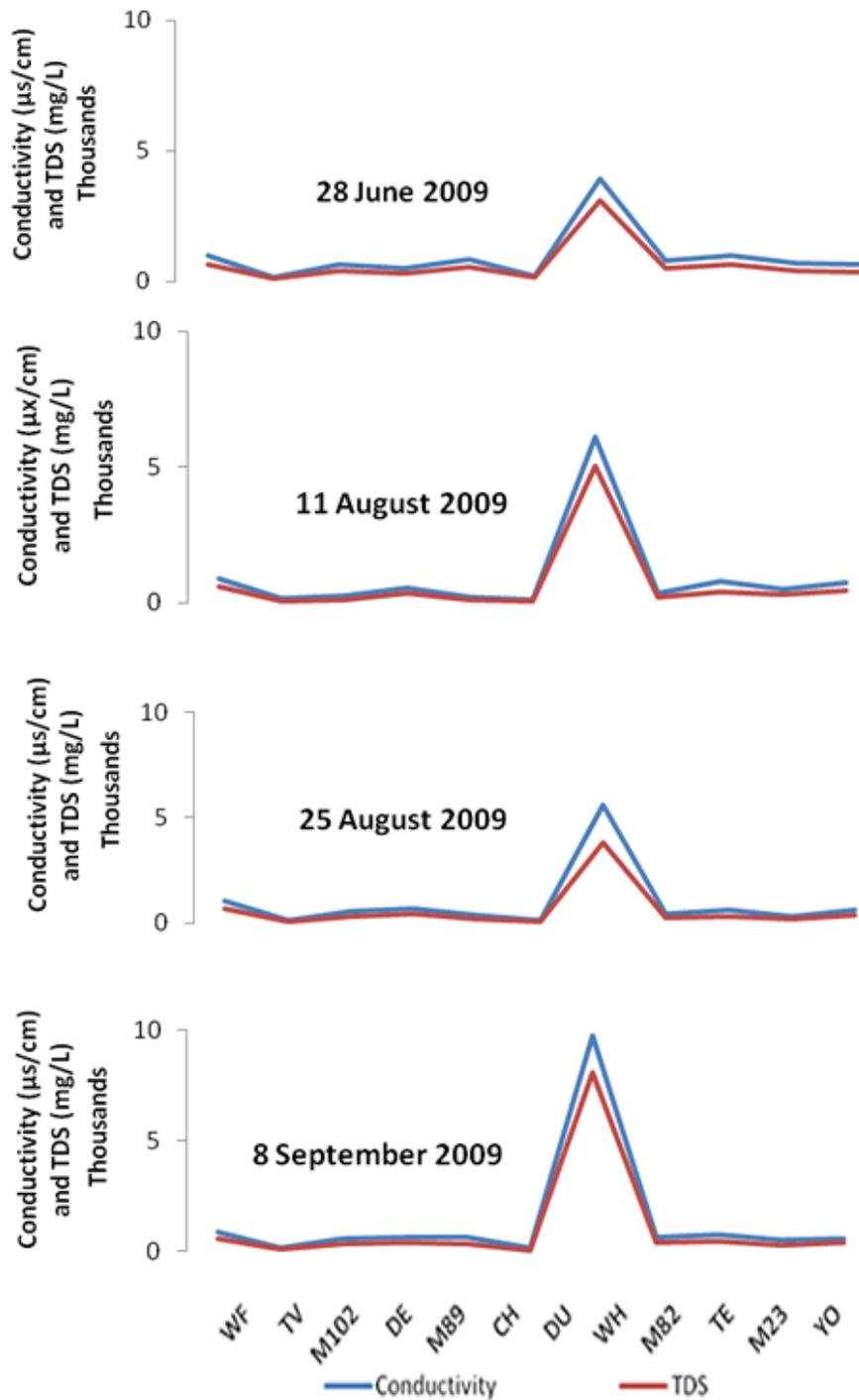


Figure 7. TDS concentrations (mg/L) and Specific Conductivity (us/cm) at sample locations between June - September, 2009.

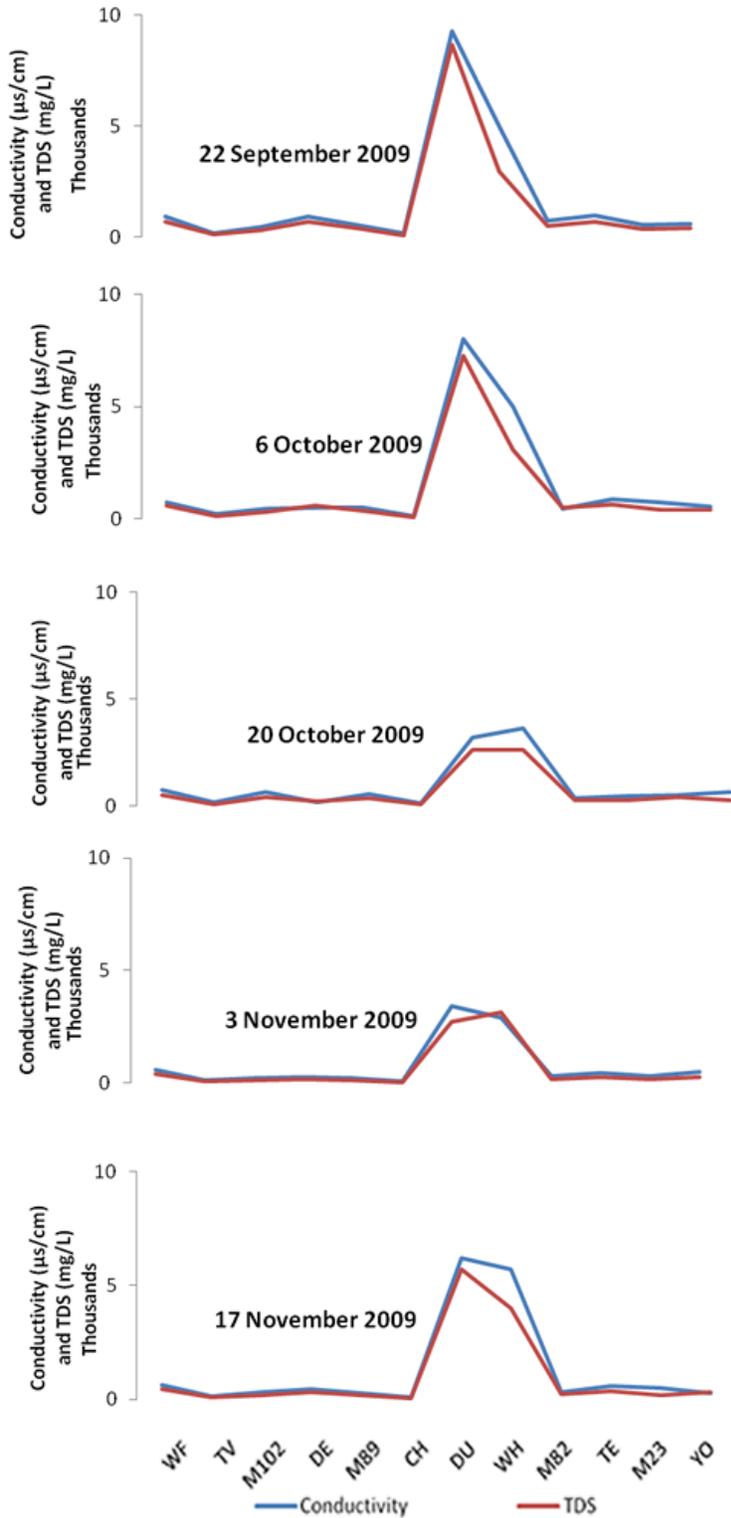


Figure 8. TDS concentrations (mg/L) and Specific Conductivity (us/cm) at sample locations between September - November, 2009.

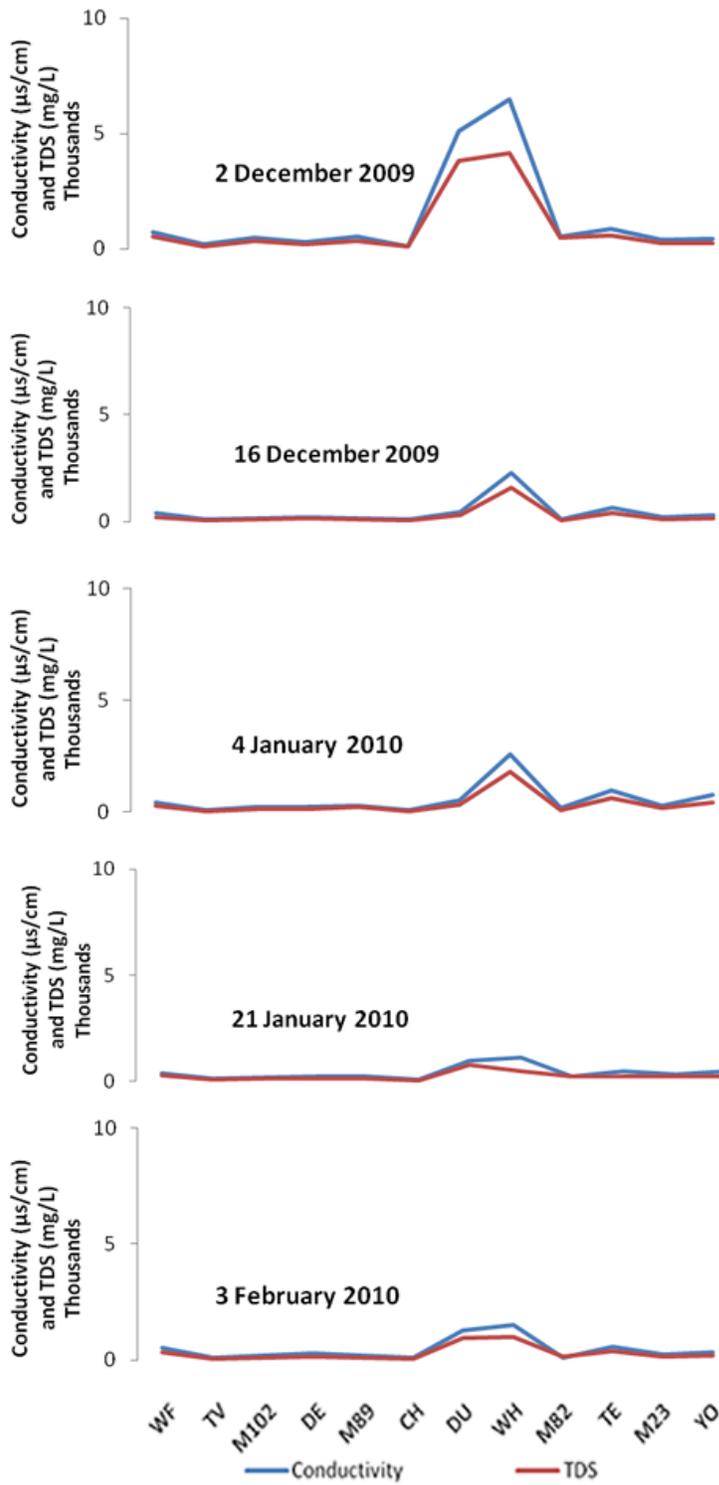


Figure 9. TDS concentrations (mg/L) and Specific Conductivity (µs/cm) at sample locations between December 2009 – February 2010.

CONCLUSIONS

Much progress has been made in year one towards reaching the goals of this two-year project. Stakeholders were brought together and important decisions were made to craft a water quality monitoring program for the Monongahela River. Sampling and analysis protocols were determined and implemented according to EPA guidelines. Resultant data was carefully recorded.

Outreach efforts were undertaken including the establishment of a very useful and user friendly website with a GIS database and map to display the data. A project fact sheet was developed, and numerous presentations were made to diverse audiences to share the data generated by this program and to raise awareness of the project and the public's access to the results.

Some difficulties were encountered that required adjustments to the project's implementation. A fishing reporting component was originally proposed to be incorporated into the GIS mapping illustration on the project website. It was to rely on reports from 2 avid fishermen, one a WV DNR Biologist. Soon after the project got underway, a fish kill event on Dunkard Creek and the resultant investigation consumed both of these individuals' time and they were not able to make regular reports on fishing success. A decision was made to create a color-coded mapping feature to display the total dissolved solids thought to be a better outreach tool useful to a broader public.

Because flow data is necessary to determine loading, we have had to develop some formulas to estimate stream flow based on drainage basin size at a couple sampling locations. While we have a high level of confidence in the calculations, year two of the project will establish continuous monitors at these locations.

Year two of the project will also see the addition of four more sampling locations. Monitoring of additional tributaries, some with industrial activities, will be added to the program. Because of the interest level in this project now, and the completely operational nature of the project website, we will be working closely with the media to help raise awareness of the program and the public's ability to access the information via the internet.

PROJECT PUBLICATIONS

We have not yet published any formal articles, but have received quite a bit of media attention. Attached are news articles in reference to our project (Attachments 2-3).

INFORMATION TRANSFER

Raising the awareness of the general public to Monongahela River water quality issues and making the project results readily accessible to the public are principal components of this project. A project website, www.MonWQ.net, was created to disseminate as much pertinent information generated by this project in the timeliest fashion possible. Presentations of the data generated have been presented at numerous public forums. A project fact sheet was produced and disseminated at various meetings and also available in a printable format on the project website (Attachment 1). We anticipate presenting project findings at this year's state water conference, an information transfer project funded through the USGS 104b program.

PROJECT WEBSITE

HOME PAGE

Because the internet is the best way to disseminate the project results to the most people in the timeliest fashion, a website has been developed as the primary tool for information transfer. A domain name, www.MonWQ.net, was selected. Short and descriptive, it was decided upon for its simplicity and will hopefully be easy to remember. The site's home page briefly describes the Monongahela River and the project (Figure 10). It includes hot button links to the other pages on the site including a page detailing the study, a project map, graphically depicted resultant data, measured parameter descriptions, project participants, printable fact sheet, links and contact information. A rolling slide show of pictures representing the sampling locations is also a component of the website's home page. Usage has steadily increased since the site went online (Figure 12).

Monongahela River Water Quality Study



Introduction

The West Virginia Water Research Institute (WVWRI) is undertaking a comprehensive water quality monitoring and reporting project for the Monongahela River. Bi-weekly samples will be collected and lab analyzed. The resultant data will be presented a useful manner via this website utilizing a Geographic Information System database to organize and present the assembled

water quality data. The project is being funded by the WV Water Research Institute and by grants from the U.S. Geological Survey, Longview Power and supporting organizations such as the West Virginia Division of Natural Resources, Allegheny Power, U.S. Army Corps of Engineers, Pennsylvania Fish & Boat Commission and others.

Monongahela River

Known locally as "The Mon," the Monongahela River originates in north-central West Virginia and flows through south-western Pennsylvania to Pittsburgh where it meets the Allegheny River to form the Ohio River. It is 128 miles long and has a drainage basin of 7,140 square miles. The Native American word "Monongahela," means "falling banks," in reference to the geologic instability of the river's banks.

Formed by the confluence of the West Fork River and the Tygart Valley River at Fairmont, WV, the Mon is navigable for its entire length. A series of locks and dams maintain a minimum depth of 9 feet to accommodate barge and tow boat traffic. In Pennsylvania the Mon is met by two major tributaries: the Cheat River which joins in Pt. Marion, and the Yaoughoghery River which joins in McKeesport.

Water Quality Study

The WVWRI is creating a database that compiles watershed data and makes it readily available to the public. Fifteen locations have been selected for sampling including 4 sites on the main stem of the Monongahela River and at the mouths of 12 of its largest tributaries. Using a GIS database and map, this data can be publicly accessed and results compared over time and between sampling sites.

WVWRI is working to identify and compile existing water quality data for the Monongahela River, collect additional data as necessary, and present this data in a useful and user friendly manner on this website. The WVWRI has established working relationships with the WV Department of Natural Resources, U.S. Army Corps of Engineers, Allegheny Energy, the Morgantown Utility Board, PA Fish & Boat Commission, as well as with watershed associations in both West Virginia and Pennsylvania. Water quality data is useful to these groups as well as to anglers and other users of the Monongahela River who can benefit from having information about current water quality conditions. This database compiles available data and makes it readily available to identify upsets in water quality, help to eliminate duplicate sampling efforts, allow evaluation of historic water quality trends, and provides a framework for other data sources. Identified data gaps and needs may then be filled by a monitoring program initiated through a cooperative effort between operators, researchers from the WVWRI and local watershed associations.

- Home
- Water Quality Study
- Links
- Map
- Data
- Water Quality Parameters
- Project Participants
- Printable Fact Sheet
- Contact Us



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 academia, and the Public.

The West Virginia Water
 Research Institute is a
 Program of the National
 Research Center for Coal &
 Energy at West Virginia
 University.



West Virginia Water Research Institute

NRECE



West Virginia University

MAP PAGE

Utilizing the ArcGIS program, this interactive and user friendly map serves as the foundation to share the sample locations with website visitors (Figure 11). A “zoom” feature allows site visitors to see the sampling locations as well as anyplace in the watershed at a detailed level. Maps can be displayed showing streets and highways, topographic features, or high resolution aerial imagery (Figure 12). Watershed boundaries for the Monongahela River and the monitored tributaries are outlined. Monitoring site data is graphically displayed on the map by sampling date. A color coded “dot” display indicated levels of TDS by color and size of the dot located at the monitoring site (Figure 13).



Figure 11. Website screen image of interactive ArcGIS map.

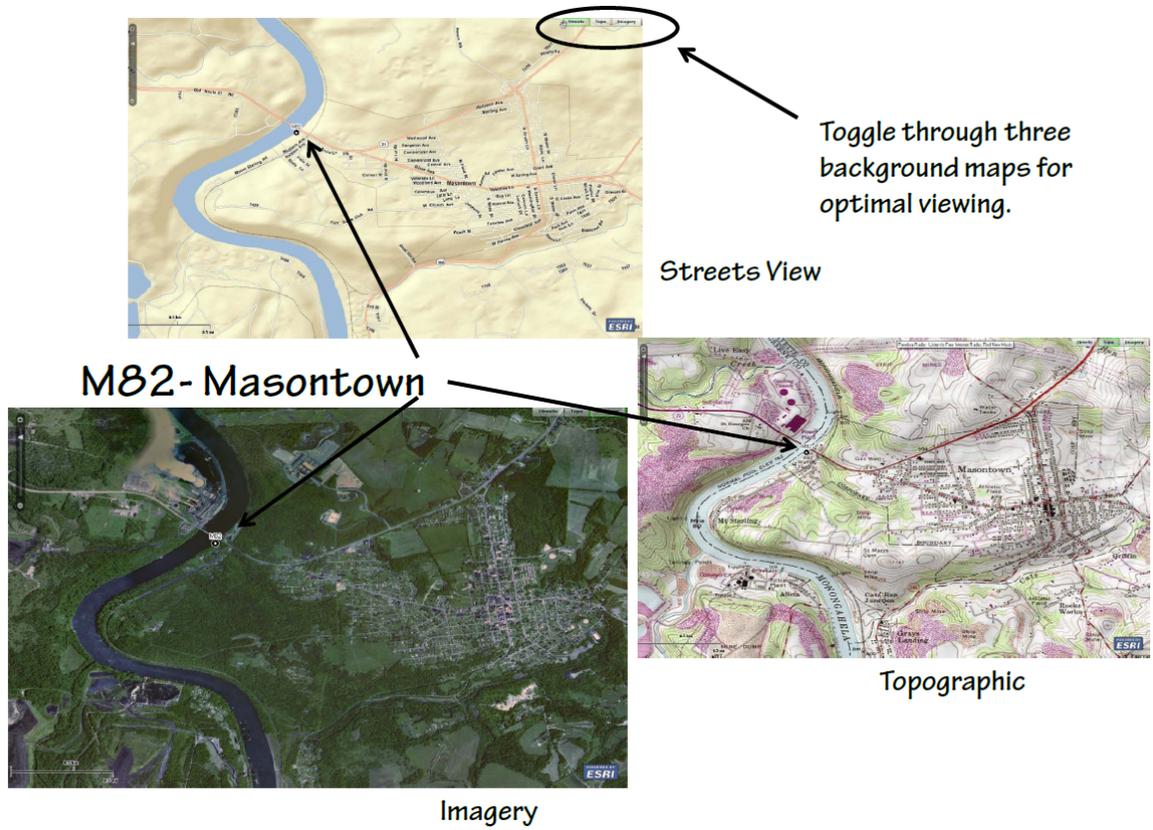


Figure 12. Project website map provides users with street view, imagery, or topographic background images.

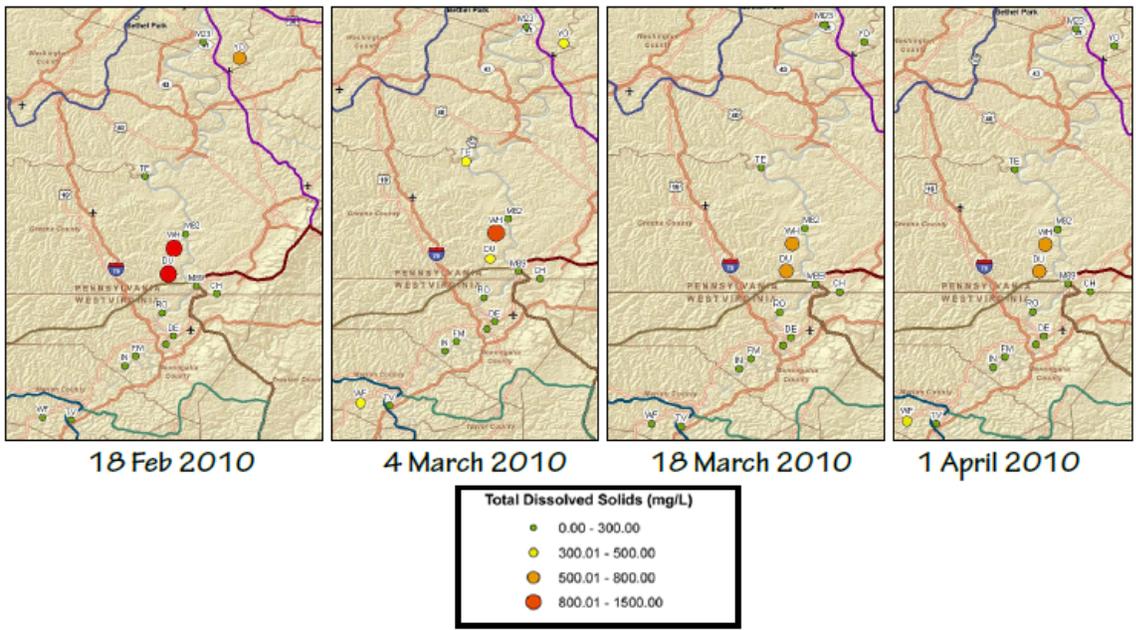


Figure 13. Sequential screen images from project website, showing color-coded TDS loadings using ArcGIS.

DATA PAGE

The webpage depicting the project data allows the site visitor to query the data by monitoring location. Graphs are then generated for each monitored parameter (Figure 14). Lab analyzed data for the various components of TDS are compiled and depicted in “stacked bar graphs.” These stacked bar graphs are constructed for each monitoring date and depict TDS loading for all monitored locations. The TDS loading graphs are organized by month (Figure 15).

Select site to view by date:

choose by site	submit
choose by site	
WFJ West Fork River	
TVJ Tygart Valley River	
INJ Indian Creek	
FMJ Flaggy Meadows Run	
M102 f Monongahela River (mile 102)	
DEJ Deckers Creek	
ROJ Robinson Run	
M89 f Monongahela River (mile 89)	
CHJ Cheat River	
DUJ Dunkard Creek	
WHJ Whittely Creek	
M82 f Monongahela River (mile 82)	
TEJ Tenmile Creek	
M23 f Monongahela River (mile 23)	
YOJ Youghiogheny River	

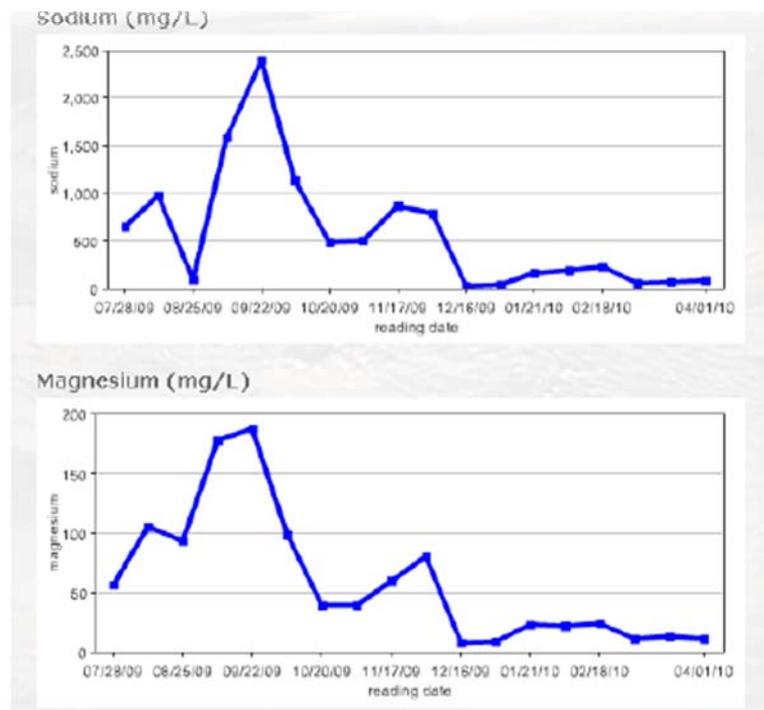


Figure 14. Screen image of website data graphs page.

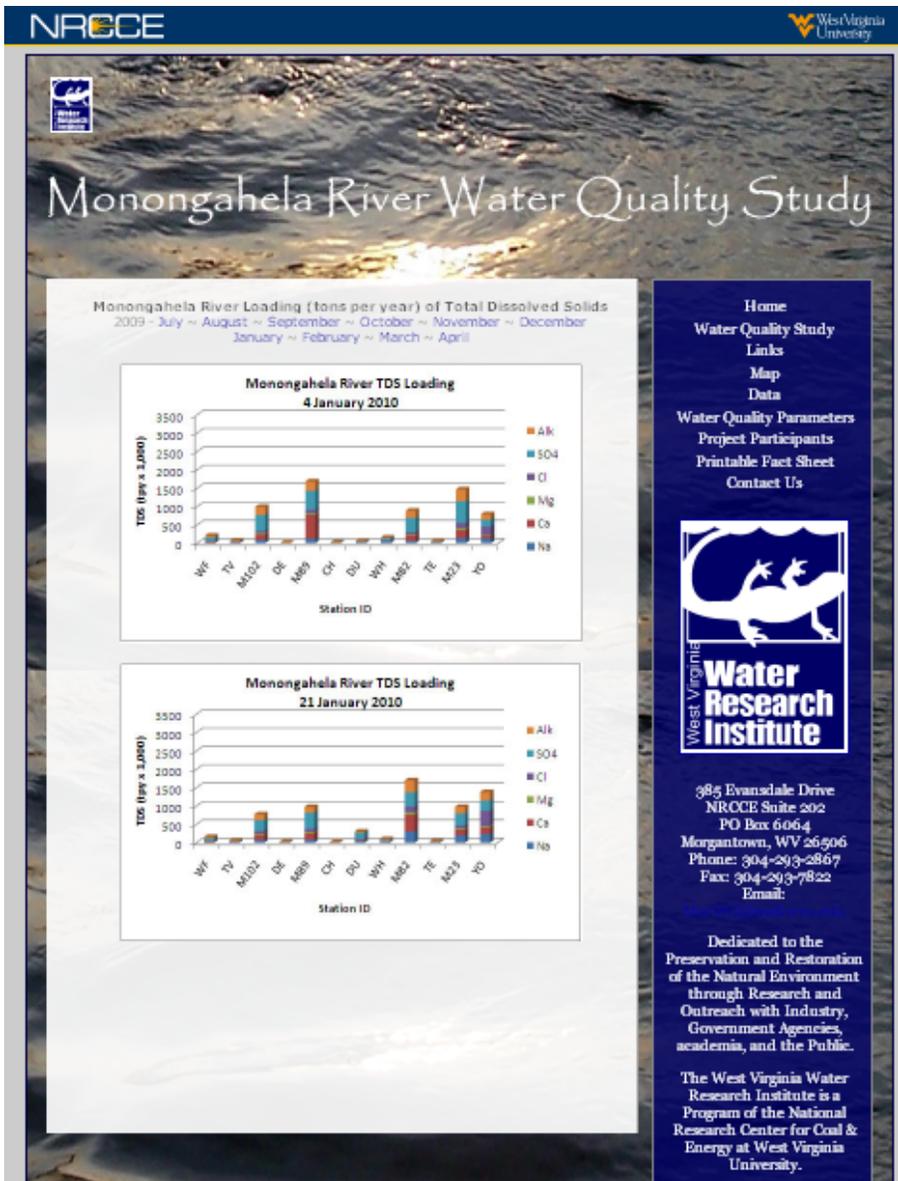


Figure 15. Screen image of TDS loading stacked bar graphs page on MonWQ website.

WEBSITE TRAFFIC

The website has received more than 500 unique visitors and over 9000 hits between when it became available online in November 2009 through the project reporting period. (Figure 16).

Monthly history

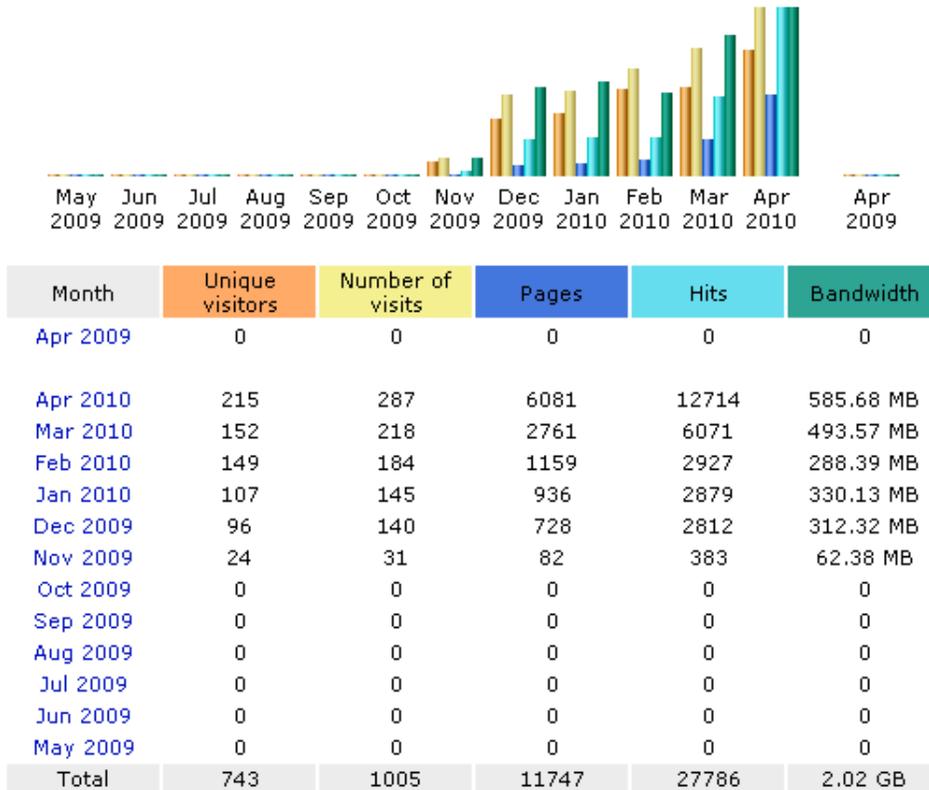


Figure 16. Monthly user statistics from the project website.

PRESENTATIONS

Because the data generated by this project is extremely pertinent to the public dialog currently being undertaken regarding the water quality of the Monongahela River, its presentation has been of interest. The Upper Monongahela River Association held a series of “Water Quality Forums” where ongoing project updates were presented. Presentations were made at these forums each month they were held between June 2009 and February 2010. At the July Forum, project staff Dave Saville, Melissa O’Neal and Jen Fulton gave a presentation about the project and its significance and implementation.

The results of this project were presented by Dr. Paul Ziemkiewicz, Principal Investigator and Director of the WV Water Research Institute, at the 5th Annual Mon River Summit, held at the Waterfront Place Hotel. This event was attended by nearly 200 people interested in the Monongahela River. Dr. Ziemkiewicz also gave presentations about the project to the Youghiogheny River Watershed Association, the Acid Mine Drainage Taskforce, the Technical Committee of the WV Coal Association and the Water Resources Section of the WV Department of Environmental Protection.

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STUDENT SUPPORT

Graduate students and undergraduate students have been utilized in the collection of bi-weekly water sampling, data management, and website design. This has provided these students and young professionals with field experience in water chemistry sampling procedures, GIS/database experience, and website management.

Graduate Students

Alison Anderson, M.S. in Fish and Wildlife, expected 2011.

Undergraduate Students

Melissa O'Neal, B.S. in Fish and Wildlife, expected 2011.

Eric Baker, B.S. in Civil and Environmental Engineering, 2010.

Category	Number of students supported with 104b base grant	\$ Value of students supported with 104b base grant	Number of students supported with matching funds	\$ Value of student support with matching funds	Total number of students supported	Total \$ value of student support
Undergraduate	2	\$1,418.50	0	0	2	\$1418.50
Masters	1	\$449.56	0	0	1	\$449.56
Ph.D.	0	-	-	-	-	-
Post-Doc	0	-	-	-	-	-
Total	3	\$1868.06	0	0	3	\$1868.06

NOTABLE AWARDS

There were no notable awards received during this reporting period.

ATTACHMENT 1 – PROJECT HANDOUT



Monongahela River Water Quality Study

The West Virginia Water Research Institute is undertaking a comprehensive water quality monitoring and reporting project for the Monongahela River. Bi-weekly samples are being collected and lab-analyzed with the resultant water quality data organized and presented via a website utilizing a Geographic Information System map and database.

Water Quality Study

The West Virginia Water Research Institute began monitoring the water quality in the Monongahela River Basin in July of 2009. Initially, 8 tributary and 4 mainstem stations were sampled bi-weekly. Three additional tributary stations were added to the sampling regime on March 1, 2010.

As a means of displaying the water quality data to the public, a website was developed to provide easy to understand visualizations of the water quality in the Mon River basin. Geographic Information System (GIS) mapping also provides users of the site with the ability to see the Mon River watershed and specific sampling locations.

Water quality analysis consisting of 19 different field and lab determined parameters are available on the website, along with easy to understand descriptions of each measured parameter.

Many users of the Monongahela River such as recreationists, anglers, industry, policy makers and regulators will benefit from having accurate and current information about water quality conditions.



Monongahela River

Known locally as “The Mon,” the Monongahela River originates in north-central West Virginia and flows through south-western Pennsylvania to Pittsburgh where it meets the Allegheny River to form the Ohio River. It is 128 miles long and has a drainage basin of 7,340 square miles. The Native American word “Monongahela,” means “falling banks,” in reference to the geologic instability of the river’s banks.

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For more information,
or to view the map and sampling results, visit:
www.MonWQ.net

The Monongahela River Water Quality Study is being funded by the WV Water Research Institute and the U.S. Geological Survey.

The West Virginia Water Research Institute is a program of the National Research Center for Coal & Energy at West Virginia University.

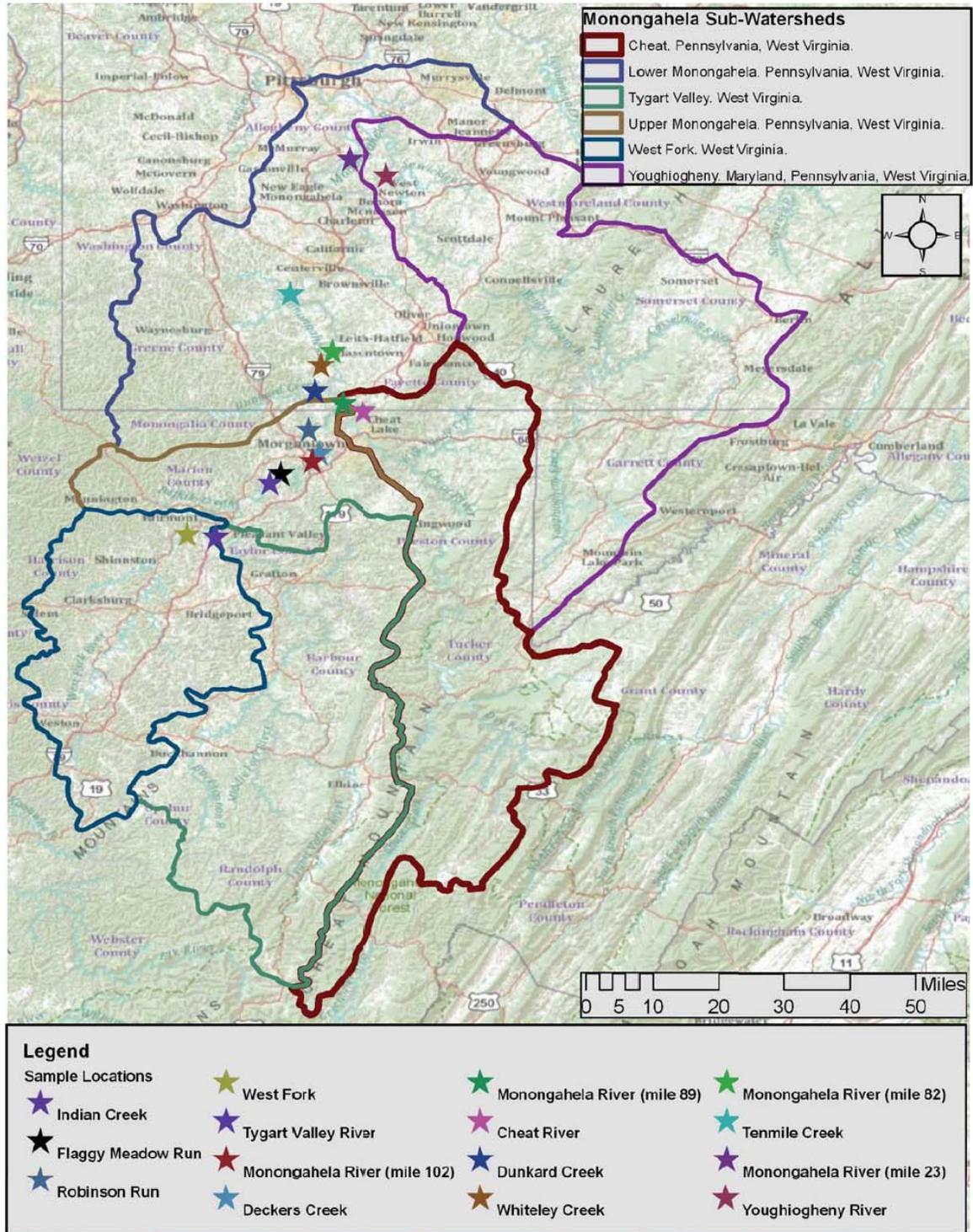


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Monongahela River Water Quality Study



Monongahela River Water Quality Study

Sampling Parameters and Descriptions

To determine the baseline quality of a water body, water sampling must be performed. The sampled parameters vary depending on the goals of the project team. In the case of the Monongahela River Water Quality Study, Total Dissolved Solids and its constituents were the parameters of interest. Because of this, the following parameters are sampled for this study:

pH

Values of pH in surface water outside acceptable ranges can indicate human impacts such as agricultural runoff, mining, or infiltration of untreated wastewater. Low pH is acidic and can cause corrosion of pipes, as well as increased dissolved metals concentrations in surface water. High pH is alkaline and can cause scale buildup in fixtures, bad taste, and reduce the effectiveness of chlorine disinfection, as well as increased metal concentrations in stream sediments.

Acidity

Low pH values indicate that surface water is acidic. High acidity values in surface water may come from several sources, such as mining and acid precipitation. Acid precipitation may cause the dissolution of aluminum in soils with poor buffering capacity, which in turn causes acidity to increase in surface water when the soil enters the stream as runoff. As acidity increases, dissolved metal concentrations increase, which in turn may cause problems for aquatic life in streams and rivers.

Alkalinity

High pH values indicate that surface water is alkaline in nature and that the water has a greater neutralization capacity. Typically, a small to moderate amount of alkalinity in water is also important to have for the well-being of the organisms that live in the water body. However, too much alkalinity can be toxic to wildlife. High alkalinity can also cause impacts to humans, including scale buildup in fixtures, bad taste, and reduce the effectiveness of chlorine disinfection. Alkaline water may also impact irrigation if the alkalinity of the water is greater than the alkalinity of the surrounding soil.

Electrical Conductivity

Electrical conductivity is an indicator of dissolved metals. Some common metals that may be found in surface water include: iron, aluminum, calcium, magnesium, and others. High conductivity levels may be due to several different factors, including: untreated wastewater infiltration, mining, and agricultural runoff. High conductivity concentrations can be damaging to aquatic life because of increased salinity in the stream and possible smothering of the stream bottom.

Oxidation-Reduction Potential (ORP)

ORP is the potential of a chemical species to acquire (reduction) or lose (oxidation) electrons. An oxidizing substance, such as chlorine, will have a positive ORP value, while a reducing agent, such as hydrogen sulfide, will have a negative ORP value. High or low ORP values could indicate the presence of large amounts of certain chemical species, such as chlorine or hydrogen sulfide, which may affect aquatic life.

Temperature

Temperature has a large impact on the biological activity of aquatic organisms. All aquatic organisms have a preferred temperature range. If the water temperature gets too far above or below this range, then the biological community becomes stressed and may have difficulty maintaining a stable population.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic invertebrates or certain fish.

Total Dissolved Solids (TDS)

TDS is a general indicator of overall water quality. It is a measure of inorganic and organic materials dissolved in water. High levels of TDS in surface water may be due to factors such as sedimentation, mining, or storm water runoff. Increased TDS may impart a bad odor or taste to drinking water and cause scaling of pipes and corrosion.

Total Suspended Solids (TSS)

TSS, or turbidity, is the measure of the suspended particles in the water column. High levels of turbidity can come from many sources, such as urban runoff, soil erosion, wastewater discharges, agriculture, and removal of riparian zones. Increased levels of turbidity may cause water to darken, which in turn leaves less light for aquatic plants to perform photosynthesis. This in turn decreases the amount of dissolved oxygen being added to the water, which can affect aquatic organisms that are higher on the food chain. Extreme levels of TSS can also clog fish gills.

Cations/Anions

Specific cations and anions will also be sampled as part of this project. Both dissolved and total concentrations will be determined for all species. Dissolved concentrations allow the researcher to infer more detailed water chemistry information, while total concentrations are used to promulgate and enforce water quality regulations.

Monongahela River Water Quality Study

Sampling Parameters and Descriptions (Continued)

Aluminum (Al)

Aluminum is the third most common element on Earth. In most forms, aluminum is not very soluble in water. However, low pH waters, such as those associated with mine drainage, may contain large amounts of dissolved aluminum due to dissolution of aluminum-containing minerals within the local geology. When aluminum precipitates within the water column, it is in the form of an aluminum hydroxide. Aluminum hydroxide may be very harmful to aquatic life due to smothering of the stream bed of the water body. Aluminum may also clog the gills of aquatic organisms if the concentration is high enough.

Bromine (Br)

Bromine is a chemical element found in the halogen group. At room temperature, it is a reddish-brown liquid that is slightly soluble in water. Dissolved bromine comes from several sources, including surrounding geology, fluids used in gas well drilling, seawater infiltration, and industrial waste. Elevated levels of dissolved bromine may interfere with water treatment, as well as pose a possible increased cancer risk to humans and wildlife.

Calcium (Ca)

Calcium is an element that is found naturally in water due to its abundance in the Earth's crust. Large bodies of surface water, such as rivers, typically contain 1-2 mg/L of calcium. High levels of calcium in surface water mean that the water is hard, which helps aquatic life by buffering the pH of the water and protecting those organisms with gills from direct metal uptake. However, if calcium and hardness are too high, hardening of pipes and staining may occur.

Chlorine (Cl)

Chlorine occurs naturally as a green gas. It appears in many different compounds. The most important chlorine compound for many forms of life is NaCl, or salt. Chlorine (as the Cl⁻ ion) is the most abundant dissolved ion in salt water, and is also found in freshwater in much smaller concentrations. Freshwater chlorine is usually derived from chlorine mineral dissolution. Other sources of chlorine in freshwater may include wastewater runoff and breakdown of chlorinated compounds. High amounts of dissolved chlorine can be very harmful to wildlife due to the oxidative properties of chlorine. When chlorine concentrations reach a certain level within the organism, it combines with the water and oxygen to create hydrochloric acid, which destroys animal tissues.

Iron (Fe)

Iron is the most abundant metal in the Earth's core and is found in a large range of compounds. It is also very important to humans and other organisms, as it is partially responsible for transporting oxygen through the bloodstream. Iron is easily dissolved in water and can be found naturally occurring in water bodies. High levels of precipitated iron oxides may cause smothering of stream bottoms and plugging of organism's gills.

Magnesium (Mg)

Magnesium is found in large concentrations in both the Earth's crust and the human body. It is highly soluble in water, and is the third most abundant element in sea water. Concentrations of magnesium in freshwater vary according to surrounding geology. Along with calcium, magnesium concentrations are used to determine water hardness. High concentrations of magnesium cause similar problems to high concentrations of calcium, including staining and hardening of pipes and fixtures.

Manganese (Mn)

Manganese is commonly found in soil in its oxide form (pyrolusite). It is used in the steel making process, and is also an essential nutrient for most organisms. High concentrations of manganese in humans can cause many different health problems, including Parkinson's disease and bronchitis. Manganese is also soluble in water, with large concentrations causing health problems in aquatic life. Manganese can also bioaccumulate through the food chain, causing top predators to have unhealthy levels of manganese in their bodies.

Sodium (Na)

Sodium is a very common element found in rocks and soils. It is needed for all life forms to aid in the transmission of nerve impulses. It is also highly soluble in water and will react violently with water to form lye and hydrogen gas. Sodium is found naturally in freshwater bodies. Concentrations of sodium vary greatly, and are dependent on the surrounding soil and geology. Too much sodium can raise the pH level of a water body to the point where it is too high for certain species of aquatic life to survive.

Sulfate (SO₄⁻²)

Sulfate is a salt consisting of one sulfur atom and four oxygen atoms with an oxidation number of -2. Sulfate is naturally occurring in almost all water bodies. It usually comes from oxidation of sulfite ores, dissolution of sulfate minerals, shale, and industrial wastes. High concentrations of dissolved sulfate may give water an unpleasant taste and may be corrosive to plumbing. It may also have health effects including nausea and diarrhea.

Sulfur (S)

Sulfur is a non-metal that is a yellow solid at room temperature. Sulfur is found in many different minerals and is extracted by melting the surrounding rock and collecting the molten sulfur. It may also be produced from hydrogen sulfide. It is a required nutrient for life on Earth and it is an essential building block of cells. It is insoluble in water. However, high concentrations of sulfur-containing compounds, such as sulfate, may be found in water due to human activities, such as mining.

For more information about the sampled parameters (including measurement units, ranges, and analysis techniques), visit our project website at www.MonWQ.net

ATTACHMENT 2

ENVIRONMENTAL NEWS ARTICLE: SALT-LOVING ALGAE WIPE OUT FISH IN APPALACHIAN STREAM.

Environmental News

Salt-loving algae wipe out fish in Appalachian stream

A salt-loving alga that killed tens of millions of fish in Texas has struck for the first time in an Appalachian stream that flows along the border of Pennsylvania and West Virginia. *Prymnesium parvum* or "golden algae" caused the sudden death of thousands of fish, mussels, and salamanders in early September along some 30 miles of Dunkard Creek. University and government scientists fear the disaster could presage further kills in the region. Streams at risk due to high concentrations of total dissolved solids (TDS) include portions of the northern branch of the Potomac River and 20 other streams in West Virginia, according to state scientists. Pennsylvania, Maryland, Virginia, and Kentucky also have many vulnerable rivers and streams, according to U.S. EPA scientists.

Dunkard Creek is a tributary to the Monongahela River, where last year high TDS levels fouled industrial equipment and ruined the taste of drinking water. Faced with projected increases in TDS as a result of the burgeoning and water-intensive natural gas hydraulic fracturing activity at the Marcellus Formation, Pennsylvania Department of Environmental Protection (PA DEP) recently proposed TDS standards for end-of-pipe discharges of 500 parts per million (ppm) TDS and 250 ppm each for sulfate and chloride.

Despite historically high TDS levels, the creek was a good fishing stream with small mouth bass, muskie, mussels, and salamanders, according to biologist Frank Jermolich with the West Virginia Department of Natural Resources. In just a few days the algal bloom wiped out the creek's 18 species of fish and 14 species of freshwater mussels—the most diverse population of mussels in the Monongahela basin. "This is the worst fish kill I've experienced in 21

years in West Virginia," says Paul Ziemkiewicz, director of the Water Research Institute at West Virginia University.

Relatively high levels of sulfate and other dissolved salts have been common in Dunkard Creek over the past 10 years as a result of ac-



Muskies are among the over 16 species of fish killed by the golden algae bloom on Dunkard Creek.

tive and abandoned coal mine discharges, according to West Virginia monitoring data. But immediately before the bloom, chloride (300 ppm), sodium (>3000 ppm), TDS (9500 ppm), and electrical conductivity (>50,000 microsiemens per centimeter) all skyrocketed to unprecedented levels, prompting biologists to initially blame the chemical contamination for the aquatic devastation.

Now that the algae have been identified as the immediate cause of the fish kills, biologists wonder if the soaring salt levels somehow initiated the bloom. If so, there is evidence that Dunkard Creek is not alone in recently receiving record high chloride, associated with hydraulic fracturing or coal-bed methane wastewaters, not coal mine water, according to Ziemkiewicz. Using water monitoring and stream flow data, he calculated chemical loadings to the Monongahela and its tributaries. "Our mass balances can account for most of the sulfate but not the sodium and chloride," he says. "Concentrations

of sodium and chloride were much higher than usual in Dunkard Creek during the fish kill—but even these high levels do not account for the loads in the main stem of the Monongahela River. We are missing major sources of those ions" he says. It is not currently possible to track the fate of hydraulic fracturing wastewater because, unlike coal mine discharges, it is not subject to permitted discharge controls under the Clean Water Act.

Midas touch

First identified in the 1930s, *P. parvum* is a microscopic flagellated organism that caused massive fish kills in the Sea of Galilee and in Israeli fish farms in the 1950s. Toxic blooms have also occurred in brackish waters in Europe as far north as Scandinavia and in China.

The algae thrive in naturally brackish water typical of rivers and reservoirs in East Texas, Oklahoma, and Wyoming. Since the first documented fish kill in Texas in 1985, when more than 100,000 fish died in the Pecos River, the organism has killed more than 18 million fish valued at more than \$7 million. In 2001, *P. parvum* killed the entire year's production of striped bass in Texas's Dundee State Fish Hatchery.

P. parvum's numbers usually remain low. But sometimes it rapidly reproduces with blooms that give the affected water a golden color. In Texas, blooms usually occur during the cooler months when the alga seems to have an advantage over other algae that grow best in warm waters.

The algae's toxins do not threaten humans, livestock, or wild animals. But the algal toxins break gill membranes so that unwanted chemicals, in particular calcium, pour in, says James Grover, a biologist at the University of Texas Arlington. "The cells fill up with calcium and explode," he says.

ATTACHMENT 3

DOMINION POST ARTICLE – PA: DISSOLVED SOLIDS IN RIVER TOO HIGH.

Pa.: Dissolved solids in river too high

Page 1 of 1

Publication: The Dominion Post; Date:2009 Aug 13; Section:Area News; Page Number: 1-D



Pa.: Dissolved solids in river too high

W.Va. DEP says water is safe

BY ALEX LANG
The Dominion Post

The levels of total dissolved solids (TDS) in the Monongahela River exceed acceptable standards set by Pennsylvania and federal authorities.

West Virginia doesn't have a measure for acceptable standards for TDS in water, said Pat Campbell, assistant director of Water Quality and the West Virginia Department

of Environmental Protection. But, Campbell said there is little cause for panic.

"There is not an immediate human health risk," he said.

TDS measures all the elements dissolved in water and can include sulfur, nitrates and sodium. The river water was tested at Point Marion, Pa., according to the Pennsylvania Department of Environmental Protection.

The results showed the TDS levels ranged from 500 to 600 milligrams per liter. Acceptable numbers are below 500, according to the U.S. Environmental Protection Agency.

Campbell said they first learned of the issue about a year ago, when river levels were dramatically low.

They have been monitoring it since.

If TDS levels remain high, the water could taste salty and can cause spotting on glassware.

Morgantown Utility Board (MUB) General Manager Jim Green said he wasn't aware of the issue, and MUB has not received any complaints about the taste of the water. MUB treats and supplies drinking water for the area.

There currently is no way to filter out TDS, Green said. The only way to remove the TDS would be to

build a new plant.

The area saw a lot of rain in the past few days, Green said, which will help lower that concentration.

There is no harm in drinking the water, he said, and residents should not hesitate to drink tap water.

Campbell said TDS isn't as big of a concern as other increases, such as iron, but it is still something that the DEP will have to manage.

To fix the problem, he said they have to do some fact-finding to try to figure out what is causing the increase in the TDS levels in the river.

Some of the causes could be acid mine runoff and other manufac-

turing waste.

Once they determine the problem, Campbell said they can run into a couple different issues. It could cost a lot of money to fix the problem or the technology to do so might not be readily available.

He said both Pennsylvania and West Virginia need to work at finding ways to reduce the amount of TDS going into the river.

The agency has done a lot of work to clean up the river the past few years, Campbell said.

He didn't think the latest findings would drive boaters and swimmers out of the river.

"We would hope not," he said.

Information Transfer Program Introduction

The WV Water Research Institute information transfer program consists of communicating research project results to a diversified audience which ranges from regulatory agencies, academia, industry, watershed associations, legislators, general lay persons to others. Information transfer occurs in a wide variety of ways including a web site (www.wvri.nrcce.wvu.edu), program newsletters, fact sheets, brochures, conferences and workshops, briefings, and meetings.

Two additional web sites were developed; one (www.wvbrownfields.org) for the brownfields center, a program of the WVVRI, and one (www.monWQ.net) specific to a USGS 104b-funded project on managing TDS in the Monongahela River. A quarterly newsletter, annual report, and five year report were developed specific to the brownfields program. Numerous fact sheets were developed on WVVRI projects as those projects were funded and undertaken.

Upcoming events include a state water conference, a state brownfields conference, extension training workshop, community redevelopment workshops, and sustainable energy briefings with redevelopment authorities. A revised WVVRI brochure is under development for distribution at this year's state water conference.

Last year the WVVRI hired its first full-time outreach coordinator in response to the growth in research and funding of the WVVRI programs and projects. This year, a second part-time position was added to support the outreach coordinator.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	6	0	0	0	6
Masters	3	2	0	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	9	2	0	0	11

Notable Awards and Achievements