

Mosquito Creek Phase 2

**WATERSHED-SCALE ASSESSMENT
FOR ACIDIFICATION ABATEMENT**

FINAL REPORT



**Pennsylvania Growing Greener Program
Project No. 350344**

September 19, 2002

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FOR ACIDIFICATION ABATEMENT**

FINAL REPORT

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INTRODUCTION

The Mosquito Creek watershed, shown by Figure 1, was once a premier trout fishery for Clearfield, Elk, and Cameron Counties, Pennsylvania. Decades of acid rain, however, have severely impacted most of its tributaries and main stem, and remaining populations of trout and other aquatic life are stressed and isolated by acidified runoff. The 90 square mile watershed is dominated by sandstone bedrock, which has no inherent buffering capacity (alkalinity) to neutralize this acidity, and cumulative acidification of the soils is a long-term problem that cannot be immediately corrected by eliminating the atmospheric source of the acid. Although it is believed that regulation of upwind sources is diminishing acid deposition with time, the existing acidification impacts to Mosquito Creek will likely continue for the foreseeable future.

Starting in 2000, the Pennsylvania Growing Greener Grant Program has funded a series of projects to develop and implement an organized and long-term restoration plan for Mosquito Creek. Phase 1 activities involved construction and monitoring of an alkalinity-generating vertical flow wetland (VFW) on a headwaters tributary of Mosquito Creek. Concurrent Phase 2 activities involved a watershed-scale monitoring program to assess the actual scope of acid rain impacts and provide data for planning of future restoration activities. Beginning in 2002, a Phase 3 Grant will fund construction and monitoring of additional headwaters VFWs and other experimental treatment technologies, in conjunction with surface liming conducted by Penn State under a separate Grant. This work will test the synergistic effects of multiple headwater alkalinity sources on the main stem of Mosquito Creek. A final Phase 4 Grant will fund preparation of a comprehensive project report detailing the results of these restoration activities and evaluating the cost-effectiveness of and best implementation approaches for the various acid abatement technologies employed.

This report summarizes the project goals and objectives, methods, results, and conclusions specific to the Phase 2 Grant activities. A short summary narrative of the project is included in Appendix A for Grant program use.

Project Goals and Objectives

The main objective of the Phase 2 project was to collect concurrent water quality samples and flow measurements from the major tributaries and main stem of Mosquito Creek, using a systematic approach to provide reliable background data. A secondary objective was to establish permanent sampling stations for long-term monitoring within the watershed. The goals of this sampling were to provide a better understanding of the patterns and locations of the acidification problems within the watershed, and to provide data for siting and sizing future acid abatement projects in support of development of the overall progressive restoration plan. Other summary goals and outcomes for this project are provided by the Accomplishment Worksheets in Appendix B.

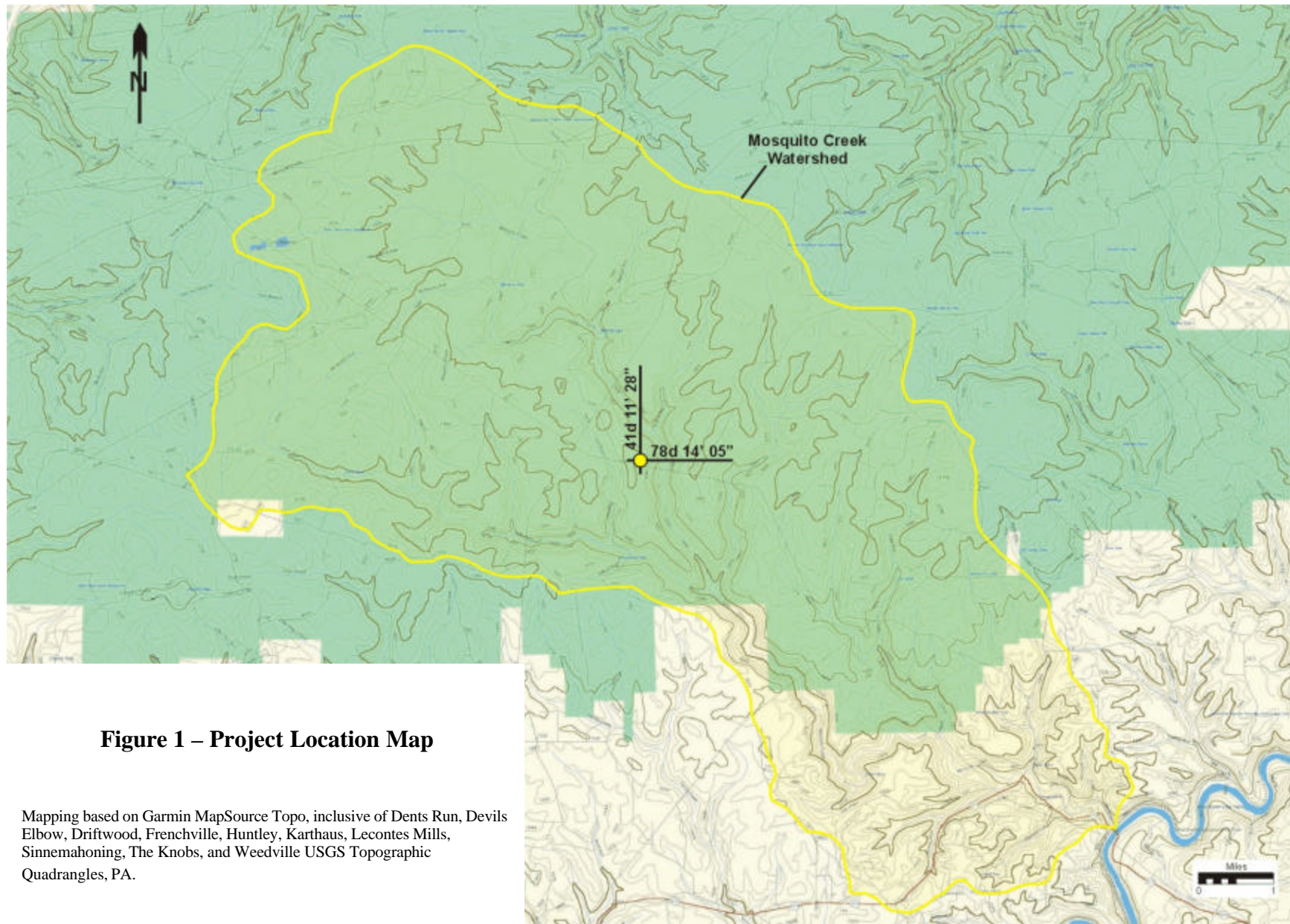


Figure 1 – Project Location Map

Mapping based on Garmin MapSource Topo, inclusive of Dents Run, Devils Elbow, Driftwood, Frenchville, Huntley, Karthaus, Lecontes Mills, Sinnemahoning, The Knobs, and Weedville USGS Topographic Quadrangles, PA.

Project Partners

Phase 2 and the other ongoing phases of the restoration project have been initiated by the Mosquito Creek Sportsman Association (MCSA), an organization of concerned citizens who have been seeking to restore the quality of Mosquito Creek for over 20 years. With technical support from Gannett Fleming, Inc., the MCSA has completed Phase 2 in partnership with the following agencies and organizations:

Penn State University Environmental Resource Research Institute
Pennsylvania Game Commission
Pennsylvania DCNR Bureau of Forestry
Pennsylvania Fish and Boat Commission
Pennsylvania Department of Environmental Protection
Pennsylvania Department of Corrections Quehanna Boot Camp
Wood Duck Chapter Trout Unlimited
Canaan Valley Institute
Clearfield County Conservation District
USDA Natural Resource Conservation Service

METHODS

As shown by Figure 2, the Phase 2 monitoring program includes 14 MCSA sample points located on Mosquito Creek, Gifford Run, and their major tributaries. Sample points are also shown for the Phase 1 Penn State monitoring program, which contributed additional data to the watershed assessment. The MCSA sample points were selected to assess the discharge quality of each major tributary and the cumulative quality in the main stem at several key locations.¹ Gannett Fleming conducted the initial monitoring station construction and sampling. MCSA members were then trained in sample collection and flow measurement methods, and MCSA volunteers conducted the sampling thereafter with oversight by Gannett Fleming. The following summarizes the water quality sampling and analysis methods, and flow measurement method, which were employed.

Water Quality Sampling

Water samples were collected at the selected sample points using the grab method with sample bottles provided by the Penn State Environmental Resources Research Institute (ERRI) laboratory. Field parameters measured at the time of sampling included flow, temperature, pH, and conductivity. Samples were transported in coolers for deliver to the ERRI laboratory, which performed the analysis of the laboratory parameters. Table 1 provides a summary of the sample parameters and analysis protocols used for the Phase 2 monitoring program.

¹ Except for Panther Run, which is too far from any access point to be reasonably sampled in a day's hike, and was not included in the monitoring program.

Figure 2 – Mosquito Creek Phase 2 Sample Points



Table 1 – Mosquito Creek Phase 2 Sampling Parameters

Parameters	Units	Analysis Method
<i>Field</i>		
Flow	gallons/minute (gpm)	Cross-Sectional Velocity
pH	standard units (SU)	pH Meter
Temperature	degrees Centigrade (C°)	Thermometer
Conductivity	microsiemens (μ ohms/cm)	Conductivity Meter
<i>Laboratory</i>		
pH	standard units (SU)	
Conductivity	microsiemens (μ ohms/cm)	
Acidity	milligrams/liter (mg/L)	
Alkalinity	milligrams/liter (mg/L)	
Acid Neutralization Capacity (ANC)	milligrams/liter (mg/L)	
Chemical Oxygen Demand (COD)	milligrams/liter (mg/L)	
Dissolved Aluminum	milligrams/liter (mg/L)	
Total Iron	milligrams/liter (mg/L)	

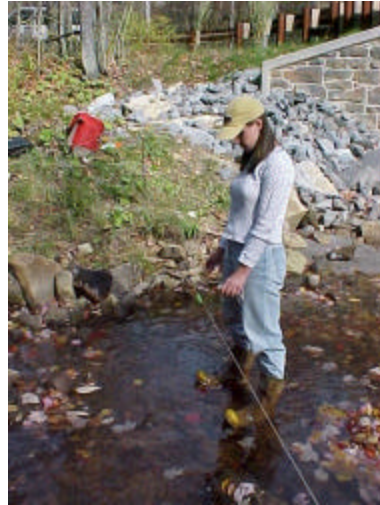
Flow Measurements

All flow measurements were taken using a cross-sectional velocity method. It was desired to establish permanent cross section stations that would be simple and convenient for volunteer samplers to use. The method selected was to drive rebar stakes on either side of the stream to establish a section perpendicular to flow. A hook was attached to one of the rebars with a pipe clamp to serve as the zero end for a measuring tape. A string and line level was then used to determine the level point on the opposite rebar, and another pipe clamp attached to mark this level on it. Thereafter, the measuring tape could be hooked at the zero end rebar, stretched tight across the stream, and clamped to the level point on the opposite rebar using a vise-grip. The sampler would then take flow depth and velocity readings at the selected increment points on the tape. When the stations were first established, the height of the tape above the stream bottom was also measured to develop a cross section profile for the stream. Figure 3 illustrates the basic steps in this process.

Figure 3 – Basic Steps in Establishing and Using a Cross-Sectional Velocity Flow Measurement Station



1) Drive rebar end stakes on both sides of stream, perpendicular to flow.



2) Set level points on end stakes using a line level and string.



3) Hook or clamp tape measure at level points, stretched tightly.



4) Completed flow measurement station (remove tape after measurement).



5) Measure bottom to tape (first time) and water depth at each increment.



6) Take velocity measurement at each increment.

Flow velocity measurements were initially taken using Gannett Fleming's Marsh-McBirney electromagnetic flow meter. Later measurements were taken using Global Water Flow Probes purchased by the MCSA through the Phase 1 Grant. These instruments are propeller-based velocity meters with digital readouts of instantaneous velocity (0.5 ft/s accuracy) and time-averaged velocity (0.1 ft/s accuracy). They allow determination of the bulk water column flow velocity by moving the propeller head up and down evenly through the entire column and reading the time-averaged velocity. To improve measurement accuracy in small streams, different measurement increments were used for different stream sizes depending on their width. For streams of less than 10 feet in width, measurements were taken every 0.5 feet across the channel; for streams of 10 feet to 50 feet in width, measurements were taken every foot; and for streams greater than 50 feet in width, measurements were taken every 2 feet. The total flow volume for the cross section was then determined by multiplying the incremental section areas by their respective flow velocity readings, as follows:

$$Q = 448 \times I \times \sum (D_i \times V_i)$$

Q – Flow Volume (gpm)

I – Measurement Increment Width (ft)

D_i – Flow Depth of Increment *i* (ft)

V_i – Flow Velocity at Increment *i* (ft/s)

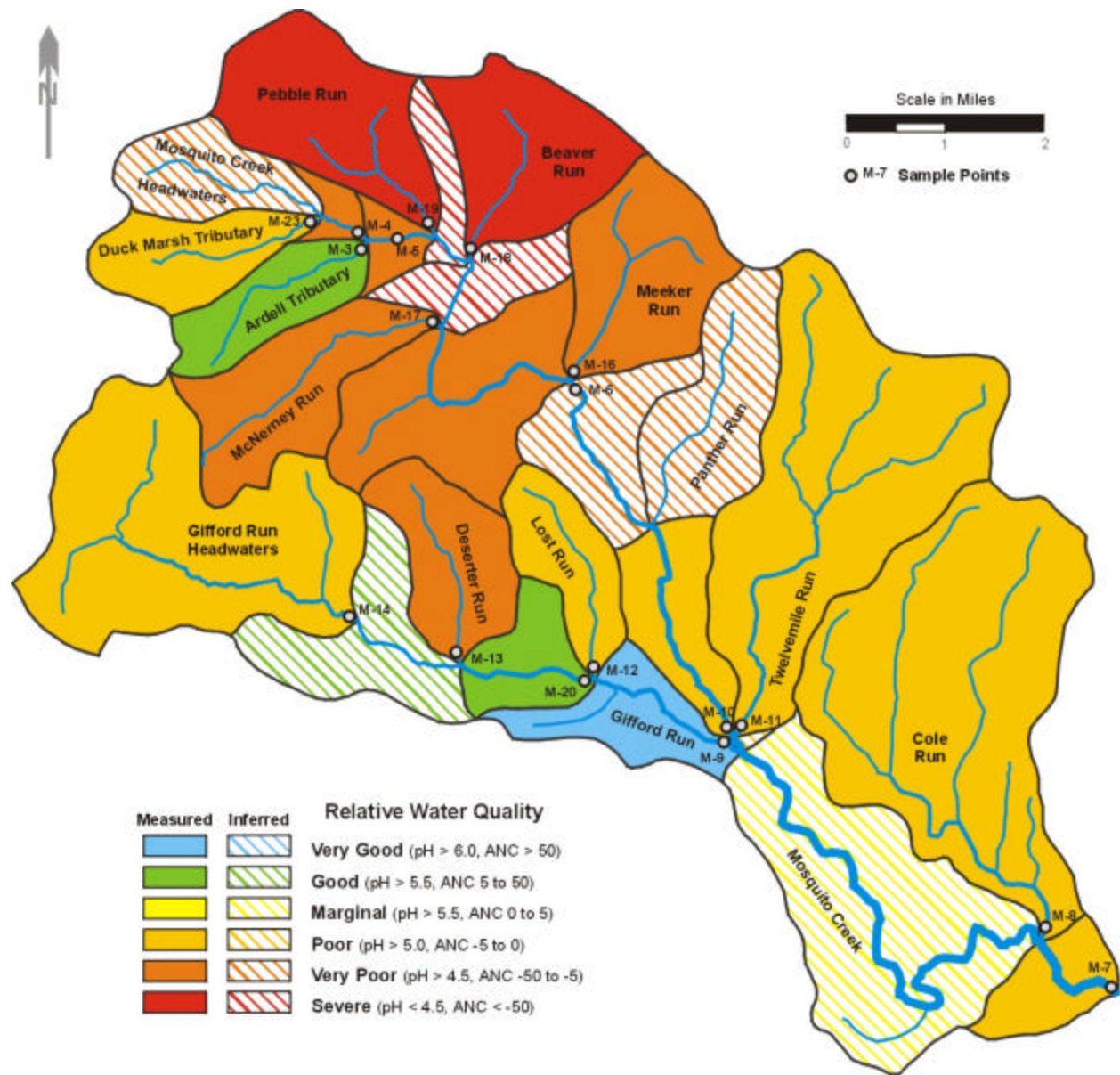
RESULTS

A total of six (6) sample runs were conducted under Phase 2 between October 2001 and April 2002, with summary results contained in Appendix C. The following provides an assessment of the water quality and flow characteristics interpreted from these data for the Mosquito Creek watershed.

Figure 4 shows the average water quality in the Mosquito Creek watershed based on pH and ANC categories that reflect the relative suitability of the streams to support fish populations. Fish are normally able to survive where the ANC is positive, but are generally stressed or absent where the ANC is negative for any significant period of time. Stream pH is similarly important for fish, with a pH of 5.5 SU or greater generally necessary for long-term survival of trout. Similar water quality maps for each sample run are contained in Appendix D. The individual sample run maps also show the comparative flow volumes discharging from the mouth of Mosquito Creek on their respective sample dates.

Based on this assessment, the majority of the Mosquito Creek watershed is of poor quality or worse, with stream reaches in those categories unlikely to support any significant fish populations. Only the lower portion of Gifford Run and the Ardell Road tributary consistently show good water quality. In Gifford Run, this is attributed to lime sand dosing applied to the stream for a number of years. The Ardell Road tributary is being treated by the VFW system constructed under Phase 1. It is likely that both of these streams would show poor water quality or worse if not for these treatment efforts.

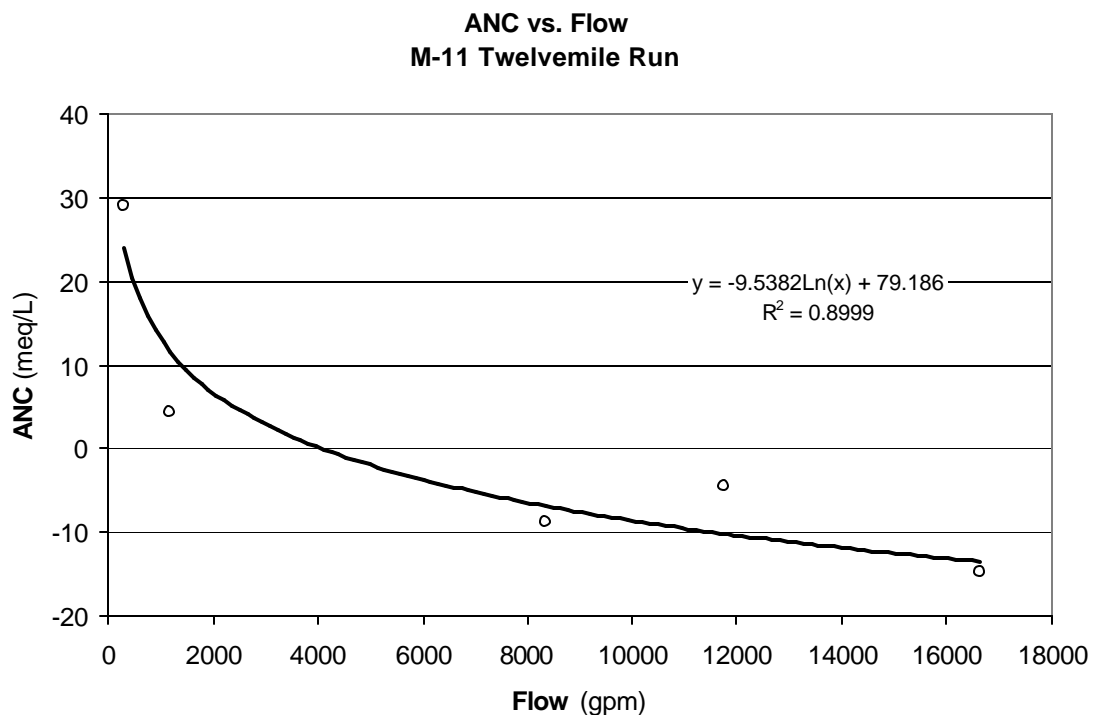
Figure 4 – Average Water Quality Conditions in the Mosquito Creek Watershed



The highest levels of acidification occur in the upper headwaters of Mosquito Creek, particularly in Pebble Run and Beaver Run. Both of these tributaries consistently show severe acidification, and no aquatic macroinvertebrates were observed in them during sampling. Surrounding tributaries down to and including Meeker Run show very poor water quality. Panther Run is currently inaccessible for sampling, but is likely also poor or very poor quality. Farther downstream, Twelvemile Run and Cole Run do show good quality during low flow periods, but are poor quality on average. Given the differing water quality inputs from the tributaries, the mouth of Mosquito Creek can vary from very poor to good quality. It is speculated that a change in the bedrock composition trending from northwest to southeast may have some relation to the slightly better downstream water quality. Bedrock exposures of quartz-rich conglomerates are prominent in the headwaters areas, but not found in the lower elevations downstream, and quartz-rich soils tend to be acidic.

Prior to this monitoring program, it was speculated that the acidification of the Mosquito Creek watershed was episodic, with higher acidity occurring in junction with higher rates of runoff of acidic precipitation. To confirm this, plots were generated of ANC versus flow for each sample point, with the results contained in Appendix E. These plots show that, in most streams, ANC has a strong logarithmic correlation to flow. Figure 5 provides an example of the relationship in Twelvemile Run, which has a positive ANC at low flow, but a negative ANC at higher flows.

Figure 5 – Example Plot of ANC vs. Flow



An analysis of this type allows categorization of the various tributaries and main stem segments according to their response to episodic acidification. Streams that show acceptable water quality at low flow may only require periodic treatment during high flows, while streams with poorer quality at low flow may require full time treatment. Table 2 provides a summary of the stream average flows, maximum observed flows, calculated flow at which a negative ANC is predicted to begin to occur (ANC threshold) based on the relationships in Appendix E, and the percentile of occurrence that this threshold flow represents out of the observed flow range. Streams with a significant percentage of their flow range showing a positive ANC have been categorized as candidates for periodic high flow treatment. Those with only a small baseflow having positive ANC, or that never show a positive ANC, will likely require full time treatment.

Table 2 – Categorization of Potential Treatment Requirements

Sample Point		Average Flow (gpm)	Maximum Flow (gpm)	ANC Threshold (gpm)	Threshold Percentile
<i>Candidate for High Flow Treatment</i>					
M-9	Gifford Run Downstream	13,913	30,494	29,326	97%
M-20	Gifford Run at Lost Run	10,502	24,186	22,707	92%
M-7	Mosquito Creek Downstream	79,929	147,619	113,270	71%
M-12	Lost Run	1,852	4,814	964	45%
M-14	Gifford Run Upstream	12,812	51,662	3,213	43%
M-11	Twelvemile Run	7,638	16,619	4,032	35%
M-10	Mosquito Creek Midstream	27,428	57,482	6581	24%
<i>Will Require Full Time Treatment</i>					
M-8	Cole Run	9,764	21,127	1291	1%
M-17	McNerney Run Downstream	3,331	11,805	198	< 1%
M-13	Deserter Run	2,642	6,702	0	0%
M-16	Meeker Run	924	2,070	0	0%
M-17A	McNerney Run Midstream	3,702	16,619	0	0%
M-18	Beaver Run	3,371	15,098	0	0%
M-19	Pebble Run	4,347	19,820	0	0%

The categorization shown in Table 2 agrees with the general observation that the acidification problem in the Mosquito Creek watershed is concentrated primarily in the headwaters, represented by Pebble Run, Beaver Run, McNerney Run, and Meeker Run. Cole Run also appears to be problematic, with acidification over most of its flow range. Another avenue of assessment is to compare the relative contributions of each tributary or reach to the overall ANC deficiency problem. ANC can be approximately correlated to alkalinity by a factor of $ANC = 20 \times \text{Alkalinity}$. Converting a negative ANC value to alkalinity roughly approximates the amount of alkalinity that would be needed to achieve a neutral ANC, and this alkalinity concentration deficiency can be expressed as a loading by multiplying it by the associated stream flow. Table 3 provides a ranking of the sample points according to their approximated average ANC loading as alkalinity equivalent, with negative values representing an ANC deficiency, and positive values an excess of available ANC/alkalinity. The approximated loadings are only intended for a relative comparison and do not represent actual alkaline addition requirements.

Table 3 – Relative Average ANC Deficiencies or Excesses

Sample Point		ANC Loading as Alkalinity (lbs/day CaCO ₃)
<i>Deficient Points</i>		
M-19	Pebble Run	-126
M-18	Beaver Run	-83
M-10	Mosquito Creek Midstream	-62
M-8	Cole Run	-26
M-13	Deserter Run	-22
M-17A	McNerney Run Midstream	-21
M-17	McNerney Run	-16
M-14	Gifford Run Upstream	-10
M-16	Meeker Run	-5
<i>Excess Points</i>		
M-12	Lost Run	3
M-11	Twelvemile Run	5
M-7	Mosquito Creek Downstream	154
M-20	Gifford Run at Lost Run	155
M-9	Gifford Run Downstream	546

Again, it is observed in Table 3 that the greatest source of ANC and alkalinity deficiency is concentrated in the headwater areas, particularly Pebble Run and Beaver Run. Although not sampled directly, it is likely that the uppermost headwaters of Mosquito Creek have comparable deficiencies to Pebble Run and Beaver Run. Panther Run is probably slightly deficient, similar to Meeker Run. The lower portions of Gifford Run, where lime sand addition has been conducted, are the principal source of alkalinity in the main stem below the confluence with Mosquito Creek. The main stem above Twelvemile Run still carries a substantial deficiency from the headwaters tributaries.

DISCUSSION

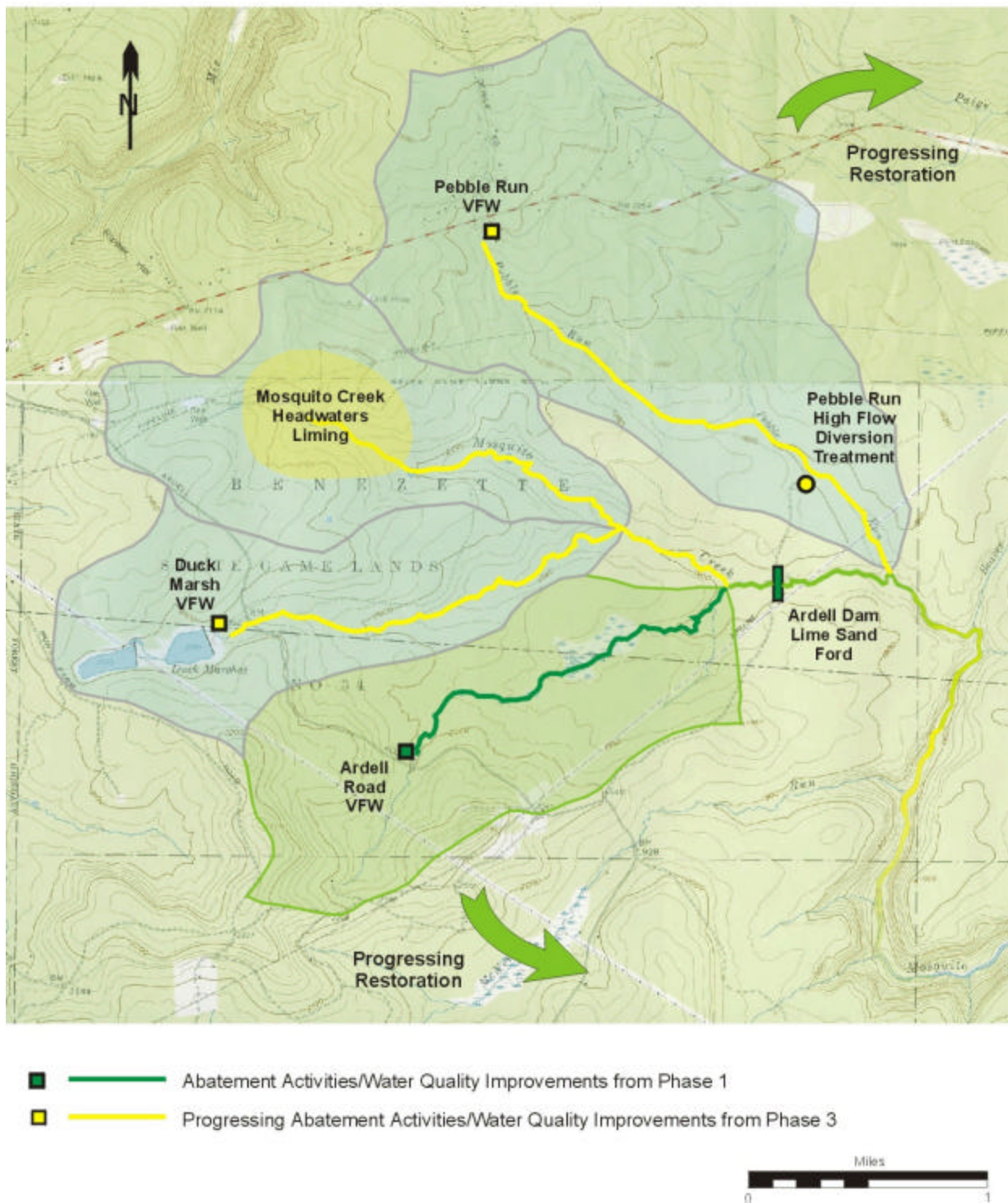
The following provides summary of the general progressive restoration plan developed for Mosquito Creek based on the findings of the Phase 2 assessment, and discussion of the project costs, public outreach program, and lessons learned.

Progressive Restoration Plan

Overall, the findings of the Phase 2 study are that the headwaters areas of Mosquito Creek are the primary source of downstream acidification. As such, the progressive restoration plan for the watershed has been focused on alkaline addition projects in these areas. Under Phase 3, projects will be implemented on the Duck Marsh Tributary (VFW construction), Upper Mosquito Creek headwaters (forest and riparian liming by Penn State), and Pebble Run (VFW construction and possibly a high flow diversion treatment system farther downstream). Efforts in these contiguous watersheds are expected to have a mutually supportive effect in the downstream main stem of Mosquito Creek, with improvements potentially extending to the confluence with Beaver Run and beyond. Figure 6 illustrates this concept and that of progressing headwaters restoration. The results from Phase 3 will be used in development of a final progressive restoration plan for the watershed based on extrapolation of these mutually supportive treatment effects to other downstream tributaries.

Pending the outcome of Phase 3, conceptual plans for future activities include treating additional tributaries in a downstream order (Beaver Run, McNerney Run, Meeker Run, and Panther Run). Parallel efforts would also occur in the Gifford Run watershed to address its headwaters, Deserter Run, and Lost Run. As more headwaters areas are treated, it is anticipated that negative ANC flow thresholds will become progressively greater in the downstream portions of Mosquito Creek and its major tributaries, and that this will allow more efficient application of high flow diversion treatment along these reaches. The ANC thresholds on Gifford Run indicate that this type of treatment is already applicable to that stream. Other activities may include treatment of small tributaries along the main stem in advance of the progressing headwaters treatment, providing refuges for fish populations during high flow acidification, from which they could return to the main stem during the better quality low flow periods.

Figure 6 – Progressing Headwaters Restoration from Phases 1 and 3



It is anticipated that the findings from the current Grant activities will lead to better treatment approaches and predictive methods. Each new stage of acid abatement activities will require monitoring and assessment of previous stages to determine the appropriate location and sizing of the next treatment approach. As such, the overall effort is considered a progressive restoration plan, rather than a comprehensive one-time blueprint of future activities. For a summary of the progressive restoration plan as it stands at this time, Figure 7 shows a conceptual layout of the treatment activities that could ultimately occur if full restoration of Mosquito Creek were to be achieved using the current approaches.

Cost Analysis

The total Grant budget of \$28,250 included \$500 for administration and \$27,750 in contractual services, which were broken down into \$22,400 for design and survey, \$3,600 for sample analyses, and \$1,750 for travel and supplies. Overall, this level of funding was found to be adequate to complete the project. The sample analysis cost was greater than anticipated, totaling about \$5,000, but it was possible to complete the sample point establishment and sampling assistance for less than originally planned, allowing the project to be completed within budget. For the 14 sample points, the average cost to establish and sample a point for six months works out to approximately \$2,000 per point. Similar watershed assessment projects will likely encounter comparable monitoring costs in relatively remote watersheds.

Public Outreach Program

With assistance from Gannett Fleming and Penn State, the MCSA has initiated an active information dissemination process to keep the public informed of the progress of these projects and other phases of the ongoing restoration efforts. This has included participation in meetings with the public and elected officials, newspaper stories, and development of informational fliers for general distribution. Samples of these informational materials can be found in the Mosquito Creek Phase 1 Final Report. This type of public outreach will continue through Phase 3 and include the findings of the Phase 2 assessment. The Phase 4 Grant will also fund preparation of a comprehensive project report for this and other project phases. This report will provide perhaps the most important form of information dissemination by providing permanent project documentation and guidance for future projects of this nature in other watersheds impacted by atmospheric acidification.

Lessons Learned

The Mosquito Creek watershed demonstrated some of the difficulties in conducting a monitoring program in remote areas. Some sample points required hikes of several hours to reach, and the mouth of Panther Run was effectively inaccessible due to its isolation. Other points with poor road access were inaccessible during the winter months due to snow and ice. However, these problems are common to any remote region. It was decided for safety reasons that all samplers would work as teams and have known destinations and return times, as the area has no effective cell phone coverage.

Figure 7 – Conceptual Final Scope of Mosquito Creek Restoration Activities



One approach that may be employed in the future is to establish two sample stations where the mouth of a tributary is remote, with the secondary station being farther upstream at a more accessible point. If the downstream point cannot be reached, the upstream point can be sampled as a surrogate. This method was tested on McNerney Run, with sample point M-17 at its mouth and sample point M-17A at its crossing of Ardell Road. The relationship between upstream and downstream flows was found to be very strong ($R^2 = 0.986$), indicating that the downstream flow could be accurately estimated from the upstream reading. There was also no statistical difference in water quality on average between the two points, indicating that M-17A is a viable surrogate for M-17. The drainage area at M-17A represents 73% of the watershed of M-17, and its flow averages a comparable 77% of that at M-17, again showing a potential for approximating downstream flows based on a unit area runoff volume. This approach may be applied for monitoring Panther Run under Phase 3, with an upstream sample point used to extrapolate downstream conditions based on unit area runoff volumes and assumed comparable water chemistry. Application of this form of surrogate sampling should only be applied where it can be demonstrated that such relationships exist in area streams, and where the stream to be surrogate sampled is close to and of similar nature to the one used to test the relationships.

CONCLUSIONS AND RECOMMENDATIONS

Phase 2 of the Mosquito Creek project succeeded in its goals of characterizing the water quality patterns in the watershed and providing data for development of a long-term progressive restoration plan. It was recommended as part of Phase 3 that the monitoring be continued under that Grant in order to establish a longer term baseline record for comparison to water quality improvements resulting from future acid abatement activities. This continued monitoring is already in the process of implementation. In addition to the observations made regarding the methods applied, there are several general conclusions and recommendations that have developed over the course of the Phase 2 project, summarized as follows:

- All monitoring programs must include concurrent flow measurements with collection of water quality samples. Sizing of acid abatement systems is based on flow capacity and required acid loading reductions in streams, both of which require flow data to determine.
- Whenever possible, all samples in a watershed-scale monitoring program should be collected on the same day to reflect contemporaneous runoff conditions.
- Monitoring parameters for streams acidified by atmospheric deposition should include alkalinity as well as ANC and acidity. Alkalinity is a better measure for use in the physical sizing of systems and design performance predictions, while ANC appears to be a better measure of overall stream health.
- Where limestone addition is a component of acid abatement activities, calcium is also a useful parameter for tracking output and assessing downstream dilution effects.