Report for 2004PA26B: Controls on Nutrient Levels for Spruce Creek and a Major Tributary

There are no reported publications resulting from this project.

Report Follows

Abstract:

Spruce Creek, one of the premier trout fisheries in the state, economically bolsters an otherwise agricultural economy. Although both the tourism and agriculture industries are essential to the Spruce Creek watershed region's economy; agricultural land use, if not properly managed, does present potential environmental risks to the stream. In order to monitor the health of the stream, we conducted a baseline study focusing on nitrates and phosphates, total dissolved solids, pH, temperature, and discharge. The baseline water quality dataset for Spruce Creek will be used to understand the physical and chemical aspects of the stream so as to highlight conditions that lead to stream impairment. In this study, we utilize high frequency sampling and analysis (HFSA) techniques, as our previous work and recently published work of others indicates that HFSA leads to more accurate predictive models.

Two students will measure the nutrients (phosphorus and nitrogen), pH, total dissolved solids, turbidity, and temperature of the water and the discharge of the stream at ten sampling sites for ten consecutive weeks in the summer of 2004 and continue monitoring the stream at least twice a week throughout the 2004-2005 academic year. This study builds upon two consecutive years of HFSA we have completed in the watershed. Previous years included abnormally dry (2002) and abnormally wet (2003) springs and summers. Because there is very little overlap of conditions between these two years of data, a third year of data is needed to complete predictive models which we are designing. Few studies have examined stream chemistry with as much frequency over such a long duration of three years. This large dataset will clearly identify what 'normal' physical and chemical conditions versus abnormal conditions would be on the stream.

The objectives of the study are threefold:
1. Illustrate the influence of agricultural inputs to the stream: The dataset may quantify the effect of agricultural practices in the Spruce Creek watershed. The data will allow us to complete the development of a predictive model that will help avoid impairment of the stream's health. Additionally, the data will allow us to help engineer solutions to minimize agricultural influence upon the stream.
2. Provide research experience for undergraduates: The students involved in the experience will gain invaluable practical training in water quality assessment and collection of information.
3. Involve and spark interest in the local community: The dataset will be assessable to the community and presented at local meetings. The study will provide valuable information to a community that relies so heavily on the health of the stream.

Statement of Critical Need:

Spruce Creek is a well-known trout stream in south-central Pennsylvania. Outfitters, guide services, and eateries augment the economy in the Spruce Creek watershed. As such, the economic health of the village of Spruce Creek, which relies heavily upon tourist/recreation business, is intimately tied to the stream's health. This tourist business has seen declines a number of times over the past 20 years as fish kills affecting local waterways have occurred.

Nutrient loading has been the primary suspected cause of some of these fish kills. Furthermore, Spruce Creek is a major tributary to the Little Juniata River and part of the Juniata River drainage basin. This basin supplies water for residential and industrial use to a multi-county area, including three municipalities (Alexandria, Petersburg, and Huntingdon) less than 20 miles downstream of Spruce Creek. Increased understanding about influences upon water quality of Spruce Creek has significant economical, environmental, and societal value.

During the winter and spring of 2001, concerned citizens from Spruce Creek, PA approached a representative of the Geology Department from Juniata College (Huntingdon, PA) and asked for assistance in assessing water quality for Spruce Creek and collecting baseline water quality data for future assessments. Based upon this request, Geology faculty at Juniata College (Dr. Ryan Mathur and Dr. David Lehmann) investigated previous work and existing data for the stream. They talked with a wide variety of regulatory personnel and researchers including representatives from the PA DEP, PA Geologic Survey, and academic institutions. Although there was some data relating to macroinvertebrates for the stream, at that time there was no recent data on background levels of nutrients or seasonal variation of nutrients for Spruce Creek. All parties with whom the Geology Department checked indicated that they did not intend to examine nutrient levels on a regular basis. However, there was general agreement that this type of examination could prove valuable for recognizing and quantifying many forms of stream degradation and stream health. This background research was performed as a community service by Juniata College.

Because of their interest in and concern for local stream water quality, in May, 2001, faculty and students from Juniata College began rigorously studying the water quality of Spruce Creek, paying particular attention to phosphate and nitrate levels in conjunction with recording discharge, conductivity (an indirect measurement of total dissolved solids or TDS), temperature, turbidity, and pH. Funding for this initial work has come primarily from Juniata College, the Geologic Society of America (student grant), and local citizens from Spruce Creek. This has clearly been an example of academic/professional organization/municipal combined efforts.

Baseline data collected by the Geology Department is beginning to elucidate a better understanding of variable nutrient level patterns, localized areas of nutrient loading, and the interactions between stream flow dynamics and nutrient levels. Teeters and others (2002) presented these initial findings at the national Geological Society of America Conference at Denver, CO in October, 2002 and at a local meeting of the Colerain Rod and Gun Club. Because of the quality of initial results and positive feedback, the Geology Department supported two students for an expanded study of Spruce Creek during the summer and fall of 2003. In addition to collecting more data to understand baseline conditions of the stream, this continued investigation is leading to a better understanding of surface water and groundwater influences upon nutrient loading. Furthermore, a comparison of the summers of 2002 and 2003 is leading to a better understanding of how unusually dry (2002) and unusually wet (2003) seasons may influence water quality of Spruce Creek. An analysis of relationships between land use and nutrient loading, as well as a comparison/contrast of

nutrient loading during wet and dry seasons will be the topics of two professional papers that will be presented at conferences within the next six months.

Based upon the data that Juniata College has collected during the past year and a half, it is apparent that a more complete understanding of the stream's health would develop if we also had data from a major tributary of Spruce Creek. Ideally, sampling and measurements of Spruce Creek and the tributary should occur nearly synchronously. With two nearly synchronous datasets, we can begin to establish regional and seasonal patterns so as to be able to identify any events that deviate from the 'normal' conditions of the stream. By examining two streams, we can also collect better data to investigate how bedrock geology and land use may affect water quality. With this in mind, we propose to compare land use, bedrock geology, and water quality of the upper portion of Spruce Creek (above Warriors Mark Run) and Warriors Mark Run. These are ideal drainages to compare because they have similar hydrogeologic characteristics, flow through similar geologic units and combine to form the lower portion of Spruce Creek. The obvious difference between the two drainages is the surrounding land use patterns.

Statement of Results of Benefits:

In order to understand the general health of Spruce Creek, we will obtain baseline physical and chemical information for the upper portion of Spruce Creek and for Warriors Mark Run. These baseline data sets will highlight nutrient loading into the streams via surface or groundwater sources, seasonal discharge patterns, and turbidity fluctuations. Over the proposed study period (one year), we will collect a minimum of 120 data sets. Each data set will address water chemistry and stream hydrology for 10 sample locations (five per stream). Using these data sets, we will compare different measurements of water quality and stream characteristics by both date and sample location. We will use multivariate analysis to investigate relationships between nutrient levels, physical characteristics of stream water, and stream discharge. Additionally, we will investigate if local changes in nutrient levels or physical characteristics of stream water may be related to land use or bedrock geology.

In this project, we will utilize high frequency sampling and analysis (HFSA), collecting and analyzing data (including water chemistry data) between two and five times per week. Most previous studies of nutrients in streams have utilized more temporally spaced out data sets or have concentrated on specific events that researchers believe may be related to nutrient loading. Temporally-spaced data sets do not offer the resolution to identify stream response to nutrient loading, and based upon our preliminary data, may bypass significant loading events. Following some loading events, nutrient levels returned to pre-event levels within two to three days. To address our concerns regarding poor resolution of stream assessment based upon infrequent sampling, we developed HFSA. HFSA offers the benefit of identifying specific loading events without making assumptions about when and where those loading events will occur. Additionally, HFSA facilitates a more precise and complete picture of stream response to and recovery from loading events. Independent of our work, Harris and Hollabaugh (2003) found that an HFSA-like approach helped elucidate an

understanding of stream response to loading events that was not available through standard sampling techniques.

Preliminary data indicates that HFSA may allow differentiation of nutrient loading from springs and surface water. Immediately following some storm events, nutrient levels increase almost synchronously with discharge. This, we believe records nutrients delivered from runoff. In some cases, three to twelve days following the initial nutrient spikes, secondary—but equally significant—nutrient spikes occur. These may record spring influence. In light of karstic conditions and extremely complex hydrogeologic conditions for the area, HFSA offers a viable approach to start to differentiate potential roles of groundwater and runoff to nutrient loading.

We are presently seeking additional funds to use infrared technology to precisely locate springs in Spruce Creek and Warriors Mark Run to further investigate the role of groundwater in nutrient loading. This project proposed here would provide valuable background data to understand the timing of nutrient loading related to springs.

With a firm understanding of the patterns present in the chemical and physical datasets, we will be able to confidently identify anomalous or detrimental events to the 'normal' stream health. Integration of information from these datasets will lead to a clear evaluation of the overall stream health and to the development of an effective, efficient risk analysis model for Spruce Creek.

Nature, Scope and Objectives:

This proposal seeks funds to:

- Train students in HFSA field sampling, laboratory techniques, and water quality analysis. This is an ongoing process that has already begun. Training will be completed on or before June 1, 2004.
- Continue assessment of Spruce Creek drainage basin. This is an ongoing process that has already begun. We plan to continue this assessment through the grant period.
- Compare water quality dynamics between a major tributary of Spruce Creek and the upper portion of Spruce Creek. We have begun to collect data from both streams and plan to continue collecting data through the time-frame covered by this grant.
- Investigate the relationships between land use, bedrock geology and nutrient loading in these streams. We have begun analysis of nutrient loading and bedrock geology. We will begin investigation of land use immediately upon receiving notification of these funds.
- Develop a predictive risk analysis model for Spruce Creek that identifies conditions that create high risk for stream impairment and when and where those conditions occur. Model development is an ongoing process on which we are already working. However, a sophisticated model requires the data we would gather under this grant. We predict that we can begin to finalize our model by November 1st, 2004. Previous years' data suggests that by October 1st, nutrient loading becomes much simpler and more predictable until the following spring. As a precaution, we would like to wait an additional month before starting to finalize our model.

- Provide background data to facilitate effective and efficient stream remediation in the event that Spruce Creek tributaries are negatively impacted at some time in the future. We have begun this process. At the request of citizens' group from Spruce Creek, we are presently preparing a response to a Chapter 71, PA DEP Public Comment request regarding development in the watershed. We plan to provide data as requested. Additionally, we are presently collaborating with the USGS to identify the best way to make data accessible to interested parties. We have also communicated with other groups examining portions of the Spruce Creek watershed and with State and regional interested groups. We will make data intranet or e-mail accessible within one month of receiving notification of this grant.
- Based upon our risk analysis and present land use, identify and propose best management practices to prevent impairment and improve stream quality. This is an ongoing process, but we will have a report prepared by November 1, 2004
- Provide communication about our findings to the Spruce Creek watershed community, regulatory agencies, and professionals working with similar watershed issues across the United States. This project will result in a minimum of two presentations at regional or national professional meetings, three public presentations to the community, and one journal publication during the grant period. We will prepare a final report that will define and interpret stream water quality and will present a water quality risk analysis model. This report will be provided to the granting agency and could also be available on-line.

Although not the primary goal of this specific project, Juniata College hopes to provide the technical expertise and labor to serve as an outreach to the south-central Pennsylvania community for protecting and enhancing local watersheds. This grant would support the development of our envisioned community—academic interactions.

Methods, Procedures and Facilities:

We propose that two appropriately trained Juniata College students (junior or senior standing with outstanding academic credentials and requisite upper level science courses) work ten forty-hour weeks as paid interns during the summer of 2004. These students along with four others will continue their research efforts throughout the semester as credit (unpaid) internships. Three professors will supervise students, assist in the field and lab to assure data quality, and oversee report preparation. The students will sample five locations along each of the streams. To ensure quality and reproducible results, careful and precise field and lab techniques are critical. Therefore, we intend to utilize only students who have demonstrated a high proficiency of requisite skills and an ability to excel at semi-independent work.

In order to accomplish the objectives stated above we will:

1) Measure pH, temperature, total dissolved solids, discharge, turbidity, nitrogen, and total phosphorous concentrations. To improve the efficiency of measuring discharge, we plan to install several stream gages that allow us to record depths of flow at specified intervals. A rating curve will be developed at these sites, thus allowing for determination of flows as well as depth. A hydrologic model (e.g. the U.S. Army Corps of Engineers HEC-HMS) will be calibrated for the flows and rainfall as obtained from a variety of sources such as the National Weather Service.

2) A GIS database will be developed that includes land use, topography, geology, and historical photographs (to name a few). The GIS will be used in conjunction with a GPS to verify land use and to locate site specific information such as springs and point source discharges.
3) Examine published topographic and geologic maps and confirm surface geology with outcrop exposure.
4) Present study updates and final outcomes at both public meetings to communities in and near the watershed and at professional conferences.

Juniata College has two fully stocked environmental geochemistry laboratories in Brumbaugh Science Center in which sample analysis will take place. Students working on this project will have an office, dedicated to their research project, with campus network accessibility in the Geology wing of Brumbaugh Science Center. To measure nutrient levels, we utilize HACH photospectrometry per state regulatory agency guidelines. To increase the precession of measuring extremely low levels of phosphates and to give us the capability of looking at other potential ions of concern, we are in the process of purchasing an ion chromatograph. Field equipment that will be available for this work includes a Global Water flow meter, HACH's highest quality pH, temperature, and conductivity meters (multiple sets to ensure no down time due to equipment failure), and ReelLogger equipment. Students will have access to a wide array of other modern scientific equipment, including TRIMBLE GPS units, a fluorimeter and GC and HPLC systems. By December, 2003 we will have an analytical SEM installed on campus, funded by a $300,000 NSF grant to the Geology Department. The SEM may prove useful in imaging macroinvertebrates or other organisms that are included in bioassessments. This commitment to quality extends even to basic equipment. For example, if students working on this project require microscopes, they will have access to Leitz and Zeiss petrographic microscopes and Meiji's highest quality stereo-zoom microscopes.

The College maintains a fleet of vehicles that are available to use by students or faculty for research projects at modest charges. Extensive camping, sampling, and mapping equipment are available for this project if needed. Likewise, the College maintains a tool/machine shop in Brumbaugh Science Center so that we can build specialized equipment or customize stock equipment in-house. For data analysis, we have licenses for a wide variety of statistical and graphical software including Excel, MiniTab, SAS, Corel Draw, PowerPoint, and Adobe Illustrator. We have a color plotter on campus for preparing posters up to 42" wide.

Principal Findings and Significance:

Nutrient Transport: Typical sources of nitrates within stream water include septic tanks, leach pools, refuse dumps, animal feed lots, fertilizers, municipal and industrial wastewater, urban drainage, and decaying plant debris (NMENV). Within this particular watershed, the only possible sources are septic tanks, leach pools, animal feed lots, and fertilizers. Typical sources of phosphates within a stream system include animal wastes, fertilizers, sewage, detergents, and road salts used in winter (FOSC). For the Spruce Creek watershed, the possible sources include animal wastes, fertilizers, and sewage.

It is possible that the differences in nitrates and phosphates are due to different sources for the nutrients. The source of phosphates could be fertilizers, whereas the source of nitrates could be animal wastes. Another possible explanation is that nitrates and phosphates enter the stream system differently. Our data indicates that nitrates are present in the system regardless of discharge, but phosphates appear to enter most noticeably during increases in discharge. It is possible then that nitrates enter the system through groundwater inputs, whereas phosphates enter the system through overland flow.

Increases in nitrates and phosphates coinciding with increases in turbidity would suggest that the increased sediment load is likely responsible for the increases in nutrient concentrations. This sediment load likely contains many particles that have been recently washed from agricultural fields, like particles of fertilizer and animal waste. These particles, while not dissolved, will still add nitrates and phosphates to the stream system.

CAFO versus Traditional Agriculture: Even though nitrate concentrations are similar on Spruce Creek and Warrior's Mark Run, the total amount of nitrate in kilograms per day varies greatly between the two streams. The reason for this variation is that Spruce Creek, with its larger discharge, is able to dilute its total nitrate load to concentrations that are comparable to those on Warrior's Mark Run. This indicates that the agriculture along Spruce Creek is contributing a larger total nitrate load into the stream system than Warrior's Mark Run.

Seasonal Changes in Nitrate Concentration: Nitrate concentrations are higher during the spring and summer months than during the fall and winter months. Discharge rates do not dramatically increase or decrease during this transition which indicates that the drop in nitrate concentration is not associated with a change in discharge. This shift would signify that a major source of nitrate is removed from the stream system around the beginning of September. Farm owners typically stop/lessen the amount of fertilizer/manure that they spread on fields at the end of the growing season, which is typically around the start of September for this particular area. (NOTE: The growing season may end around the start of September, but fertilization continues well into October) This decrease in manure spreading coincides closely with the drop in nitrate concentrations in the Spruce Creek watershed indicating that the spreading of manure/fertilizer is the likely source of the nitrates.

Effects of Nutrient Input on Water Quality: Nitrate levels for ambient water should be 0.31 mg/L or less to ensure a healthy stream system (EPA, 2000). During the summers of 2002, 2003, and 2004, there was not a single nitrate concentration that was at or below this level.

Warrior's Mark Run: The headwaters of Warrior's Mark Run consistently contain a lower concentration of nitrate than its stream waters. This indicates that there is a significant source of nitrate directly downstream from the headwaters. Water interaction with bedrock in stream bottoms is very unlikely; the rock units that underlie the stream are typically limestone (Coburn, Loysburg, Axemann, Stonehenge, Warrior Run, and Pleasant Hill Formations) and dolomite (Bellfont, Nittany, and Gatesburg Formations), with an occasional shale (Reedsville and Juniata Formations) or sandstone unit (Bald Eagle and Juniata Formations). These rocks do not have the chemical makeup necessary to add such

significant concentrations of nitrate to the stream system. The likely source of this nitrate is from the surrounding agricultural land use.

Although there is no source of nitrates near the headwaters, there is a significant source of phosphates. This source could be the underlying bedrock, the Bald Eagle sandstone and conglomerate, which contains phosphatic minerals.

Undergraduate Students Supported:

Elizabeth A. Diesel, 2005, Bachelor of Science, Environmental Science and Studies/Geology
Evan Teeters, 2005, Bachelor of Science, Geology
Mathew Sauers, 2005, Bachelor of Science, Geology
Caitlan Zlatos, Current student, Environmental Science and Studies/Geology
Lori Hodel, Current student, Geology
Greg Pierotti, Current student, Geology
Dane Fischer, Current student, Geology
Allison Phillips, Current student, Geology
Melissa Wilson, Current student, Natural Sciences/Geology

Publications:
None, but Elizabeth A. Diesel is preparing an article for submission in fall 2005.

Presentations and Other Information Transfer Activities:
1. Presentation at the National Geological Society of America conference in Denver, Co on November 11 2004 by Elizabeth Diesel.
2. Presentation at the Geological Society of America conference in Reston, VA on April 14 2004 by Elizabeth Diesel.
3. Caitlan Zlatos presented project information at the Environmental Symposium at Penn State University in March 2004
4. Elizabeth Diesel also gave a presentation at Penn State in April 2005.
5. The information was also presented at the Juniata College research symposium in April 2004 and 2005 by Elizabeth Diesel and Melissa Wilson.
6. Results from the work were discussed with the community during meetings held in the town Warrior's Mark, PA during the spring of 2004 and winter of 2005.

Awards:
None