Assessment and Restoration of Chestnut Branch of Mantua Creek: An Educational Partnership

Gordon Williams**, Lisa Callahan***, John Witthohn****, Joseph Orlins, PhD, P.E.*

*Contact: Department of Civil and Environmental Engineering, Rowan University, 201 Mullica Hill Road, Glassboro, NJ 08028-1701; PH (856) 256-5328; FAX (856) 256-5242; email: orlins@rowan.edu
**Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA; Student; email: gowillia@vt.edu
***Department of Civil and Environmental Engineering; Rowan University, Glassboro, NJ; Student; email: call5194@rowan.edu
****Department of Civil and Environmental Engineering; Rowan University, Glassboro, NJ; Student; email: witt9449@students.rowan.edu

Abstract

The Chestnut Branch of Mantua Creek is a typical stream in an agricultural watershed undergoing suburban development. The stream bisects the campus of Rowan University and collects all the storm water from the campus and surrounding community. Recent development in both Rowan University and the surrounding area has led to an increase in the amount of impervious surface, which in turn caused an increase in runoff and a decrease in the water quality of the stream. In addition, excess runoff has caused severe bank erosion in many locations along the stream corridor.

The restoration project is being completed in a partnership between the Gloucester County Planning Division and the Rowan University Civil and Environmental Engineering Department. Undergraduate engineering students are taking part in the project by conducting field surveys, monitoring water quality, developing a computer model of the stream, and designing bank stabilization measures. Working with faculty and engineers from county and state agencies, students are gaining hands-on experience in all aspects of non-point source pollution control.

With a grant from the National Science Foundation Research Experience for Undergraduates (REU) in Pollution Prevention, a student from Virginia Tech joined Rowan University to help in this project. Students have continually measured and analyzed stream water quality, completed a topographic survey of the area, used computer software to develop an accurate map of the stream, and conducted a hydraulic study of the drainage area. Students are currently installing instruments to measure stream flow and creating a computer model of the stream in HEC-RAS. Over the next two years, student teams will complete the site assessment and bank stabilization design. Academic-public partnerships such as this can provide valuable experiences for students, improve environmental quality, and provide a worthwhile service to the community.

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Introduction

The Chestnut Branch of Mantua Creek is a stream that runs through a mixture of developed agricultural and suburban land. The Chestnut Branch is part of the Mantua Creek watershed and originates near the campus of Rowan University, in the town of Glassboro, New Jersey. The general location of the watershed is shown in Figure 1. After Chestnut Branch leaves the Rowan University campus, it flows by the LiPari Landfill, into Alcyon Lake, merges with the Mantua Creek, and eventually flows into the Delaware River.

Over the past few decades this area has had a large increase in residential and commercial developments, including a 25% increase in residential land since 1970 (DVRPC 2001). In addition, the campus of Rowan University has grown significantly in the past 75 years, and has plans for continued growth. All of the development has increased the amount of impervious land, resulting in increased storm water runoff, which has led to moderate to severe bank erosion. The sediment released due to erosion decreases the water quality of the Chestnut Branch and has had a negative impact on the aquatic ecology downstream from the campus.

Sediment is considered the most significant type of non-point source (NPS) pollution in streams. The EPA has recently classified non point source pollution as the most serious water quality problem faced today (Fair 1998). When sediment settles in a stream, it hinders most of the biological processes occurring on the stream bottom. This includes killing both plant life and fish eggs, and clogging fish gills (NJDEP 2000). Sediment also acts as a vehicle for other pollutants such as phosphorus, heavy metals, chlorinated hydrocarbons, microorganisms, and organic nitrogen to travel downstream. The addition of excess phosphorus, a limiting nutrient, into the stream from agriculture and residential uses leads to uncontrolled algae growth. The excess nutrients have lead to algal blooms and decreased amounts of dissolved oxygen (DO), which has caused fish kills near Alcyon Lake. Sediment also affects the water quality from the prospective of recreational purposes.

Students and faculty in Rowan University's Civil and Environmental Engineering Department, in cooperation with the Gloucester County Planning Division, are currently working on the engineering design for bank stabilization of the Chestnut Branch. One component of this project is monitoring the water quality of the stream at different locations through the campus. Students are tracking the change in several water quality parameters as the creek passes through the campus. Additional phases of the project include detailed mapping of the stream corridor, modeling of stream levels and velocities and the design of bank stabilization measures. Two types of bank stabilization methods will be used to control the erosion on the Chestnut Branch: soft engineering such as vegetation and bio-logs, and hard engineering such as riprap.

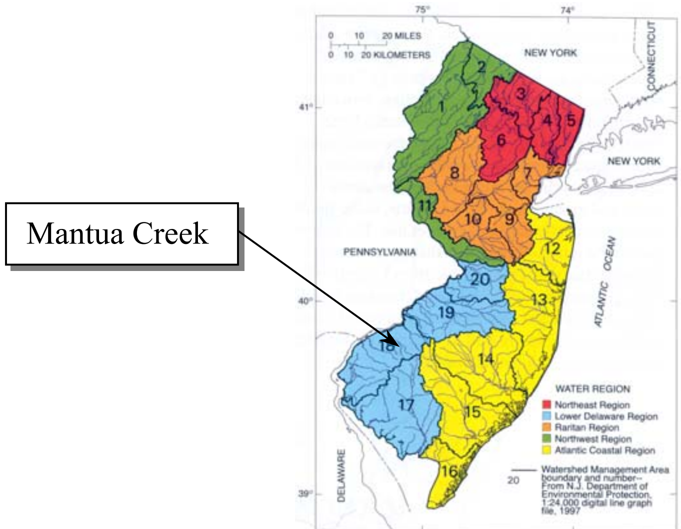

Figure 1: Location of Mantua Creek (from Watt, 2000).

Site Hydrology

The headwaters of the Chestnut Branch originate near the Rowan University campus, and drain an area of approximately 1.46 km^2. The terrain is generally flat, with sandy loam soils. The watershed was divided into four sub-areas for hydrologic analysis, comprising two source or "upstream" regions (U1, U2), a "middle" region (M), and a "downstream" region (D). The NRCS TR-55 method was used to estimate peak discharge for a variety of rainfall events. Peak discharges for each sub-area are summarized in Table 1.

Table 1. Summary of Peak Discharge Calculations

	Peak Discharge (cfs) for return periods of:						
Sub-Area	1 year	2 years	5 years	10 years	25 years	50 years	100 years
U1	56.8	79.9	124.5	163.8	190.7	222.6	259.5
U2	27.7	40.6	66.9	93.1	112.5	134.3	158.7
M	87.2	126.5	190.3	249.4	289.7	337.5	392.7
D	47.3	72.1	120.8	166.4	198.7	235.7	278.9
Total (cfs)	**219**	**319**	**502**	**673**	**792**	**930**	**1090**

Water Quality

Undergraduate engineering students are monitoring the water quality of the Chestnut Branch as a way to judge the effectiveness of the bank stabilization efforts. Data will be collected pre and post construction to determine a before and after comparison. Five parameters are being periodically tested at seven locations, allowing the students to determine how the water quality changes as the streams runs through the campus. The five quality parameters being tested are dissolved oxygen (DO), temperature, conductivity, pH, and turbidity.

Seven locations were chosen to gage the water quality parameters and are located where the stream enters and exits the campus, and where other significant flows enter the stream (Table 2). The two major discharges to the stream being monitored are the drainage flow from a pond and the (former) flow from dewatering at an on-campus construction site (Figure 2). At the construction site, the foundation of a new academic building on campus is below the water table, so it was necessary to lower the groundwater level in the area during construction. All of the pumped groundwater was collected and discharged directly into the creek. Monitoring locations were placed upstream and downstream of the construction dewatering discharge point, as well as in the dewatering source.

Table 2. Descriptions of Water Quality Monitoring Locations

(List is in order of downstream to upstream)

Location	Description
A	Exiting the Campus/ Heavy Foliage/ Higher Velocity
B	After fully mixed with Construction Drainage
C	Upstream of Construction Drainage Mixing
E	Near Student Center and Patio/ After Maintenance area parking lot
F	Chestnut Branch after Entering Campus/ Very Low Velocity
G*	Discharge Flow from Pond/ Low flowrate/ Shallow
D*	Discharge from Construction Dewatering/ Groundwater

*Locations G and D are not in the Chestnut Branch, but located in the influent stream directly before the confluence with Chestnut Branch (A, B, C, E, F are all located in the actual stream). Samples are no longer taken at Location D since the dewatering has stopped.

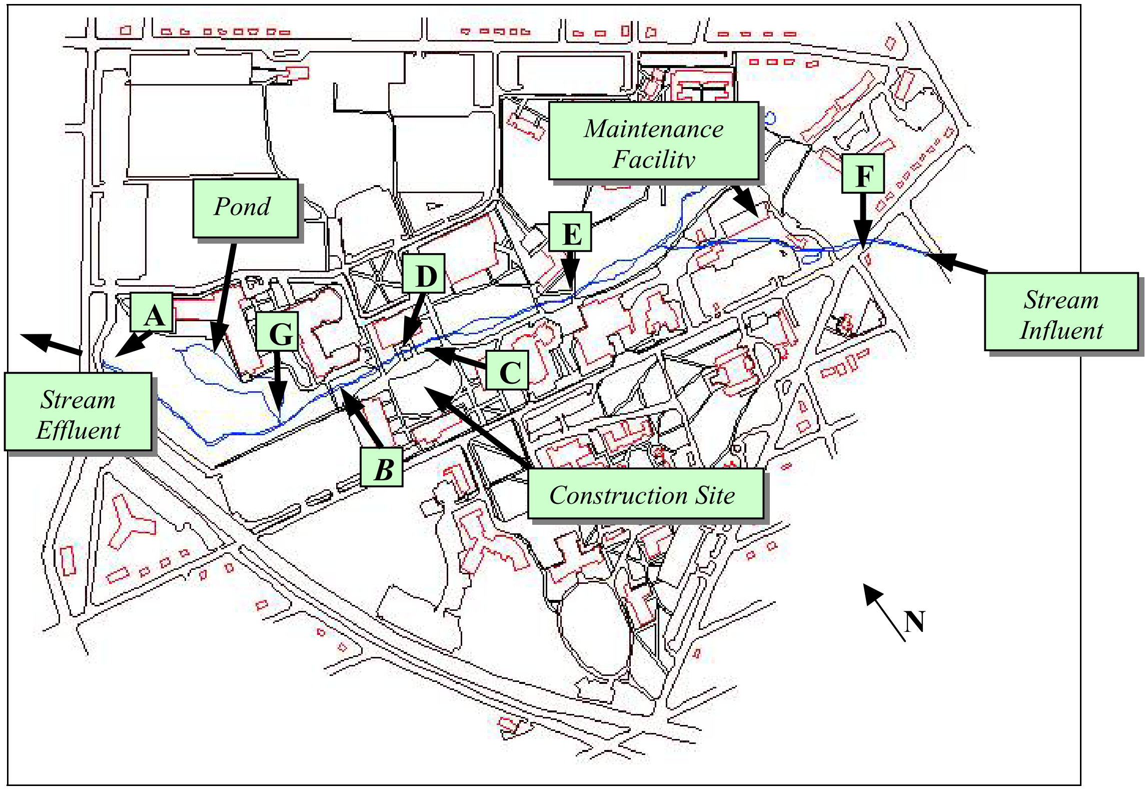

Figure 2. Rowan University Campus Map showing Chestnut Branch and Water Sampling Locations A-G.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen gas that is dissolved in a volume of water and fluctuates depending on temperature and atmospheric pressure. The amount of DO in a stream is a good indicator of the health of the stream and the quality of water. The DO is necessary for both fish and plant respiration. Typically, a DO level below 4.0 mg/L is considered poor (DVRPC 1998). When microbes in the stream consume biological matter, dissolved oxygen is also consumed. Oxygen from the atmosphere diffuses into the water to replenish the consumed DO. If there is too much waste in the stream, microbes will consume more, decreasing the DO to dangerous levels.

The dissolved oxygen in the Chestnut Branch is measured using a field DO probe. The level of dissolved oxygen increased as the water travels over the campus (Figures 3 and 4). The lowest concentration of DO occurred at location F (the most upstream location). This can be explained by the small base flow discharge at location F, which has nearly stagnant velocities. The rate of oxygen diffusion is dependent on the amount of surface area exposed to the air and the amount of mixing in the water. As the stream discharge increases across the length of campus due to increased base flow, the water becomes more turbulent, increasing the level of DO. There is a jump in DO from the construction drainage where the flow has a four-foot drop out of a pipe, which causes rapid mixing. The small stream that feeds into Chestnut Branch from the pond near the Engineering building also has a higher amount of dissolved oxygen due to aeration and mixing.

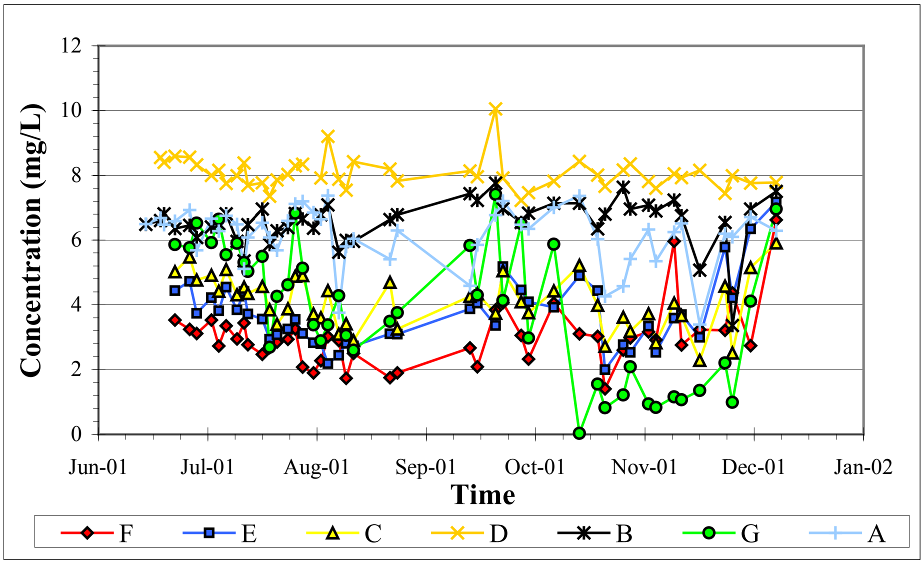

Figure 3. Dissolved Oxygen Concentration at sampling locations A-F, June-December 2001.

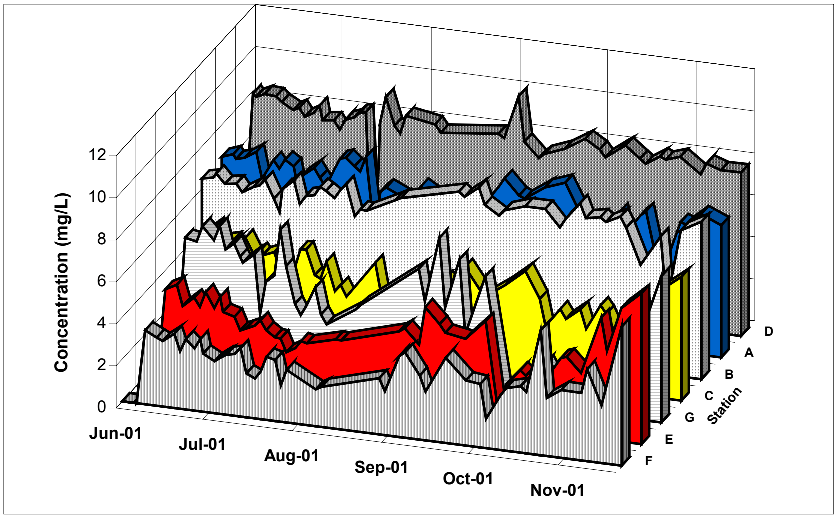

Figure 4. Variation in Dissolved Oxygen Concentration with Station.

Temperature

The temperature of the stream water is important because of its effects on aquatic organisms and dissolved oxygen saturation concentration. If the temperature becomes too warm, the amount of dissolved oxygen will drop, which if low enough can be harmful to the aquatic life. Normal fluctuations in temperature are expected because of changes in the ambient air temperature and weather patterns. The temperature was measured using the field DO probe (Figure 5). The difference in temperatures between locations can be explained by such factors as amount of tree cover or shade from buildings. The construction water, coming from the ground (Location D), was typically constant, and the rest vary with the outside air temperature.

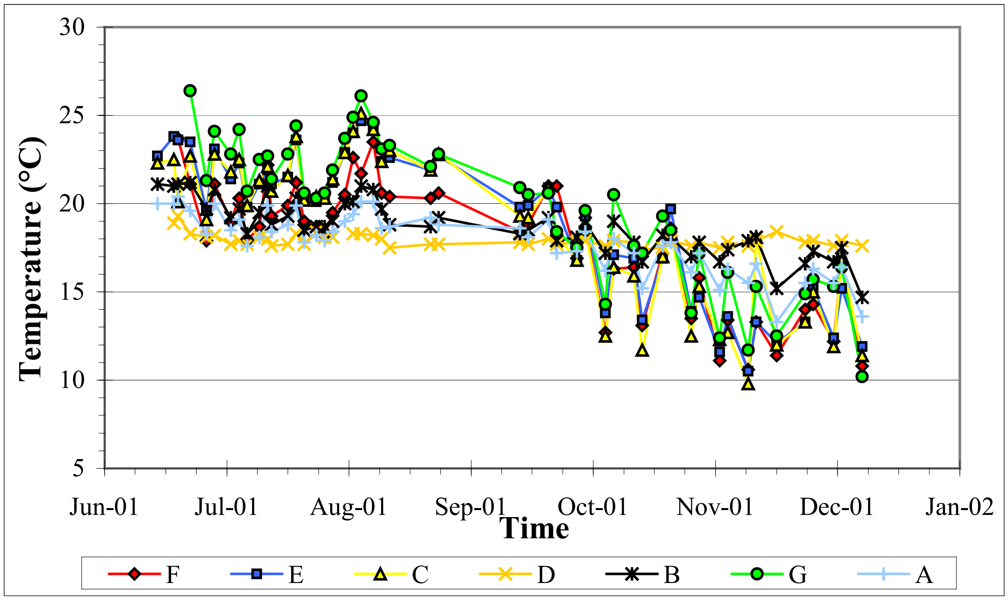

Figure 5. Temperature at sampling locations A-F, June-December 2001.

pH

The pH level is a measure of the level of acidity or alkalinity in the stream. Depending on the types of aquatic life, values lower than 5.5 or higher than 8.5 are typically considered harmful to the health of the stream. The pH can also change throughout the day as photosynthesis is taking place in the stream and the amount of dissolved carbon dioxide changes in the water. The pH level is measured using a field probe. The pH level in the Chestnut Branch is fairly constant over time, but changes between sampling locations (Figure 6). As the water travels from locations F to C, the pH in the water seems to slowly increase until it mixes with the construction water. When construction water (typically around a pH of 5.0) mixes with the stream, it causes the stream pH to drop, as seen at location B. The pH from the pond drainage is higher, but it does not have a noticeable effect on the stream pH after mixing (pH of locations A and B are about the same). This is because the pond discharge is much lower than the flow of the stream.

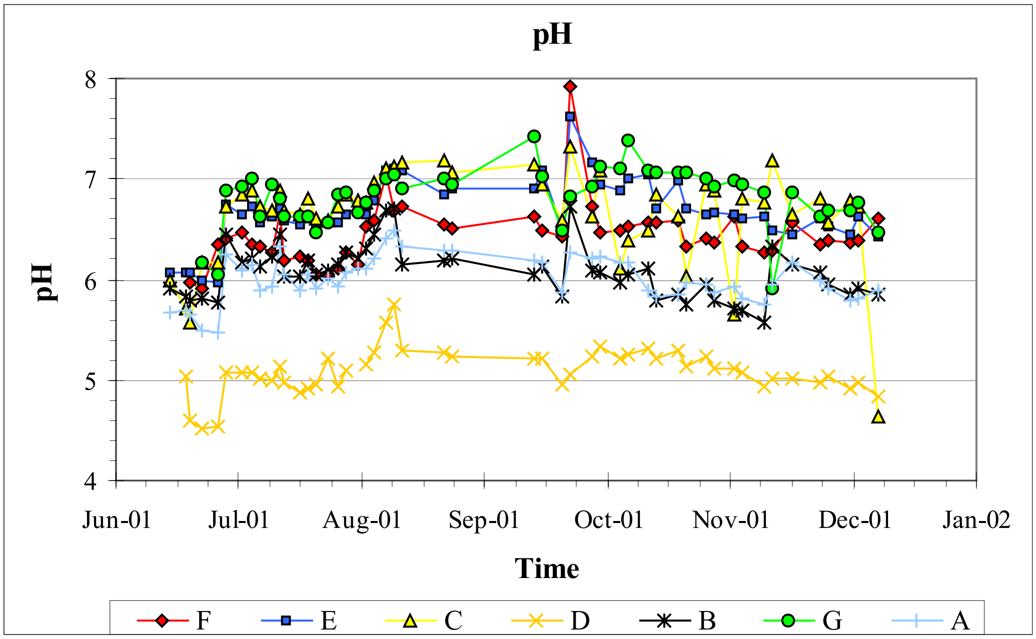

Figure 6. pH at sampling locations A-F, June-December 2001.

Conductivity

Conductivity is a measure of the amount of salinity and dissolved solids in the water and is an indicator of contamination in the water (DVRPC 1998). Also, a high level of salinity can kill fresh water fish (ANJEC 1992).

Where the stream enters the campus at location F, the conductivity levels are relatively low. As the flow passes locations E and C, the highest conductivity levels are observed. The jump in conductivity between locations E and F may be from some unknown pollutant. The maintenance facilities are in this area, and it is possible that winter salts and deicing chemicals in storage are leaching into the stream (Figure 2). The fluctuations of conductivity in the stream on different days may be due to storm water diluting the levels of dissolved solids in the water. These wavering levels are not seen at location D, where the conductivity levels stays constant at 280 μS. The lower level at D seems to decrease the conductivity in the stream when the drainage is fully mixed, as seen by the drop in conductivity between locations C and B. This may also explain the slight increase in conductivity at the locations downstream of location D after the dewatering stopped. Outflow from the pond also has a lower conductivity than the stream, which could explain the small drop between locations B and A.

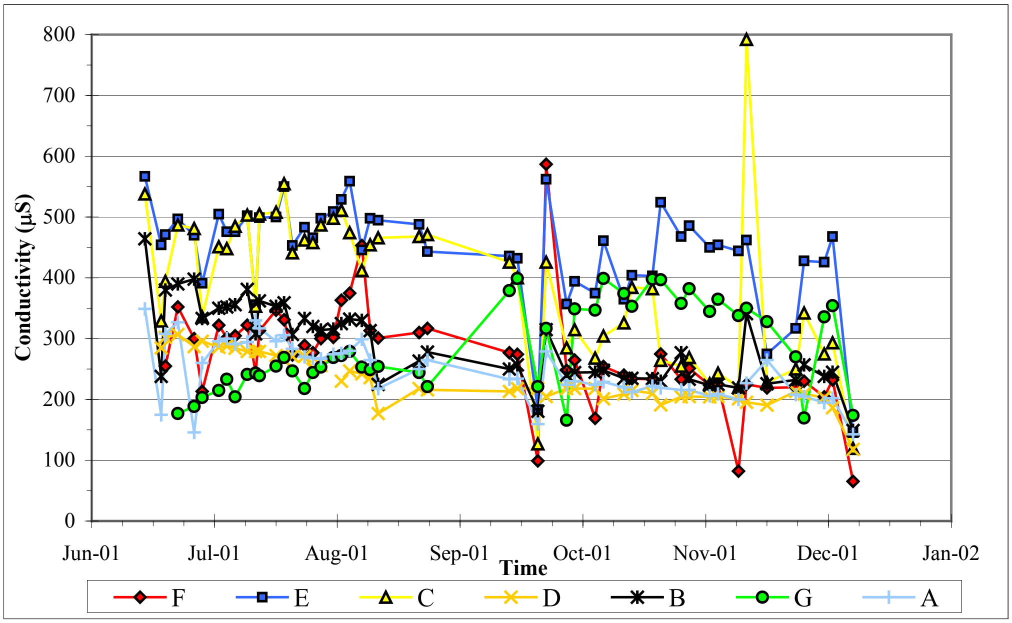

Figure 7. Conductivity at sampling locations A-F, June-December 2001.

Turbidity

Turbidity is a measure of the total suspended solids (TSS) in the water, which is what gives stream water a "cloudy" look. The most common suspended solid is sediment, which can cause damage to both fish and plant life. Turbidity is also an indicator of the amount of erosion occurring on the bank. For average flow conditions, the turbidity was found to be below 10 NTU at all locations (Figure 8). In general, turbidity does not significantly change between sampling stations on any given day. The exception to this is sampling location D, which is the pumped ground water discharging from the construction site. As expected, in rainy conditions, an increase in turbidity is observed. This is due to the increased stream flow erosion as well as erosion from the surface runoff, and explains the peaks in turbidity over time. However, the largest jumps in the level of turbidity however are not related to bank erosion. On June 25th, July 30th, and October 30th 2001, erosion control measures on the active construction site failed, resulting in high turbidity at locations D, B, and A.

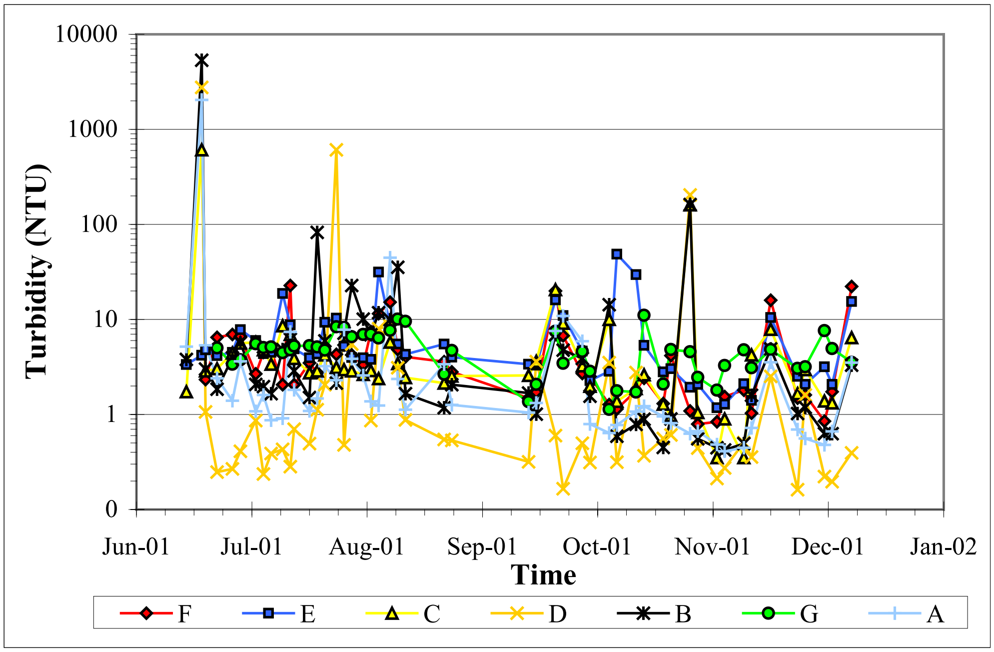

Figure 8. Turbidity at sampling locations A-F, June-December 2001.

Rowan Engineering Students will continue the water quality testing through the completion of the project to determine the effectiveness of the restoration. The New Jersey Department of Health and Environmental Chemistry Laboratory will do further testing of stream near Alcyon Lake for different bacteria, nutrients, and pesticides through all phases of the project, to evaluate the its overall effectiveness.

Surveying and Topographic Mapping

Another focus of the restoration project is to make a computer model of the stream to better analyze areas requiring stabilization. Undergraduate students have created a detailed topographic map of Chestnut Branch and surrounding areas that pass through the campus. Students used a Leica Total Station Instrument (TSI) and prism rod to perform the survey. Over 8000 survey points were collected along the stream corridor. Survey data was used to generate contour maps of the stream, as shown in Figure 9.

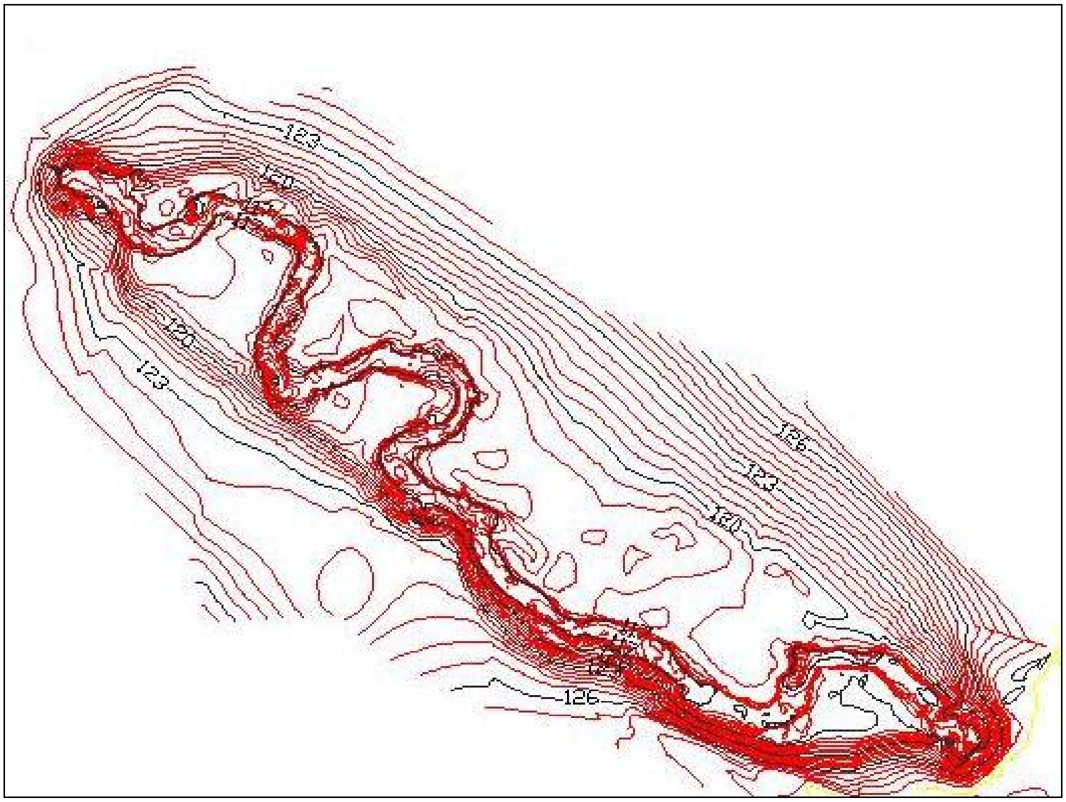

Figure 9. A portion of the Chestnut Branch topographic survey.

Computer Modeling

Stream velocities and water levels will be modeled using the US Army Corps of Engineer's HEC-RAS computer program. Stream geometry information will be extracted from the topographic survey results for input to the program, as shown in Figure 10. Using HEC-RAS the high velocity areas of the stream will be determined for different flow conditions. The model will also provide information on flood plain areas and where stabilization would be most effective.

Boundary conditions for the model include stream discharge and a starting water level at one cross section. Stream flow measurements are currently being taken, to develop a stage-discharge rating curve that will complement the existing peak discharges estimated using the TR-55 method.

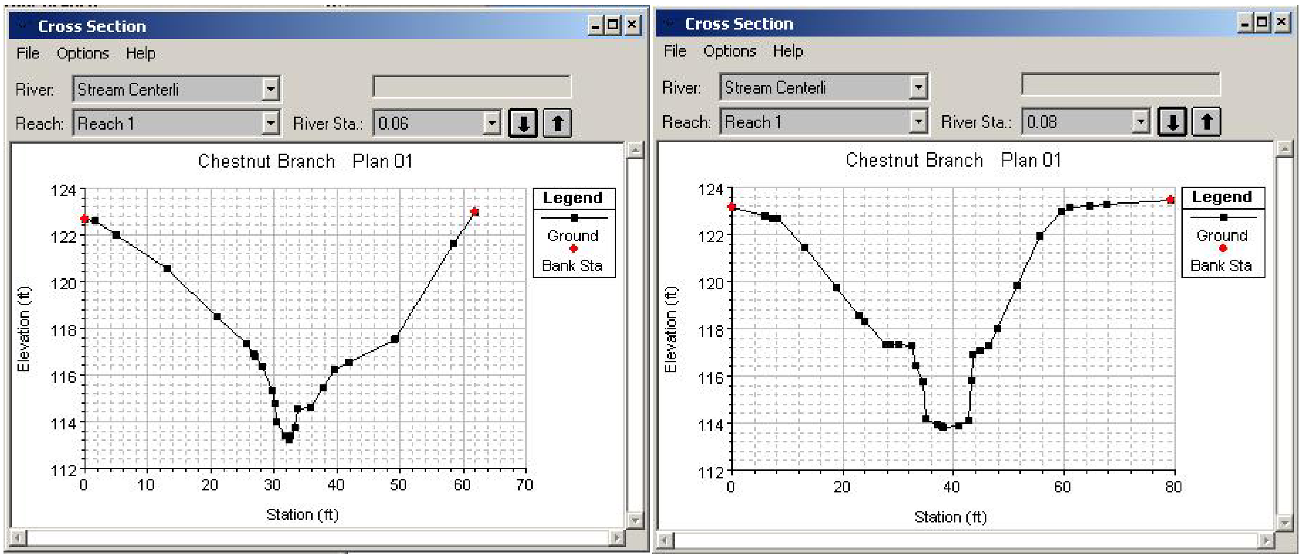

Figure 10. Sample Cross Section of Chestnut Branch in HEC-RAS.

Stabilization Measures

Students will have the opportunity to work with professional engineering, state and county agencies in the design and implementation of long term stabilization measures. Depending on the stream velocity in areas requiring stabilization, one of three methods will be used. These methods (in increasing order of stability) are vegetation (soft engineering), bio-logs (soft engineering), and riprap (hard engineering). The ideal stabilization measure is to plant vegetation, as this is the least intrusive technique to the natural environment. The difficulty with using the vegetation is that it can be washed away in a large storm event if the root system has not had enough time to develop (USDA 1998). Vegetation is also in danger of being accidentally mowed down by inattentive campus maintenance personnel. Bio-logs, a type of soil bioengineering, are a wrap of natural and synthetic fibrous materials (USDA 1998). Vegetation is able to create a better root system in the bio-log, decreasing the likelihood of a washout. The most environmentally intrusive, and therefore least desirable stabilization technique is riprap. In riprap, the stream bank or channel bottom is covered with a rock bed. Often concrete is poured to hold the rocks in place. Riprap can withstand the greatest stream velocities that would destroy the soft engineering measures. Students will use engineering design and judgment to create the most environmentally friendly, yet long term and withstanding stabilization measures, which will withstand the future demands of the developing region.

Conclusions

Proper storm water management practices are crucial in protecting the quality of our waterways. Problems like those found in Chestnut Branch are common to many developing areas. In cases like this, where development preceded storm water management regulations, creative solutions are required to restore and improve ecosystem health. Students and faculty are working closely with county and state officials to address bank erosion and developing bank stabilization designs. In this effort, students have developed a detailed topographic map of the stream, and are conducting ongoing water quality evaluations. Baseline data collected over a one-year period will provide a metric for comparison to post-remediation conditions.

The positive significance of this project can be observed at many levels:

- The hands-on project gives students a valuable opportunity with real-world engineering experience, working with engineering professionals;
- The project provides positive and long-term changes to the stream ecology, thus providing service to the community; and
- Students gain a better understanding of the temporal and spatial nature of water quality, and how streambank erosion followed by stabilization can impact water quality.

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