North Carolina
Department of Transportation
Highway Stormwater Program

NPDES

2006 Annual Report

For submittal to
NC Department of Environment and Natural Resources
Division of Water Quality

NC Department of Transportation
NPDES Permit No. NCS000250

June 2007

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1. Introduction

This 2006 Annual Report documents programs developed by the North Carolina Department of Transportation (NCDOT) to control stormwater runoff through the Highway Stormwater Program (HSP). The HSP is a statewide initiative to comply with NCDOT's National Pollutant Discharge Elimination System (NPDES) permit (permit number NCS000250) and meet the objectives of the NCDOT's Environmental Stewardship Policy. Adopted on February 7, 2002, the policy states that NCDOT has the following responsibilities:

- Safeguarding the public's health by conducting our business in an environmentally responsible manner;
- Demonstrating our care for and commitment to the environment; and
- Recognizing that our customers expect us to provide mobility and a quality of life that includes the protection of the natural resources and the cultural and social values of their community.

This policy is reflected in the guiding principles of the HSP:

- Comply with National Pollutant Discharge Elimination System (NPDES) Stormwater Permit;
- Design sustainable programs that are effectively integrated into NCDOT; and
- Develop proactive fiscally responsible solutions that improve program delivery, form partnerships, have technical merit, and meet water quality objectives.

This Annual Report is submitted as required by Part III.A of NCDOT's NPDES permit to document permit compliance from April 1, 2006, through March 31, 2007. The report is organized as follows:

- Section 1, Introduction, describes the HSP.
- Section 2, Permit Compliance Status, provides a brief review of compliance actions within each of the permit programs. Note that only management measures which required action in Year 2 are discussed.
- Section 3, Water Quality Improvements, discusses the qualitative impacts NCDOT's program has had to date.
- Section 4, Successes in the Highway Stormwater Program, addresses programmatic improvements to achieve the goals of the NPDES permit and the HSP.

2. Permit Compliance Status

2.1. Illicit Discharge Detection and Elimination Program (IDDEP)

To ensure that illicit discharges, spills, and illegal dumping into the NCDOT municipal separate storm sewer system (MS4) are detected and eliminated, NCDOT has implemented training, inspections, reporting, investigations of reports, and a tracking database.

Permit Ref.	Management Measure	Action
II.A.(a)	Provide illicit discharge identification training.	NCDOT has prepared and regularly distributes a training document for staff, contractors, and volunteers to identify and report illicit discharges. Volunteers are trained through the Adopt-a-Highway Program with a brochure describing illicit discharges and how to report them. The brochure is also made available to the traveling public at rest areas and welcome centers. NCDOT staff receive additional training through the Stormwater Pollution Prevention Plan (SPPP) training and a mini-poster discussed in staff meetings.
II.A.(b)	Perform illicit discharge inspections.	NCDOT personnel look for illicit connections and illegal dumping as they perform various field activities. Additionally, inspections are performed when potential illicit discharges are reported by the public.
II.A.(c)	Maintain a standard point of contact.	A standard report form is used to document all illicit discharges. The forms are available to the public through the brochures mentioned above and NCDOT's website, and to NCDOT staff through NCDOT's intranet and training. These reports are submitted to one individual in the NCDOT Roadside Environmental Unit.
II.A.(d)	Report illicit connections.	NCDOT has investigated all reports submitted in 2006. During Year 2 of the permit, 48 reports of potential illicit connections were submitted to the North Carolina Department of Environment and Natural Resources (NCDENR), Division of Water Quality (NCDWQ) Regional Offices. The reports are submitted monthly as they are collected.
II.A.(e)	Maintain a tracking database.	An Access database has been used to track all reports of illicit discharges. NCDOT is developing a web-based IDDEP reporting system that will make it easier to report and track illicit discharges.

2.2. Post-Construction Controls

2.2.1. Stormwater System Inventory and Prioritization Program

The statewide Stormwater System Inventory will support the Retrofit Program by identifying implicit outfall locations. These locations are potential sites for retrofitted stormwater controls, also known as best management practices (BMPs). The Inventory also supports the Total Maximum Daily Load (TMDL) Program, the Illicit Discharge Detection and Elimination Program, and other Post-Construction Controls programs required under the permit.

Permit Ref.	Management Measure	Action
II.B.1.(a)	Continue to build a stormwater system inventory of existing stormwater outfalls to sensitive waters.	NCDOT continues to inventory its roadway and facilities systems, and to identify implicit outfalls to sensitive waters through its Environmental Sensitivity Mapping (ESM) and GIS-based databases.
II.B.1.(b)	Include in the inventory outfalls from new construction projects to all surface waters and wetlands.	Outfalls and discharge points from new construction are identified in the ESM as the construction projects are updated annually in the database.
II.B.1.(c)	Include outfalls for NCDOT industrial facilities in the inventory.	Outfalls and discharge points for NCDOT industrial facilities are updated biannually through the Stormwater Pollution Prevention Plan (SPPP) biannual inspection process and are mapped on the ESM annually.
II.B.1.(d)	Develop field outfall inventory procedure for priority areas.	NCDOT and NCDENR's Shellfish Sanitation and Recreational Water Quality Section have discussed the prioritization of inventories in sensitive coastal watersheds. In partnership with these agencies and other public and non-profit entities, NCDOT has developed a proposed multi-tiered field inventory process and prioritization framework, and will continue to develop this process with NCDWQ.

2.2.2. Stormwater Control Retrofits

To address pollutant loading from activities associated with its existing highway system, NCDOT has identified appropriate locations and implemented stormwater control retrofits.

Permit Ref.	Management Measure	Action
II.B.2.(a)	Identify appropriate retrofit sites.	NCDOT continues to identify locations for implementing Stormwater Controls. To date, NCDOT has identified over seventy (70) locations. These sites are located on primary routes that drain to sensitive waters. NCDOT will continue to collect and prioritize these sites as they are identified.
II.B.2.(b)	Implement/Install BMP retrofits.	NCDOT has implemented 48 Pet Waste Stations, applied latex asphalt in trout stream areas, and identified where NCDOT coordinates street sweeping activities in Year 2. In addition, NCDOT conducted an inventory of stormwater control retrofits that have been constructed by Division forces. The results of this report will be available in Year 3.

2.2.3. Stormwater Control Toolbox for Post-Construction Runoff

To ensure that the appropriate stormwater controls are used in the linear highway system, NCDOT has developed a Stormwater Control Toolbox, evaluated the suitability of stormwater controls, and implemented new technologies for the treatment of highway runoff.

Permit Ref.	Management Measure	Action
II.B.3.(c)	Evaluate design-related BMPs.	NCDOT continues to address stormwater during the planning phases and to sponsor research to evaluate stormwater control effectiveness and pollutant reduction. Research results document the efficiency of the control. Efficient and cost-effective controls are incorporated into NCDOT's design and planning processes when applicable. Examples of the ongoing research include studies involving Dune Infiltration systems with NC State University, and impervious area connectivity with the University of North Carolina – Charlotte.
II.B.3.(d)	Submit BMP Toolbox to NCDWQ for approval.	The initial chapters of the Stormwater Control Toolbox were submitted to NCDWQ on June 30, 2006. Additional chapters were submitted in January 2007 and NCDENR approved the Toolbox with requested changes to Chapter 3 on February 1, 2007. See table below for a list of chapters and their status.

Stormwater Controls Toolbox Outline

Chapter Description	Status
Chapter 1 – Introduction	Approved by NCDENR February 1, 2007
Chapter 2 – NCDOT Best Management Practices	Approved by NCDENR February 1, 2007
Chapter 3 – Level Spreader	NCDENR requested update in lieu of recent changes to NCDENR BMP Manual. Update is in process for release in Fall 2007.
Chapter 4 – Preformed Scour Hole	Approved by NCDENR February 1, 2007
Chapter 5 – Dry Detention Basin	Approved by NCDENR February 1, 2007
Chapter 6 – Grass Swale	Approved by NCDENR February 1, 2007
Chapter 7 – Forebay	Approved by NCDENR February 1, 2007
Chapter 8 – Hazardous Spill Basin	Approved by NCDENR February 1, 2007
Chapter 9 – Bridge Deck Drainage Control Systems	Submittal to NCDENR anticipated in Fall 2007
Chapter 10 – Stormwater Wetland	Submittal to NCDENR anticipated in Fall 2007
Chapter 2.4 – Stormwater Management Plans	Submittal to NCDENR anticipated in Fall 2007
Chapter 3 – Level Spreader (Updated)	Submittal to NCDENR anticipated in Fall 2007
Appendix – Drawing Details	Submittal to NCDENR anticipated in Fall 2007

2.2.4. Stormwater Control Inspection and Maintenance Program

NCDOT has established the Stormwater Control Inspection and Maintenance Program to help with the inspection, operation, and maintenance of stormwater controls.

Permit Ref.	Management Measure	Action
II.B.4.(a)	Evaluate BMP inspection and maintenance needs	The inspection and maintenance needs of stormwater controls currently in place at NCDOT facilities and some controls in the Toolbox were evaluated. Information from the evaluation was used to develop the Inspection and Maintenance Manual.
II.B.4.(b)	Develop a BMP Inspection and Maintenance Manual.	NCDOT submitted an initial draft Inspection and Maintenance Manual to NCDENR on February 16, 2007 which NCDENR approved.
II.B.4.(c)	Develop and implement a BMP Inspection and Maintenance Program.	NCDOT has initiated an Inspection and Maintenance Program which includes stormwater control inspection, assessment, maintenance, and tracking. In Year 2, NCDOT assessed 477 stormwater controls statewide and is developing a database to track their assessments. A training program for appropriate NCDOT staff is currently being pilot-tested to implement the tracking activities. Additional training for performing assessments and maintenance are being evaluated. Four NCDOT staff have completed certifications in NCSU's Stormwater BMP Inspection and Maintenance Certification.
II.B.4.(d)	Submit BMP Inspection and Maintenance information to NCDENR for review.	To date, 477 stormwater controls have been inspected and assessed for adequate functionality. Additional chapters will be added to the manual and submitted for NCDENR approval as developed. See table below for a summary of stormwater control types included in the inventory.

Stormwater Control Types included in the 2006 Inspection and Maintenance Inventory.

Stormwater Control Type	Total
Bioretention Basin	13
Bridge Drainage System	5
Dry Detention Basin	29
Infiltration Basin	36
Filtration Basin	8
Forebay	1
Swale	13
Hazardous Spill Basin	70
Level Spreader	31
Buffer	7
Pet Waste Station	65
Preformed Scour Hole	145
Proprietary Stormwater Controls	
Swirl Concentrator/Oil Water Separator	3
Catch Basin Insert	29
Stormwater Wetland	7
Wash Pad	4
Wet Detention Basin	11
TOTAL	477

2.2.5. Post-Construction Runoff Controls

NCDOT and NCDWQ will work together to develop the Post-Construction Runoff Controls Program (also know as the Stormwater Control Program) to apply the Stormwater Control Toolbox and other structural and nonstructural runoff control measures.

Permit Ref.	Management Measure	Action
II.B.5.(a)	Post-Construction Stormwater Control Measures	NCDOT continues to implement the post-construction control measures as required by water quality regulations and NCDOT practices.
II.B.5.(b)	Develop a Post-Construction Stormwater Program.	NCDOT has initiated developing a Post-Construction Stormwater Program to apply the Stormwater Control Toolbox and identifying additional Post-Construction controls that are currently integrated into NCDOT's business practices.

2.2.6. Vegetation Management

NCDOT maintains its well-established Vegetation Management Program to minimize environmental impacts through the continued application of its *Vegetation Management Manual* (October 1998) and training.

Permit Ref.	Management Measure	Action
II.B.6.(a)	Implement appropriate pest control practices.	NCDOT continuously consults with NCSU and NCDA, seeking guidance and receiving training, to ensure that the appropriate amount and type of pest controls are applied.
II.B.6.(b)	Use appropriate vegetation management materials.	NCDOT strictly applies vegetation management materials in compliance with their labeling.
II.B.6.(c)	Provide training on vegetation management.	NCDOT provides annual training for NCDOT staff and contractors responsible for vegetation management.

2.3. Encroachment

NCDOT will assist NCDENR to ensure that all discharges to NCDOT's highway drainage system are properly permitted. In addition, NCDOT will coordinate the process of reporting those nonpermitted or under-permitted discharges that can negatively affect NCDOT's discharges.

Permit Ref.	Management Measure	Action
II.C.(a)	Require certification of stormwater permit coverage and compliance.	NCDOT continues to require all facilities requesting to connect to NCDOT roadways to certify that the facility has the appropriate NPDES permitting.
II.C.(b)	Develop and implement strategies to address new development or redevelopment that adversely impact or have the potential to adversely impact NCDOT's discharges.	NCDOT and NCDWQ have collaborated on an encroachment strategy. NCDOT's current strategy includes requiring entities which connect to NCDOT right of way to certify they are adequately permitted through NCDENR and identify discharges which may impact NCDOT's drainage through the Illicit Discharge Detection and Elimination Program. In areas where the requirements of Part II.C *Total Maximum Daily Load Assessment* are activated, NCDOT and NCDENR will further work together to assess the impacts of indirect discharges to NCDOT's discharge affected by Part II.C. The strategy may be revised as necessary to maintain compliance. In coastal areas, NCDOT has further worked with NCDENR's Shellfish Sanitation and Recreational Water Quality branch to identify the impacts from various runoff sources including non-NCDOT sources.

2.4. Construction

2.4.1. Sediment and Erosion Control Program

The purpose of this program is to protect the quality of water at NCDOT's construction sites by ensuring that proper sediment and erosion control practices are followed. NCDOT continues to implement its manual, *Best Management Practices for Construction and Maintenance Activities* (August 2003).

Permit Ref.	Management Measure	Action
II.D.1.b(i)	Implementation of the NCDENR Division of Land Resources Erosion and Sediment Control Program delegated to NCDOT by the Sedimentation Control Commission in February, 1991, and as may be subsequently amended.	NCDOT continues to implement the Erosion and Sediment Control Program delegated by the Division of Land Resources. This program is reviewed annually by the NCDENR Division of Land Resources.
II.D.1.b(ii)	NCDOT shall incorporate the applicable requirements of NCG010000, the North Carolina General Permit to Discharge Stormwater under the National Pollutant Discharge Elimination System associated with construction activities issued October 1, 2001, and as may be subsequently amended, into its delegated Erosion and Sediment Control Program.	NCDOT has incorporated the applicable requirement of the NCG01000 into its delegated Erosion and Sediment Control Program, and continues to operate under the delegated program, as approved by the Division of Land Resources.

2.4.2. Borrow Pit and Waste Pile Activities

The Borrow Pit and Waste Pile Activities Program ensures that reclamation plans are followed at all borrow pits and waste piles.

Permit Ref.	Management Measure	Action
II.D.2.(a)	Implement erosion and sediment control measures on all borrow pits/waste piles.	NCDOT continues to implement erosion and sediment control measures required on borrow pits and waste piles as required by the North Carolina Sedimentation Control Commission.
II.D.2.(b)	Implement approved reclamation plans on all borrow pits/waste piles.	NCDOT continues to implement reclamation plans in accordance with a written protocol and the North Carolina Mining Commission.
II.D.2.(c)	Develop and Implement Borrow Pit Discharge Management Program.	NCDOT continues to implement the Borrow Pit Discharge Management Program developed with NCDWQ which includes the application of appropriate management measures and an inspection and maintenance program for borrow pits. Additionally, over 2,400 NCDOT staff have completed and passed the Erosion and Sediment Control/Stormwater Certification training for inspectors, installers and supervisors which includes discussion of borrow pit management.
II.D.2.(d)	Pilot Study	NCDOT continues to implement the Pilot Study through sponsored research programs. A draft report from the researchers is currently under review by NCDOT. A draft copy is attached as Appendix A.

2.5. Industrial Activities

To ensure that NCDOT's industrial facilities are meeting permit requirements, NCDOT has implemented, maintained, and evaluated the effectiveness of the Stormwater Pollution Prevention Plans (SPPP) for each of its industrial facilities. In addition, NCDOT performs qualitative discharge monitoring at each facility.

Permit Ref.	Management Measure	Action
II.E.1.(a)	Maintain and implement a SPPP for each covered industrial activity and related facility.	Each active industrial facility has implemented a Stormwater Pollution Prevention Plan. Annual and semiannual requirements are documented in the SPPP at each facility as required by Part II.E.2 of the permit.
II.E.3.(a)	Perform visual monitoring at each facility.	Outfall monitoring is performed at each individual stormwater outfall semiannually as required by the permit and the SPPP for each facility.

2.6. Education and Involvement Program

2.6.1. Internal Education

NCDOT continues to develop and implement an internal education program to train NCDOT personnel and contractors to be aware of stormwater pollution. A summary of training can be provided upon request.

Permit Ref.	Management Measure	Action
II.F.1.(a)	Provide pollution prevention awareness training for construction workers.	Stormwater pollution awareness training is provided to NCDOT personnel and contractors to address pollution prevention through construction and post-construction activities.
II.F.1.(b)	Provide pollution prevention awareness training for maintenance workers.	Stormwater pollution awareness training is provided to NCDOT staff, Adopt-A-Highway volunteers, and prison laborers to address general stormwater pollution, prevention, and reporting.
II.F.1.(c)	Provide pollution prevention awareness training for NCDOT staff.	Stormwater pollution awareness training is provided to NCDOT staff to address pollution prevention through the Stormwater Pollution Prevention Plans.

2.6.2. External (Public) Education

NCDOT continues to develop and implement an external education program to educate the public about stormwater quality and NCDOT's efforts.

Permit Ref.	Management Measure	Action
II.F.2.(a)	Update and submit an External Education and Involvement Plan to NCDWQ for approval.	Approval for the External Education and Involvement Plan submitted to NCDWQ on April 1, 2006 has not yet been received. However, NCDOT continues to identify and participate in public educational opportunities.
II.F.2.(b)	Provide pollution prevention awareness educational materials to general public.	Numerous pollution prevention awareness materials have been distributed through the State Fair, rest areas, and NCDOT's website. Educational programs have targeted school-aged children through teacher out-reach materials and the motoring public through mail-outs included in license renewal notices. Additionally, NCDOT shares its programs with other environmental professionals through providing speakers to professional organizations such as the Water Resources Research Institute, the American Public Works Association, and the American Society of Civil Engineers. See the External Education and Involvement Plan for further details.
II.F.2.(c)	Maintain a public education website.	The Highway Stormwater Program public education website went live on March 17, 2005. It is available at http://www.ncdot.org/environment/stormwater/

Permit Ref.	Management Measure	Action
II.F.2.(d)	Develop educational partnerships.	NCDOT has developed partnerships with numerous agencies, including NCDENR's Office of Environmental Education. See the External Education and Involvement Plan for further details.
II.F.2.(e)	Continue public involvement programs.	100,000 volunteers have participated in the Adopt-A-Highway program, through which they receive information on illicit discharges. Additionally, the Adopt-A-Highway program boasts over 3.6 million pounds of roadside litter was collected in 2006, with over 240,000 pounds being recycled.

2.7. Research Program

NCDOT's Research Program sponsors and supports research conducted at state universities. This research evaluates the impacts and effects of water quality in the highway environment.

Permit Ref.	Management Measure	Action
II.G.2.(b)	Submit the Research Plan to NCDWQ for approval.	The Research Plan was submitted to NCDWQ on April 1, 2006. NCDOT continues to identify and support research opportunities.
II.G.2.(c)	Implement the Research Plan.	NCDOT continues to sponsor research. The Research Plan will be fully implemented upon receiving approval from NCDWQ.

3. Water Quality Improvements

Through the implementation of its Environmental Stewardship Policy and the HSP, NCDOT continues to contribute to water quality improvements statewide. Further qualitative improvements will continue as NCDOT applies structural and nonstructural stormwater controls in retrofit and post-construction practices.

Furthermore, NCDOT drafted additional guidance for personnel and contractors to avoid adverse stormwater and water quality impacts to include in its *Standard Specifications for Roads and Structures* (July 2006).

4. Successes in the Highway Stormwater Program

Throughout the development of the HSP, NCDOT has successfully fostered department-wide communications to form applicable, effective processes and programs that meet the goals of the HSP and the Environmental Stewardship Policy. Additionally, the HSP has provided additional opportunities for open communication between NCDOT and NCDWQ.

Activities related to the HSP continue to be integrated into NCDOT business operations and other environmental programs, such as the Merger Process, resulting in a cohesive and effective use of resources with respect to environmental issues. Examples of these successes follow:

- *Unique Transportation Land Use Layer*. In partnership with the NCDWQ's Modeling & TMDL Unit, NCDOT developed the first GIS-based land use cover layer for the Falls Lake watershed which includes data for transportation land uses. The layer was provided to NCDENR for use in developing total maximum daily loads (TMDLs) for the watershed and qualifying NCDOT's wasteload allocation.
- *Coastal Partnering Initiatives*. Since 2004, NCDOT has been working closely with NCDENR's Shellfish Sanitation and Recreational Water Quality Section and the NC Coastal Federation (NCCF) to develop methods for enhancing the identification and distribution of information related to stormwater problem areas potentially affecting shellfish harvesting waters. This innovative partnership is designed to improve the efficiency and effectiveness of various NCDOT NPDES permit compliance initiatives in the coastal zone while also supporting the goals of NCDENR's Coastal Habitat Protection Plan.

  In 2006 NCDOT along with its project partners, NCDWQ, NCCF and the Town of Cedar Point, initiated development of a fecal coliform TMDL for several impaired embayments along the White Oak River. This project, partially funded by a 319 grant, includes extensive dry and wet weather sampling to better quantify the extent of impairment and support a detailed source assessment. The resulting water quality modeling and TMDL analysis will be used to support development of an implementation plan to restore the shellfish harvesting uses.
- *State-wide Stream Mapping*. NCDOT has contributed to the success of the Stream Mapping Program by participating as a core member of the Technical Advisory Committee since 2004. NCDOT also contributed prioritization information to Phase II of the mapping program and funds a Stream Mapping Coordinator position within NCDENR's 401 Unit.
- *Innovative stormwater controls at a LEED-certified (Leadership in Energy and Environmental Design) rest area.* NCDOT's new initiative to implement "green" building concepts in its rest areas in Wilkes County have been teamed with stormwater controls.
- *Partnerships with regulatory agencies and environmental organizations.* NCDOT participates in many projects that are initiated by other organizations. Participation can include providing expertise and input, to implementing stormwater controls. Below is a brief list of these partnerships.
  - *House Creek Stormwater Control Research Partnership.* NCDOT participates in a research project initiated by the Ecosystem Enhancement Program (EEP) to study the water-shed wide affects of stormwater controls. NCDOT will design, construct, and maintain several stormwater controls for the study.

- *Research on wetlands along highways.* NCDOT has coordinated a contract with NCSU Department of Biological and Agricultural Engineering school to study roadside wetlands.
- *NCDENR's Ocean Outfall Study.* NCDOT provides assistance, as needed, to support NCDENR's study.
- *Knowledge share to identify potential retrofit locations.* NCDOT is working to develop open communications with other agencies such as NCDENR's Watershed Restoration Coordinators to identify potential locations for retrofit projects.
- *Use Restoration Waters Program Partnership.* NCDOT is working with NCDWQ's Use Restoration Waters Program coordinator to develop a sustainable communication protocol for sharing information on restoration opportunities associated with stormwater management. Initial partnership activities have led to the identification of a NCDOT stormwater control retrofit opportunity designed to advance the goals of the McDowell Creek watershed restoration plan developed by Charlotte-Mecklenburg Storm Water Services. Construction of the retrofit is scheduled for the later half of 2007.
- *Pet Waste Stations.* Since the spring of 2006, NCDOT has been installing pet waste stations at rest areas, welcome centers, and visitor centers across the State to reduce the potential for nutrient and bacteria/parasite contamination from pet waste (mainly dogs and cats). These "stations" consist of a post with a pet waste sign and bag dispenser. Currently, NCDOT staff has installed 90 pet waste stations at 31 rest areas. Sites have been selected based on a high potential for surface water contamination and the high potential for usage based on the number of travelers that utilizes a particular rest area.

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Attachment A
Final Report

NCDOT Research Project HWY-2006-22

Stilling Basin Design and Operation for Water Quality

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Introduction

Many construction projects involve the need to pump turbid water from borrow pits or other excavations into stilling basins prior to discharge. The design and operation of these basins needs to be optimized to provide the best water treatment prior to discharge. This project was designed to provide an evaluation of stilling basin designs and operations which will minimize turbidity in discharged water. The purpose is to provide several options for installing and operating stilling basins in the Coastal Plain where pumping from borrow pits and excavations may result in water with significant turbidity. This phase of the study was conducted in our laboratory and at our Sediment and Erosion Control Research and Education Facility in Raleigh, NC.

Materials and Methods

There were two phases to this project, one conducting screening tests in the laboratory and one testing different designs in a simulated borrow pit in the field. The initial screening consisted of seven different PAM products with varying charge, charge densities and molecular weight. Charges included neutral, cationic and anionic. The charge densities of the anionic and cationic polymers ranged from 5 – 50% and the molecular weights ranged from low to high. PAM products tested included Cytec Industries Super Floc N300, N300 LMW, A150, A150 LMW (Cytec Industries, Patterson, NJ, USA); NALCO 9909, 9919 (NALCO Industries, Chicago, IL, USA); and Geofloc 1800 (GeoSpec, Inc., Raleigh, NC, USA). The products were individually evaluated for turbidity reduction using a jar test. A jar test consisted of filling a 100 mL specimen cup with 100 mL of deionized (DI) water, adding 5 g of soil, then pipetting a PAM solution into the cup to result in a specified concentration. The cup was then shaken for 10 seconds to induce contact between the polymer and the soil. After 20 seconds of settling, turbidity was measured using a nepholometer (McVan Instruments, Victoria, Australia) inserted into the cup and read after 10 seconds. The readings were later corrected using a regression curve developed from readings of formazin standards taken after each set of samples was read.

Stock solutions of PAM were made by adding 500 mg of granular PAM to 1 L of DI water and stirring until the PAM was completely dissolved. The solutions were allowed to age for 12 – 24 hours before use. Seven concentrations evaluated in the initial screening: 0 (control), 0.25, 0.5, 1, 2, 5 and 10 mg L^{-1}.

The stock solution was diluted to produce PAM solutions having concentrations of 25 mg $L^{-1,}$ 50 mg $L^{-1,}$, 100 mg $L^{-1,}$, and 250 mg L^{-1}. These dilutions enabled us to produce the range of concentrations evaluated in our screenings by adding 1 mL of PAM solution to the 100 mL sample cups. This provided the same final volume (101 mL) of all of the test solutions.

The second round of laboratory screenings was conducted using turbid water generated in the lab. The turbid water was generated by first adding 5g of soil to 100 mL of DI water in a specimen cup. The cup was shaken for 10 seconds and allowed to settle for 20 seconds, After settling, the supernatant was decanted into a 1 L sample bottle. This decanting process was repeated twice into the same 1 L bottle. The sample bottle was then filled with tap water and shaken to suspend the sediment. This process produced turbid water consisting primarily of fine sediment that would maintain a fairly stable turbidity level over a few hours. This procedure, as compared to the procedure using 5 g of bulk soil, produced turbid water that more closely resembled the turbid water being produced in the field. Screenings with the turbid water were conducted using the same jar test described above.

The turbid water was generated using tap water initially, however a preliminary round of screenings suggested that a discrepancy existed between the turbidity levels obtained in the field and those obtained in the lab. The PAM was noticeably more effective at reducing turbidity in the field compared to the lab results. A chemical analysis of the two water sources indicated that the pond water contained higher concentrations of ions than the tap water.   As a result, all PAM screenings were generated using pond water in order to more closely simulate the natural waters where PAM might be used.

A simulated borrow pit operation was developed at the Sediment and Erosion Control and Research Facility located at the Lake Wheeler Field Laboratory to evaluate the effectiveness of a number of turbidity reduction options for pumped construction site water. The Sediment and Erosion Control Facility consists of a 300 m^3 source pond and three sediment basins varying in dimension. A 12” PVC pipe, with a valve to control flow rates, exits the bottom of the source pond and delivers water to the basins for testing. Borrow pits typically have to pump water out of the pit to obtain the borrow materials, and this water is often turbid from the excavation activities. To simulate this turbidity, water from the pond was released into the pipe at (flow = 0.5 cfs) which emptied into a 40’ x 20’ x 3’ basin while adding soil to the stream over a 30 minute period. Buckets of soil were added through a hole in the pipe at a controlled rate for 30 minutes.   A single, porous baffle of jute and coir geotextile was installed at about 1/3 of the length of the basin to retain the heaviest materials in the upper part of the basin. The rate of soil addition and flow was determined through a series of preliminary runs to produce a reasonably stable turbidity of approximately 400 -600 NTU. This coincided with turbidities which were occurring at several borrow pits which had been particularly problematic.

The soils used to generate the turbid water came from two borrow pits in the Coastal Plain region of the state. The borrow pit water being pumped at these sites was highly turbid and traditional treatment in stilling basins was not working well. Two large truckloads, approximately 20 cu yds, of each soil were delivered to SECREF and moved into covered storage shelters. The exact source locations are unknown and both sites encompassed very large acreages. It is likely that each sample is a mixture of materials from different depths mixed during the course of excavation and loading the truck. . One site was east of Plymouth, NC where the NC 64 Bypass was under construction, immediately adjacent to the Tidewater Research Station. The second site was northwest of Lumberton, NC, at the site of Interstate 95 construction.

The turbid water was pumped to a second basin using a Hypro model C-35 pump with a 3 inch intake and a 2 inch discharge. The size of the second basin, was 30’ x 15’ x 4’ and it functioned as a stilling basin.. The flow rate of the pump was calibrated before testing began. During a test the initial flow rate of the pump was set at approximately 80 GPM, and then reduced to 50 GPM once the level of water in the basin approached the top of the outlet. The initial pumping rate was higher just to fill the basin more quickly. The 50 GPM flow rate was determined based on the pumping capacity of the Hypro pump and was felt to be proportional to rates seen on actual construction sites, given the scaled down dimensions of our pumping operation. A standard stilling basin for NC DOT is 180’ x 90’, or 16,200 square feet. Ours is 30’ x 15’, or 450 square feet, which is approximately 2.8% of the standard basin. This means that 50 GPM is about the same as 2,000 GPM into a standard basin, which is a relatively high pumping rate. The stilling basin was had a 6 inch flashboard riser outlet. ..For our testing the boards were set to overflow once the depth reached 3 feet . The outlet of the flashboard riser was connected to a 6 inch PVC pipe through the dam. Additional 6 inch pipes were added to bring the flow approximately 120’ downhill and into a sediment bag. The sediment bag was tested as a post stilling basin polishing system. The sediment bag was made of a polypropylene non-woven geotextile fabric and had dimensions of 10 x 15 feet. A weir was constructed below the sediment bag to measure the flow of water exiting it. A tarp was placed under the sediment bag to ensure that all of the water permeating through the bag was collected and diverted over the weir. The bag sat on a pad of 12 x 12 inch Geogrids, a honeycomb material used for permeable pavement, to allow flow through the bottom. A tarp was placed under the Geogrids to capture the flow from the bag and direct it into the weir.

The testing we conducted consisted of both physical and chemical treatments in all combinations. The physical variables were included changes to the basin configuration: open, porous baffles, and a rock baffle. The baffle treatments that were evaluated in our testing were installed in the simulated stilling basin. The jute/coir baffles were faced with woven jute fabric having 1 inch holes and backed with a coir mesh erosion control blanket. Three of these baffles were spread across the entire cross sectional width of the

basin. The baffles were 3.5 feet tall and were spaced 10 feet apart from one another. The first baffle was installed 10 feet from the entrance of the basin and the third baffle was installed 8 feet from the outlet. The single rock baffle was constructed using class B stone and was located 12 feet from the entrance of the basin and 20 feet from the outlet. The baffle stood 3.5 feet high and had a width of 4 feet at its base. The baffle spanned the entire cross sectional width of the basin. This is the standard baffle currently used in stilling basins.
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The chemical variables involved no treatment and treatment with two different types of PAM. The two PAM products (SF N300 and NALCO 9909) used in field testing were determined through a series of laboratory screenings. The most effective dosing concentration of each PAM was also determined through the laboratory screenings to be 5 mg L^{-1}. The PAM was introduced into the pumping system as a solution using a variable speed, peristaltic pump. The PAM was injected directly into the intake hose of the Hypro pump as the turbid water was being pumped from the simulated borrow pit to the stilling basin. The peristaltic pump was calibrated to maintain 5 mg PAM L-1 at both pumping rates (80 and 50 GPM) used in testing. A fresh stock solution of PAM was made before each test using a sump pump to mix granular PAM in a 55 gallon drum until it was completely dissolved. The concentration of the stock solution (3.5 g gal-1) was based on the pumping capacity of the peristaltic pump and allowed for the proper dosing of PAM given the pumping rates of both the peristaltic pump and the Hypro pump. PAM solution was continuously injected into the intake of the water pump flow for the duration of the test.

Sampling was accomplished using ISCO Model 6700 automatic samplers. One sampler collected borrow pit water at the rate of 500 ml every 15 minutes throughout the duration of a test. The sampling program was initiated at the start of pumping which represented time zero of a test. The intake of this sampler was located in close proximity to the intake of the Hypro pump. These samples were indicative of the initial turbidity levels of the untreated turbid water. A second sampler was located at the outlet of the stilling basin. The intake of this sampler was located on a T-post in close proximity to the flashboard riser outlet and took samples from 1.5 inches below the top of the outlet. A bubbler was installed at the top of the flashboard riser and was utilized to measure the flow exiting the outlet. The sampling program was initiated automatically at a level indicative of a steady state of flow. Samples (500 mL) were automatically collected every 2 minutes for a duration of at least 30 minutes. A third sampler was located at the weir below the sediment bag below the stilling basin. A bubbler on this sampler was installed to measure the flow over the weir. The sampling program was initiated manually immediately after the first sample was taken at the stilling basin outlet. Samples (500 mL) were taken every 2 minutes for at least 30 minutes.

Results

The two Coastal Plain soils did have significant smectite content with high cation exchange capacity (Table 1). They also had significant clay content. This confirmed our hypothesis that this was the reason why these borrow pits had so much difficulty with turbidity.   In a previous study, we also found certain soils from this region would produce relatively stable turbidity.

A screening of polyacrylamides with different properties indicated that the anionic PAMs were not very effective on the suspended materials but cationic and neutral PAMs were effective flocculators (Figure 1).   The anionic PAMs reduced turbidity at the lowest concentration (0.5 mg L^{-1}), particularly the least ionic (A100), but additional PAM resulted in less flocculation in most cases. The two cationic PAMs appeared to flocculate somewhat better than the neutral PAM, but only slightly. For further testing, we dropped out several of the least effective anionic PAMs.

Table 1. Results of the analysis of the Plymouth (P) and Lumberton (L) sediment samples.

Particle Size Distribution (%)				**Dominant Mineralogy of Clay Fraction (percent)***			**Soil pH**	**Cation Exchange Capacity (meq/100g)+**	
	Sand	Silt	Clay	Kaolinite	Vermiculite	Smectite		Fine Clay	Coarse Clay
P	58	12	30	55	25	20	4.7	23.1+/-0.01	16.6 +/-0.6
L	55	13	32						

Plymouth Soil

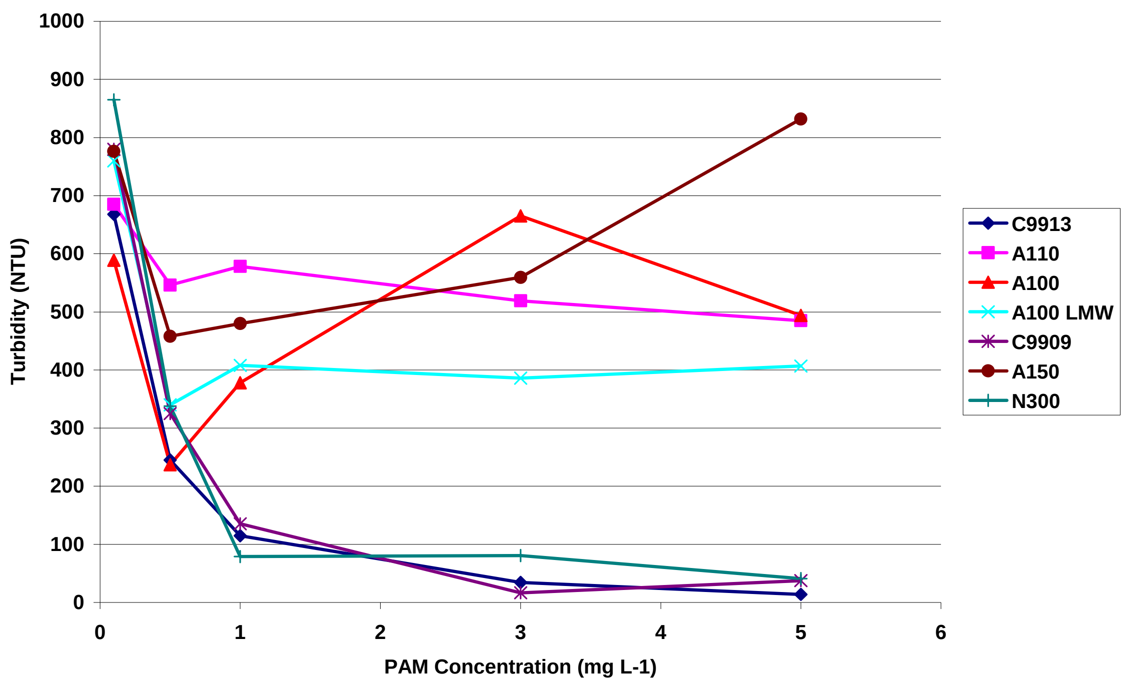

Figure 1. Results of screening tests for seven PAMs using the Plymouth sediment to generate turbidity. PAMs with a "C" are cationic, "A" are anionic, and the "N" is neutral. The usual method of screening PAMs for effectiveness involves adding soil to water and shaking them with different PAMs. Following this procedure for the Plymouth soil, we found that even the anionic PAM (GF 1800) was very effective at reducing turbidity (Figure 2).

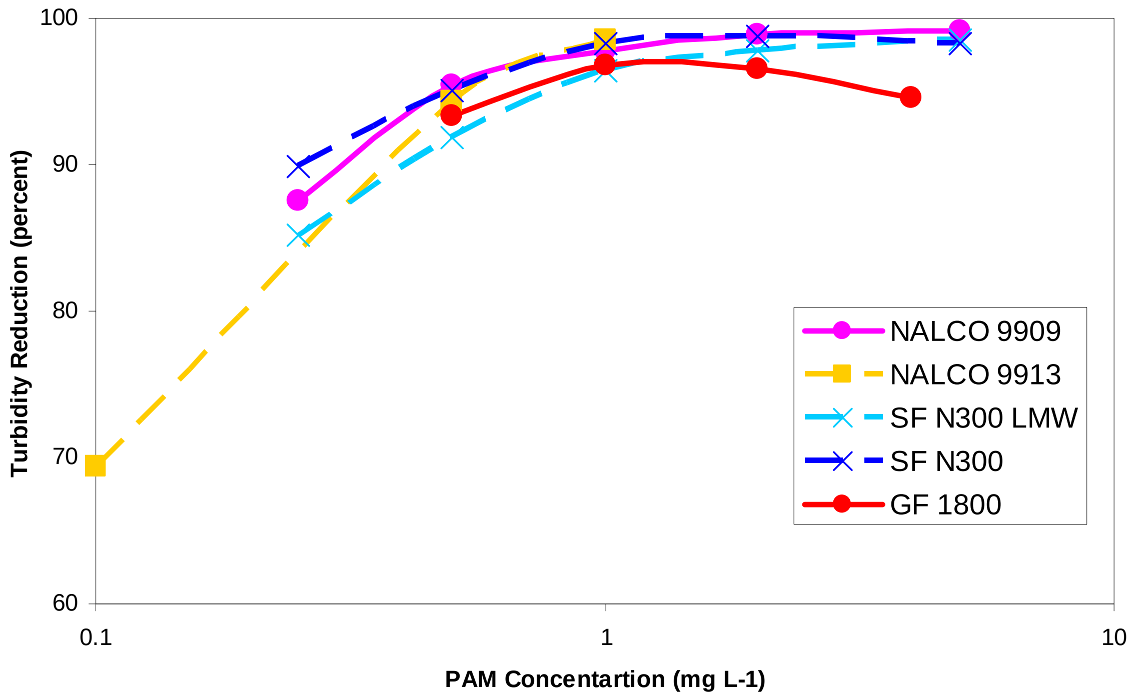

Figure 2. Turbidity reduction for the Plymouth borrow pit soil when mixed with PAM with different properties. This represents the results of mixing 5 g soil with 100 mL water, which produced about 3,000 NTU with no PAM.

However, when we conducted the screening using only the supernatant from the soil-water mixture, the results were very different. The cationic PAM (NALCO 9909) reduced turbidity by more than 90% while the anionic PAMs achieve a peak of 70% at 0.5 mg L^{-1} but were less effective at other concentrations (Figure 2). The neutral PAM achieved more than 80% reduction at 1 mg L^{-1} or more. As it turned out, these results are much more representative of those we found in the field tests. A comparison of the responses of both soil sources shows that they had remarkably similar responses to the PAMs we tested (Figure 4).

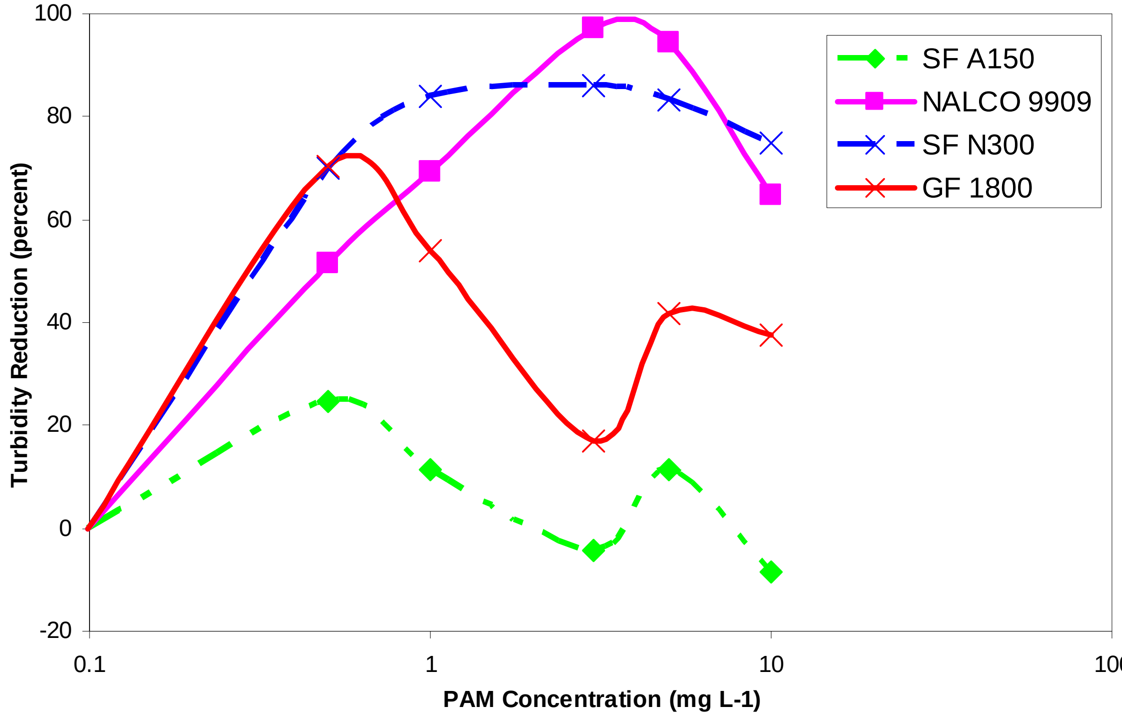

Figure 3. Turbidity reduction for supernatant from the Plymouth borrow pit soil when mixed with PAM with different properties. This involved only the turbid water after allowing the soil to settle for 30 seconds, which resulted in about 600 NTU with no PAM.

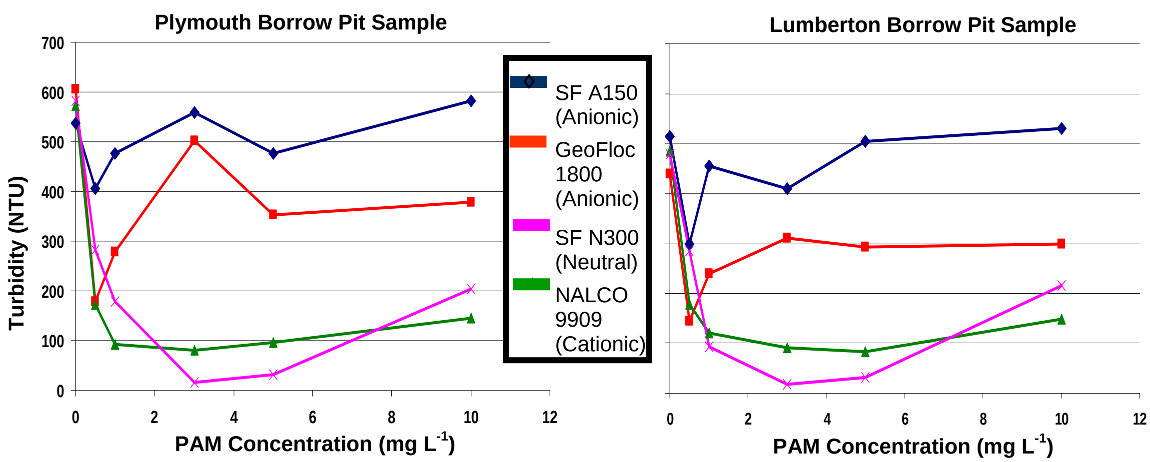

Figure 4. Results of the laboratory screening of PAM for flocculation of the two sediment sources.

In order to determine the relative toxicity of the PAMs to aquatic biota, we had an anionic, a cationic, and the neutral PAM tested in a standard effluent toxicity assay. This was the 7-day *Ceriodaphnia dubia* reproduction test, considered among the most sensitive aquatic bioassays. Among these, the neutral PAM was the least toxic and the cationic was the most toxic (Figure 3). In fact, even at the highest dose (50 mg L^{-1}) the neutral PAM was relatively non-toxic. The addition of turbidity (60 NTU, Plymouth soil source) to the assay did not have appreciable effects.

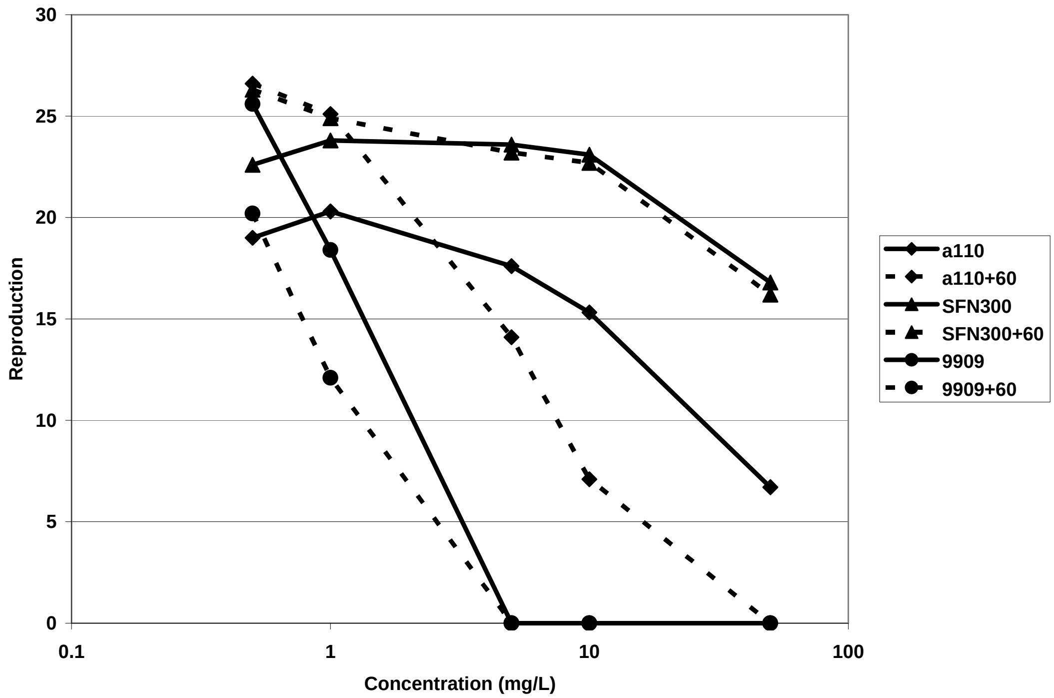

Figure 5. Toxicity of PAM to *Ceriodaphnia dubia* in a 7-day reproduction assay. The three PAMs are anionic (A110), neutral (N300), and cationic (C9909). The dashed lines indicate tests conducted with an initial turbidity of 60 NTU (+60) using the sediment from Lumberton.

The controlled field testing at SECREF was conducted by mixing sediment from the two sources into water flowing into a sediment basin with a porous baffle (Figure 5). The resulting turbid water was pumped to a stilling basin with no baffles, porous baffles, or a rock (Type B) baffle. The PAM solutions were introduced at the pump intake at a dose of 5 mg/L. The pump was run at 50 gpm, which results in an approximate two hour retention time in the stilling basin. The water leaving the stilling basin was drained through a geotextile bag as a test of its potential for further polishing. Samples were taken using automatic samplers placed at four points in the system.

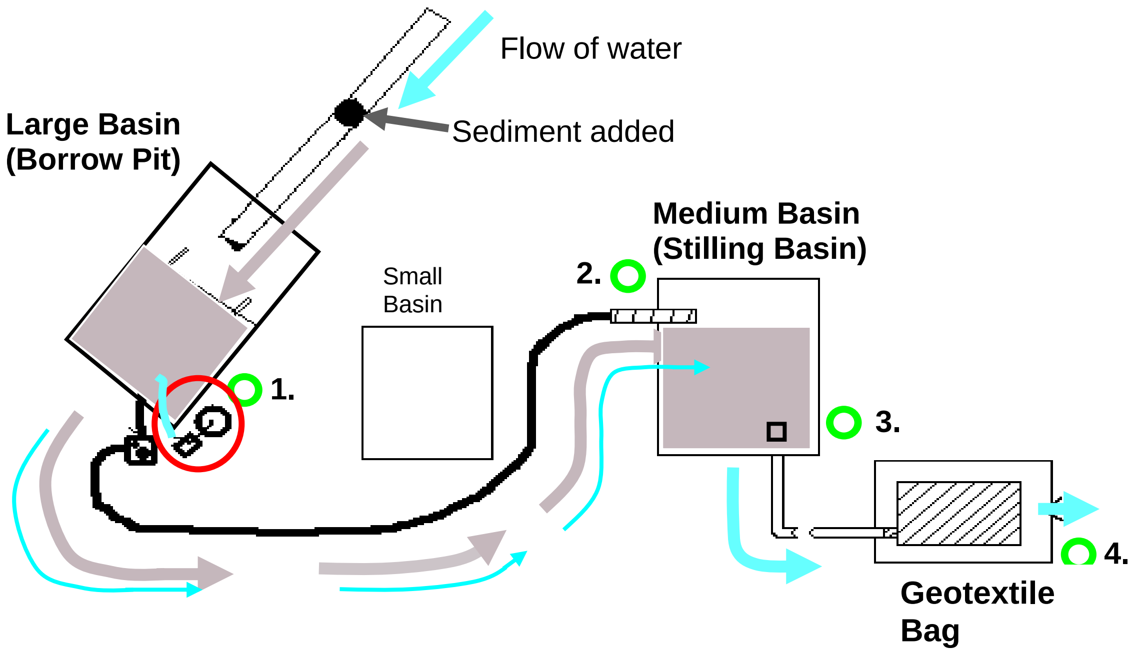

Figure 6. Diagram of the simulated stilling basin system used for controlled field tests at SECREF. Each number represents a sampling point. The pump and PAM dosing system are indicated by the red circle.

The samples for treatment comparisons were taken when flows equilibrated at the outlets, which is what occurs at borrow pits most of the time when pumping occurs. This is illustrated by the turbidity and flows during an untreated, open basin test (Figure 5). Turbidity in the simulated borrow pit basin were generally in the 400-700 NTU range. The reduction in turbidity by passing this through the stilling basin and geotextile bag was mostly <25% (Figures 5 and 6). The one exception was a test with the Plymouth sediment in which the geotextile bag reduced turbidity 75% (Figure 5). This was an anomaly caused by the use of the bag after many other tests, resulting in a relatively clogged bag with abnormal filtration capacity.

The cationic PAM was the most effective, with up to 99% turbidity reduction. The additional treatment through the geotextile bag did not have much effect in further reducing turbidity. The neutral PAM reduced turbidity 80-90% for the Plymouth sediment and 60-85% for the Lumberton sediment. The flocs formed were noticeably smaller than those for the cationic PAM treatment. The geotextile bag did provide some additional trapping for the Lumberton sediment source.

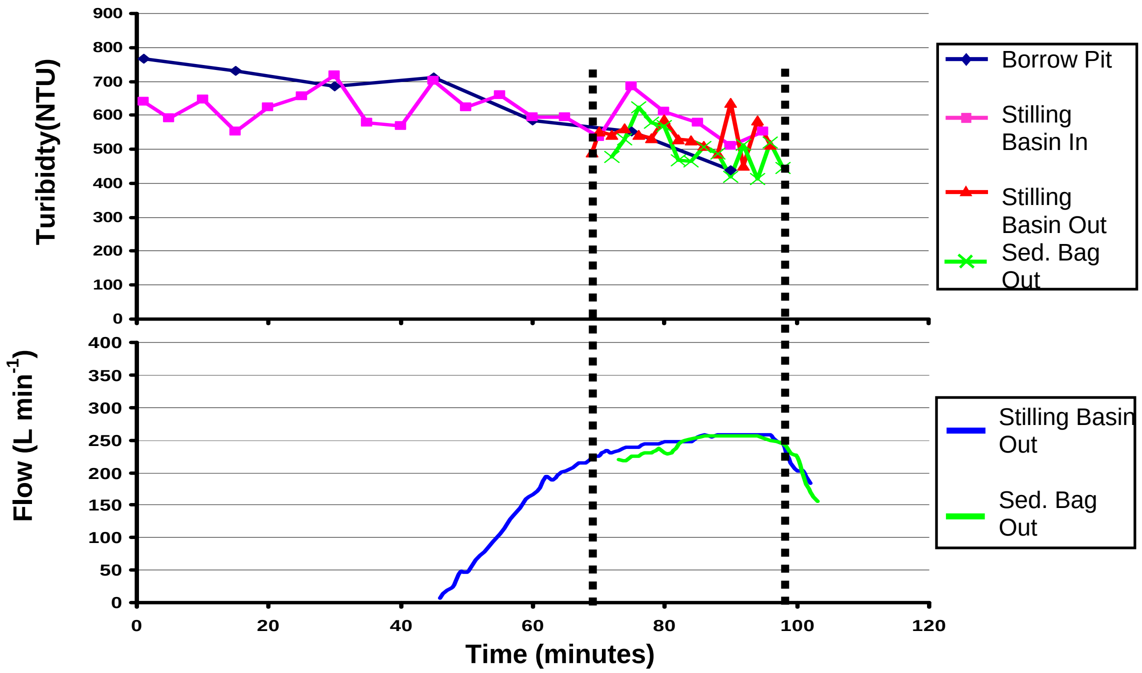

Figure 7. Turbidity and flows during a test of the stilling basin with no PAM added.

The baffles did not appear to provide any benefits either with or without PAM treatment. This is likely due to the way the test was conducted. We mixed the sediment with the water flowing into the simulated borrow pit, but we installed a baffle to collect the coarse material. As a result, we were pumping only the finer, hard to settle solids, so even under ideal settling conditions there was little settling which occurred. The flocculation with the cationic PAM produced large enough flocs that they settled even in the open stilling basin. The rock baffle appeared to reduce settling by the smaller flocs formed with the neutral PAM.

The outlet of our stilling basin was a flashboard riser which therefore dewatered from the top of the water column. We did note that the PAM treatment process produced some floating flocs as well as those that settled. Because our sampler intake was approximately two inches below the surface, these were not sampled during our testing. The baffles effectively removed these floating flocs but the open basin released them.

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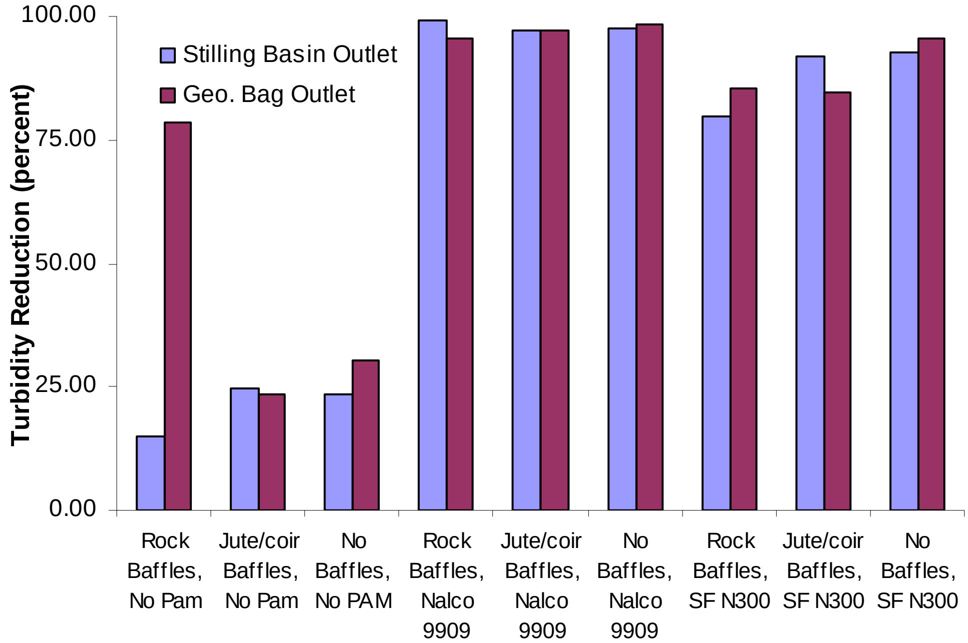

Figure 8. Turbidity reduction for the Plymouth sediment measured at the stilling basin outlet (Flbd. Riser Out) and the geotextile bag (Geo. Bag) outlet. The stilling basin had either a single rock baffle (Rock), three porous baffles (Jute/coir), or no baffle (None).

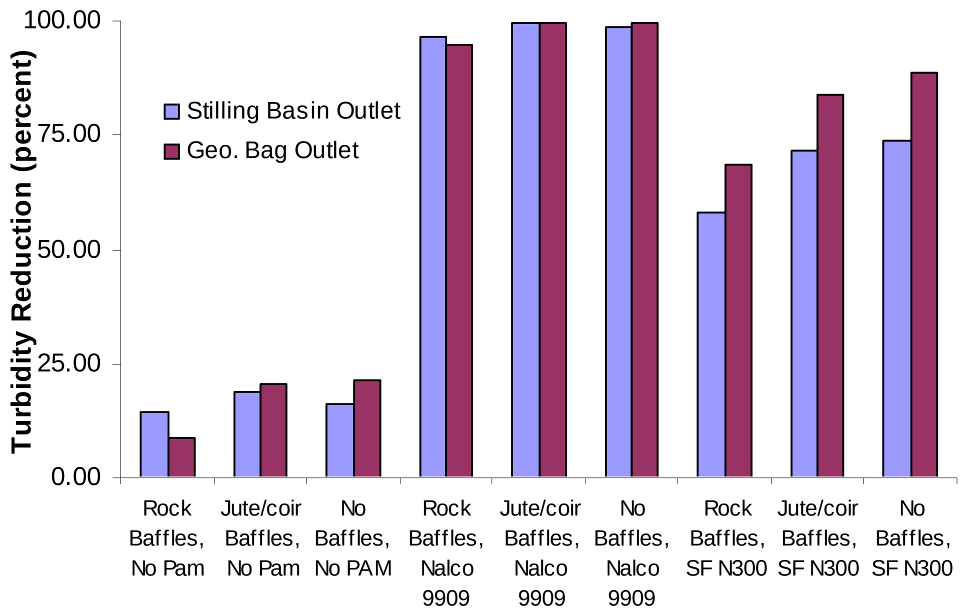

Figure 9. Turbidity reduction for the Lumberton sediment measured at the stilling basin outlet (Flbd. Riser Out) and the geotextile bag (Geo. Bag) outlet. The stilling basin had either a single rock baffle (Rock), three porous baffles (Jute/coir), or no baffle (None).

We also tested standard sediment bags with and without PAM to determine their effectiveness in removing turbidity. These tests involved all of the same procedures at the basin tests but we pumped into a 10' x 15' geotextile bag instead. The Plymouth soil was used for these tests, which were done in triplicate. The results for a test with no PAM and one with PAM added are shown in Figures 10 and 11, respectively. When no PAM was added, the bag removed an average of 18% of the turbidity, while the turbidity reduction was almost 98% with PAM.

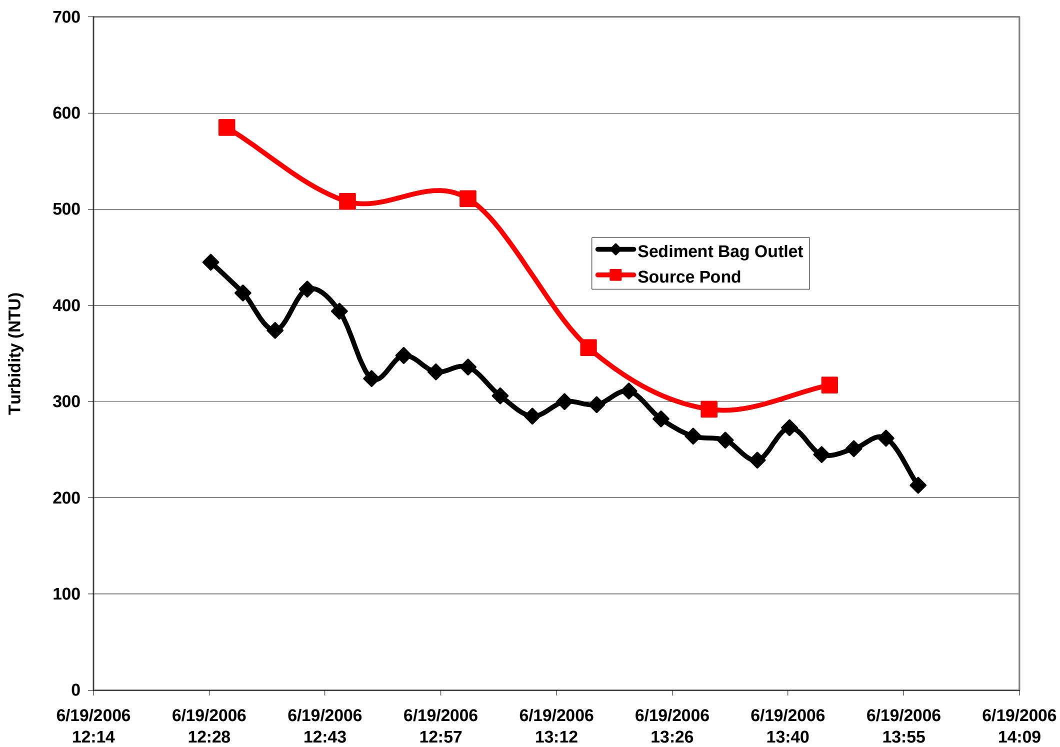

Figure 10. Effects of pumping turbid water through a geotextile bag.

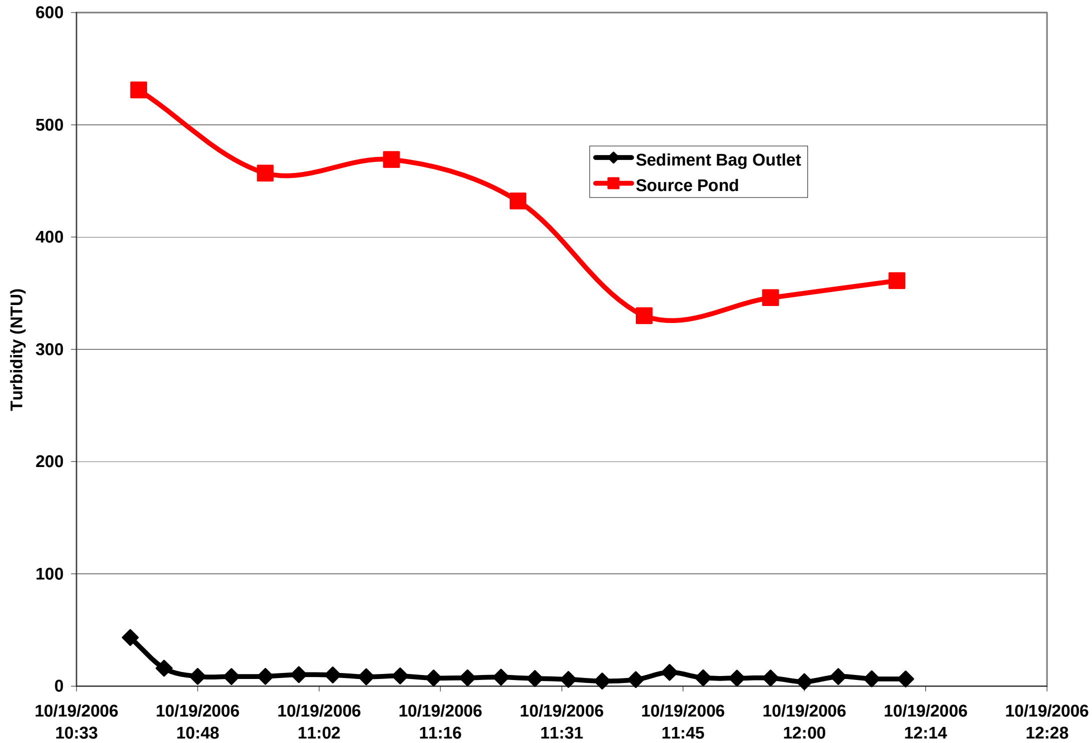

Figure 11. Effects of pumping turbid water through a geotextile bag after dosing with 5 mg L^{-1} cationic PAM.

Recommendations:

- The use of stilling basins will not likely result in significant reductions in turbidity in water pumped from borrow pits in these types of soils.
- Some sediment sources, particularly those with significant smectite content, will not be flocculated by anionic PAM but can be flocculated by neutral or cationic PAM.
- The flocculation process reduced turbidity regardless of the inclusion of baffles. However, at least one baffle is recommended when PAM is being used in case floating flocs are formed.
- The neutral PAM was almost as effective as the cationic PAM and was even less toxic than the anionic PAM, so it may be an alternative where the anionic PAMs that are available will not work.