POLITICAL, ECONOMIC AND ENGINEERING CHALLENGES FOR REDUCING SEDIMENT LOADS IN STREAMS IN THE GEORGIA PIEDMONT

Philip D. Freshley

AUTHOR: Environmental Soil Scientist, LandTec S.E. INC., 1901 Cedar Road, Watkinsville, GA 30677.
REFERENCE: Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Monitoring of turbidity of storm water runoff from construction sites and the storm flow in receiving streams is required under Georgia's NPDES program (General Permit No. GAR 100000). Current standards for in-stream and effluent water quality are more stringent than the capabilities of current erosion and sediment control practice, and in many cases, less than sediment concentrations in streams in undeveloped watersheds. Permit holders have significant liability in non-compliance. Separating runoff impacts from in-stream variability is difficult. Fine clay particles common in the regions soils are difficult to remove from runoff. Modification of standards to recognize different levels of BMP performance, and utilizing storm flow data from undisturbed watersheds as a baseline is recommended.

INTRODUCTION

The Georgia Piedmont has been subject to extensive soil erosion and stream sedimentation (E&S) due to abundant rainfall (110-130 cm/yr) and a long history of land disturbance beginning with extensive row crop agriculture in the 1800's to early-1900's, and dominated from the late 1900's to the present by extensive commercial and residential development due to population growth. The U.S.D.A. Natural Resources Conservation Service (USDA-ARS, 1998) estimates an average of 0.5 feet of topsoil has been lost in this region over the last two centuries. From 1935 to 1960, sediment loads in rivers of the Piedmont declined due to conversion of agricultural lands to forestry (Hewlett and Nutter, 1969). Since 1969, there has been an increasing trend of conversion of farm and forest to urban uses. From 1982 to 1992, urban land represented the single largest increase in Georgia land use with approximately 700,000 acres converted (Cosby and Liles, 1992). Studies in one Piedmont County indicate that sediment loads and storm water flow volume in streams have been increasing in developing areas in proportion to development density (Landers, et al., 2002). The net effect is increasing sediment movement in and from watersheds of urbanizing areas.

To control erosion and sedimentation, the State of Georgia passed the Georgia Erosion and Sedimentation Act in 1975 and has amended the law in 1980, 1985, 1989 and 1994. The law has resulted in the requirement of various best management practices (BMPs) for agriculture, forestry and construction. Improvements have been made in sediment retention. However, degradation of streams due to sedimentation in expanding urban and suburban areas from 1980-2003 has resulted in demands for additional controls and more stringent enforcement of existing law. During this same period, the U.S. Environmental Protection Agency (EPA) has required implementation of Phase 1 and 2 of the National Pollution Discharge Elimination System (NPDES) for construction sites. To facilitate additional regulation of E&S, the State impaneled a technical group to review current water quality standards for suspended sediments and make recommendations on improving the standard. The panel (known as Dirt 1) recommended an in-stream turbidity standard of 25 NTU. This standard was intended to be indicative of the average sediment load carried by the stream (GA Board of Regents, 1995).

A second technical panel (known as Dirt 2), was assembled in 1996 with the charge to review available technology and regional site conditions and develop a set of design, structural, and vegetative practices for construction sites that would achieve the water quality criteria suggested by Dirt 1. Dirt findings found runoff treatment could be significantly improved with innovative computer model-aided design that produced a system of controls using available technology. A successful demonstration project was conducted which achieved site discharge water quality two orders of magnitude better than typical practice in most rain events (CFRDC, 2001).

During the Dirt 2 study period (1996-2001), The Georgia DNR Environmental Protection Division (EPD) promulgated a general NPDES permit for construction activities (GAR 100000). The permit went through several revisions due to legal challenges by concerned citizens and environmental groups culminating in a document that was negotiated between stakeholder groups and EPD. The final document is the result of compromise by these various groups and was implemented August 1, 2000. The permit requires monitoring the turbidity of discharges or receiving streams at construction sites during significant rain events. The regulatory limit for in-stream turbidity is an increase of no more than 25 NTU between upstream and downstream points. The regulatory limit for discharges from a construction site is from 50-750 NTU based on the site and watershed size. In general, sites near first order streams are typically required to meet a 50 to 150 NTU discharge standard. However, the permittee is not liable for exceeding the limit if an approved erosion control plan is in place and properly maintained. The Permit is scheduled for renewal in mid-2003.

The permitted community has reported difficulty in meeting the standards and relating the monitoring results to on-site performance. At the time this paper was written, innovative practices such as those espoused by Dirt 2 are not required of a permittee. The goal of this paper is to increase understanding of the engineering and risk management challenges faced by the regulated community in complying with current and proposed legislation.

BASELINE STREAM SEDIMENT LOADS

Before we can understand man's impact on stream sediment, it is essential to first define sediment movement in relatively undisturbed "natural" watersheds and streams to establish a baseline or ambient condition for comparison. In all streams, sediment concentration varies with depth, velocity, turbulence, particle size and shape, channel geometry, physical and chemical properties of water, watershed size and topographic characteristics, climatic conditions and time (Chang, 2002). Any sample collected is influenced to varying degrees by all twelve properties. The result is that sediment concentration varies widely on a site-specific basis, even in systems undisturbed by man. Stream flow is generally subdivided into two types, storm flow and base flow, each with its own unique sediment load. During storm flow, suspended sediments can be greater than base flow by more than three orders of magnitude (Bonta, 2000). Most of the sediment movement occurs during storm flow events. Studies in Georgia and Wisconsin, indicate 99% of the sediment load occurs in storm flow and 80-90 % occurs during 2-3% of the total flow period (Chang, 2002; Landers, et al., 2002).

In general, undisturbed forested watersheds have the lowest sediment yield (Hewlett, 1982). Even in these undisturbed systems, sediment export is significant. For example, a long-term forest management study in the Piedmont indicated that an undisturbed forested watershed (used as a control) had annual sediment yield estimated at 82 lb/ac/yr or 26 tons per sq. mi. annually (Hewlett, 1979). These data suggest that sediment, to some degree, is ubiquitous in Piedmont stream systems. The question for scientists is how much is too much and how do you tell?

AN EXAMPLE FROM BIRDHOLE CREEK

Birdhole Creek, a first order stream near the author's home was sampled using NPDES sampling methods. Multiple samples were collected over a 48-hour period and indexed to stage and channel velocity. Birdhole Creek is a first order tributary of Wildcat Creek and the Oconee River in South Oconee County, GA. The watershed is undeveloped with land use dominated by pasture and forest. Stream banks and adjacent toe slopes are stable and vegetated by mature hardwood forest. The watershed is representative of relatively undeveloped stable landscapes in the Piedmont.

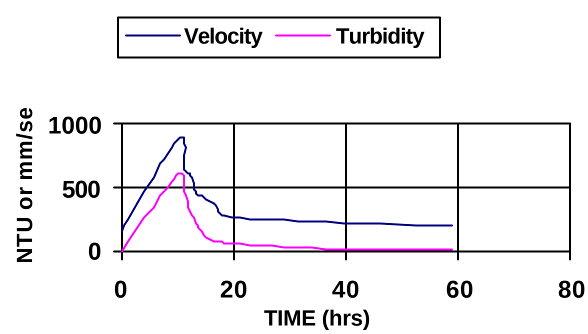

Figure 1. Birdhole Creek Turbidity

Following a week with no rain, base flow turbidity samples ranged from near 0 to 3 NTU. The storm flow resulting from a 1.7 inch (over 12 hrs) rain event are shown in Figure 1. Peak flow was reached 10.33 hours after the storm began. At peak flow, stream turbidity was near 600 NTU, gradually decreasing to about 8 NTU over 60 hours. Stream velocity and stage height curves were strongly correlated with turbidity. On this same creek a flashier storm in the summer produced a peak flow turbidity of 980 NTU. During the sampling period, samples were collected simultaneously in riffle and pool areas that were approximately 3 meters apart. Only the riffle data is presented in Figure 1. It is interesting to note that the pool samples averaged 37.5 NTU less than the riffle samples with a range of 1 to 71.3 NTU less. These data suggest that in-stream sediment concentration varies over short distances during storm events due to channel geometry and subsequent changes in velocity.

This example of an undisturbed watershed is provided to illustrate that under storm flow conditions, turbidities in the hundreds to near 1,000 NTU do occur naturally. Sediment concentration varied over time, and horizontally and vertically in the channel. During base flow, Birdhole Creek had low turbidity (1-3 NTU). This example is consistent with the three orders of magnitude change cited by Bonta (2000) and the study done on mountain streams by Sutherland, et al. (1998) that suggested that storm flow sediment concentrations were highly variable and base flow sediment data were easiest to correlate with stream biodiversity.

In summary, suspended sediment is a natural and common component of stream flow in the GA Piedmont. Stream sediment concentration is low for long periods (weeks-months) during base flow punctuated by short periods (hours to days) of high flow and high concentration following storm events when most sediment movement occurs. Storm flow sediment concentrations in the hundreds of mg/L or NTU appear to be common in undeveloped watersheds in Georgia. Developing a stage-TSS curve for a stream cross-section and access to stage data is required to estimate total mass moved and average sediment concentration (Chang, 2002). In the absence of pre-development data, baseline stream sediment loads can be estimated by collecting stage and sediment concentration data from streams in relatively undisturbed forested watersheds with similar climate, soils, topography, area, and channel geometry.

PERFORMANCE OF EROSION CONTROL PRACTICES

Rates of soil erosion and the effectiveness of common control measures have been extensively researched and modeled (Wischmeier and Smith, 1978; Warner and Schwab, 1998). Relevant research for the Georgia Piedmont was conducted as part of the Dirt 2 Panel (CFRDC, 2001). This research identified the performance of current practice, quantified the relationship of turbidity to suspended solids for Piedmont soils, and developed erosion control systems with computer modeling to greatly improve sediment retention (Warner and Collins-Camargo, 2001). In studies of current practice, effluent sediment was found to range from 300 to 3,500 NTU with an average of 1,767 for road construction with typical BMPs installed. Residential and commercial sites had turbidity of similar magnitude. Unpublished NPDES permit compliance data from detention basin discharges was observed to range from 150 to 12,000 NTU. These data suggest that effluent turbidity of over 1,000 NTU is common from sites with typical BMPs in place. An example of typical practice is mulch and silt fence with rock check dams in channels that discharge to a retrofitted detention basin or temporary sediment pond prior to discharge. This is the minimal practice accepted in most communities.

Sediment concentrations in unmanaged runoff are useful as a reference. Accepted models (USLE, SEDCAD; Warner and Schwab, 1998) suggest that sediment concentrations in runoff from sloping bare soils can exceed 2% solids (20,000 mg/L). In this circumstance, applying BMPs sufficient to retain 90% of the mobilized sediment results in a 2-3000 NTU discharge. In order to meet an NPDES discharge limit of 50 NTU, BMP sediment capture must exceed 99%. The Dirt 2 Panel recognized the capabilities of current practice and concentrated their efforts on improving the 75-90% efficacy of current practice to a system capable of 95-99% retention. Dirt 2 was able to achieve a 99% + retention on a demonstration site by utilizing perimeter hydraulic controls that slowed runoff and maximized infiltration, while applying filtration (sand filter) to the final effluent to remove clay particles that escaped the detention pond (Warner and Collins-Comargo, 2001).

THE CLAY CONUNDRUM

The particle size distribution of soils is commonly assessed by textural class (USDA) that subdivides soil particles into three major groups; sand (0.05-2.0 mm), silt (0.05-0.002 mm) and clay (<0.002 mm). Most soils of the Piedmont have high (20-40%) clay content near the surface (Perkins, 1987). Clay particles are very small, have a high surface area per unit weight (specific surface), and stay suspended in the water column for hours to days as predicted by Stokes' Law (Hillel, 1998).

The properties of clay produce unique challenges for sediment control. Clay particles are smaller than the openings in filter fabrics used for silt fence and other BMPs. Typical storm water detention ponds do not provide enough hydraulic detention time for settling. Consequently, very fine silt and clay particles pass through typical BMPs and into streams where they stay suspended until reaching quiescent waters of lakes or reservoirs. In addition, the high specific surface of clay produces disproportionately high turbidity per unit mass compared to larger sand and silt size particles. Erosion research and models (Wischmeier and Smith, 1978) are based on particle mass per volume of water (mg/L), reported as total suspended solids (TSS). It is difficult to relate turbidity (an optical measure of light scatter) to TSS because of the varying particles size distributions encountered from site to site (Beschta, 1980).

For Piedmont sites sampled in the Dirt 2 study, the relationship of TSS (mg/L) to turbidity (NTU) was approximately 1.7 NTU/(mg/L) for samples where sand and silt had been removed by innovative practice, and 1.3 under typical practice (Warner and Collins-Comargo, 2001). For perspective, if we started off with an unmanaged runoff of 15,000 mg/L and through excellent controls, achieved 99% retention to 150 mg/L of clay particles, we would still have a turbidity of approximately 255 NTU. In short, an excellent job that is out of compliance with GAR 100000 outfall standards.

There are innovative techniques for dealing with colloidal size particles including flocculants (gypsum, polyacrylamide, chitosan), sand filters, and robust settling basins with passive dewatering. However, these technologies are not foolproof and are not specifically required by the State. The application of these and other Dirt 2 technologies often requires more expense and design/implementation expertise than what is currently allowed as accepted practice. However, Dirt 2 studies suggest that on many sites, innovative design and practice can be cost effective once the investment is made in innovative site design.

In summary, current practice, if implemented properly, is capable of sediment retention of 75–90%. This results in an effluent that is typically in the range of 1,000-10,000 NTU or mg/L (maximum concentration). Innovative practice is capable of 90-99% retention producing an effluent typically in the range of 100-1,000 NTU or mg/L (maximum). Natural waters in undeveloped watersheds likely have maximum concentrations in the 500-1,000 NTU range. Unmanaged runoff has maximum concentrations in the range of 10-50,000 mg/L or NTU. The percent of fine silt and clay in the soil texture eroded accounts for some of the variability with fine textured soils typically producing higher sediment concentrations. The current in stream change and outfall standards for construction sites are in the 25-750 NTU range (approximately 15-600 mg/L in the Piedmont). In conclusion, available data suggest that current standards are one to two orders of magnitude less than the capability of current practice, and in many circumstances, less than the baseline water quality from undisturbed Piedmont watersheds during storm flow.

LEGAL ISSUES

The NPDES permit provides for increased fines (up to $50,000 per day) and citizen suits under federal law (Clean Water Act). For the permittee, significant liability is present in the circumstance where the effluent standards are lower than what can be achieved with standard practice and the only defense is the implementation of acceptable BMPs based solely on the judgement of the designer and/or regulator. Under these circumstances, risk management is difficult. Citizen suits are often the last resort of down stream landowners when regulatory efforts are not sufficient to mitigate sedimentation damages due to development. Successful cases have been brought against developers in Georgia for sediment related damages (Stack & Associates, 2002). Many of these cases involve ponds or lakes that are filling with sediment. In these cases, the issue becomes one of simple trespass (appropriating the use of downstream ponds for sediment retention without permission) and is easy to prosecute and settle. Lawyers may use this simple approach, rather than making the complex argument of NTUs and BMPs before a jury (Stack and Associates, 2002). The "smoking gun" in these cases is sediment deposits coupled with pictures of failed or absent BMPs: clear, unambiguous physical evidence that changes have occurred and the cause.

POLITICAL AND REGULATORY ISSUES

Over its decade long history, the development of the NPDES Permit for construction activities has been a contentious process, pitting environmental and development interests and mediated by EPD. Both groups represent a significant block of voters and money that must be considered by politicians. The process has been adversarial in nature with the current permit reflecting a compromise of two competing positions. The environmental side has typically taken the position that the more stringent the standards the better, while the permitted community has fought for reduced monitoring liability and more flexibility in design and implementation.

The issue is exacerbated by the fact that the regulatory agency charged with implementation, EPD, has publicly stated that the funding and staff to enforce the permit is not available. EPD has proposed a user fee system to generate funds to hire staff for administration and enforcement (EPD, 2002). Implementation issues are complicated further by the involvement of multiple agencies with technical staff from the Department of Transportation (DOT), the GA Soil and Water Conservation Commission (GSWCC), local Soil and Water Conservation Districts, County and City Code Officers, and the USDA Natural Resources Conservation Service (NRCS). These agencies are all involved in training, technical support, review of plans, and development of standards.

In summary, the current NPDES standards are the result of a negotiated settlement between stakeholder groups, and do not reflect the full body of scientific data available. Enforcement and training efforts are limited by inadequate funding of responsible agencies. Technical standards and interpretations may vary due to the involvement of multiple agencies and staff with diverse backgrounds and training.

CONCLUSIONS

The current NPDES turbidity standards for sediment in effluent discharged from construction sites are more stringent (an order of magnitude or more) than the performance capability of current erosion and sediment control practice. In many circumstances, the effluent standards are lower than what is observed in storm flow from streams in undisturbed watersheds (pre-development or baseline condition). In fine textured soils common to the GA Piedmont, turbidity, the selected NPDES water quality standard, overestimates the mass of sediment present in the water column (relationship is greater than 1:1). Natural in-stream variability of turbidity can be higher than the in-stream standard of a 25 NTU allowable increase.

Under these circumstances, compliance with the effluent and in-stream standards is judged to be unattainable by many in the regulated community. Innovative practices are available to improve performance but require additional expense, are not specifically required in most locales, and often are insufficient to achieve compliance. The permit provides no credit for improvements in effluent quality that do not meet the standard. The lack of enforcement in some areas encourages non-compliance with BMP requirements. The end result is that the stringent standards are a disincentive to improving water quality because they are viewed as unattainable. Why spend money for nothing?

Permit holders are allowed an exemption from liability for violating standards by having an approved BMP plan in-place on the site. However, the appropriateness of BMPs in any given circumstance is subject to interpretation. Due to the varied background of designers, practitioners, and regulators, this standard may not be decisive in determining compliance. Risk management by permittees and enforcement by regulators is difficult in this circumstance.

RECOMMENDATIONS

The goal of the NPDES program is improvement of water quality. Standards must be relevant to practice. In the interest of providing data that is useful to both the regulated community and the public, the following changes to NPDES monitoring are suggested for scientific debate.

1. Abandon in-stream monitoring in its present form. Effluent impacts are often disguised by in-stream variability.
2. Change the monitoring parameter from turbidity to total suspended solids to allow easier comparison between sites and with existing soil loss models.
3. Require outfall monitoring of settleable solids as well as TSS to better relate water quality to performance.
4. Include a measure or observation of outfall sediment accrual and particle size in the monitoring program .
5. Establish a baseline on empirical TSS/stage data from undeveloped reference watersheds. This value would then be used to develop appropriate outfall standards for streams under storm flow.

Resolution of these issues should benefit the TMDL process as well.

And finally, the discussion of sediment control issues must focus beyond the regulation of single sites. The single site is only problematic until it is completely stabilized. Some practitioners maintain that the time between disturbance and stabilization and the quality of the stabilization are the most meaningful indicators of stream impact for individual sites. Cumulative effects of multiple projects and storm water detention pond hydrology design criteria are significant factors in stream degradation and produce longer lasting effects. Preservation efforts for urban streams must address these hydrology issues that control bank erosion to be successful, regardless of E&S efforts on individual sites.

REFERENCES

Beschta, R.L. 1980. Turbidity and suspended sediment relationships. In: Sym. Watershed Mgmt., Vol 1, ASCE, pp. 271-282.

Bonta, J.V., 2000, Impact of coal surface mining and reclamation on suspended sediment in three Ohio watersheds. J. Am. Water Resour. Assoc., 36, 869-887.

Chang, M., 2002. Forest Hydrology. Appendix C. Measurements of stream sediment. CRC Press. NewYork, NY.

Chattahochee-Flint Regional Development Center. 2001. Making the transition to performance: Reports of the soil erosion and sedimentation control technical study committee. CFRDC. Franklin, GA.

Cosby, E and F.G. Liles. 1992. Georgia's land: Its use and condition. Summary of the 1992 National Resources Inventory. GA SSWCC and USDA NRCS. Athens, GA.

Environmental Protection Division. 2002. Memorandum of 12-13-02 to E&S stakeholders from Harold Reheis identifying proposed changes to the E&S Act for the 2003 legislative year. GA DNR, EPD, Atlanta, GA.

Georgia Board of Regents Scientific Panel. 1995. Erosion and sedimentation: Scientific and regulatory issues. J.E. Kundell-Panel Convener, T.C. Rasmussen-Drafting Subcommittee Chair. Georgia Board of Natural Resources. Atlanta, GA.

Hewlett, J.D. 1982. Principles of forest hydrology. UGA Press, Athens, GA

Hewlett, J.D. 1979. Forest water quality: An experiment in harvesting and regenerating Piedmont forest. A Georgia Forest Research Paper. School of Forest Resources. UGA. Athens, GA.

Hewlett, J.D. and W.L. Nutter. 1969. An outline of forest hydrology. UGA Press. Athens, GA.

Hillel, D. Environmental soil physics. Academic Press. San Diego, CA.

Landers, M.N., P.D. Ankcom, K.W. McFadden and M.B. Gregory. 2002. Does land use affect our streams? USGS Water-Resources Investigations Report 02-4281.

Perkins, H.F. 1987. Characterization data for selected Georgia soils. Special Publ. No. 43. GA Aric. Exp. Stations. UGA. Athens, GA.

Sutherland, A.B., K.H. Barnes, J.L. Meyer, D.M. Walters, and B.J. Freeman. 1998. Effects of sedimentation on biodiversity in Southern Appalachian rivers and streams. Institute of Ecology, UGA. Athens, GA.

Stack & Associates, PC. 2002. Personal conversations with environmental lawyers regarding general circumstances involved in sediment trespass cases. Atlanta, GA.

USDA-ARS. 1998. Overview of watershed studies at the J. Phil Campbell, Sr. Natural Resources Conservation Center. Southern Piedmont Conservation Research Unit. USDA-ARS. Watkinsville, GA.

Warner, R.C. and F.X. Collins-Comargo. 2001. Erosion prevention and sediment control computer modeling project for the CFRDC Dirt II Committee. Surface Mining Institute. Lexington, KY.

Warner, R.C. and P.J. Schwab. SEDCAD 4: Design manual and users guide. Civil Software Design. and Biosystems and Ag. Eng. Dept. Univ. of Kentucky. Lexington, Ky.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses. A guide to conservation planning. Agriculture Handbook No. 537. USDA. Washington, D.C.