April 15-17, 2008

Proceedings of the Eighteenth Tennessee Water Resources Symposium

Proceedings from the

Eighteenth Tennessee
Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 15-17, 2008

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Symposium Contest Guess-the-Picture Question: In which watershed would you find this?

PREFACE

On behalf of this year's planning committee, I welcome you to the Eighteenth Tennessee Water Resources Symposium. The planning committee encompasses a hard-working team of professionals that has put together both an informative and challenging program for 2008. Focusing on the themes of urban watershed management and water resource management during a drought, this year’s symposium is especially timely as Tennessee and the region face these important issues. I hope you take full advantage of the conference: the technical programs and exhibits, the chances to network with professionals who share common interests, and the entertainment opportunities provided by the golf tournament and the Fun Run.

I very much appreciate the spirit of cooperation, good humor, and can-do attitude that each member of the planning committee has brought to this process. The TN AWRA is especially grateful to Lori Crabtree for her acute attention to detail and efficient planning and coordination skills. Lori has been a tremendous asset in furthering this organization, especially in maintaining and growing the Web site.

I owe my sincere gratitude to past President Paul Davis for his experience, vast knowledge, and enthusiasm. I would be remiss if I did not thank Brian Waldron for his wonderful system of organizing and managing the dozens of abstracts we received. Also, a much-deserved thanks goes to Amy Knox at the TTU Water Center for once again producing our proceedings on the convenient pocket-size disk. Amy does great work in a timely fashion and is great to work with.

Thanks also to our loyal sponsors and exhibitors who continue to support our symposium financially and by attending. Without their support, our meetings would not be as fulfilling. Please express your appreciation to them by visiting their displays.

We thank all of our conference participants, ranging from businesses to NGOs to presenters and moderators (and everyone in between), who contribute to making our meeting a meaningful and enriching event, which is important as we face the challenging and valuable issues related to water resource management.

Dennis George, President, Tennessee Section AWRA, 2008 Conference Chair

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TENNESSEE WATER RESOURCES SYMPOSIUM

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- Brian Waldron, Ground Water Institute, The University of Memphis
- Forbes Walker, University of Tennessee, Biosystems Engineering & Soil Science
- Sherry Wang, Tennessee Department of Environment and Conservation, Water Pollution Control

8:00 a.m.
Tuesday, April 15
Free CADDIS Workshop

1:30 – 3:00 p.m.
Tuesday, April 15
Keynote Address *by* Jeff Eger, General Manager, Sanitation District #1, Kentucky

12:30 – 1:30 p.m.
Wednesday, April 16
Luncheon Presentation *by* Marge Davis
Tennessee Bottle Bill

SESSION A

DROUGHT PANEL

SESSION 2A

GEOMORPHOLOGY

GIS APPLICATIONS

STRESSORS I

BASEFLOW

SESSION 2C

GROUNDWATER

CONSTRUCTION SEDIMENT

EDUCATION

SOURCE TRACKING

SESSION 3A

PUBLIC WATER SUPPLY

PLANNING AND POLICY

SESSION 3B

WATER QUALITY STANDARDS AND ASSESSMENT

URBAN CORRIDORS

SESSION 3C

WATERSHED MODELING

RISK ASSESSMENTS

PROFESSIONAL POSTERS

STUDENT POSTERS

SESSION A

DROUGHT PANEL
3:30 p.m. – 5:00 p.m.

The Hydrologic Drought of 2007: A Historical Perspective
Paul S. Hampson, USGS

Trends in Tennessee Droughts
Joanne Logan, Associate Professor, UT Biosystems Engineering & Soil Science

Operations of the Tennessee River Reservoir System in Extreme Drought
Mike Eiffe, Water Supply Manager, TVA (Paper Not Available)

Ohio Dry—Recent Drought Conditions in the Ohio Valley
Deborah Lee, Water Management Program Manager, USACE—Great Lakes & Ohio River Division (Paper Not Available)

THE HYDROLOGIC DROUGHT OF 2007: A HISTORICAL PERSPECTIVE

Paul S. Hampson[1]

Long-term streamflow records from 1930 to present were examined for 12 stations across Tennessee to compare 2007 with previous drought years. During this time, four dry periods comparable in severity and areal extent to 2007 have occurred; 1930-32, 1941-43, 1953-55, and 1986-88. In 2007, only one of the 12 stations established a new record 7-day average low flow for the period 1930 to present but a total of 5 stations across the State reached the second lowest 7-day averages ever recorded. Overall, the streamflow data indicates that the 2007 hydrologic drought was roughly equal in severity to the 1931-32 and 1953-55 but of greater areal extent than either of the previous periods.

1 USGS, Nashville, TN

TRENDS IN TENNESSEE DROUGHTS

Joanne Logan[1]

Droughts are part of the natural pattern of climate variability in any climate. There are 2 major types of droughts – agricultural drought and hydrological drought. Agricultural drought is defined as a seasonal shortage of soil moisture that negatively affects crop production. Hydrological drought, on the hand, is characterized by a prolonged period of below normal precipitation, causing deficiencies in water supply as measured by levels of lakes and reservoirs, streams, and groundwater, as well as severe shortages in soil moisture. The National Climatic Data Center estimates moisture deficits and surpluses at the divisional scale; Tennessee has 4 distinct climate divisions – East, Plateau, Middle, and West. The Palmer Drought Severity Index (PDSI), ranging from -4.0 extreme drought to +4.0 extremely moist, measures the duration and intensity of the long-term drought-inducing circulation patterns. Palmer Hydrological Drought Index (PHDI) measures hydrological impacts of drought which take longer to develop and longer to recover from. The Palmer Z Index measures short-term drought on a monthly scale. Based on the historical PDHI, there have been many hydrological droughts across Tennessee since 1900, with especially long and widespread droughts in the periods of 1913-15, 1924-26, 1930-32, 1940-43, 1953-54, 1986-88, and more recently, 2007-08. Tennessee experienced an especially long drought-free period (25 years) from the mid 1950's to the early 1980's. Based on the Palmer Z-Index since 1900, the critical month of August for crop production has suffered extreme soil moisture deficits 4 times in the East, 2 times in the Plateau, 5 times in the Middle, and 7 times in the West; in 2007 all 4 divisions were rated at the same time as severe for the first time. Severe August drought has occurred 9-10 times for all divisions since 1900, for a rate of about 1 year in 11. Division-based drought indices have their limitations, but they do provide a quick and easy method to assess state-wide droughts in an historical context.

1 UT Biosystems Engineering and Soil Science, loganj@utk.edu

SESSION 2A

GEOMORPHOLOGY
8:30 a.m. – 10:00 a.m.

Using Rock Cascades at Stream Fords to Control Streambank Erosion and Sedimentation in the Hatchie Watershed
Alan Schlindwein

Variability in Frequent Floods and Channel Dimensions in Tennessee
T.H. Diehl

Hydrology of an Alluvial Fan in Eastern Tennessee: Geologic Constraints on Streamflow, Aquatic Habitat, and Flood Hazards
David E. Jackson

GIS APPLICATIONS
10:30 a.m. – 12:00 p.m.

Tools for Integrating HSPF Output into GIS
Gerald Burnette

Applying "FREE" GIS in the Conasauga River Watershed
Frank Sagona and Frank Perchalski

Using Geographic Information System Techniques in Hydrologic Analysis
David E. Ladd

STRESSORS I
1:30 p.m. – 3:00 p.m.

CADDIS Stressor Identification: The Lower Falling Water River
John Harwood and Brooke Coffey

Assessing Fish Density within Two Reaches of Pleasant Grove Creek, an Impaired Watershed, Logan County, Kentucky
Dereck Eison and Andrew Barrass

Clear-Cut Within the Watershed of a High Quality Stream of the Western Highland Rim: Analysis of Four Years of Macroinvertebrate Data
Timothy C. Wilder and Joseph C. Augustin

STRESSORS II
3:30 p.m. – 5:00 p.m.

Functional Connections Between Stream Fish Communities and Hydrology in the Tennessee River Valley
Rodney R. Knight and M. Brian Gregory

Trends in Index of Biotic Integrity Scores in the Tennessee Valley
J. Hagerman, D. Matthews, C. Saylor, G. Shaffer, and A. Wales

Instream Flow Studies in the Stones River, Rutherford County, Tennessee
Kimberly Ann Elkin

USING ROCK CASCADES AT STREAM FORDS TO CONTROL STREAMBANK EROSION AND SEDIMENTATION IN THE HATCHIE WATERSHED

Alan Schlindwein[1]

Past agricultural and forestry practices in western Tennessee resulted in elevated sediment loading into local headwater streams. This sediment load was commonly transported through channelized tributaries to the Hatchie River. Deposited sediment formed valley plugs along the Hatchie, flooding bottomland hardwood forests. These forests died and over time, the floodplain upstream of valley plugs aggraded and these forests reestablished. However the wide extent of these valley plugs has severely impacted the ecological communities of the Hatchie. Efforts by the USDA and cooperating agencies have dramatically improved land-use practices reducing the watershed sediment delivery. However, these streams are still capable of transport this sediment load and are now eroding their banks and channel beds. In many case the resulting channel incision has cut through farm stream fords placing a hardship on landowners. The Nature Conservancy in cooperation with Western Tennessee River Basin Commission has targeted several headwater streams, including Richland Creek, for concentrated restoration efforts. Stantec proposed a practice developed in western Iowa, where bridge loss along loess-based channels was halted with rock cascades. Sediment collects upstream of these cascades and the upstream channel banks then self-stabilize. On Richland Creek, these rock cascades are proposed at several re-established stream fords. If these initial structures stabilize local streams similar to the Iowa experience, the spacing of these structures in western Tennessee headwater streams will be determined for use in more extensive sediment reduction efforts.

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VARIABILITY IN FREQUENT FLOODS AND CHANNEL DIMENSIONS IN TENNESSEE

T.H. Diehl

ABSTRACT

The bankfull discharge of a stream (Q_{bf}) is widely used as a geomorphic reference representing the discharge that forms the channel and transports the most sediment. The bankfull cross-sectional flow area (A_{bf}) is an important channel characteristic used in stream management and restoration. In Tennessee, linear log-log regional curves have been developed to estimate Q_{bf} and A_{bf} for some hydrographic regions based on data from reference reaches along relatively natural channels. Geomorphic conditions at non-reference sites can also be described using discharge and flow areas based on annual recurrence intervals, such as the 1.25-year and 1.5-year annual peak discharges ($Q_{1.25}$, $Q_{1.5}$) and cross-sectional areas ($A_{1.25}$, $A_{1.5}$). These indices generally reflect conditions close to bankfull and can similarly be regionalized to indicate differences between reference and disturbed conditions. While a 1.5-year recurrence interval is generally thought to be characteristic of bankfull flow, in Tennessee the 1.25-year indices correspond more closely to bankfull.

Values for $Q_{1.25}$ at 453 gaged sites in Tennessee and surrounding states were estimated from log-Pearson type III distributions constructed from data-derived Q_2 through Q_{500} recurrence intervals at each site. At ungaged sites, $Q_{1.25}$ values were estimated by the same method applied to recurrence intervals computed using regional regression equations developed for flood estimation purposes. Application of the ungaged site method to gaged sites resulted in errors of estimation of $Q_{1.25}$ that were similar to errors in estimating Q_2 from existing data at the same sites. Regression equation estimates of $Q_{1.25}$ ranged from 28 to 390 percent of actual values with 90 percent of the estimates falling between 50 and 189 percent of the actual value.

At stream gage sites where measurements bracketed the $Q_{1.25}$ estimates, $A_{1.25}$ values were estimated by interpolation. The $A_{1.25}$ values were grouped by hydrographic region, plotted versus drainage area, and compared to A_{bf} regional curves. For the Highland Rim and Cumberland Plateau regions, $A_{1.25}$ and A_{bf} values were generally similar. In the West Tennessee region, $A_{1.25}$ and A_{bf} values were similar for small drainage areas, but $A_{1.25}$ values were much larger for large drainages areas. In the Blue Ridge and Valley and Ridge regions of east Tennessee, $A_{1.25}$ values were consistently much larger than A_{bf}.

HYDROLOGY OF AN ALLUVIAL FAN IN EASTERN TENNESSEE: GEOLOGIC CONSTRAINTS ON STREAMFLOW, AQUATIC HABITAT, AND FLOOD HAZARDS

David E. Jackson, P.G.[1]

The Davis Creek - Dry Creek watershed in Greene County, Tennessee comprises an alluvial fan complex that partially overlies karst conditions in the Knox Dolomite. The juxtaposition of alluvium over variable geologic terranes affords abrupt transitions in flow regimes and stream habitats. Extending to the eastern continental divide, the fan's upper watershed is drained by perennial stream reaches designated as Exceptional Waters by the Tennessee Department of Environment and Conservation (TDEC). However, lower-slope to valley floor channel flow is ephemeral, exhibiting sinking hydrology amidst widely distributed clastic debris that overlie structurally-controlled karst oriented along fold axes. Lower channels are largely non-supporting of aquatic habitats and previously were excluded from TDEC's promulgated list of surface waters and designated use classifications. Mapping of fan deposits and relict stream channels, along with observations following a tropical storm, indicate that rainfall events of ≥50-year return intervals dramatically alter channel routing and morphology and pose extreme risks to human life and property. Conspicuous as geomorphic features in the arid west, alluvial fans are less evident in the Southeastern U.S. where they typically are obscured by advanced erosional processes, forest cover and/or infrastructure. Recognition and understanding of their peculiar hydrology are needed to ensure appropriate administration of water quality regulations and to provide for effective flood safety.

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TOOLS FOR INTEGRATING HSPF OUTPUT INTO GIS

Gerald Burnette[1]

HydroGeoLogic, Inc. (HGL) has developed tools that allow the St. Johns River Water Management District to integrate results of HSPF models into GIS. The tools catalog the results found in HSPF models and provide on-demand retrieval of results for visualization and analysis tasks.

SJRWMD manages flow, water usage, flood control, water quality and resource sustainability in an 18-county area in East Central Florida. The District uses the HSPF watershed model to simulate the hydrologic cycle and associated water quality processes on pervious and impervious land surfaces and in streams and well-mixed impoundments within the District area.

SJRWMD has implemented GIS using ESRI's ArcHydro data model. HGL modified the ArcHydro framework to provide a seamless linkage between GIS objects and HSPF models. Because HSPF models are developed for specific subwatersheds, similar models are grouped into modeling scenarios. Engineers use the custom tools to associate a model with a given scenario and register the model to the geodatabase. This process creates records in the geodatabase that describe the model. Several geoprocessing activities create records in other geodatabase tables that provide links between ArcHydro entities and modeled lands and reaches. Finally, the parameters simulated in the model are cataloged for future use.

Other tools allow users to quickly analyze and visualize the impacts of alternative water resource management options. Users select land areas or reaches of interest. An interface tool presents a list of models applicable to the selection, along with parameters associated with each model. The user selects the model(s) and parameter(s) of interest. This information is combined with information stored during the model registration process to retrieve the desired data into geodatabase tables designed for model output. These tables may then be accessed by standard or custom visualization programs for analysis and output.

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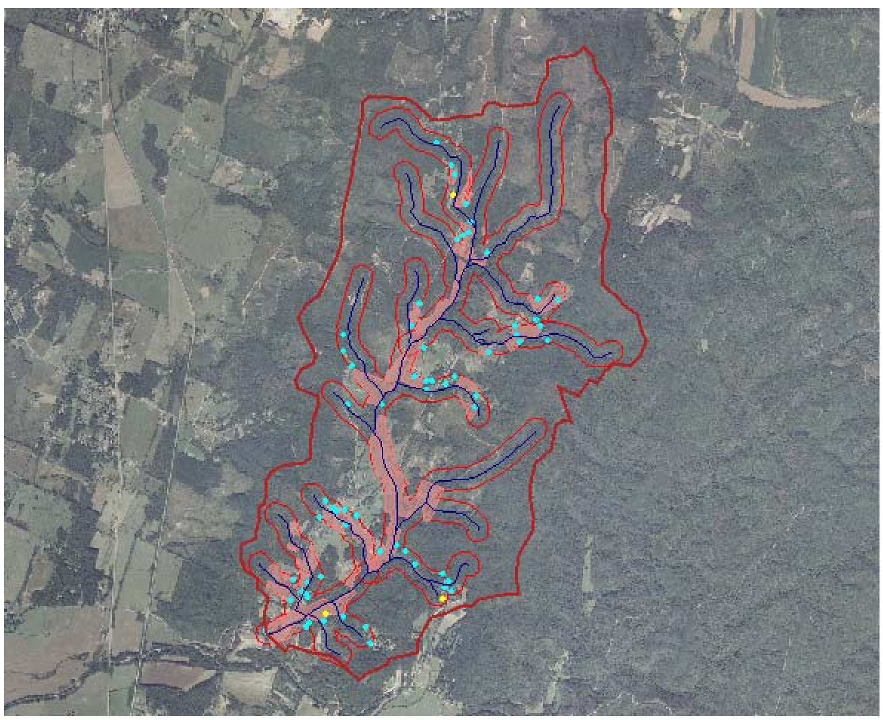
APPLYING "FREE" GIS IN THE CONASAUGA RIVER WATERSHED

Frank Sagona[1]* and Frank Perchalski[2]*

The 90-mile Conasauga River starts in the Blue Ridge Mountains of Georgia, flows into Tennessee, and then swings back into Georgia. The river supplies the carpet industry around Dalton, agricultural uses in both states, a population of more than 125,000 people, and is home to 72 native fish species, more than the Columbia and Colorado combined. Several stream segments are listed by both states as not supporting beneficial uses, a designation under the Clean Water Act. Fecal coliform bacteria are cited as one cause for impairment. Each state has completed a total maximum daily load (TMDL) allocation to bring the segments back into acceptable water quality standards. The next step is implementation of fixes. Septic systems and livestock operations are cited as contributing sources of the bacterial impairment. To locate and then target treatments of this "non-point source" of pollution relies on an effective and relatively inexpensive survey technique: aerial remote sensing and GIS. With a limited budget for treatments, and even less for study, readily available digital photography from USDA and local counties, and open-source GIS software were obtained. Houses and agricultural operations within a 100-foot buffer along blue-line streams were identified. This analysis serves as a basis to apply a variable cost-share rate grant for homeowner repairs. The tag-team presentation demonstrates a practical solution for data collection and analyses used in developing a TMDL implementation project in the Conasauga River watershed.



Example of open-source GIS used to create 100-foot buffer along Ball Play Creek showing

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2 President, Aerial Terrain Sciences LLC, 6878 Manassas Gap Lane, Hixson TN 37343 fperchalski@comcast.net

locations of septic systems, agricultural fields, and livestock operations for TMDL implementation.

ABOUT THE PRESENTERS

Frank Sagona has more than 27 years experience in water quality resource management. He works with the Conasauga River Alliance to develop plans and implement projects to reduce fecal coliform levels in the Conasauga River. Previously he worked with the Tennessee Valley Authority water resource group, the Southeast Watershed Forum on growth-related issues, and AquaShield Inc. a stormwater treatment manufacturer. Frank has a Masters of Science in Water Quality Management from Tulane University, and operates his consulting business from Catoosa County.

Frank Perchalski, also retired from TVA, has four decades of experience in aerial mapping and data collection especially in the fields of remote sensing and photogrammetry. This has included positions as principal engineer and chief photogrammetrist in private industry, management of FHWA's remote sensing research program, establishment of fully operational Remote Sensing Section for the Florida DOT (where he developed the FLUCCS inventory approach in the early 1970s), promotion and implementation of innovative aerial mapping and data collection applications for the Tennessee Valley Authority, and, currently, offering similar services through Aerial Terrain Sciences, LLC, in Hamilton County, Tennessee.

USING GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES IN HYDROLOGIC ANALYSIS

David E. Ladd[1]

The U.S. Geological Survey (USGS) Tennessee Water Science Center collects and analyzes hydrologic data to help local, State, and other Federal agencies make decisions that affect citizens across Tennessee. Many surface-water analyses require the computation of terrain characteristics such as land-surface slope, stream slope, or percentages of various land-use types for a given area. The determination of these characteristics for small areas by manual methods may require substantial time and effort as well as the application of professional judgment. At a state-wide or regional scale, the manual calculation of such characteristics can be impractical, if not impossible. Utilization of manual methods for tasks such as construction of potentiometric-surface contours and delineation of hydrogeologic unit contacts also can be difficult and time consuming, especially for large areas.

The use of geographic information system (GIS) technology to calculate hydrologic and hydrogeologic characteristics can save substantial time and effort and may provide more precise and consistent results than manual methods. GIS techniques also can be applied to display three-dimensional representations of subsurface and other hydrogeologic data to enhance visual analyses. Although preparing data for GIS analysis can be difficult and dependent on dataset availability and user expertise, the benefits of GIS analysis usually outweigh the preparation costs. This presentation will demonstrate some of the GIS methods used by the USGS Tennessee Water Science Center to analyze hydrologic and hydrogeologic data.

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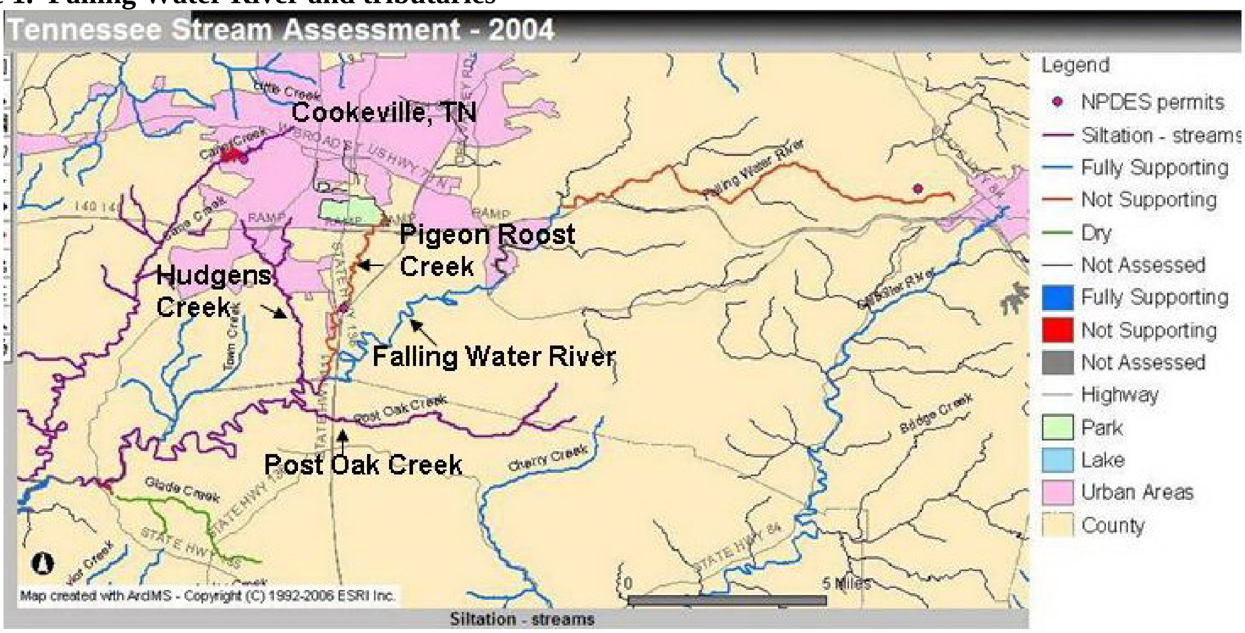
CADDIS STRESSOR IDENTIFICATION:
THE LOWER FALLING WATER RIVER

John Harwood[1] and Brooke Coffey[2]

TENNESSEE CADDIS TEST CASE: THE LOWER FALLING WATER RIVER

Stressor identification of stream impairment represents a revolution in water quality management. Rather than regulate pollution sources based on general chemical and biological standards, stressor identification can be used to directly and efficiently identify the source(s) of stream impairment. Stressor identification can facilitate cost-effective and efficient stream remediation, e.g., through the TMDL program. The EPA is putting stressor identification procedure on the Internet in a stepwise procedure known as CADDIS - Causal Analysis/Diagnosis Decision Information System (http://cfpub.epa.gov/caddis/). We are testing use of the CADDIS procedure to diagnose causes of impairment in Tennessee Streams.

Figure 1. Falling Water River and tributaries



(http://gwidc.memphis.edu/website/wpc_arcmap/viewer.htm).

Our first test case is diagnosis of impairment of the lower Falling Water River and its Tributaries, in Putnam and White Counties. Stakeholder involvement is a key component of the CADDIS process, important both in identifying data for the analysis and in suggesting the "candidate causes" of impairment which are evaluated. Our stakeholder team consists of representatives of TDEC, US FWS, City of Cookeville, and two non-profit organizations. Our analysis of stream impairment is based on macroinvertebrate and periphyton surveys performed by TDEC or contracted by the City of Cookeville. Evaluation of candidate causes of impairment utilizes chemical and physical data supplied by TDEC and the City of Cookeville, and on site observations.

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The river and tributaries are shown in Figure 1. The river begins near Monterey, Tennessee, in Putnam County, flows down the Highland Rim through the City Lake impoundment of Cookeville, and ends at Burgess Falls impoundment in White County, which feeds into Center Hill Lake.

STEPS IN THE CADDIS ANALYSIS

After assembling as much data as is for a case available, the first step of CADDIS analysis is to define the case. The Year 2006 303(d) publication lists the lower Falling Water River with impairments due to low dissolved oxygen (D.O.), nitrates, and loss of integrity due to siltation. A second stretch of 11.2 miles (upstream of City Lake) is listed impaired in Putnam Co. due to nutrients and low D.O. The river is designated for uses including domestic water supply, fish and aquatic life, recreation, livestock water and wildlife, and irrigation (Rules of Tennessee Department of Environment and Conservation Division of Water Pollution Control Amendments, Use Classification for Surface Waters, 2004); the river currently fails to support one or more of these uses. The river and tributaries are shown in Figure 1. The CADDIS analysis is to determine biological stressors, and it is necessary that biological findings be used to define the case for CADDIS analysis. Tennessee relies on macroinvertebrate biological surveys in assessing stream condition at this time.

When we began our analysis, the most recent macroinvertebrate sampling data for the lower Falling Water River had been obtained at two sites in August 9, 2002. This data was felt to be insufficient to be used as the basis for determining biological effect of candidate stressors. The City of Cookeville voluntarily engaged a private firm, Pennington & Associates, to perform a semiquantitative macroinvertebrate survey of five sites on the river. This survey was performed on June 5, 2007. The results of this survey, which includes habitat assessment, indicated two separate impairments, one up stream of City Lake (Impairment A), and one downstream of the confluence of Pigeon Roost Creek with Falling Water River (Impairment B). A site between these impairments was found to be unimpaired with respect to macroinvertebrate and habitat metrics used by the State, and was designated to be the reference site in the CADDIS analysis.

The data indicates two biological effects active at both impairments, an increase in % Nutrient Tolerant macroinvertebrate taxa (%NUTOL), and a decrease in EPT Richness (see TDEC, "Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys, Revised" (2006)). These biological effects were investigated at each impairment.

The second task in CADDIS analysis is listing all possible "candidate causes" of impairment. Sources of possible candidate causes include causes listed in the 303(d) list, suggestions by stakeholders, and candidate causes discussed on the EPA CADDIS website. While obviously non-viable causes should not be included, it is best to include even low likelihood causes as candidate causes. We selected seven candidate causes for the lower Falling Water River: sediment, dissolved oxygen, algae, metals, ammonia, habitat, and ionic strength.

The most helpful, if at first confusing, innovation of the EPA stressor identification procedure is the formalization of analysis of "evidence" for a case. Types of evidence may be either "from the case" (nine types of evidence) or "from elsewhere" (six types). The analyst must distribute the extant data among the different types of evidence, as appropriate. In the lower Falling Water River case, we could evaluate (from the case) spatial/temporal co-occurrence, evidence of exposure or biological mechanism, causal pathway, stressor-response relationships from the field, and (from elsewhere) stressor-response relationships from other field studies and mechanistically plausible cause. (The remaining types of evidence apply to field or laboratory experiments, to ecological modeling results, or to data obtained through longer-term monitoring of the impairment under study.)

In evaluating data for each type of evidence, scores are assigned based on whether the evidence supports the finding of the candidate cause placing stress on the biological community, contradicts that finding, or is insufficient to support or contradict. The scores range from "+++" to "0" to "---". Assignment of each score is defined individually for each type of evidence. E.g., for spatial and temporal co-occurrence evidence, a score of "+" reflects the finding "The effect occurs where or when the candidate cause occurs, OR the effect does not occur where or when the candidate cause does not occur", and leads to the interpretation "This finding somewhat supports the case for the candidate cause, but is not strongly supportive because the association could be coincidental."

Important types of evidence in the lower Falling Water River case are spatial/temporal co-occurrence, evidence of exposure or biological mechanism evidence, and stressor-response relationships from the field. Spatial/temporal co-occurrence evidence includes only measurements taken at the time and place of the biological sampling. These measurements are compared with the biological effect. Increased fine sediment, low dissolved oxygen, habitat degradation and ionic strength were measured at the time of macroinvertebrate samplings, and these measurements could be compared with biological effect among sites. For evidence of exposure or biological mechanism, the distrubutions of macroinvertebrate functional feeding groups were compared at the different sites (An Introduction To The Aquatic Insects Of North America, Third Edition, edited by Richard W. Merritt, Kenneth W. Cummins, Kendall/Hunt Publishing Co., 1996). This evidence was used to evaluate the candidate causes algae and sediment (Figure 2). Stressor-response relationships from the field were evaluated by plotting %NUTOL and EPT Richness against the candidate causes sediment, D.O., algae, habitat, ionic strength (Figure 3).

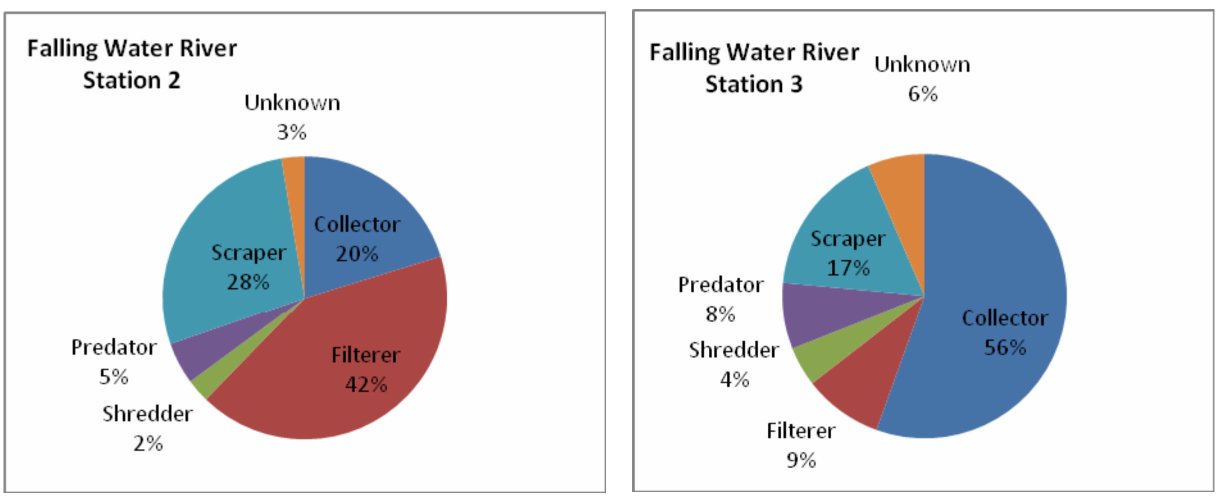

Figure 2. Example charts of mactroinvertebrate functional feeding groups used as evidence of exposure or biological mechanism

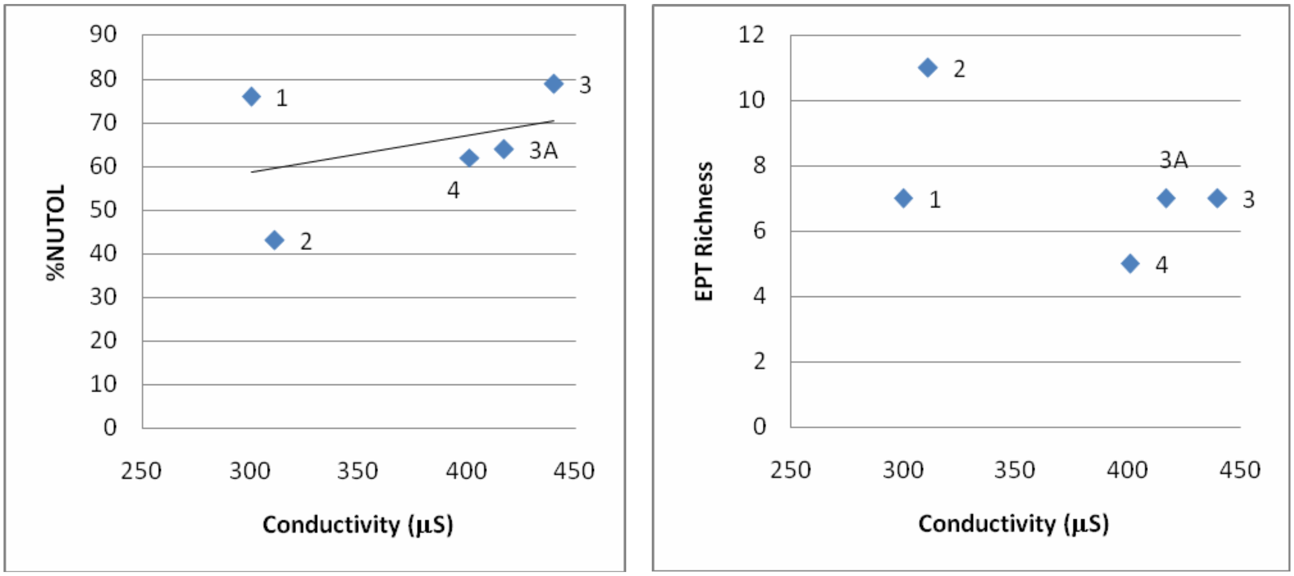

Figure 3. Example graphs of biological affect against candidate causse, used in evaluating stressor-response relationships from the field.

In the case of ammonia, no field measurements have been taken of ammonia in Falling Water River. For this candidate cause, only evidence of "causal pathway" (that ammonia may be preent in the lower Falling Water River) and of "mechanistically plausible cause" (that ammonia can cause the biological effects) could be evaluated.

STRESSOR IDENTIFICATION RESULTS FOR THE LOWER FALLING WATER RIVER

The result of a CADDIS analysis is often not proof of stressors active in a system, but rejection of stressors shown to not be active. The process is iterative throughout, and the first analysis may best serve to indicate what further analysis may be necessary to positively identify active stressors.

We find that multiple candidate causes could be responsible for each of the impairments. The apparent causes of impairment for each specific effect do not differ in this case. Only the effect of increased %NUTOL is supported by stressor response curves using data from the field, EPT richness does not show any response gradient when plotted against any candidate cause. Impairment A shows support for the scenario of excess sediment through three types of evidence, and supports ammonia through two types of evidence. Impairment B shows varying levels of support for each of five candidate causes: the scenarios for sediment and ionic strength are supported by four types of evidence, the scenario for algae and habitat is supported by three types of evidence, and ammonia is supported by only two types of evidence.

Evidence for the probable causes identified for each specific effect are shown in Tables 1 and 2.

Table 1. Identify Probable Cause, Biological Effect: Decreased EPT Richness.

	Probable Cause						
	Impairment A		Impairment B				
Evidence For:	Sediment	Ammonia	Sediment	Algae	Ammonia	Habitat	Ionic Strength
	Spatial/ Temporal		Spatial/ Temporal			Spatial/ Temporal	Spatial/ Temporal
			Evidence of Exposure	Evidence of Exposure			
	Causal Pathway	Causal Pathway	Causal Pathway	Causal Pathway	Causal Pathway		Causal Pathway
	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible

Table 2. Identify Probable Cause, Biological Effect: Increased % NUTOL.

	Probable Cause						
	Impairment A		Impairment B				
Evidence For:	Sediment	Ammonia	Sediment	Algae	Ammonia	Habitat	Ionic Strength
	Spatial/ Temporal		Spatial/ Temporal			Spatial/ Temporal	Spatial/ Temporal
			Evidence of Exposure	Evidence of Exposure			
	Causal Pathway	Causal Pathway	Causal Pathway	Causal Pathway	Causal Pathway		Causal Pathway
						Stressor response from the field	Stressor response from the field
	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible	Cause is mechanistically plausible

Impairment A

The scenario for impairment from excess sediment can be characterized as *probable* based on the fact that it is supported by three characteristics of causal relationship: Spatial/temporal co-occurrence, causal pathway, and mechanistically plausible cause each support this scenario. Evidence of exposure at this impairment scored negative, but the uncertainty of this score is high given that an increase in % filter collectors is not a necessary symptom of the impairment. The scenario for ammonia toxicity is *probable with low confidence*, given that it is only supported by two characteristics of causal relationship but all evidence strengthens the case for this cause: causal pathway and mechanistically plausible cause are the only characteristics which support this scenario. Additional information should be collected about ammonia levels at this location, no direct measurements of the stressor or proximate stressor are available for the present analysis.

Impairment B

Excess sediment, algae, habitat degradation, and ionic strength are all *probable* causes of impairment. The scenario for impairment from excess sediment is supported by four characteristics of causal relationship and all evidence strengthens the case for this cause: spatial/temporal co-occurrence, evidence of exposure, causal pathway, and mechanistically plausible cause all support this scenario. Ionic strength is also supported by four characteristics: spatial/temporal co-occurrence, causal pathway, stressor response relationships from the field, and mechanistically plausible cause. Habitat degradation is supported by evidence from spatial/temporal co-occurrence, stressor response relationships from the field, and mechanistically plausible cause. The case for ionic strength is supported by evidence of exposure, stressor response relationships from the field, and mechanistically plausible cause. One scenario, ammonia toxicity, is classified as *probable with low confidence* because only two types of evidence support the case. The supporting evidence for this scenario comes from causal pathway and mechanistically plausible cause. Additional information could be collected about this candidate cause, especially since measurements of the proximate stressor were never collected.

CONCLUSION

Through CADDIS, we find that the most likely stressors of the system, with some variation among different impaired sites, are sediment (suspended and bedded), habitat, and ionic strength.

ASSESSING FISH DENSITY WITHIN TWO REACHES OF PLEASANT GROVE CREEK, AN IMPAIRED WATERSHED, LOGAN COUNTY, KENTUCKY

Dereck Eison[1]* and Dr. Andrew Barrass[2]

Pleasant Grove Creek is located within the Western Pennyroyal Karst Plain Ecoregion north of the Tennessee state line. The impaired watershed is currently the focus of several surveys by the state of Kentucky, Environmental Protection Agency, and Austin Peay State University. The watershed is a 303(d) listed stream and is located in the northern portion of the Red River that flows into Tennessee. The topography is an area composed of karst fractures and caves. Ninety five percent of the land is allocated to agricultural practices. Historically few streams in this region have been sampled for fish. In 1994 and 1998, the Kentucky Department of Water sampled Pleasant Grove Creek for macroinvertebrates and fish. Although fish were collected during these studies, little fish data exists in the technical reports. Objectives of this study were to assess environmental health of Pleasant Grove Creek utilizing the Kentucky Index of Biotic Integrity by comparing historical data with data collected in 2007. Fish assemblages were compared to habitat changes and another watershed, Whippoorwill Creek. Protocols for sampling surface waters set forth by the state of Kentucky were followed except for electroshocking. Data indicate that Pleasant Grove Creek continues to be an impaired stream. Results concluded that total fish density and biological index scores were significantly different between the two sampling sites. High levels of dissolved oxygen, variation in habitat, and observed animal waste inflows suggest that eutrophication with sedimentation influence fish density within and among the watersheds.

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CLEAR-CUT WITHIN THE WATERSHED OF A HIGH QUALITY STREAM OF THE WESTERN HIGHLAND RIM: ANALYSIS OF FOUR YEARS OF MACROINVERTEBRATE DATA

Timothy C. Wilder[1] and Joseph C. Augustin[2]

In 2002, Weyerhaeuser purchased Willamette Industries, Inc. in a hostile take-over bid. In Tennessee, the land holdings of Willamette included approximately 174,000 acres in Wayne, Lewis, Hickman, Perry and Humphries Counties. The following year, Weyerhaeuser sold these lands, and lands in other southeastern states, to reduce its debt. The lands formerly owned by Willamette passed to several interests, corporate and private, and the timber management practices on those lands changed. Some large clear-cuts were initiated. One of these was on a tract of approximately 5,000 acres in southern Lewis County south of the Buffalo River. All but the lowest portion of the watershed of one stream, Cow Hollow Branch, lies within this tract of land. In late 2003, clear-cutting began on this tract. Forestry BMPs were employed at the site.

To assess impacts, a reach of Cow Hollow Branch was selected immediately downstream of the tract to be clear-cut. The site was revisited in the spring for four consecutive years beginning in April 2004. The stream channel and substrate were documented with photographs. Samples of the macroinvertebrate community were collected using two rapid assessment methods; Rapid Biorecon and SQSH kick. Finally, macroinvertebrate data were collected from the selected reach data for hypothesis testing with a Surber sampler. Five Surber replicates were collected in each of the four years. Data was analyzed using Multi-Response Permutation Procedure (MRPPP) to detect variance among each year's Surber sample replicates. Preliminary results are that the clear-cutting has not caused observable impacts to Cow Hollow Branch.

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FUNCTIONAL CONNECTIONS BETWEEN STREAM FISH COMMUNITIES AND HYDROLOGY IN THE TENNESSEE RIVER VALLEY

Rodney R. Knight[1] and M. Brian Gregory

Ecologically relevant hydrologic characteristics and how those characteristics interrelate with fish communities are not as easily defined. Numerous studies in the United States and elsewhere have sought to identify hydrologic characteristics that define and support the structure or health of specific components of aquatic communities. Many of these studies were completed in small watersheds or involved only selected species thus limiting the applicability to larger, regional scale watersheds. In this paper, we present three hydrologic characteristics determined to be ecologically relevant to the fish communities in small to medium watersheds in the Tennessee River Valley. The identification of hydrologic characteristics relevant to fish communities in streams of the Tennessee River valley will provide scientists and resource managers with regional-scale information useful for the development of instream-flow policy.

Functional connections between hydrology and stream fish communities were identified between three hydrologic characteristics: constancy, the frequency of moderate floods, and streamflow recession rates and one metric of stream fish community health: the insectivore fish community component metric of the Index of Biotic Integrity (IBI) score. For this metric of the IBI score, higher scores indicate lower fish-community disturbance. Functional connections for these hydrologic metrics are important to fish for reasons that include habitat availability as well as sources of food.

Constancy of streamflow (streamflow stability) is critical to maintaining wetted perimeter. Increased values of constancy were correlated with increased values of insectivore scores. Available wetted perimeter is important for providing fish with habitat for spawning and for providing increased surface area for invertebrate colonization and reproduction. The *frequency of moderate flooding* provides sufficient streamflow velocity to remove silt and sediment, while also providing adequate habitat disturbance to stimulate invertebrate growth. Site scores for insectivorous fishes increased as the frequency of moderate flooding decreased. Removal of silt from gravel / cobble substrate provides good habitat for invertebrate growth. Additionally, moderate floods remove sources of turbidity from the water column which is important for insectivorous fishes that sight feed. Increased *rate of streamflow recession* was associated with decreased insectivore fish scores and effect fish communities in two ways. First, increased recession rates potentially strand fish in pools and other areas that are disconnected from flowing water. Additionally, increased recession rates are indicative of streams that have a greater overall variability in streamflow, such as lower low-flow values and higher high-flow values. This variability may lead to the inevitable stranding of fish as the result of low streamflow as opposed to being stranded quick streamflow recession. Regardless of the reason for stranding, fish are potentially subsequently subjected to increased water temperatures and low dissolved oxygen regardless of whether they were stranded by low-streamflow values or quick recession rates. Second, quick recession rates potentially remove as potential food sources invertebrates that were suspended during high streamflow events.

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TRENDS IN INDEX OF BIOTIC INTEGRITY SCORES IN THE TENNESSEE VALLEY

J. Hagerman[1], D. Matthews, C. Saylor, G. Shaffer, and A. Wales

The Index of Biotic Integrity (IBI) is a tool to measure the health of fish communities in streams. TVA has been using the IBI as a measure of water quality since 1986 and as a corporate indicator since 2000. The database of IBI scores developed over the past two decades was examined to evaluate temporal trends. In addition, the relationship between trends and variability in IBI scores was compared to other factors that could potentially influence these scores, such as weather and human population density.

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INSTREAM FLOW STUDIES IN THE STONES RIVER, RUTHERFORD COUNTY, TENNESSEE

Kimberly Ann Elkin[1]*

The Stones River is found in one of the fastest growing counties in Tennessee. Instream flow data was collected in 2007 to understand the biology, water quality, hydrology, and stream geomorphology of the Stones River. Instream flow methods used include the Index of Biotic Integrity, Rosgen Geomorphic Stream Classification, and the Indicators of Hydrologic Alteration. An IBI score of 36 indicated a fairly healthy fish population on the West Fork Stones River at Barfield Crescent Park, and an IBI of nine indicating a poor fish population on the West Fork Stones at the Thompson Lane Trailhead. This river is a C1 type stream dominated by limestone/bedrock with cobble, and an average water surface slope of 0.046 in a 300 ft. riffle/pool/run sequence, a sinuosity (k) of 1.58, and a w/d ratio of 23 feet in a pool. Flow below a low-head dam was 1.05 cfs using a Sontek FlowTracker, and there was no flow coming over the dam due to the 2007 drought. Flow above a golf course intake pipe was 2.15 cfs during the summer, while flow below the golf course intake pipe was 1.68 cfs. Summer water quality measurements included an average water temperature of 24 C, average DO of 7.2 mg/L, average pH of 8.0, and average conductivity of 0.345 mS. Dominant fish species in the West Fork Stones River include *Pimephales notatus*, *Notropis boops*, *Etheostoma crossopterum*, *Etheostoma blennioides*, *Gambusia affinis*, and *Lepomis megalotis*. *Lampsilis fasciola* was the most common mussel found in the West Fork Stones River.

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SESSION 2B

NPDES COMPLIANCE
8:30 a.m. – 10:00 a.m.

Total Maximum Daily Loads: Technical Approaches and Implications
Dustin G. Bambic

Your Permit Audit: What to Expect
Tom Lawrence

Understanding Waterkeeper's Impact: A Review of Recent Legal Challenges and New Rules Relating to the 2003 Clean Water Act Revisions for Confined Animal Feeding Operations
Shawn A. Hawkins

URBAN WATERSHED MANAGEMENT
10:30 a.m. – 12:00 p.m.

Observations of Linear Construction Compliance in Tennessee
Taylor McDonald

Stormwater Treatment Feasibility Study for A Large Industrial Facility Using SWMM5
Ken Barry, Angela Hemrick, Brent Wood, and Paul Platillero

Tennessee Environmental Council: Agenda for a Sustainable Tennessee
John McFadden

BMPs
1:30 p.m. – 3:00 p.m.

Exfiltration from Pervious Concrete into a Compacted Clay Soil
John Tyner

Removal of Waterborne Pathogens Using an Antimicrobial Perlite Filter Media
Mark B. Miller

Characterization of Physical, Chemical and Biological Properties of a River Impoundment with Reference to a Dam Removal Feasibility Study: The Lowhead Dam on the Harpeth River in Franklin, TN
Michael Cain

BASEFLOW
3:30 p.m. – 5:00 p.m.

Baseflow Characteristics of Streams in the Mid-South Region
Jerry Anderson

A Computer Program for Estimating Flow-Duration and Low-Flow-Frequency Characteristics for Unregulated Streams of Tennessee
George S. Law, Gary D. Tasker, and David E. Ladd

Restoring Stream Baseflow at an Existing Sewer Line Stream Crossing
Richard D. Martin, William E. Griggs, and Heather J. Brown

TOTAL MAXIMUM DAILY LOADS: TECHNICAL APPROACHES AND IMPLICATIONS

Dustin G. Bambic[1]

An astonishing number of the nation's waterbodies are categorized as impaired by anthropogenic pollutants. Under the requirements of the federal Clean Water Act, most of these waterbodies shall be remediated using a Total Maximum Daily Load (TMDL). Each TMDL evaluates the maximum pollutant that the waterbody can receive and still meet water quality standards, and allocates that load (minus a margin of safety) to the point and non-point sources within the watershed. This paper reviews the possible strategies to develop TMDLs, which can be categorized as load-based or number-based. Load-based TMDLs use a mass balance approach to allocate the allowable mass loading, while number-based TMDLs simply apply a numeric target to the receiving water and/or discharges. Numeric targets often relate to the value (concentration) of the applicable water quality standard, but may pertain to a number of different parameters; for instance, percent impervious area of the impaired watershed. Also discussed are the implications of these different TMDL development strategies on the implementation phase, during which best management practices (BMPs) are designed and installed in order to reduce pollutant loading. In some cases, individual dischargers are held accountable for their allowable loading, while in other approaches all dischargers within the watershed are given one allocation to share. This critical review should be of interest to an array of stakeholders involved with compliance with water quality standards, including watershed groups and staff from municipal, agricultural, state, and federal agencies. Examples from TMDLs across with nation, with particular emphasis on the Southeast Region, are presented.

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YOUR PERMIT AUDIT – WHAT TO EXPECT

Tom Lawrence, P.E.*

NON-POINT SOURCE MANAGEMENT
OUTREACH AND EDUCATION

Like having a tax audit at work, notice of an upcoming NPDES Permit audit can fill NPDES compliance personnel with dread, even if everything seems to be running well. Those who have not gone through the process have no idea what to expect and those that have may remember horror stories form previous audits of the storm water or other programs. In addition, the audit is added on top of everything else that needs to be done for regular day-to-day operations.

Storm water NPDES Permit audits are becoming more and more common as NPDES permits mature and as more permits are being issued, due to Phase II requirements and the expansion of the list of activities requiring NPDES permits. Regardless of the specifics of the permits, in general, NPDES permits are subject to review by the issuing agency or the EPA.

During the review process the reviewers will usually request to review self-reporting documents that have been submitted, as well as the supporting documentation for the submitted reports. Additionally, often the reviewers will want to interview personnel, look at methods of data collection, and evaluate program effectiveness.

The presentation will tell the intriguing, sometimes humorous, story of a permit review of the Municipal Storm Water Program where the author worked as the Storm Water Manger, including preparation for the review through the review process followed by the results of the review. Additionally, the author has looked at audits of other storm water programs to identify commonalties and differences. Tips will be given for procedures that can be implemented to make an audit successful for the storm water program, while also improving current program operations. Lessons learned from having gone through the audit process will help other storm water personnel relax and maybe even enjoy their audit.

BIO: Tom Lawrence is a registered Professional Engineer in Tennessee, Illinois and California. He has been active in the field of environmental engineering for over 18 years, specializing in water resources protection. He has worked for the Los Angeles County Department of Public Works, the City of Memphis Public Works Division and two consulting firms. He is currently a storm water consultant focusing on solutions for municipal and industrial permit compliance.

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UNDERSTANDING WATERKEEPER'S IMPACT – A REVIEW OF RECENT LEGAL CHALLENGES AND NEW RULES RELATING TO THE 2003 CLEAN WATER ACT REVISIONS FOR CONFINED ANIMAL FEEDING OPERATIONS

Shawn A. Hawkins[1]

The Environmental Protection Agency issued new permitting and effluent limitation regulations for concentrated animal feeding operations (CAFOs) in a 2003 amendment to the Clean Water Act. These regulations were subsequently challenged in the United States Court of Appeals (*Waterkeeper Alliance et al. v.EPA*, 399 F.3d 486 (2nd Cir. 2005)). EPA has responded with new rules in 2006 and 2007 that address issues in the 2003 amendment that the court vacated and remanded. This presentation will review *Waterkeeper Alliance et al. v.EPA*, other current legal challenges to CAFO regulation under the Clean Water Act, as well as the newest regulation revisions. Four issues will be covered in detail. 1. The agricultural stormwater exemption now appears clearly defined in terms of nutrient application rates. How does this affect current land application practices given the uncertainty in crop yields, manure and soil analyses, and the ability to accurately apply manure at a set rate? 2. Language within NMPs for Class I CAFOs is germane to the permitting process, must be reviewed and approved and made available to the public. Are bio-security and trade secrets compromised? 3. The terms of a NMP serve as "effluent limitations." Can versatility and flexibility be built into a document originally intended for "planning" purposes? 4. The "Duty to Apply" provision of the rule, which required all CAFOs to apply for a permit unless a "no potential to discharge" status was granted, was vacated. Does this bring the basis for enforcing Clean Water Act jurisdiction over CAFOs into question?

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OBSERVATIONS OF LINEAR CONSTRUCTION COMPLIANCE IN TENNESSEE

Taylor McDonald, MS, CPESC, Environmental P

The emphasis and methods employed in fulfilling environmental obligations in relation to the construction of public linear transportation projects has drastically changed and improved in recent years. Much effort has been placed on inspections and subsequent reporting and this large undertaking has in many respects been successful. While the "stick" aspect of compliance has become well defined through thorough reporting, stop work orders and project fines, the "carrot" aspect has been largely overlooked. With over $500 million in linear construction projects ongoing or completed, several observations on what is and has not been effective will be shared. This will not be a presentation of standard BMPs.

STORMWATER TREATMENT FEASIBILITY STUDY FOR A LARGE INDUSTRIAL FACILITY USING SWMM 5

Ken Barry, P.E, D.WRE[1*]; Angela Hemrick, P.E, P.G.[2].; Brent Wood, P.E.[3].; and Paul Platillero, P.E.[4]

S&ME, Inc. (S&ME) performed a feasibility study for the treatment of stormwater discharges from a large industrial facility. The stormwater discharges directly into a perennial stream. The objective of this feasibility study was to identify and evaluate various alternatives to reduce the Total Suspended Solids (TSS) and oil and grease concentrations in the stormwater discharge.

The stormwater drainage system consisted of a large and complex network of inlet points and connecting pipes covering over 100 acres, including three distinct manufacturing areas each of which contributes a different particle-size distribution and loading to the total TSS. In addition to discharging stormwater runoff, approximately 1.6 million gallons per day of industrial effluent (primarily cooling water) flows through the system.

Three categories of stormwater treatment technologies were researched for efficacy and costs: 1) controls at the stormwater inlet, 2) in-line treatment devices, and 3) settling basin and treatment wetlands. Representative products or approaches were carried through to the evaluation of alternatives. The wetland was eliminated after preliminary sizing calculations indicated it would be larger than the area available.

Stormwater modeling was performed using the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM) Version 5.0, Build 5.0.005a in order to evaluate the relative effectiveness of treatment alternatives. The SWMM model was used to evaluate twelve combinations of treatment ranging from no treatment to a combination of inlet controls and in-line treatment with a settling basin. Stormwater sampling was conducted to collect data for calibration of the model.

Inlet controls and/or in-line treatment were projected to remove from 15% to 27% of TSS from the modeled storm flow. The settling basin was projected to remove 77% of modeled TSS. Adding inlet controls and/or in-line treatment only increased modeled TSS removal by 3%.

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4 formerly S&ME, now with Strata Environmental, Knoxville TN

TENNESSEE ENVIRONMENTAL COUNCIL: AGENDA FOR A SUSTAINABLE TENNESSEE

John McFadden

More than two hundred citizens representing at least eighty Tennessee communities, organizations and agencies gathered at Lipscomb University in Nashville on November 15, 16, and 17, 2007 to begin a multi-phase, year-long process of crafting the state's first sustainability agenda. Assembled under the banner "Many Voices. A Common Vision", the participants spent three days in working meetings outlining key issues and goals, and discussing strategies and tactics for sharing resources and information. The meeting, titled "The Summit for a Sustainable Tennessee ", was organized by the Tennessee Environmental Council (TEC) and Tennessee Conservation Voters (TCV) with help from dozens of volunteers from several local and statewide organizations.

The goal of the Summit and the ongoing visioning process is to develop a working plan for raising Tennessee's overall quality of life by making the state more sustainable. Two closely related, over-arching themes emerged from the Summit: the need to raise public awareness about the urgency of responding quickly and boldly to growing environmental threats to the state's climate, water, air, wildlife and natural landscape and the overwhelming economic benefits in store for the thousands of Tennessee households, communities and companies that are shifting to more sustainable products, policies and practices.

During the Summit for a Sustainable Tennessee, scores of scientists, engineers, ecologists, executives, farmers, educators, activists, organizers, students and other interested citizens examined issues and opportunities related to clean energy, natural infrastructure, healthy communities, quality growth and sustainable design and development. A wide range of creative approaches were proposed at the Summit focusing around the idea of "sustainability" as a source for economic opportunity and community vitality.

Among the most popular strategies and tactics:

• providing creative market incentives for private business and consumers making more sustainable choices

• developing a major statewide public information campaign directed at business, consumers and students emphasizing the many practical benefits of greener lifestyles and practices

• providing incentives and public-private partnerships to encourage investment in and development of denser, more walkable, transit-oriented communities

• promoting healthier, more locally-sourced food systems throughout the state

• working to promote energy efficiency and renewable energy sources as the core components of the states energy plan

• purchasing and preserving up to a million acres of greenspace across the state, beginning with land along the state's Mississippi corridor

TEC Executive Director John McFadden spoke for both organizations when he said "TEC and TCV wish to thank and congratulate the eighty-plus organizations and agencies who participated in the first annual Summit for a Sustainable Tennessee. It was an historic gathering that set the stage for a level of statewide cooperation and collaboration that is unprecedented in Tennessee history. The Summit is all about the opportunity of change”

A top-level leadership committee made up of officers from more than twenty Tennessee organizations agreed at the Summit that TEC staff would take the lead in planning and promoting subsequent events and Regional Opportunity Forums. University of Tennessee Knoxville was named the site of the first regional event, which is scheduled for Thursday, January 24, 2008.

In mid to late January, TEC/TCV will distribute a detailed summary of the ideas and key strategies generated at the Summit, as ways for attendees to stay involved and other interested citizens to join the process of creating and carrying out a common vision for a sustainable Tennessee. TEC and TCV are currently working toward a conservation lobbying day on the hill. Given 30 days notice, we will be asking folks to take a day off of work and bring 10 friends (or as many as you can) to lobby on behalf of the environment and public health – its time we had a rally on the legislative plaza like never before! For Summit summary information and news about upcoming Opportunity Forums, visit: www.sustainabletn.org.

EXFILTRATION FROM PERVIOUS CONCRETE INTO A COMPACTED CLAY SOIL

J. Tyner

Pervious concrete typically has an infiltration rate capacity far exceeding any expectation of precipitation rate. The limiting factor of a pervious concrete system is often defined by how quickly the underlying soil will accept the water temporarily stored within the concrete and/or stone base. This issue is of particular importance when placing pervious concrete atop fine textured soils. Our research describes the exfiltration from 12 pervious concrete plots placed atop a compacted clay soil. Several treatments were applied to the soil surface prior to placement of the concrete in an attempt to increase the exfiltration rates, including:1) control – no treatment; 2) soil surface trenched and backfilled with stone; 3) soil ripped with a sub-soiler; and 4) placement of shallow boreholes backfilled with sand. We will present a comparison of the exfiltration rates from the different soil treatments.

REMOVAL OF WATERBORNE PATHOGENS USING AN ANTIMICROBIAL PERLITE FILTER MEDIA

Mark B. Miller[1]*

An innovative antimicrobial perlite (AMP) filtration technology designed to remove a wide variety of waterborne pathogens is introduced; and, independent laboratory and field test results are provided. The media uses an EPA-registered water soluble organosilane quaternary amine antimicrobial solution (3-trimethoxy silyl propyl dimethyl octadecyl ammonium chloride) that covalently bonds to perlite. Treatment with AMP is instantaneous as an antimicrobial "sword" physically pierces the outer membrane of the microorganism on contact, providing for total pathogen destruction. Destroyed pathogens easily pass through the filter media with minimal reduction in flow rate. The AMP does not rely on physical trapping, leaves no chemical residue, requires no external energy source, contains no moving parts, and is non-toxic. Independent 48-hour acute toxicity testing yielded zero mortality of test organisms, confirming that the antimicrobial agent does not leach. A series of laboratory tests achieved 90 to >99% efficacy against *E. coli* from simulated stormwater runoff with influent concentrations of 150 to 36,000 col/100ml, loading rates of 9 to 30 gpm/ft^2, and simulated flows of 52,000 to 173,000 gpd. Field testing in an ultra-urban setting in Los Angeles achieved an average efficacy of 95% against total coliforms and 99.9% efficacy against *E. coli* and enterococci under moderate to extreme influent concentrations at 19 gpm/ft^2. An ongoing field test in Georgia has maintained high efficacy performance against total coliforms with constant saturation to >35 million gallons of water at 20 gpm/ft^2. The AMP technology can provide treatment for a wide variety of water protection programs and pathogenic conditions.

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CHARACTERIZATION OF PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF A RIVER IMPOUNDMENT WITH REFERENCE TO A DAM REMOVAL FEASIBILITY STUDY: THE LOWHEAD DAM ON THE HARPETH RIVER IN FRANKLIN, TN

Michael Cain[1]

The City of Franklin has been drawing water from the Harpeth River into a reservoir for drinking water production since 1951. The city built the lowhead dam in 1961 to facilitate increased demand. This dam creates an impoundment on the Harpeth River that is 1.7 miles in length and poses an impediment to wildlife movement and affects water quality within and below its confines.

In 2007 Harpeth River Watershed Association (HRWA) began working with Tennessee Wildlife Resources Agency (TWRA) to study the characteristics of the impoundment on the Harpeth River in terms of volume and composition of the accumulated sediment with an emphasis on possible contaminants from a battery reclamation/smelting operation 21 miles upstream, as well as other traditional anthropogenic sources such as agriculture.

The current study, which will lay a foundation for a dam removal feasibility study, is focusing on mapping the impoundment, mapping the accumulated sediment behind the impoundment, pulling sediment samples and testing for metals such as lead, cadmium, and mercury that are often associated with lead smelting, as well as standard chemical screening for nutrients and other parameters. In addition, a biological survey of fish species, mussels and macroinvertebrates will be conducted both above and below the impoundment to get baseline data. While this data is being collected, decisions will be made on what further constituents should be looked for and assessed under this study.

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BASE FLOW CHARACTERISTICS OF STREAMS IN THE MIDSOUTH REGION

Jerry Anderson

The determination of baseflow or the contribution of ground water to a stream flow has been a point of interest since the development of hydrographs to represent the flow in a stream. Horton (1933) described a method of shifting a “normal depletion-curve” horizontally across a hydrograph, noting that segments of the hydrograph that coincide with this curve represent periods during which stream flow is equal to groundwater discharge and then estimating ground water discharge during periods of surface runoff by simply connecting the points where the hydrograph departs from the normal depletion curve. Barnes (1939) posed those three individual components of runoff, i.e. surface flow, interflow, and ground water could be distinguished by plotting the logarithms of flows against time. Classical hydrograph analysis (Nathan and McMahon, 1990) involves the decomposition of stream flow into the three major components of surface runoff, interflow, and base flow. Arnold, Allen, Muttiah, and Bernhardt (1995) suggest that base flow, or shallow ground water discharge to streams, is useful in obtaining estimates of recharge. Schwartz (2007) contends that base-flow time series derived from gauged streamflow support diverse applications in engineering hydrology, catchment analysis, hydrogeologic investigations, regional low-flow analysis, and recharge estimation. United States Geological Survey (USGS) recognizes several different methods to develop the base flow of a stream all of which involve the analysis of daily stream flow in a stream. Additionally several programs are available to perform hydrograph separation on stream flows.

MIDSOUTH REGION

The MidSouth region is crossed by five major streams and has many tributaries that have had stream flow gauges in place for a variety of number of years. For the purpose of this study the MidSouth area of interest will be the counties of Shelby, Fayette, and Tipton in Tennessee and the counties of DeSoto and Marshall in Mississippi. The five major streams are from the north (1) Hatchie River, (2) Loosahatchie River, (3) Wolf River, (4) Nonconnah Creek, and (5) Coldwater River. The headwater of most of all of these streams (except for the Loosahatchie) is in Marshall and Benton Counties of North Mississippi. These streams are entrenched in the surface of one of the most prolific water bearing sand aquifers in the United States. Table 1 lists the various streams that were studied, the gage number, and the description, the longitude and latitude of the gage, and drainage area above the gage.

Table 1 Selected Streams in MidSouth Region

Site Number	Site Name	Latitude	Longitude	HUC	Drainage Mi^2	complete contiguous years
	State of Tennessee					
7030240	LOOSAHATCHIE RIVER NEAR ARLINGTON, TN	35°18'39.11"	89°38'22.13"	8010209	262	1970-2006
7030280	LOOSAHATCHIE RIVER AT BRUNSWICK, TN	35°16'52"	89°45'56"	8010209	505	1940-1949 1951-1964
7030295	LOOSAHATCHIE R TR AT NEW ALLEN RD AT MEMPHIS TN	35°14'14.95"	89°57'05.14"	8010209	1.26	1977-1982
7030392	WOLF RIVER AT LAGRANGE, TN (FAYETTE COUNTY)	35°01'57"	89°14'48"	8010210	210	1995-2006
7031500	MARYS C NR FISHERVILLE TENN	35°07'44"	89°42'37"	8010210	13.6	1955-1956
7031650	WOLF RIVER AT GERMANTOWN, TN	35°06'59"	89°48'05"	8010210	699	1970-1985 1991-1995 1997-2006
7031680	FLETCHER CREEK NEAR CORDOVA, TN	35°11'21"	89°45'42"	8010210	1.45	1975-1982
7031683	FLETCHER CR AT WHITTEN RD AT MEMPHIS TN	35°11'16"	89°50'09"	8010210	21.4	1978-1981
7031685	FLETCHER C TR AT CHARLES BRYAN RD, NR CORDOVA,TN	35°10'06.90"	89°49'27.47"	8010210	3.18	1975-1976
7031692	FLETCHER CREEK AT SYCAMORE VIEW ROAD AT MEMPHIS	35°10'09.41"	89°51'57.74"	8010210	30.5	1997-2006
7031700	WOLF RIVER AT RALEIGH, TN	35°12'05.74"	89°55'22.13"	8010210	771	1937-1962 1964-1969
7031740	WOLF RIVER AT HOLLYWOOD ST AT MEMPHIS, TN	35°11'16"	89°58'32"	8010210	788	1997-2006
7032200	NONCONNAH CREEK NEAR GERMANTOWN, TN	35°02'59"	89°49'08"	8010211	68.2	1970-1983 1986-1994 1997-2006
7032222	JOHNS CREEK TRIB AT HOLMES RD, NR MEMPHIS, TN	35°00'20"	89°52'16"	8010211	5.83	1976-1984
7032224	JOHNS CREEK AT RAINES RD AT MEMPHIS, TN	35°02'05"	89°53'10"	8010211	19.4	1976-1981
	State of Mississippi					
7275900	COLDWATER RIVER NR OLIVE BRANCH, MS	34°54'27"	89°45'12"	8030204	191	1997-2006
7277700	HICKAHALA CREEK NR SENATOBIA, MS	34°37'55"	89°55'28"	8030204	121	1987-2006

METHODS

Partial Duration Curves

Various authors have reported that partial duration curves can be used to indicate values of base flow or groundwater contribution to streamflow. The partial duration flow curve is a cumulative frequency curve that shows the percent of time which specified discharges are equaled or exceeded in a given period. All of the mean daily flows for a given stream at a given gage are used for a partial duration flow curve as opposed to the annual maximum flow where the largest mean daily flow to occur in a given year is used to predict frequency events. Cross (1949) reported that the Q90 is the value used as a measure of the groundwater contribution to streamflow. Stricker (1993) observes that base flow can be compared to the flow duration curve of a stream. Streamflow hydrographs for 35 stations in the southeastern coastal plain of SC, GA, AL, and MS were separated using base flow recession curves (Riggs, 1963). Stricker reported that baseflow values for streams with a mean base flow greater than 10 cfs that either the 60- or the 65 percent duration flow would give reasonable estimates of the mean annual base flow. Equations were also presented for a closer estimate, however the equation represent the baseflow as approximately linear with either Q60 or Q65. For the purposes of this study, Q60 will be used.

Stricker also noted the relationship of streamflow to groundwater discharge and how aquifer lithology affected the shape of the flow duration curve of streams. Stricker reported that several authors (Ackroyd and others, 1967; Pettyjohn and Henning, 1979) had noted that this shape is governed in part by the water yielding properties or groundwater storage potential of the basin. Since a stream is a basin component, a stream in a basin underlain by sand and gravel with good storage and water yielding properties will have a flatter flow duration curve than a stream in a basin underlain by clay which will store large volumes of water but does not yield it readily. Stricker cautions on this interpretation of the flow duration curve, usually the flatter the curve, the more ground water storage is available for release to streams in the basin. Conversely, when a stream is flashy, the steeper the partial duration curve becomes which indicates a smaller ground water storage capacity available to the streams in the basin.

Table 1 lists the streams that were considered during the partial duration analysis. The mean daily flows were downloaded from the USGS NWIS site for the various station numbers listed in Table 1. The data was sorted in descending order from highest daily value. The probability that Q was equaled or exceeded was calculated using the Weibull criteria

$$P(X \geq x) = \frac{m}{N+1} \qquad (1)$$

where m is the order of the value of the unique observation of Q and n is the total number of observations. Table 2 list the Q_{60} for all of the streams that are being studied in this phase. Additionally, the values of average annual flow rate per square mile and the intensity in inches per year are presented. Figure 1 is a plot of the a partial durations series for the Wolf River at LaGrange, TN.

Table 2. Base flow values as Q_{60} for the streams in the MidSouth Region

Site Number	Site Name	Drainage Square miles	Q_{60}, cfs	$Q_{60/DA}$, cfs/mi^2	Intensity in/yr
	State of Tennessee				
7030240	LOOSAHATCHIE RIVER NEAR ARLINGTON, TN	262	109.00	0.416	5.647
7030280	LOOSAHATCHIE RIVER AT BRUNSWICK, TN	505	118.00	0.234	3.172
7030295	LOOSAHATCHIE R TR AT NEW ALLEN RD AT MEMPHIS TN	1.26	0.08	0.063	0.862
7030392	WOLF RIVER AT LAGRANGE, TN (FAYETTE COUNTY)	210	163.00	0.776	10.536
7031500	MARYS CREEK NR FISHERVILLE TENN	13.6	1.00	0.074	0.998
7031650	WOLF RIVER AT GERMANTOWN, TN	699	450.00	0.644	8.739
7031680	FLETCHER CREEK NEAR CORDOVA, TN	1.45	0.19	0.131	1.779
7031683	FLETCHER CR AT WHITTEN RD AT MEMPHIS TN	21.4	1.20	0.056	0.761
7031685	FLETCHER C TR AT CHARLES BRYAN RD, NR CORDOVA,TN	3.18	0.27	0.085	1.153
7031692	FLETCHER CREEK AT SYCAMORE VIEW ROAD AT MEMPHIS	30.5	2.70	0.089	1.202
7031700	WOLF RIVER AT RALEIGH, TN	771	340.00	0.441	5.986
7031740	WOLF RIVER AT HOLLYWOOD ST AT MEMPHIS, TN	788	530.00	0.673	9.130
7032200	NONCONNAH CREEK NEAR GERMANTOWN, TN	68.2	3.30	0.048	0.657
7032222	JOHNS CREEK TRIB AT HOLMES RD, NR MEMPHIS, TN	5.83	0.34	0.058	0.792
7032224	JOHNS CREEK AT RAINES RD AT MEMPHIS, TN	19.4	1.30	0.067	0.910
	State of Mississippi				
7275900	COLDWATER RIVER NR OLIVE BRANCH, MS	191	81.00	0.424	5.757
7277700	HICKAHALA CREEK NR SENATOBIA, MS	121	46.00	0.380	5.161

Computer Program PART

Rutledge (1998) states that PART is a computer program which uses streamflow partitioning to estimate a daily record of base flow under the streamflow record. Rutledge contends that the method of base flow record estimation is a relatively arbitrary procedure f estimating a continuous record of groundwater discharge, or base flow, under the streamflow hydrograph. If the stream flow record is incremental (such as daily) instead of continuous, estimates of ground water discharge can be made on an incremental basis. Rutledge further notes that when the period of analysis is long enough that the effect on the water balance of changes in storage can be considered negligible; the mean groundwater discharge can be considered the effective recharge. Rutledge (1998) discusses the computer program PART as a means of base flow separation to estimate the groundwater recharge to the stream. PART uses streamflow partitioning to estimate a daily record of base flow under the streamflow record. The program scans the record for days that fit a requirement of antecedent recession, designates base flow to be equal to streamflow on these days, and then linearly interpolates the daily record of base flow for days that do not fit the requirement of antecedent recession. The program is applied to a long period of record to give an estimate of the mean rate of ground-water discharge. Rutledge recommends for interbasin comparisons that the program should only be executed with data from a uniform time period in the basin because of climatic variation. The program works on the basis of the calendar year. Consequently, the computer program SCREEN is initially run using data from the various stations to determine the contiguous calendar years and to determine a uniform time period within basins. Rutledge also provides basin size limits. For estimating recharge or discharge only drainage areas larger that one square mile should be used. This is so the requirement of antecedent recession will exceed the time increment of the data (1 day). It has been suggested that the upper limit of drainage area be less than 2000 square miles, but Rutledge recommends that 500 square miles be used as the upper limit for selection of streamflow gaging stations for data analysis. Table 3 provides the values of stream flow, base flow, and base flow index for 17 streams in the study area. Two values for the area above the Germantown gage on the Wolf River are presented because of two different discharge periods. The station 0730240 Loosahatchie River near Arlington, TN has been left out because of the difficulty with the program's inability to read the USGS data file. The values that are reported in Table 3 represent the annual mean stream flow rate in cfs and inches per year as well annual mean base flow rate in cfs and inches per year. The baseflow index (BFI) is also reported which represents the mean annual base flow rate divided by the mean annual stream flow rate. The inches per year calculations represents the summation of the mean annual stream flow rate and summation of the mean annual base flow rate, respectively, divided by the drainage area.

Program WHAT

Web-Based Hydrograph Analysis Tool (WHAT) is a group of computer programs hosted at the website **http://cobweb.ecn.purdue/~what/** that performs computer based hydrograph separation using three techniques (Lim, et al, 2005). Three baseflow separation modules are provided by this computer program. "Local Minimum Method" is the same program provided by the USGS HYSEP (HYdrograph SEParation). This method in WHAT tends to overestimate the base flow since it does not consider flow duration. Results for the selected basins are shown in Table 4.

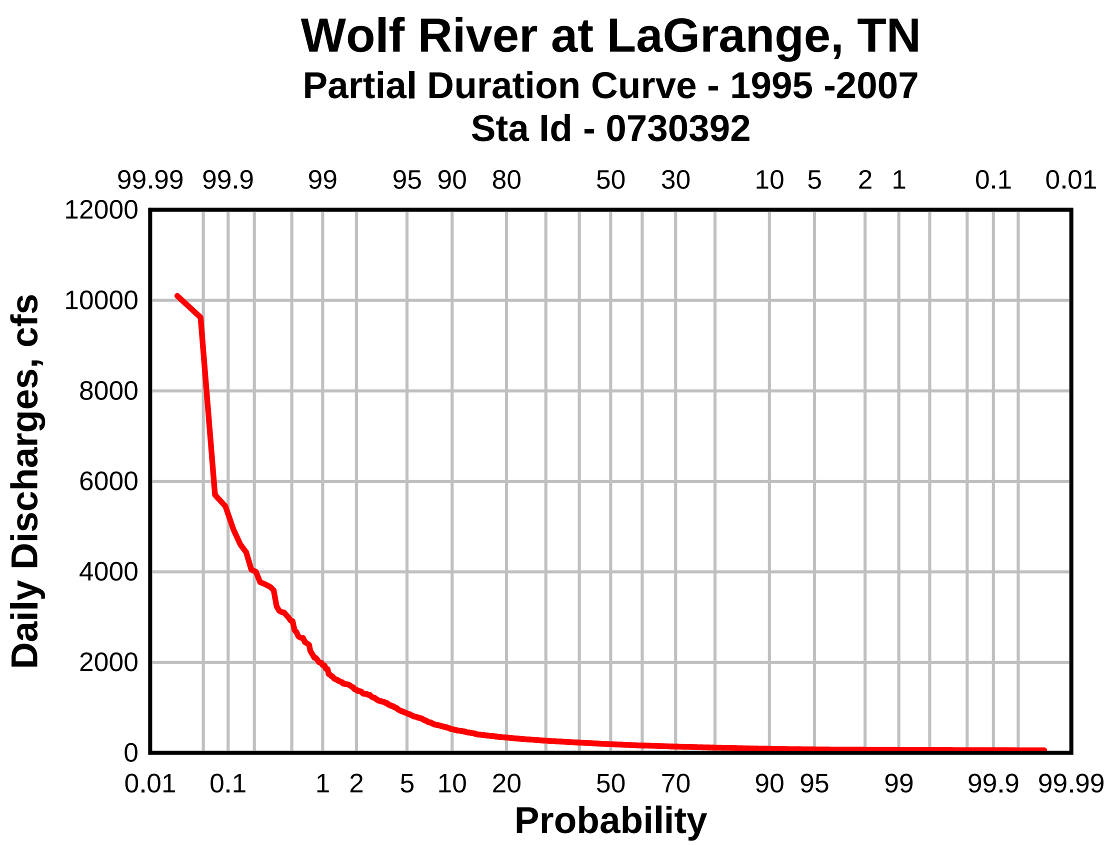

Figure 1. Partial Duration Curve for Wolf River at LaGrange, TN.

Since the WHAT system does not consider the duration of flow in the "Local Minimum Method", two additional digital filter methods, namely the BFLOW filter and Eckhardt (2005) filter method, are also used. Lyne and Hollick (1979) developed the BFLOW filter which uses digital filter method. Subsequently, a DOS-based BFLOW filter program was developed by Arnold and Allen (1999). Only one filter parameter is need for the

BFLOW filter. Nathan and McMahon (1990) found that the filter parameter of 0.925 gave realistic results when compared to manual separation.

Table 3. Mean Base Flow and Base Flow Index as determined by PART

Site Number	Site Name	Drainage Square miles	Time Period	Mean Streamflow		Mean Baseflow		Baseflow Index %
				cfs	In/yr	cfs	In/yr	
7030280	LOOSAHATCHIE RIVER AT BRUNSWICK, TN	505	1951-1962	666.63	17.93	141.22	3.8	21.2
7030295	LOOSAHATCHIE R TR AT NEW ALLEN RD AT MEMPHIS TN	1.26	1977-1982	1.69	18.23	0.18	1.98	10.8
7030392	WOLF RIVER AT LAGRANGE, TN (FAYETTE COUNTY)	210	1997-2005	318.17	20.58	198.56	12.84	62.4
7031500	MARYS CREEK NR FISHERVILLE TENN	13.6	1955-1956	13.15	13.13	1.11	1.11	8.4
7031650	WOLF RIVER AT GERMANTOWN, TN	699	1997-2006	1042.51	20.26	645.07	12.54	61.9
7031650	WOLF RIVER AT GERMANTOWN, TN	699	1997-2005	1080.15	20.99	658.05	12.79	60.9
7031680	FLETCHER CREEK NEAR CORDOVA, TN	1.45	1976-1981	2.19	20.52	0.15	1.43	7.0
7031683	FLETCHER CR AT WHITTEN RD AT MEMPHIS TN	21.4	1978-1981	37.18	23.6	1.68	1.07	4.5
7031685	FLETCHER C TR AT CHARLES BRYAN RD, NR CORDOVA,TN	3.18	1975-1976	5.24	22.4	0.41	1.75	7.8
7031692	FLETCHER CREEK AT SYCAMORE VIEW ROAD AT MEMPHIS	30.5	1997-2005	58.89	26.23	4.07	1.81	6.9
7031700	WOLF RIVER AT RALEIGH, TN	771	1951-1962	972.11	17.13	533.09	9.39	54.8
7031740	WOLF RIVER AT HOLLYWOOD ST AT MEMPHIS, TN	788	1997-2005	1286.25	22.17	773.19	13.33	60.1
7032200	NONCONNAH CREEK NEAR GERMANTOWN, TN	68.2	1997-2005	116.49	23.2	9.28	1.85	8.0
7032222	JOHNS CREEK TRIB AT HOLMES RD, NR MEMPHIS, TN	5.83	1976-1981	7.91	18.43	0.79	1.84	10.0
7032224	JOHNS CREEK AT RAINES RD AT MEMPHIS, TN	19.4	1976-1981	30.92	21.65	2.25	1.58	7.3
7275900	COLDWATER RIVER NR OLIVE BRANCH, MS	191	1997-2005	247.33	17.59	103.49	7.36	41.8
7277700	HICKAHALA CREEK NR SENATOBIA, MS	121	1997-2005	182.5	20.49	61.88	6.95	33.9

BFLOW Filter Technique

The baseflow component of the streamflow time series can be separated using data processing or filtering procedures. These methods tend not to have any hydrological basis but aim to generate an objective, repeatable and easily automated index that can be related to the baseflow response of a catchment (Nathan and McMahon, 1990). The baseflow index (BFI) or reliability index, which is the long-term ratio of baseflow to total streamflow, is commonly generated from this analysis. The one parameter digital filter method has been proposed by various researchers (Lyne and Hollick, 1979; Nathan and McMahon, 1990; Arnold, Allen, Muttiah, and Bernhardt, 1995; Arnold and Allen, 1999). The following equation details the process by which the baseflow is separated from the flood hydrograph.

$$q_t = \beta q_{t-1} + \frac{(1+\beta)}{2}(Q_t - Q_{t-1}) \qquad (2)$$

Where,

qt = filtered surface runoff (quick response)at time step, k (one day)
Qt = original streamflow
β = filter parameter (0.925)

The value of 0.925 was determined by Nathan and McMahon (1990) and Arnold et al (1995) to give realistic results when compared to manual separation techniques. The baseflow, bt, was calculated with the equation

$$b_t = Q_t - q_t \qquad (3)$$

The filter was passed over the streamflow data three times (forward, backward, and forward), based on estimates of baseflow from pilot studies of stream flow records. Results obtained by Arnold and Allen (1999) using the automated recession curve displacement method were comparable to estimates of recharge from field based water balance methods. It was also noted that this method could give consistent, repeatable results which were comparable with the manual Rorabaugh recharge estimates. Values of the BFI for the streams in this study are present in Table 4.

Eckhardt Filter Technique

Since the use of one representative filter parameter in the BFLOW filter does not reflect the type of aquifer, Eckhardt (2005) proposed a two parameter based filter technique using a filter parameter and a BFI_{max} parameter. Eckhardt found that the filter parameter is not that sensitive to the filtered results, while BFI_{max} values greatly influence the results.

$$b_t = \frac{(1 - BFI_{\max})*\beta + b_{t-1} + (1-\beta)*BFI_{\max}*Q_t}{1-\beta*BFI_{\max}} \qquad (4)$$

Where

b_t = the filter base flow at the t time step;
b_{t-1} = the filter base flow at the t-1 time step;
BFI_{max} = the maximum value of long term ratio of base flow to total streamflow;
β = the filter parameter; and
Q_t = the total streamflow at the t time step.

BFI_{max} is the new variable introduced in the digital filter method by Eckhardt (2005). Lim *et al* (2005) reports that Eckhardt used values of 0.80 for perennial streams with porous aquifers, 0.50 for ephemeral streams with porous aquifers, and 0.25 for perennial streams with hard rock aquifers for BFI_{max} if no local values are known. Values of BFI for the Eckhardt filter technique were compared to those obtained by using BFLOW on 50 gaging stations in Indiana with an R^2 value 0.90 or greater. The conclusion was drawn that since the BFLOW method had been favorably compared to the manual method of baseflow separation, then the Eckhardt filter technique would compare favorably as well. Results for the streams in the study are presented in Table 4.

CONCLUSIONS

Five different methods were used to compute the baseflow values for 17 different streams in the Chickasaw Basin in west Tennessee and portions of the Coldwater River Basin in northern Mississippi. Table 5 contains those values (except for the PART value of Loosahatchie River near Arlington, TN).

Table 4. Values of Base Flow Index (BFI) and Base Flow, inches/yr using WHAT

Site Number	Site Name	Drainage Area Square miles	Time Period	Local Minimum Base Flow Index (BFI)	Local Minimum Base Flow inches/yr	BFLOW-single filter Base Flow Index (BFI)	BFLOW-single filter Base Flow inches/yr	Eckhardt – dual filter Base Flow Index (BFI)	Eckhardt – dual filter Base Flow inches/yr
7030240	LOOSAHATCHIE RIVER NEAR ARLINGTON, TN	262	1977-1982	0.357	6.391	0.427	7.640	0.425	7.609
7030280	LOOSAHATCHIE RIVER AT BRUNSWICK, TN	505	1951-1962	0.310	5.493	0.350	6.354	0.360	6.533
7030295	LOOSAHATCHIE R TR AT NEW ALLEN RD AT MEMPHIS TN	1.26	1977-1982	0.110	2.068	0.190	3.415	0.120	2.130
7030392	WOLF RIVER AT LAGRANGE, TN (FAYETTE COUNTY)	210	1997-2005	0.620	12.815	0.670	13.741	0.640	13.154
7031500	MARYS C NR FISHERVILLE TENN	13.6	1955-1956	0.120	1.544	0.150	1.978	0.090	1.142
7031650	WOLF RIVER AT GERMANTOWN, TN	699	1997-2005	0.640	13.452	0.650	13.708	0.630	13.149
7031680	FLETCHER CREEK NEAR CORDOVA, TN	1.45	1976-1981	0.080	1.727	0.150	2.993	0.080	1.735
7031683	FLETCHER CR AT WHITTEN RD AT MEMPHIS TN	21.4	1978-1981	0.090	2.018	0.150	3.535	0.090	2.047
7031685	FLETCHER C TR AT CHARLES BRYAN RD, NR CORDOVA,TN	3.18	1975-1976	0.120	2.643	0.150	3.439	0.180	4.046
7031692	FLETCHER CREEK AT SYCAMORE VIEW ROAD AT MEMPHIS	30.5	1997-2005	0.110	2.792	0.160	4.270	0.190	5.033
7031700	WOLF RIVER AT RALEIGH, TN	771	1951-1962	0.660	11.294	0.620	10.688	0.600	10.233
7031740	WOLF RIVER AT HOLLYWOOD ST AT MEMPHIS, TN	788	1997-2005	0.640	14.143	0.640	14.173	0.620	13.664
7032200	NONCONNAH CREEK NEAR GERMANTOWN, TN	68.2	1997-2005	0.160	2.579	0.210	3.399	0.120	1.920
7032222	JOHNS CREEK TRIB AT HOLMES RD, NR MEMPHIS, TN	5.83	1976-1981	0.120	2.139	0.190	3.441	0.120	2.230
7032224	JOHNS CREEK AT RAINES RD AT MEMPHIS, TN	19.4	1976-1981	0.090	1.875	0.170	3.689	0.200	4.316
7275900	COLDWATER RIVER NR OLIVE BRANCH, MS	191	1997-2005	0.440	7.708	0.510	8.950	0.500	8.811
7277700	HICKAHALA CREEK NR SENATOBIA, MS	121	1997-2005	0.370	7.513	0.420	8.618	0.430	8.731

Table 5. Comparison of Base Flow, inches/yr, for all five methods

Site Number	Site Name	Drainage Area square miles	Time Period	Partial Duration inches/yr	PART inches/yr	Local Minimum inches/yr	BFLOW single filter inches/yr	Eckhardt dual filter inches/yr
7030240	LOOSAHATCHIE RIVER NEAR ARLINGTON, TN	262	1977-1982	5.647		6.391	7.640	7.609
7030280	LOOSAHATCHIE RIVER AT BRUNSWICK, TN	505	1951-1962	3.172	3.800	5.493	6.354	6.533
7030295	LOOSAHATCHIE R TR AT NEW ALLEN RD AT MEMPHIS TN	1.26	1977-1982	0.862	1.980	2.068	3.415	2.130
7030392	WOLF RIVER AT LAGRANGE, TN (FAYETTE COUNTY)	210	1997-2005	10.536	12.840	12.815	13.741	13.154
7031500	MARYS C NR FISHERVILLE TENN	13.6	1955-1956	0.998	1.110	1.544	1.978	1.142
7031650	WOLF RIVER AT GERMANTOWN, TN	699	1997-2005	8.739	12.540	13.452	13.708	13.149
7031680	FLETCHER CREEK NEAR CORDOVA, TN	1.45	1976-1981	1.779	1.430	1.727	2.993	1.735
7031683	FLETCHER CR AT WHITTEN RD AT MEMPHIS TN	21.4	1978-1981	0.761	1.070	2.018	3.535	2.047
7031685	FLETCHER C TR AT CHARLES BRYAN RD, NR CORDOVA,TN	3.18	1975-1976	1.153	1.750	2.643	3.439	4.046
7031692	FLETCHER CREEK AT SYCAMORE VIEW ROAD AT MEMPHIS	30.5	1997-2005	1.202	1.810	2.792	4.270	5.033
7031700	WOLF RIVER AT RALEIGH, TN	771	1951-1962	5.986	9.390	11.294	10.688	10.233
7031740	WOLF RIVER AT HOLLYWOOD ST AT MEMPHIS, TN	788	1997-2005	9.130	13.330	14.143	14.173	13.664
7032200	NONCONNAH CREEK NEAR GERMANTOWN, TN	68.2	1997-2005	0.657	1.850	2.579	3.399	1.920
7032222	JOHNS CREEK TRIB AT HOLMES RD, NR MEMPHIS, TN	5.83	1976-1981	0.792	1.840	2.139	3.441	2.230
7032224	JOHNS CREEK AT RAINES RD AT MEMPHIS, TN	19.4	1976-1981	0.910	1.580	1.875	3.689	4.316
7275900	COLDWATER RIVER NR OLIVE BRANCH, MS	191	1997-2005	5.757	7.360	7.708	8.950	8.811
7277700	HICKAHALA CREEK NR SENATOBIA, MS	121	1997-2005	5.161	6.950	7.513	8.618	8.731

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A COMPUTER PROGRAM FOR ESTIMATING FLOW-DURATION AND LOW-FLOW-FREQUENCY CHARACTERISTICS FOR UNREGULATED STREAMS OF TENNESSEE

George S. Law[1], Gary D. Tasker[2], and David E. Ladd[3]

ABSTRACT

Up-to-date low-flow-frequency and flow-duration prediction methods for unregulated rivers and streams of Tennessee have been developed. Prediction methods include traditional regional-regression (RRE) equations and the newer region-of-influence (ROI) method. The prediction methods were developed using continuous-record streamflow data from about 350 streamgages and instantaneous-discharge measurements from over 700 partial-record stations in the study area. The methods can be used to estimate the 7Q10 and 30Q5 low-flow-frequency statistics; the mean-annual and mean-summer flows; and the 99.5-, 99-, 98-, 95-, 90-, 80-, 70-, 60-, 50-, 40-, 30-, 20-, and 10-percent flow durations. A computer application was developed that automates the calculation of these streamflow characteristics for unregulated rivers and streams of Tennessee (see attached example).

Regional-regression equations were computed using multivariable regional-regression analysis. The two regions of Tennessee are the western part of the state and the middle plus eastern part of the state and are generally defined by the Tennessee River as it runs south to north from Hardin County to Stewart County. Total drainage area (DA), a geology factor (GF), a climate factor (CF), and a soil factors (SF) are the basin characteristics used in the multivariable-regression equations. The USGS StreamStats geographic information system (GIS) is used to compute basin characteristics for input to these equations. Average deleted-residual prediction errors for the west Tennessee equations ranged from 18 to 127 percent for the 10-percent duration to 7Q10, respectively. Average deleted-residual prediction errors for the middle plus east Tennessee equations ranged from 23 to 92 percent. These equations are included in the computer program to allow easy comparison of results produced by the region-of-influence method.

The region-of-influence method calculates multivariable-regression equations for unregulated sites using basin characteristics from 45 similar sites selected from the study area. Explanatory variables that may be used in region-of-influence method equations are the same as for the regional-regression equations. The USGS StreamStats GIS application is used to compute basin characteristics for input to the region-of-influence method. The region-of-influence method is free to drop insignificant basin characteristics from the estimation equations. Average deleted-residual prediction errors for the region-of-influence method tended to be smaller that the west Tennessee equations and slightly smaller than those for the middle plus east Tennessee equations and ranged from 20 to 94 percent.

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Example of output from flow-duration and low-flow computer program for Tennessee

Flow-duration and low-flow computer program, TDEC Version 3.0.3

Streamflow estimates for:

Big Creek at Little Town, Tennessee

LAT: 35 0 0 LNG: 83 0 0 DA: 40.00 GF:120.0 SF: 53.0 CF: 2.36272

Region-of-Influence, N=45:

MNO	STANO	LAT	LNG	DA	GF	CF	SF	USS	LOCATION
0009	2385500	34.788	84.975	40.0	120	2.363	53	1.91	MILL CR DALTON GA
0937	3578504	35.320	86.004	47.7	120	2.370	60	1.10	BRADLEY CR DUNCANTOWN TN
0318	3605555	36.052	87.908	32.2	121	2.352	73	2.78	TRACE CR DENVER TN
1139	3605550	36.057	87.898	30.6	121	2.352	72	2.79	TRACE CR DENVER TN
1026	3595500	35.486	86.091	40.7	128	2.362	25	0.87	L DUCK R 2 MANCHESTER TN
0268	3578500	35.356	85.979	38.4	115	2.351	59	1.09	BRADLEY CR PRAIR PLNS TN
1140	3605720	36.171	87.866	50.6	120	2.347	88	2.63	B RICHLAND CR HLLS CR TN
1086	3602220	35.992	87.439	46.7	120	2.344	68	1.63	PINEY R DICKSON TN
1085	3602209	36.010	87.444	44.2	119	2.344	67	1.66	PINEY R OAK GROVE TN
1025	3595300	35.480	86.079	35.8	130	2.362	25	0.87	L DUCK R 1 MANCHESTER TN
1103	3603479	36.039	87.639	26.4	122	2.345	57	2.86	HURRICANE CR NEW HOPE TN
0897	3567496	35.003	85.220	20.3	116	2.352	43	1.09	SPRING CR BRAINERD TN
1143	3605968	36.239	87.785	56.1	120	2.343	84	2.66	WHITEOAK CR CONCORD TN
1138	3605500	36.086	87.801	20.5	121	2.348	66	2.81	TRACE CR WAVERLY TN
0600	3436655	36.208	87.529	52.5	120	2.340	75	2.14	YELLOW CR RUSKIN TN
1090	3602235	35.970	87.492	22.9	124	2.345	58	2.70	GARNER CR PINEWOOD TN
1142	3605953	36.200	87.653	24.9	120	2.342	72	2.73	WHITEOAK CR SILVERTOP TN
1024	3595200	35.481	86.064	19.5	129	2.362	28	0.86	WOLF CR MANCHESTER TN
1141	3605810	36.146	87.870	17.9	120	2.348	94	2.60	L RICHLAND CR TRINITY TN
0601	3436900	36.332	87.666	34.5	120	2.338	90	2.13	WELLS CR ERIN TN
0896	3567494	34.991	85.222	15.3	120	2.352	31	0.90	SPRING CR CHATTANOOGA TN
1088	3602230	35.953	87.465	77.6	126	2.345	71	1.56	PINEY R PINEWOOD TN
1073	3601700	35.795	87.311	99.9	124	2.376	80	2.18	LICK CR LITTLELOT TN
0560	3433700	36.009	87.029	59.6	124	2.338	80	2.00	S HARPETH R LINTON TN
0440	3421200	35.717	85.768	32.1	120	2.335	53	1.05	CHARLES CR MCMINNV TN
1071	3601684	35.837	87.261	62.5	133	2.372	80	2.19	LICK CR LITTLELOT TN
1131	3604200	35.648	87.661	45.2	127	2.387	77	2.30	CANE CR FARMRS EXCHGE TN
1145	3606125	36.437	87.999	23.3	120	2.338	84	2.42	STANDING RK CR FT HNY TN
0564	3433910	36.032	87.213	66.2	111	2.345	80	1.23	B TURNBLL CR NEW HOPE TN
1075	3601848	35.567	87.402	28.2	127	2.387	79	2.29	BIG SWAN CR 2 GRDSBRG TN
0558	3433660	35.954	87.079	27.5	134	2.354	80	1.85	S HARPETH R FERNVALE TN
1070	3601683	35.845	87.245	25.6	134	2.371	81	1.73	LOCUST FK WRIGLEY TN
1132	3604240	35.709	87.775	83.9	121	2.387	81	2.26	CANE CR BEARDSTOWN TN
1074	3601846	35.563	87.389	27.4	128	2.387	79	2.30	BIG SWAN CR 1 GRDSBRG TN
0337	7028500	35.980	88.926	72.7	123	2.388	83	2.19	NF FKD DEER R TRENTON TN
1105	3603500	35.971	87.782	75.0	132	2.349	74	2.75	HURRICANE CR HCANE ML TN
1089	3602232	36.006	87.517	14.1	120	2.344	49	2.87	GARNER CR TENN CITY TN
1133	3604600	36.055	87.778	24.2	133	2.348	81	2.69	BLUE CR 1 WAVERLY TN
0301	3596000	35.471	86.122	112.2	130	2.364	26	0.98	DUCK R MANCHESTER TN
1134	3604620	36.034	87.821	31.0	135	2.350	82	2.69	BLUE CR 2 WAVERLY TN
0947	3580800	35.122	86.306	83.6	110	2.380	70	1.58	BEANS CR LEXIE CRSRDS TN
0959	3583327	35.366	87.163	28.1	118	2.394	78	2.43	FACTORY CR LIBERTY HL TN
0092	3436690	36.311	87.554	103.0	120	2.338	82	2.04	YELLOW CR ELLIS MILLS TN
1022	3595000	35.495	86.104	56.1	138	2.362	23	0.91	DUCK R MANCHESTER TN
1029	3596100	35.422	86.137	27.7	138	2.366	26	1.02	CRUMPTON CR 2 RTLG FL TN

Example of output from flow-duration and low-flow computer program for Tennessee--Continued

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Low flow and flow duration program, TDEC Version 3.0.3

Streamflow estimates for:

Big Creek at Little Town, Tennessee

LAT: 35  0  0 LNG: 83  0  0 DA:   40.00 GF:120.0 SF: 53.0 CF: 2.36272

Summary of regression results in cubic ft/s:
```

Rv	EXPECTED VALUE	90% PREDICTION INTERVAL		EY	RRE VALUE
7Q10	5.15	2.12	12.56	0.49	7.01
30Q5	6.61	2.95	14.84	0.47	9.44
MA	63.81	55.23	73.72	15.17	65.39
MS	23.85	14.39	39.55	2.81	34.19
q99.5	4.88	2.01	11.86	0.70	6.65
q99	5.32	2.25	12.56	0.70	7.33
q98	5.96	2.63	13.49	0.74	8.26
q95	6.91	3.13	15.26	0.72	10.00
q90	8.06	3.75	17.31	0.80	12.00
q80	10.19	4.89	21.22	0.95	15.79
q70	12.69	6.15	26.21	1.02	20.01
q60	16.53	8.09	33.74	1.17	25.61
q50	22.90	12.64	41.49	1.72	33.69
q40	34.19	21.66	53.96	2.80	45.29
q30	51.91	37.26	72.32	5.21	61.90
q20	76.85	60.82	97.09	10.73	86.15
q10	132.42	117.17	149.66	42.67	135.57

RESTORING STREAM BASE FLOW AT AN EXISTING SEWER LINE STREAM CROSSING

Richard D. Martin, P.G.[1], William E. Griggs, P.E.[2], and Heather J. Brown, Ph.D.[3]

Conventional gravity sewer line construction methods frequently follow and sometimes cross stream channels. In much of much of Middle and East Tennessee, streams flow atop bedrock and disturbing this confining layer, particularly by the use of explosives during trench excavation, has resulted in the diminution or, in some cases, complete loss of base flow in impacted streams. This problem was thought to be irreversible, short of excavating and re-laying the sewer line, along with installing additional anti-seep devices.

Griggs & Maloney, Inc. was asked to consult on such a condition that arose after a new subdivision was built adjacent to an unnamed tributary to Owl Creek in Williamson County, Tennessee. Specifically, approximately two hundred linear feet of this stream had all of its base flow intercepted at a sewer line crossing. The stream's base flow was noted to reappear downstream at a location where the gravity sewer closely paralleled the channel.

A review of the stream crossing design prepared by others indicated that the stream bed was excavated by the explosives and the gravity sewer line backfilled with crushed stone and capped with concrete - a standard method of construction. The Tennessee Division of Water Pollution Control required, as a component of an Aquatic Resource Alteration Permit (ARAP) issued to the subdivision developer, that this condition be corrected.

In May 2007 a coffer dam was built upstream from the area of stream piracy and the base flow pumped around the study area. Excavation of the stream channel confirmed that stone aggregate bedding and backfill was utilized and that it was serving as a preferential flow zone for stream base flow. Griggs & Maloney, Inc. recommended that low strength flowable fill be slowly poured directly from a ready mix truck into the exposed aggregate bedding, allowing it to infiltrate into the bedding and trench until reaching the stream channel surface. (Approximately 5 cubic yards of flowable fill was required to fill the interstitial spaces in the aggregate and function as impervious backfill.)

The project was completed in one day and allowed to cure overnight, with the coffer dam and base flow diversion occurring during the entire curing process. Examination of the area the following days and beyond revealed that the repair was successful in returning base flow to the surface.

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SESSION 2C

GROUNDWATER
8:30 a.m. – 10:00 a.m.

Fluorescent Dissolved Organic Material in Karst Aquifers of East Tennessee
T. Brown, L. McKay, J. Zhuang, J. McCarthy, R. Gentry, and S. Jones

Tool for Assessment of Process Importance (TAPI) at the Groundwater Surface Water Interface
Ravi C. Palakodeti, Eugene J. LeBoeuf, and James H. Clarke

Improved Surface Geologic Mapping of Two Carbonate Aquifers and an Aquitard within the Stones River Group, Murfreesboro, Tennessee
Mark Abolins

CONSTRUCTION SEDIMENT
10:30 a.m. – 12:00 p.m.

Construction Stormwater Pollution Prevention—Observations of What Works and What Doesn't
Brent C. Wood, Elizabeth M. Porter, and William K. Barry

Monitoring Strategies for Sediment Near Highway Construction Sites
William J. Wolfe

Technical Basis for a Realistic Synthetic Sediment Formulation
Adrian M. Gonzalez

EDUCATION
1:30 p.m. – 3:00 p.m.

Macroinvertebrate Mayhem: Benthic Education Programs for Kids
Jimmy R. Smith

10 Education Pieces That Work
Tom Lawrence

TN Yards and Neighborhoods: A Newly Formed Program Addressing the Challenges of Residential NPS Pollution
Ruth Anne Hanahan

SOURCE TRACKING
3:30 p.m. – 5:00 p.m.

Bacterial Source Tracking in an Eastern Tennessee Stream Using Bacteroides Host Associated Real-Time Polymerase Chain Reaction Assays
Ryan Ragsdale, Forbes Walker, Alice Layton, and Joanne Logan

Land-Use Effects on Bacteria Loads and Water Quality in Small Karst Catchments of the Upper Duck River Watershed
James J. Farmer

Assessing Sources of E. coli and Fecal Contamination in the Little River Watershed
Alice C. Layton, Dan Williams, Carol Harden, Keri Johnson, and Erich Henry

FLUORESCENT DISSOLVED ORGANIC MATERIAL IN KARST AQUIFERS OF EAST TENNESSEE

*T. Brown[1], L. McKay[1], J. Zhuang[2], J. McCarthy[1], R. Gentry[2], and S. Jones[3]

This study investigated the distribution and variance of natural background fluorescence in groundwater supplies of East Tennessee over the course of an extremely dry year. One goal was to assess the influence of fluorescent dissolved organic matter (FDOM) on the detection of low concentration dye tracer injections. A second goal was to determine if groundwater contains a unique fluorescent "fingerprint" associated with modes and sources of recharge. The fluorescent properties of raw water samples from community wells and springs were measured with a Perkin-Elmer Model LS 55 Luminescence Spectrometer. Fluorescent spectra and intensity variations were correlated with climatic conditions, geology, soils and vegetative cover. Such analyses show potential for tracking ecosystem responses to extreme climatic conditions and changing land use activities. The data provide a snapshot of spatial and temporal FDOM fluctuations in karst aquifers of the Valley and Ridge, with implications for source water protection and long-term water supply management.

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TOOL FOR ASSESSMENT OF PROCESS IMPORTANCE (TAPI) AT THE GROUNDWATER SURFACE WATER INTERFACE

Ravi C. Palakodeti[1*], Eugene J. LeBoeuf[1], and James H. Clarke[1]

Identifying dominant and rate-limiting physical and biogeochemical processes in the context of contaminant mass transfer and transformation is critically important for estimating contaminant fluxes and compositional changes across the groundwater surface water interface (GWSWI). A new, user-friendly, spreadsheet and Visual Basic-based analytical screening tool (TAPI) that enables assessment of controlling processes and transport across the GWSWI is presented. Based on contaminant properties, identified processes that may play a significant role in solute transport/transformation are evaluated in terms of a ratio of process importance (P_i) that relates the transformation process rate to the fluid exchange rate. The screening tool currently applies to 29 organic contaminants and 10 inorganic constituents of interest. Further, TAPI provides analytical contaminant transport models that may find application for sites in vicinity of surface water bodies. Application of TAPI is demonstrated through evaluation of the biodegradation process for a canal exhibiting gaining and losing characteristics.

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* Speaker

IMPROVED SURFACE GEOLOGIC MAPPING OF TWO CARBONATE AQUIFERS AND AN AQUITARD WITHIN THE STONES RIVER GROUP, MURFREESBORO, TENNESSEE

Mark Abolins[1]

Two carbonate aquifers and an intervening aquitard were mapped at the surface near the confluence of the West Fork of the Stones River and Lytle Creek (35 deg, 51 min, 18.2 sec North latitude; 86 deg, 24 min, 49.9 sec West longitude) in Murfreesboro, TN. To improve on previously-published maps, the author mapped the location of fourteen bedrock outcrops within an approximately 0.3 square km area and measured the dip and dip direction of bedding at each location. Outcrop position was determined with the Global Positioning System (GPS), and outcrop elevation was determined from a state base map having a 2 ft contour interval. Dip was measured with an angle finder, and dip direction was determined with a pendulum suspended from a tripod. Dip varies between 2 deg and 6 deg and is generally to the southwest, and strike varies between 118 deg in the northwestern part of the study area and 150 deg in the central part. In addition, a small basin was mapped in the southeastern part of the study area. Bedding attitudes and outcrop locations were used to fit a spline surface to the contact between the aquitard and the lower aquifer, and this surface was used to map the approximate location of the contact within covered areas. The elevation of the surface separating the aquitard from the upper aquifer was estimated by adding the thickness of the aquifer (28 ft) to the elevation of the spline surface. Contacts on the new map differ greatly from those mapped by Galloway (1919) and differ in horizontal position by up to 40 m from those mapped by Wilson (1965).

INTRODUCTION

Geologic maps of carbonate aquifers and aquitards in parts of the Central Basin in central Tennessee are grossly inaccurate in many places (see “Problem” below). This report describes techniques for improved surface geologic mapping (see “Methods” below). These techniques were developed during a succession of Middle Tennessee State University (MTSU) “Field Methods in Geology” courses between 2001 and 2007 and were successfully tested within a 0.3 sq. km area near the confluence of the West Fork of the Stones River and Lytle Creek in Rutherford County, Tennessee (Figure 1) during Fall 2007. See “Results” and Figure 2 for the new and improved geologic map.

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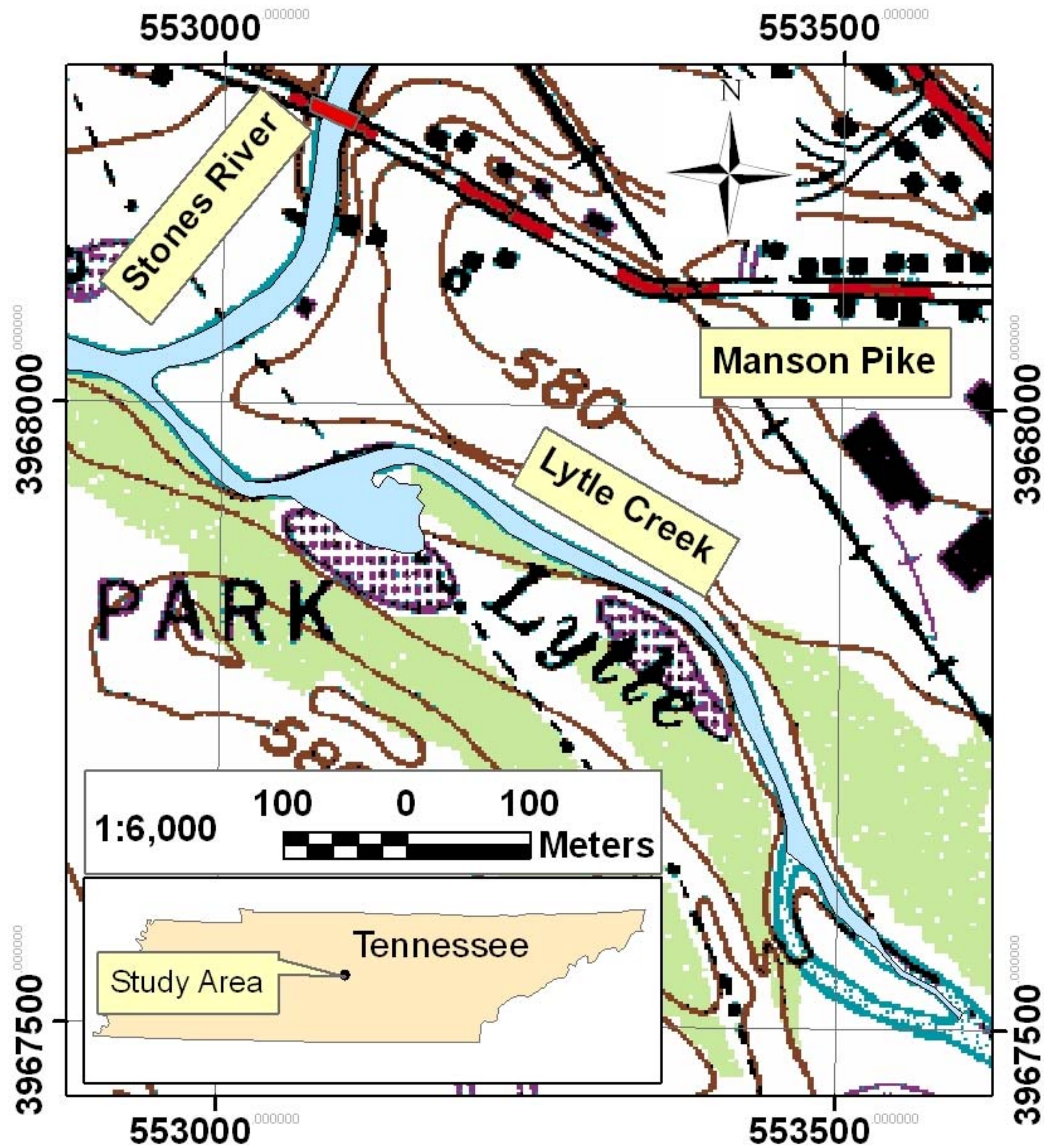

Figure 1. The study area is located within the NE quarter of the Murfreesboro 7.5' Quadrangle. Eastings and northings (in meters) are for a UTM Zone 16 projection with NAD83 datum. Water features have been modified from recent orthophotos.

STUDY AREA AND MAP UNITS

This report describes new geologic mapping within a 0.3 sq. km area (the "study area") near the confluence of the West Fork of the Stones River and Lytle Creek (35 deg, 51 min, 18.2 sec North latitude; 86 deg, 24 min, 49.9 sec West longitude) in the City of Murfreesboro, Rutherford County, Tennessee (Figure 1). Rocks outcrop along trails of the Murfreesboro Greenway System and within the Lytle Creek channel, and the greenway is accessed from the Manson Pike Trailhead on the west bank of the Stones River at Manson Pike and the Fortress Rosecrans and Overall Street Trailheads in Old Fort Park on the west bank of Lytle Creek. Galloway (1919) and Wilson (1965) mapped two carbonate aquifers and an intervening aquitard within the study area, although the locations of contacts on the Galloway map differ greatly from those on the Wilson map. According to these maps, the lower aquifer is the Murfreesboro Limestone, the aquitard is the Pierce Limestone and the upper aquifer is the lowermost part of the Ridley Limestone (but see the last paragraph in the "Discussion" for an alternative interpretation). These three formations all belong to the Stones River Group and outcrop at the surface and/or are present in the subsurface in several central Tennessee counties including parts of Wilson, Rutherford, Bedford and Marshall Counties (Farmer and Hollyday, 1999).

The Murfreesboro Limestone and most of the Ridley Limestone are aquifers and the Pierce Limestone and lower Ridley confining unit are aquitards. The Murfreesboro Limestone is the lowermost of these formations and only the upper 21.5 ft are exposed in the Murfreesboro area (Galloway, 1919), although the formation has a total thickness of roughly 428 ft there (Farmer and Hollyday, 1999). The Pierce Limestone overlies the Murfreesboro Limestone and has a thickness of 27 ft at the type location (Galloway, 1919) and 28 ft at an exposure within 1 km of the study area (Bassler, 1932). The Ridley Limestone is the uppermost unit and has a total described thickness of roughly 110 ft at a location roughly 11.5 km south of the study area (Galloway, 1919), although Farmer and Hollyday (1999) used subsurface data to show that the entire thickness of the formation is roughly 131 to 153 ft within the Central Basin. Most of the Ridley Limestone is an aquitard, but the formation includes the ~22 ft thick lower Ridley confining unit roughly 34 ft above the base of the formation (Farmer and Hollyday, 1999). The lower Ridley confining unit and Pierce Limestone, on one hand, and the Murfreesboro Limestone and the rest of the Ridley Limestone, on the other, are easily confused in outcrop (see "Problem" below).

PROBLEM

Existing bedrock geologic maps of parts of the Central Basin, Tennessee are grossly inaccurate in many places. Two facts support this statement. First, in many places, contacts were mapped differently by Galloway (1919) and Wilson (1965) suggesting that one or both of the existing maps are inaccurate where they differ. Second, subsurface investigations by Farmer and Hollyday (1999) confirmed the inaccuracy of surface geologic maps at several locations. Together, these facts suggest that, at any given location in the Central Basin, the accuracy of existing geologic maps is suspect.
Likely causes of inaccuracy are listed below.

- **Confusion between lithologically similar geologic units.** Different units resemble one another in outcrop. Specifically, the Pierce Limestone resembles the lower Ridley confining unit and the upper part of the Murfreesboro Limestone resembles the rest of the Ridley Limestone. The Pierce Limestone and lower Ridley confining unit have similar thicknesses (22-28 ft), are both thin-bedded, and generally lack wide solution-enlarged joints. In contrast, the Murfreesboro Limestone and the rest of the Ridley Limestone both appear massive, medium-bedded or thick-bedded depending on the spacing of bedding plane fractures. Both also contain many wide solution-enlarged joints.

- **Limited exposure.** Bedrock is exposed at isolated locations within areas largely covered by soil and vegetation. Consequently, geologists generally observe small (<2,500 sq. m) outcrops and most contacts are approximate (at best).
- **Inaccurate horizontal outcrop positions and elevations.** Prior to the early 21st Century, widely-available base maps did not allow accurate determination of horizontal position and elevation in vegetated low-relief areas. For example, Wilson mapped on 7.5' USGS quadrangle maps having a 10 ft contour interval in many places. Because of the large contour interval, many landscape features (e.g., small hills, subtle breaks in slope, small channels) do not appear on the maps, and, consequently, a geologist cannot easily use the 7.5' maps to determine his or her position while in the field. In addition, a geologist typically cannot see distant landmarks because of vegetation, and this problem is particularly acute along the small streams where much bedrock is exposed. For the preceding reasons, outcrop geologic mapping was difficult prior to the development of the Global Positioning System (GPS) and the creation of improved (1 and 2 ft contour interval) base maps by the State of Tennessee and local governments.
- **Lack of accurate bedding attitudes.** Bedding attitudes are variable (e.g., Farmer and Hollyday, 1999), and geologists cannot easily measure attitudes with a Brunton Pocket Transit because beds typically dip less than 7 degrees. Consequently, previous investigators had little structural information to help them extrapolate contacts through covered areas.

METHODS

Key elements in the creation of an improved surface geologic map include (1) GPS, (2) a base map having a 2 ft contour interval, (3) a large number of bedding plane dip and dip direction measurements and (4) surface-fitting.

- **GPS**. GPS was used to determine the horizontal position of fourteen bedrock outcrops with an accuracy of better than 4 m. Outcrops were classified as "aquitard" if beds were thin and lacking wide solution-enlarged joints, and they were classified as "aquifer" if medium-bedded or thick-bedded and containing abundant wide solution-enlarged joints.
- **Base map**. Elevation was determined for each outcrop from a base map having a 2 ft contour interval. (The base map was produced as part of the Tennessee State Base Mapping Program.)
- **Bedding plane dip and dip direction**. Dip and dip direction were measured with the aid of an angle finder and a pendulum suspended from a tripod. The tripod was placed directly on the exposed bed surface at each of the fourteen outcrops. Where possible, several measurements were made on a single bed surface and averaged.
- **Surface-fitting**. The horizontal position and elevation of outcrops and the dip and dip direction measurements constrained the fitting of a spline surface to the base of the aquitard [the Pierce Limestone of Galloway (1919) and Wilson (1965)]. This fitted surface was then used to map approximate contacts between map units as described in "Results."

RESULTS

Both dip and dip direction vary within the study area. These variations define three structural domains (Figure 2). These domains are described below in terms of strike and dip.

- Northwestern domain (6 attitudes). Strike ranges between 112 and 128 deg (118 deg average) and dip ranges between 2 and 5 deg SW (4 deg average).
- Central domain (2 attitudes). Strike ranges between 149 and 150 deg and dip ranges between 5 and 6 deg SW.
- Southeastern domain (6 attitudes). Dip ranges between 2 and 3 deg and attitudes define a basin.

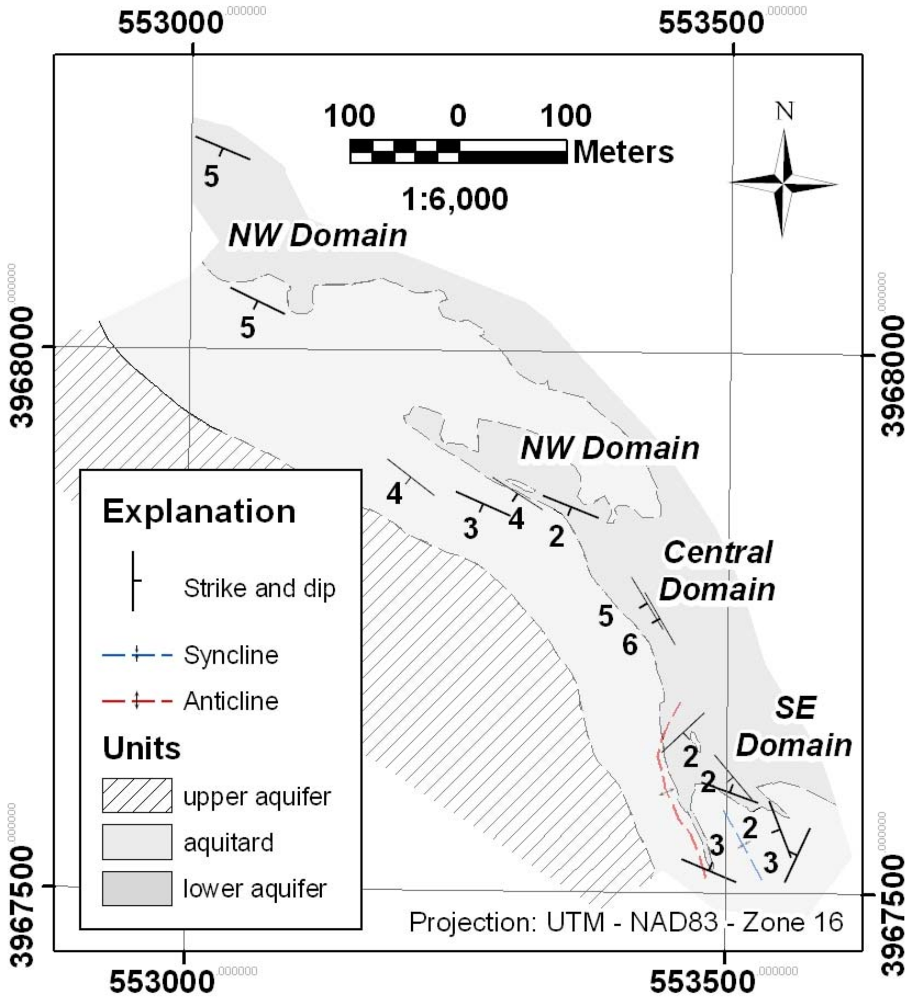

Figure 2. Map of bedrock geology near the confluence of the West Fork of the Stones River and Lytle Creek. Strike and dip symbols indicate variations in dip and dip direction. Contacts are approximate in most places and are based on curve fitting (see Figure 3 and accompanying text).

Bedding attitudes and outcrop locations constrain the fitting of a spline surface to the base of the aquitard (Figure 3), and this surface provides the basis for the approximate (dashed) geologic contacts on Figure 2. Outcrops constrain the horizontal position of the basal aquitard contact to within 2-3 m in two places (filled circles indicating "Observed" points on Figure 3). In addition, the contact between the aquitard and the upper aquifer is well-constrained in the northern part of the study area (triangles on Figure 3), and, in that area, the base of the aquitard is assumed to be 28 ft below the top of the aquitard because Bassler (1932) measured that thickness at a location within 1 km of the study area. The author added other points (open circles on Figure 3) to define a spline surface having variations in strike and dip similar to those observed at the surface (strike and dip symbols on Figures 2 and 3). Structure contours on Figure 3 show the spline surface constrained by all of the points (triangles and filled and open circles). The intersection between the spline surface and Earth surface topography (2 ft contour interval) defines the approximate contact between the aquitard and the lower aquifer on Figure 2. The approximate contact between the aquitard and the upper aquifer is based on a constant aquitard thickness of 28 ft. The new geologic map differs in detail from Wilson (1965) and differs greatly from Galloway (1919) as described under "Discussion" below.

DISCUSSION

The new geologic map (Figure 2) is broadly similar to that of Wilson (1965) in that both maps show the contact between the aquitard and the upper aquifer trending generally NW-SE and curving from a WNW-ESE orientation in the NW Domain to a NNW-SSE orientation in the Central Domain. The new map differs from the Wilson map in three ways.

- First, in the Central Domain, Wilson mapped the contact between the aquitard and the upper aquifer up to 40 m to the southwest of its location on the new map.
- Second, Wilson mapped the aquitard and lower aquifer as a single unit (the combined Murfreesboro and Pierce Limestones).
- Third, Wilson did not map the basin in the SE Domain. (The Wilson map includes no bedding plane attitudes within the study area and the basin cannot be inferred from contacts on the Wilson map.)

Taken together, these differences and similarities suggest that the Wilson map correctly depicts the overall structure and stratigraphy of the study area but does not depict small structures and may not accurately depict contact locations.

In contrast, the new map differs greatly from that of Galloway (1919). Although inaccuracies in Galloway's base map hamper comparison, it appears likely that he did not measure many bedding attitudes, and, probably for that reason, he did not recognize the continuity of a single aquitard throughout the study area. Instead, he probably thought the aquitard in the NW Domain was the Pierce Limestone and the aquitard in the SE Domain was the lower Ridley confining unit. Because of the preceding misinterpretation, he mapped contacts and units in locations differing greatly from those on both the new map and the Wilson map. Note, however, that the Galloway map may be more accurate than the Wilson map in many other areas (Farmer and Hollyday, 1999).

Note, also, that nothing observed within the study area precludes the possibility that both Galloway (1919) and Wilson (1965) misidentified the aquitard and aquifers. Specifically, the lower aquifer could be the lowermost Ridley Limestone, the aquitard could be the lower Ridley confining unit and the upper aquifer could be the overlying parts of the Ridley Limestone. To definitively identify these units, new mapping would have to encompass a larger area containing both aquitards and, preferably, at least one borehole.

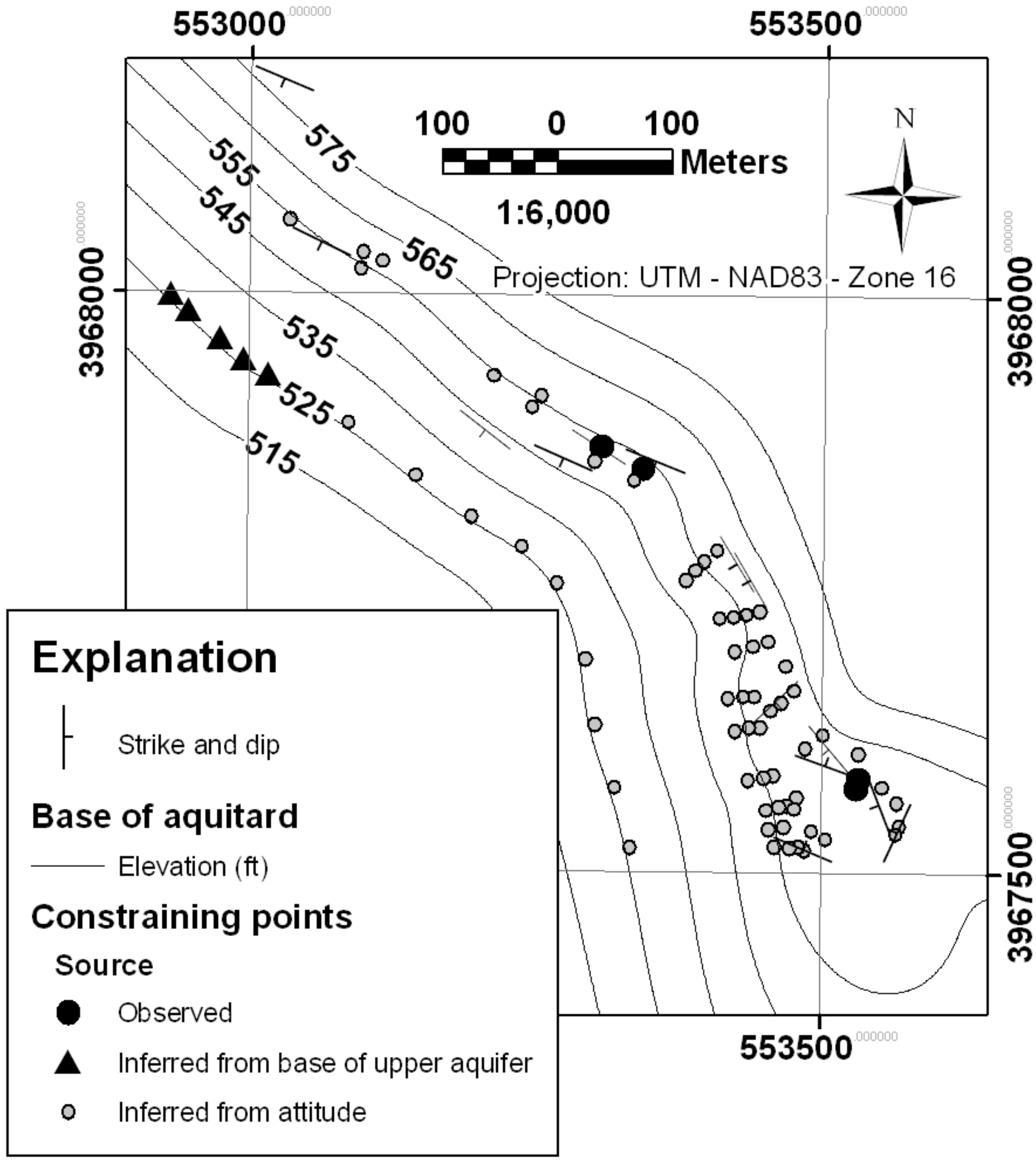

Figure 3. Structure contour map of the base of the aquitard. The spline surface is constrained by bedding attitudes at fourteen bedrock outcrops (strike and dip symbols) and by other outcrops indicated by triangles and filled circles.

IMPROVING ON THE NEW-AND-IMPROVED GEOLOGIC MAP

Aside from the suggestion in the preceding sentence, slightly better horizontal outcrop positions could be measured with the aid of GPS techniques providing horizontal accuracies as good as 20 cm, and slightly better elevations could be obtained with the aid of newer base maps having a 1 ft contour interval. However, further improvements in outcrop position data would likely result in only a small improvement in the overall accuracy of the geologic map.

CONCLUSION

New geologic mapping techniques involve the use of GPS, base maps having a 2 ft (or smaller) contour interval, numerous dip and dip direction measurements, and curve fitting. These techniques were used to map an aquitard and two carbonate aquifers within a 0.3 sq. km study area near the confluence of the West Fork of the Stones River and Lytle Creek in Tennessee. These techniques were successful in three ways. First, new mapping showed that the Wilson (1965) map was generally much more accurate than the Galloway (1919) map within the study area. Second, new mapping suggested that, in spite of the overall correctness of structure and stratigraphy on the Wilson map, approximate contacts on the Wilson map may be mislocated by up to 40 m. Third, new mapping revealed a small basin that is not shown on the Wilson and Galloway maps. These findings suggest that geologists can use the mapping techniques described here to greatly improve on existing maps of aquitards and carbonate aquifers within the Central Basin, Tennessee.

ACKNOWLEDGEMENTS

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CONSTRUCTION STORMWATER POLLUTION PREVENTION—OBSERVATIONS OF WHAT WORKS AND WHAT DOESN'T

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The Tennessee General NPDES Permit for Discharges of Storm Water Associated with Construction Activities (effective June 17, 2005) outlines procedures that developers and contractors must use to protect the quality of receiving waters for sites where one acre or more acres of land is disturbed. These requirements include application fees, the preparation of a site-specific Stormwater Pollution Prevention Plan (SWPPP) by a licensed professional engineer or landscape architect, twice-weekly inspections by qualified personnel, deadlines for repairing and/or replacing ineffective BMPs and maintaining an updated SWPPP, civil penalties for failure to comply, as well as additional requirements for discharge into impaired or high quality waters. Over the last decade, compliance with these requirements has moved from an afterthought to, in the best cases, a paradigm shift incorporating thoughtful integration into the entire design and construction process. Even with this marked improvement for some sites, there is still a disparity in approaches to the design and implementation of stormwater pollution prevention controls.

Our work over the last several years has involved both design and observation of stormwater pollution controls for construction sites. This presentation provides examples of approaches and techniques that have been successful as well as some that have not performed well. We investigate the underlying reasons for both successful and not so successful approaches as well as provide a list of typical characteristics of a successful construction stormwater pollution prevention program.

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MONITORING STRATEGIES FOR SEDIMENT NEAR HIGHWAY CONSTRUCTION SITES

William J. Wolfe
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The potential for highway construction to increase sediment loads to streams is widely recognized but difficult to quantify. Technical and budget constraints place limits on the number and location of sampling sites, the continuity of data, and the constituents that can be measured. Within such limits, optimal monitoring strategies will vary according to the monitoring goals and physiographic setting. Strategies designed to identify sediment effects on aquatic resources may differ from those aimed at understanding geomorphic processes or evaluating sediment control measures. Similarly, a monitoring strategy designed for construction traversing a large river would not be optimum for construction in small headwater basins.

A monitoring program designed for construction in small headwater basins in Middle Tennessee includes pumping and siphon-driven samplers in intermittent and ephemeral channels, continuous streamflow and turbidity measurements, periodic storm and baseflow sediment samples, and geomorphic field observations. The rationale for these components is discussed, and preliminary results are presented. A storm on January 8, 2008 provides a test of the monitoring program under near-worst-case conditions—intense rainfall on a disturbed slope after clearing but before temporary stabilization. The movement of runoff and mobilized sediment during this storm is reconstructed and the effectiveness of sediment control evaluated through streamflow and water-quality records and field observations within the construction right of way and in receiving perennial stream channels.

TECHNICAL BASIS FOR A REALISTIC SYNTHETIC SEDIMENT FORMULATION

Adrian M. Gonzalez[1]

INTRODUCTION

For some time now, it has been apparent that attaining the water quality goals of the Clean Water Act is heavily interdependent with aquatic sediment issues (e.g., suspended sediment quantity, non-suspended, bed sediment quality, etc.) (Bolton et al., 1985; Wenning et al., 2002). National environmental policy based on this knowledge was codified by the U.S. Congress through passage of the *National Contaminated Sediment Assessment and Management Act* as part of the reauthorized *Water Resources Development Act of 1992* (WRDA; Public Law 102-580). Through this legislative vehicle, the U.S. Environmental Protection Agency (EPA), in cooperation and consultation with the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geologic Survey (USGS), were directed (among other things) to establish a National Contaminated Sediment Task Force and to conduct a comprehensive national survey of aquatic sediment quality (Environmental Law Institute, 2003). Sediment quality management (SQM) has evolved under the premise that aquatic sediment plays a crucial role in the quality and function of aquatic environments, potentially acting as both sink for, and source of, chemical contaminants.

Important elements of the overall SQM paradigm are the technical tools used to evaluate and assess sediment quality. These continue to evolve and mature in their basis on current advances in scientific theory and technical practice. The sediment quality assessment "tool box" has expanded over the years to include both abiotic tools (e.g., sediment transport and migration; sampling and analysis of whole sediment and pore water; geochemical and geophysical evaluations; numeric modeling; etc.) and biotic tools (e.g., laboratory toxicity bioassays of whole sediment and pore water; in-situ bioassays; aquatic and benthic biological surveys; etc.) (ASTM, 1999; WEF, 2002; Simpson et al., 2005). Such tools have been applied to an increasing variety of investigations with numerous regulatory and technical objectives. These include objectives such as basic research on environment-contaminant interactions; hazard and risk assessments; toxicity identification evaluations (TIEs); watershed surveys and assessments; total maximum daily load (TMDL) development; etc.

Technically sound environmental management ideally would rely on comparisons between a selected endpoint within an unknown system of interest or concern (e.g., an impacted condition) and the response of the same endpoint within a known system (e.g., some control or reference condition). This basic requirement of a scientifically sound "test" is more or less easily met depending on the complexity of the environmental systems being investigated. Aquatic sediment, unfortunately, is considered as one of the more complex environmental systems that can be investigated (EPA, 1994; EPA, 1998). Its composition consists of numerous physical, chemical and biological conditions and processes all interacting to create a patch-work of local quasi-equilibria, but such conditions and parameters can vary within spatial scales of inches to feet (Besser et al., 1996; Bishop, 2005; Stemmer et al., 1990) or miles (Suedel and Rodgers, 1991). As such, meeting the basic "comparison to a known reference or control" requirement is not trivial. The technical (Kenega, 1981; Long and Chapman, 1985; McCauley et al., 2000) and regulatory environmental communities (EPA, 1998) have acknowledged, and struggled with, this obvious challenge of not having an adequate reference or control sediment system.

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The first attempts at addressing the lack of adequate sediment reference or control focused on synthesizing “sediment-like” material from “ingredients” or components of known quality and composition (Titus and Pfister, 1982; Hanes et al., 1990; Walsh et al., 1990; Ciborowski et al., 1991). The literature review performed for this work documents a 26-year progression of synthetic sediment development (from 1982 to 2008). Reviewing this history is beneficial for understanding the challenges and advances encountered by the various investigators of synthetic sediment formulations. It also documents the basis for aspects of this work that are taken from proven methods advanced previously and reported in the literature.

Initial attempts at creating synthetic sediment (also termed artificial sediment or formulated sediment) were crude and simplistic: simple mixtures of sand-, silt- and clay-sized particles homogenized and saturated with water of known composition (Ciborowski et al., 1991; 1992). Later formulations acknowledged the lack of realism in these simple mixtures of abiotic/mineral solids by including sources of bulk “organic matter” such as cellulose, peat, composed or food items (Walsh, 1992; Kemble et al., 1999). Many current protocols are still based on this formulation largely because it is simple, there is a track record of suitability for providing a simple substrate for biological organisms during bioassays, and there have been no viable alternatives proposed (EPA, 2000; OECD, 2004). Recent formulations have attempted to mimic abiotic, geochemical parameters such as carbonate dissolution, reduced sulfur chemistry, and pore water pH and oxidation reduction potential (Gonzalez, 1996). The mineral and abiotic components of sediment appear to be fairly easily replicated in synthetic sediment formulations; however, the biotic/organic carbon components of natural sediment have been more challenging to replicate with any realism and accuracy (Walsh et al., 1992; Suedel and Rodgers, 1994; Riberio et al., 1999).

This presentation reports on work intended to address the organic carbon component of synthetic sediment formulations. It lays out the technical basis for a proposed formulation that acknowledges the complexity and variability within the organic carbon component of sediment and that includes different kinds of organic carbon types and sources designed to mimic the various characteristics and physical/chemical behavior of the specific types of organic carbon found in natural sediment. The presentation concludes with a comprehensive “recipe” for realistic synthetic sediment. As in the architectural and industrial design world where “form follows function,” the proposed synthetic sediment formulation is designed to mimic natural sediment with regard to its interaction with chemical contaminants. By meeting that objective, it is anticipated that secondary biotic and abiotic processes and interactions with the synthetic sediment (either clean or contaminated) will accurately replicate those processes in natural sediment. Future work will be focused on demonstrating the same formulation’s suitability and success at replicating those secondary processes and interactions.

THEORY

Ongoing literature search performed since 2000 has resulted in over 1300 citations covering aspects of aquatic sediment science related to sediment structure and function. Numerous investigations on aquatic sediment characterization, quality, geochemistry, and toxicity have been published spanning several decades. The earliest literature documents found describe extraction of humic substances from various terrestrial and wetland media in Europe in the late eighteenth and early nineteenth centuries. One consistent theme in this body of scientific literature is that sediment as an environmental medium is one of the most complex materials found in nature. As such, there has been (and still remains) much about sediment to investigate and discover.

A consequence of this complexity is that interactions between sediment and chemical contaminants are intricate and interdependent on numerous conditions and parameters. The more common physical/chemical mechanisms that apply to sediment-contaminant interactions include:

- Covalent bonding
- Strong complexation (inner-sphere complexation)
- Weak complexation (outer-sphere complexation)
- Ion-exchange (with or without precipitation)
- Van der Waals attractions
- Hydrogen bonding
- Deep pore condensation ("absorption" partitioning)
- Shallow pore condensation ("adsorption" partitioning)

Thus, aquatic sediment is both compositionally and functionally complex. All components of aquatic sediment, both mineral (e.g., sand, silt, clay, metal oxides, metal carbonates, etc.) and biotic/organic components, can participate in one or more of these sediment-contaminant interactions.

The specific focus of this paper is sediment organic carbon (SOC). The SOC component of natural sediment is not a single entity but rather a group of materials originating primarily from the synthesis and degradation of biotic materials in nature. The identified materials comprising SOC consist of the following:

- Humic substances
- Hymatomelanic acids
- Black carbon, soot
- Carbohydrates, cellulose
- Lipids, fatty acids
- Proteins and amino acids
- Bulk organic matter (e.g., twigs, leaves, bark)

These components contribute to the traditional "total organic carbon" (TOC) measurement determined by gross oxidation; however, they are not at all equivalent in structure or function (e.g., in their interactions with chemical contaminants). It is these differences in structural and functional characteristics that have lead to seemingly inconsistent experimental results (e.g., variability in experimentally measured parameters) attempting to correlate sediment-contaminant observations to TOC. For instance, the environmental literature is replete with sediment-contaminant studies that indicate wide ranges of partition coefficients (e.g., log octanol-water partition coefficients or organic carbon-water partition coefficients), binding capacities, desorption hysteresis, bioavailability, etc. The literature review performed for this work has identified a number of these sediment functional "anomalies," and this paper identifies plausible explanations for these anomalies based on the characteristics of the individual SOC components.

APPLICATION

The investigative part of this work is planned in a step-wise manner.

First, mineral and organic materials identified to represent specific components of natural sediment will be evaluated individually for their interactions with non-polar organic contaminants, polar organic contaminants, and inorganic metal contaminants. The functionality of each component material (with respect to partitioning, absorption, and adsorption/desorption) will be described by appropriate partition model equations.

In the second phase of this work, the materials will be combined in environmentally relevant proportions to create a number of synthetic sediment formulations of various characteristics (e.g., sandy, silt/clay, high organic/"muck"). These formulations will be subjected to the same experiments conducted with individual component materials, with the same selected contaminant classes (identified previously). Comparing the behavior of contaminants with the individual components versus the combined synthetic formulations could provide useful information on equilibration requirements for spiked synthetic sediment, partitioning and binding competition of the various synthetic components for particular contaminants, the relative chemical stability of the various component-contaminant combinations, and whether the partitioning behavior can be described as a simple, additive model comprised of the individual component-contaminant partition model equations.

In the third phase of this work, the proposed synthetic sediment formulation will be evaluated directly against a sample of natural (freshwater) sediment collected from a relatively clean environment in the East Tennessee area. The natural sediment sample will be characterized completely for appropriate parameters and that information will be applied in creating a compositionally accurate representation of the natural sediment sample. The synthetic and natural sediment samples will be carried through a suite of experimental treatments with the same selected contaminant classes to determine if the synthetic sediment formulation is functionally representative of the natural sediment.

If functional equivalence of the synthetic sediment formulation can be consistently demonstrated and replicated with respect to interactions with contaminants, further studies are planned that would investigate other functions of natural sediment, such as supporting macrobiological and microbiological habitat. It is envisioned that a viable, realistic synthetic sediment formulation would be valuable for managing and evaluating sediment quality through tools such as bioassays, laboratory culturing of bioassay organisms, TIEs, TMDLs, and research on the relation between aquatic sediment quality and water quality.

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MACROINVERTEBRATE MAYHEM: BENTHIC EDUCATION PROGRAMS FOR KIDS

Jimmy R. Smith[1]

Every year, aquatic biologists at the TDEC's Nashville Field Office participate in numerous educational opportunities, including public exhibits at environmental fairs, addressing various civic groups, and interactive demonstrations at schools and summer camps. To this end we have developed an extensive portable exhibit (including displays of live organisms), as well as a series of educational games centered around benthic macroinvertebrates and freshwater ecology. This presentation will briefly describe the various ways we have found to spread the wonder and importance of the "creek critters" to a young audience.

1 Tennessee Department of Environment & Conservation (TDEC)

10 EDUCATION PIECES THAT WORK

Tom Lawrence, P.E.*

NON-POINT SOURCE MANAGEMENT
OUTREACH AND EDUCATION

Current municipal NPDES permits place a primary emphasis on public education and outreach. Of the "Six Minimum Measures" developed by the EPA for the issuance of Phase II storm water permits, the first two ("Public Education and Outreach" and "Public Participation/Involvement") directly address getting information out to the public and the other four measures include tasks for getting information out to the public and/or specified audiences. Education is also included in many industrial NPDES permits, as well as other types of permits.

Municipal NPDES program managers agree that great success is achieved by utilizing effective public education and by coordinating education with other activities such as enforcement.

Storm water program managers have many choices as to which types of outreach to use. Since the managers rarely have a background in public outreach or education, the best approach to use in a situation may not be obvious. On the other hand, the manager may choose an approach that seems like the best way to go, only to be disappointed by poor results.

This presentation will cover 10 educational and outreach approaches that have proven effective in actual environmental education outreach campaigns. The variety of examples of campaigns that worked will provide the storm water manager with ideas of cost-effective approaches that they can use to address specific issues within their community. Additionally, tips for evaluating a campaign's effectiveness and some examples of campaign approaches that did not work will be discussed.

BIO: Tom Lawrence is a registered Professional Engineer in Tennessee, Illinois and California. He has been active in the field of environmental engineering for over 18 years, specializing in water resources protection. He has worked for the Los Angeles County Department of Public Works, the City of Memphis Public Works Division and two consulting firms. He is currently a storm water consultant focusing on solutions for municipal and industrial permit compliance.

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TN YARDS & NEIGHBORHOODS: A NEWLY FORMED PROGRAM ADDRESSING THE CHALLENGES OF RESIDENTIAL NPS POLLUTION

Ruth Anne Hanahan[1]

Over the past decade, with the growth of Tennessee's population, the state's landscape has been dramatically shifting from a predominance of farmland to sprawling metropolitan areas. In conjunction with this change a growing water quality threat from residential development has emerged. In 2005, the Beaver Creek Task Force (BCTF) based on land use modeling determined that residential development is a significant contributor to nonpoint source pollution in the Beaver Creek Watershed, an 86 square mile subbasin located within the Lower Clinch Watershed. In an effort to address this problem, the BCTF first identified a tried-and-true NPS education program for homeowners entitled Yards & Neighborhoods (Y&N). This program takes a holistic approach to teaching landscaping practices that help to protect and conserve water resources. With Y&N having been successfully implemented in Florida for over a decade and currently being piloted in North Carolina, BCTF partners sought and received approval from these program administrators to adapt and test the program in the Beaver Creek Watershed. They also contacted UT Extension to become a key partner, with Extension having played a key role in the implementation of Y&N in Florida and North Carolina. In early 2007, TN Water Resources Research Center and TVA in conjunction with UT Extension took the lead on creating a Tennessee version of Y&N and successfully piloted the program in the fall. The purpose of this presentation will be to provide an overview of the newly launched TN Y&N and describe our anticipated approach to the expansion of this program across the state.

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BACTERIAL SOURCE TRACKING IN AN EASTERN TENNESSEE STREAM USING *BACTEROIDES* HOST ASSOCIATED REAL-TIME POLYMERASE CHAIN REACTION ASSAYS

Ryan Ragsdale[1], Forbes Walker[2]*, Alice Layton[3,4], and Joanne Logan[5]

ABSTRACT

A bacterial source tracking study was conducted to determine the sources of fecal contamination in Pond Creek (HUC 06010201013), a stream that fails to meet water quality standards for pathogens. Water samples and discharge were measured monthly at eight locations from November 2005 to November 2006. Grab samples were analyzed for microbial fecal indicator organisms (*Bacteroides spp., Escherichia coli,* and *Enterococcus*). The objectives of the study were to quantify total, human, and bovine associated *Bacteroides,* to investigate spatial and temporal variation of fecal indicator organisms and develop load duration curves for each sampling site.

Bacteroides host associated real-time polymerase chain reaction (PCR) assays indicated that cattle were the dominant source of fecal pollution (99 percent of total *Bacteroides*). Load Duration Curves (LDCs) indicated extensive bovine fecal pollution. Load data separated into human and bovine LDCs showed that *Escherichia coli* loads from bovine sources were mostly flow dependent whereas human associated *Escherichia coli* loads were generally flow independent. Temporal variations followed seasonal weather patterns; mean loads of all fecal indicators (except *Enterococcus*), were greatest during the months of highest precipitation and lowest in the drier months. No temporal patterns were established. We conclude that runoff transported the majority of fecal inputs to Pond Creek. Best management practices (BMPs) such as improving pastures, nutrient management, proper manure storage, controlling livestock stocking densities, vegetative filter strips, and riparian fencing with careful riparian grazing, should be implemented to reduce fecal inputs from cattle and help Pond Creek meet total maximum daily load (TMDL) targets.

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LAND-USE EFFECTS ON BACTERIA LOADS AND WATER QUALITY IN SMALL KARST CATCHMENTS OF THE UPPER DUCK RIVER WATERSHED

James J. Farmer[1]

Several streams in the upper Duck River watershed are listed by the Tennessee Department of Environment and Conservation as impaired by elevated bacteria levels. **Potential sources of bacteria in the watershed include grazing, confined-animal operations, and domestic septic systems. The relative contributions of these sources to elevated bacteria levels are not known.** The effects of land-use on stream water-quality in karst topography will be determined by studying four rural catchments in the upper Duck River watershed. Two of the study catchments will be small and in close proximity to each other to control for natural variability in water chemistry, geology, and physiography. One catchment will encompass the two small catchments, and the fourth will be located on the main stem of the Duck River. This study will be conducted in two phases. The first phase will characterize the water quality and land use across the study to identify spatial patterns. The second phase will investigate temporal variability of bacteria counts and the use of surrogates, such as turbidity, for predicting bacteria loads.

1 U.S. Geological Survey

ASSESSING SOURCES OF *E. COLI* AND FECAL CONTAMINATION IN THE LITTLE RIVER WATERSHED

Alice C. Layton[1]*, Dan Williams[2], Carol Harden[3], Keri Johnson[4], and Erich Henry[5]

WATER QUALITY MONITORING AND ASSESSMENTS

The Little River Watershed in eastern Tennessee contains 230 stream miles classified as impaired with 65% of the stream segments listing bacterial pathogens (*E. coli*) as a primary source of impairment. Land use patterns in four sub-watersheds vary from being predominantly urban/residential to being predominantly agriculture. In 2006 a water quality study evaluated the state of bacterial and fecal contamination at 33 sites in the Little River Watershed so that the relative impacts of bacterial and fecal contamination from the tributaries on the main branch of the Little River could be determined. During this sampling period 31 of the 33 sites exceeded the *E. coli* Recreational Water Quality limit of 126 CFU/100 ml calculated as the geometric mean of the 5 sample dates. *Bacteroides* real-time PCR assays were used to estimate total fecal concentration (AllBac assay) and fecal contamination attributable to cattle (BoBac assay) and humans (HuBac assay) in all samples. Fecal source identification indicated that 10 sites confined to three sub-watersheds were heavily impacted by cattle fecal contamination. Human fecal contamination was more widely distributed in the Little River Watershed than bovine fecal contamination. Comparison of the *E. coli* concentrations with fecal concentrations indicated that the HIGHEST *E. coli* concentrations were associated with cattle fecal contamination (up to 1937 CFU/100ml) and that sites with high human fecal contamination had more moderate levels of *E. coli* contamination (155 to 455 CFU/100ml). These results suggest that implementation strategies to reduce fecal contamination due to both cattle and humans will reduce *E. coli* concentrations in the Little River Watershed and associated tributaries. In addition, this water quality data collected will serve as reference point for future water quality studies after remediation practices have been implemented.

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SESSION 3A

PUBLIC WATER SUPPLY
8:30 a.m. – 10:00 a.m.

Annual Water Reuse Survey
Dennis B. George

Drought Impacts on Water Supply
Tom Moss

State Revolving Fund Loan Programs Tennessee's Largest Water Quality Funding Source
Emily A. Kelly

PLANNING AND POLICY
10:30 a.m. – 12:00 p.m.

The Atlanta Water Crisis: Tennessee Policy History and Potential Next Steps
D. Galbreath (Paper Not Available)

Drought and Water Shortage Planning in the Upper Duck River Region
H. Doug Murphy

Tennessee Management of the 2007-2008 Drought
N. Fielder (Paper Not Available)

ANNUAL WATER REUSE SURVEY

Dennis B. George[1]

"Approximately nine billion gallons of water are withdrawn from the Tennessee River system every day—mostly by municipal water systems and industry and business users, including TVA's thermoelectric generating plants, which rely on the river for cooling water. Most of the water—about 95 percent—is returned to the river for reuse. There are developments on the horizon (TVA, 2001)," however, and recent drought conditions that "could place increased stress on existing patterns of water use." Increased demands on Tennessee's water resources can be reduced by water conservation, recycling and reuse.

Water reuse involves treating domestic wastewater to a high degree and using the resulting high-quality reclaimed water for a new, beneficial purpose. Extensive treatment and disinfection ensure that public health and environmental quality are protected. The Center for the Management, Utilization and Protection of Water Resources, in cooperation with the Tennessee Department of Environment and Conservation, has initiated an annual water reuse survey for the state of Tennessee. This survey is designed to determine the current amount of reclaimed waste transformed for nonpotable (e.g., irrigation, industrial), direct potable (e.g., discharge into drinking water reservoirs) or indirect potable (e.g., recharging ground water supplies) uses occurring in Tennessee. The results of this survey are entered into a water reuse inventory database and are available to all participants at the following Web sites: www.tntech.edu/wrc/WaterReuseSurvey.htm, www.state.tn.us/environment/dws, and www.state.tn.us/environment/wpc/other.shtml. This presentation will discuss the implementation of the water reuse survey and its implications for water management in Tennessee.

REFERENCES

Tennessee Valley Authority. 2001. Water Supply Issues Take Center Stage. *River Neighbors*. Tennessee Valley Authority, Norris, TN. August.

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DROUGHT IMPACTS ON WATER SUPPLY

Tom Moss

We have a number of water systems that have been impacted by the drought, as well as private homes relying on wells and springs in Middle and East Tennessee. Many of the systems have been impacted not by their sources running out but by hydraulic or treatment capacity issues due in large part to the amount of irrigation of lawns, gardens, car washing, etc. – the water systems simply could not produce enough water or pump enough water through their water lines. However, we do have a number of systems that are suffering from dwindling water supply sources. Very few West Tennessee water systems with problems – this is due to the fact that they rely on wells drilled into sand aquifers that are not showing as large an impact from the drought. Water systems on the large rivers across the state such as the Cumberland, Tennessee, Holston and Clinch are also not suffering from diminishing water supplies.

The systems of particular concern are those that rely on Normandy Lake and the Duck River – the Duck River Utility Commission (which supplies Manchester and Tullahoma), Shelbyville, Columbia, Bedford County UD, Lewisburg and Spring Hill. Combined they serve a population of approximately ¼ million people. Maintaining in stream flow below Normandy Dam at an order of magnitude higher flow than inflow into the lake is draining the lake. Estimates are that with the abnormally dry winter the National Weather Service is predicting that Normandy Lake will be out of water by sometime between May and August of 2008.

Several public water systems employed extraordinary measures to maintain water services to their customers. Alcoa/Maryville had a project to run water 2 miles back upstream on the Little River from the backwaters of Fort Loudon Lake so that stream flow could continue and Alcoa and Maryville could continue to withdraw from the Little River. Monteagle has run pipelines to a sand mine and to Lake Louisa back to their Laurel Lake to supply their customers with water after Tracy City, Sewanee and Big Creek UD were getting to the limit of how much they could send to Monteagle due to their own dwindling lake supplies. This running of pipelines has been a stopgap measure and may not be sufficient to maintain the system until the drought ebbs. The long term solution being sought will be to connect the water systems on Monteagle Mountain to South Pittsburg, which gets its water from the Tennessee River, but this solution will likely not be in place for 3 – 5 years, long after the drought has gone.

STATE REVOLVING FUND LOAN PROGRAMS
TENNESSEE'S LARGEST WATER QUALITY FUNDING SOURCE

Emily A. Kelly, P.E.[1]

The State Revolving Fund (SRF) Loan Program provides low-interest loans to communities, utility districts and water/wastewater authorities to help finance the planning, design, and construction of water and wastewater facilities projects that protect Tennessee’s ground and surface waters and public health. The interest rates on these loans vary from zero percent to market rate based on each community’s economic index. The Tennessee Department of Environment and Conservation administers the SRF Loan Program and its 2 funds, the Clean Water State Revolving Fund (CWSRF) and the Drinking Water State Revolving Fund (DWSRF).

The CWSRF Loan Program is Tennessee’s Largest Water Quality Financing Source. From 1987 through February 2008, Tennessee's CWSRF provided 239 loans totaling **$950 million** to construct wastewater facilities that protect water quality and/or public health. Types of eligible CWSRF projects are wastewater treatment plants; infiltration/inflow correction; rehabilitation and/or replacement of sewer lines; manholes, etc.; new collector and interceptor sewers; combined sewer overflow correction; storm sewer construction; water reuse; and other projects as defined under Section 212 of the Clean Water Act. From 1996 through February 2008, Tennessee’s DWSRF provided 76 totaling **$111 million** to bring water systems into compliance with the Safe Drinking Water Act and new regulations. Types of eligible DWSRF projects are water treatment plant upgrades/expansion, new transmission lines, distribution system rehabilitation/replacement/extensions; source water/well development, water storage tanks, creation of new systems, pressure problems, capacity, water loss, compliance, and protection of public health and the environment.

The State Revolving Fund (SRF) Loan Programs are funded by the federal and state governments--Capitalized by EPA grants with a 20% state match. These loans are available to local governments—defined by TDEC Rule 1200-22-6-.02 as

- A county, incorporated town or city, metropolitan government, water/wastewater authority, or state agency that has authority to administer a water or wastewater facility, or any combination of two or more of the foregoing acting jointly to construct a water or wastewater facility
- Any publicly-owned utility district existing on July 1, 1984, or if created after that date, any publicly-owned utility district operating a water or wastewater facility with at least 500 customer connections

Key Features of the SRF Loan Programs include the following:

- Low Interest Rates
- Flexible Terms
- Loan Awards within 90 - 120 days
- Assistance to a Variety of Borrowers—Cities, Counties, Utility Districts, Authorities, Communities of all sizes
- Partnerships with Other Funding Sources—Local Governments, Other Federal and State Agencies, CDBG, RUS, RDA, STAG, etc.

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Terms of SRF Loans include the following:

- Interest Rates from 0% to market rate (The poorer the community, the lower the interest rate.)
- Fixed for the life of the loan
- Repay only the actual amount drawn down
- No origination, administration, or closing fees or wage rates
- 5 - 20 year repayment terms
- No early repayment penalty
- Non-profit program
- Reimbursement programs
- CWSRF applications may be initiated at any time
- DWSRF applications are solicited by the State Revolving Fund Loan Program on an annual or biennial basis.
- Time from Facilities Plan submittal to Loan Award—average of 120 days
- SRF Loan Program obtains environmental clearances
- No wage rates
- SRF staff assistance with filing, resolutions, loan application, planning
- SRF staff travels to the applicants for meetings to aid in file system setup, loan application completion, etc.
- Non-profit, federally-funded loan program

SRF loans save money in the following ways:

- SRF loans average 2.2% compared to market rates averaging 4.8%.
- SRF loans can fund 100% of the project's costs and provide repayment terms up to 20 years and low interest rates.

Eligible CWSRF Projects include the following Clean Water Act Section 212 and 319 projects:

- **Wastewater Treatment Plants—upgrades, expansion, new**
- **Infiltration/inflow correction**
- **Rehabilitation and/or replacement of sewer lines, manholes, etc.**
- **New collector and interceptor sewers**
- **Combined sewer overflow correction**
- **Storm sewer construction, storm water management**
- **Conveyance of recycled water from wastewater facility to end user**
- **Nonpoint source pollution control**

Cities, utility districts, water/wastewater authorities with active and/or proposed CWSRF loans:

- Benton-Decatur Special Sewer District
- Chattanooga
- Clarksburg
- Decatur
- Dresden
- Englewood
- Ethridge
- Hallsdale-Powell UD
- Kingsport
- Lafollette
- Lebanon
- Lenoir City
- City of Loudon
- Madisonville
- Nashville/Metropolitan Davidson County
- Monroe County—Tellico Area Services System
- Loudon County—Tellico Area Services System
- Marion County/Jasper
- Memphis
- Metro Nashville
- McMinnville
- Morristown
- Moscow
- Mt. Pleasant
- Oak Ridge
- Shelbyville Sweetwater
- TASS
- Wartburg
- Water Authority of Dickson County

Cities, utility districts, water/wastewater authorities that have previously taken out CWSRF loans:

- Alcoa
- Arlington
- Athens
- Atoka
- Baxter
- Bean Station
- Benton- Decatur SSD
- Bluff City
- Bolivar
- Bristol
- Brownsville
- Byrdstown

- Caryville
- Centerville
- Charlotte
- Chattanooga
- Clarksburg
- Clarksville
- Clifton
- Collegedale
- Collinwood
- Cookeville
- Cornersville
- Cross Plains
- Crossville
- Cumberland Gap
- Decatur
- Dickson
- Elizabethton
- Erin
- Ethridge
- Fairview
- Goodlettsville
- Greenbrier
- Greenfield
- Grundy County
- Harrogate
- Henderson
- Hendersonville UD
- Hohenwald
- Humboldt
- Jackson
- Jefferson City
- Jellico
- Kingsport
- Lawrenceburg
- Lebanon
- Lenoir City UB
- Livingston
- Loretto
- Loudon
- Madison County
- Madisonville
- Martin
- Maury City
- Maynardville
- McKenzie
- Millersville
- Mitchellville
- Monteagle-Grundy Co.
- Mount Pleasant
- Mountain City
- Murfreesboro
- Nashville/ Metropolitan Davidson County
- Newbern
- Newport
- Oak Ridge
- Oakland
- Oliver Springs
- Portland
- Red Bank
- Red Boiling Springs
- Ridgetop
- Ripley
- Rockwood
- Sevierville
- Shelbyville
- Sneedville
- Spencer
- Spring City
- Spring Hill
- Springfield
- Sunbright
- Sweetwater
- Tullahoma
- Unicoi
- Waynesboro
- White Bluff
- White House

Eligible DWSRF projects include the following types:
- *Water Treatment Plants—Upgrades, Expansion, New*
- Transmission Lines and Distribution System Rehabilitation, Replacement, Extension
- Source Water/Well Development
- Storage Tanks
- Consolidation
- Creation of New Systems
- Pressure Problems
- Capacity
- Water Loss
- Land
- Compliance
- Protection of Public Health and the Environment

Cities, utility districts, water/wastewater authorities with active and/or proposed DWSRF loans:
- Bon Aqua-Lyles UD
- Hallsdale-Powell UD
- Jefferson City
- Lebanon
- Livingston
- Loudon
- Maury Co. Water System
- Maynardville
- McMinnville
- Morristown
- Newport
- Ocoee UD
- Reelfoot UD
- Rogersville
- Sewanee UD
- Watauga River Regional Water Authority

Cities, utility districts, water/wastewater authorities that have previously taken out DWSRF loans:

- Bradford
- Clarksville
- Collinwood
- Crossville
- Cumberland UD
- Dekalb UD
- Dickson
- Dyersburg
- Eastview
- Elizabethton
- Gladeville UD
- Greenfield
- Hallsdale-Powell UD
- Jackson
- Kingsport
- LaFollette
- LaGuardo UD
- Lebanon
- Lenoir City UB
- Livingston
- Loudon
- Lynchburg/ Moore County
- McKenzie
- McMinnville
- Morristown
- Mount Pleasant
- Oakland
- Ocoee UD
- Pikeville
- Troy
- Union Fork/Bakewell UD
- Watts Bar UD
- West Overton UD
- West Warren-Viola UD

SRF Loan Programs Contacts:
Website: www.tdec.net/srf

Environmental Manager, Sam Gaddipati

DROUGHT AND WATER SHORTAGE PLANNING IN THE UPPER DUCK RIVER REGION

H. Doug Murphy[1]*

PLANNING AND POLICY

Central Tennessee is in the worst drought on record since the late 1800's and Tennessee rated the number one state in the nation for drought severity in the Palmer Drought Index. The Duck River runs through central Tennessee from east to west for more than 270 miles and provides water for approximately a quarter of million Tennessee residents plus industry needs and recreation opportunities. The Duck River is also known for its biodiversity and environmental importance. With the competing uses for the river and the extreme drought conditions the only reservoir, Normandy Reservoir, on the Duck River was able to be operated to maintain a steady flow of water for 2007 but could possibly not have the runoff to refill to maintain flows in 2008. Good planning for reservoir water conservation and developing strong partnerships will assure the Duck River will continue to serve the multi-uses of the region.

In July of 2007 the Duck River Agency started developing action plans to conserve water resources in Normandy Reservoir. Two previously formed groups, the Duck River Agency Technical Advisory Committee (DRATAC) and the Water Resource Council (WRC), played critical rolls to complete an emergency plan and actions to conserve water in the fall/winter of 2007 and winter/spring of 2008. The emergency plan focused on changes to the Normandy Reservoir Operating Guidelines by reducing required flows to a minimum that would rebuild reservoir water supplies and provide no significant environmental impact.

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SESSION 3B

WATER QUALITY STANDARDS AND ASSESSMENT
8:30 a.m. – 10:00 a.m.

Probabilistic Monitoring in Tennessee 2000-2010
Deborah H. Arnwine

Status of Water Quality in Tennessee 2008 305(b) Report
Courtney Brame

Regional Criteria Development in Tennessee: What's Next?
G. Denton (Paper Not Available)

URBAN CORRIDORS
10:30 a.m. – 12:00 p.m.

Preliminary Results of Metro Nashville Water Services Watershed Water Quality Management Activities
Megan Sitzlar

Chattanooga Stream Corridor Evaluation (SCORE) Program
Jonathan Hagen, Wayne Boyd, Quinn Lewis, Rebecca Robinson, and Mo Minkara

Stream Corridor Assessment Survey of Impaired Waters in a Small Tennessee Municipality: Implementation Options and Approaches
Matthew D. Smith, Eric M. Solt, and William K. Barry

PROBABILISTIC MONITORING IN TENNESSEE 2000 - 2010

Deborah H. Arnwine[1]

Since 2000, the Division of Water Pollution Control has used probabilistic monitoring studies to supplement its targeted watershed monitoring approach. Probabilistic monitoring is a strategy in which sampling stations are picked randomly. Results from the sub-sample can then be accurately extrapolated to represent overall conditions in the area of study. These projects are generally designed to answer specific water quality questions.

The advantages of probabilistic monitoring are:

•Ability to determine the status of populations of interest using relatively few sites
•Reduced sampling costs.
•Can use more intensive sampling methods.
•Statistical validity
•Standardized methodology
•Accurate large-scale assessments

This presentation will provide a brief summary of studies conducted by the division between 2000 and 2007. The current statewide wadeable streams study will be discussed in more detail along with preliminary results for pathogens and habitat assessments. Tennessee's role in a national study of flowing waters will be presented. Studies covered will include:

•2000 – 2002 Inner Nashville Basin Pilot Project
•2003 – State-Wide Impounded Stream Study
•2004 – National Wadeable Streams Assessment
•2007 – National Lakes and Reservoirs Assessment
•2007 – 2008 State-Wide Wadeable Streams Assessment
•2008 – 2010 National Flowing Waters Assessment

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STATUS OF WATER QUALITY IN TENNESSEE 2008
305(B) REPORT

Courtney Brame[1]

WATER QUALITY MONITORING

Tennessee is fortunate to have abundant water resources with over 60,000 miles of streams and rivers and almost 600,000 acres of reservoirs and lakes. Protecting these resources is one of TDEC's greatest challenges. A watershed monitoring approach is used to help organize monitoring activities and resources. Tennessee's 54 watersheds are organized into 5 groups that are assessed on a 5-year cycle.

By viewing the entire watershed, the Department is better able to address water quality problems. This approach allows for an in-depth study of each watershed. The five-year watershed cycle consists of planning, monitoring, assessment, Total Maximum Daily Load (TMDL) development and issuance of National Pollutant Discharge Elimination System (NPDES) permits. Since the 2006 report, groups 4 and 5 watersheds were assessed, while groups 1 and 2 watersheds were monitored.

Water Quality Assessment Categorization

The Water Quality Standards determine designated uses for Tennessee's waterways, define criteria for each designated use, and provide an antidegradation policy to protect existing uses. To determine if a waterbody is supportive, monitoring data are compared to water quality standards. Each river, stream, lake, and reservoir is placed into the appropriate use support category (Table 1).

Table 1: Category Classifications

Category	Use Support	Definition
1	Fully Supporting	Meets all designated uses.
2	Fully Supporting	Meets some designated uses, not assessed for other designated uses.
3	Not assessed	Insufficient data, not assessed.
4	Partially or not supporting	Not meeting all designated uses. TMDL has already been completed or is not appropriate.
5	Partially or not supporting	Not meeting all designated uses. Waters are impaired or threatened and TMDL(s) are needed.

The group 4 and 5 watershed assessments will be included in the 2008 305(b) report. An interactive map of water quality assessments is available on TDEC's website at http://www.state.tn.us/environment/water.php.

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PRELIMINARY RESULTS OF METRO NASHVILLE WATER SERVICES WATERSHED WATER QUALITY MANAGEMENT ACTIVITIES

Megan Sitzlar[1]

Metro Nashville Davidson County realizes that maintaining clean rivers and streams is pivotal to ensure community well-being and environmental health. As a result, Metro Water Services has implemented several programs geared toward monitoring and evaluating stream health, detecting and correcting illicit discharges, and improving overall watershed health through special projects and public education. Data collected thus far is showing improvements in stream health county-wide. Each program will be briefly described and a review of the preliminary results will be presented.

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CHATTANOOGA STREAM CORRIDOR EVALUATION (SCORE) PROGRAM

Jonathan Hagen*, Wayne Boyd, Quinn Lewis, Rebecca Robinson and Mo Minkara, Ph.D., P.E.[1]

A visual stream survey program and stream impairment inventory is currently being conducted by the City of Chattanooga to assess local watersheds condition and improve management and restoration decisions. This program provides a detailed and consistent approach to identify, evaluate, and correct stream channel stability, reduce sediment loading, improve in-stream habitat, and protect public and private infrastructure. By following previously established corridor assessment protocols, Chattanooga Water Quality Program staff have been collecting and analyzing key physical, hydrologic, geologic, and biologic streambank parameters.

In the first six months of this program, field crews have assessed nearly 60,000 linear feet (11.3 miles), completing a small urban watershed (Citico Creek). Field activities have allowed Water Quality staff to survey permanent stormwater quality control structures, flood control structures, and industrial and construction runoff Best Management Practices (BMPs). By employing field data in watershed simulation studies, it is estimated that nearly 800 tons per year of sediment are being lost as a result of streambank erosion from this waterway (< 1 lb/ft/day). Additional outcomes of this pilot program include the detection of 12 illicit discharges (pet waste, construction runoff, industrial and sanitary discharges). The program is being expanded city-wide utilizing a priority ranking system based on TMDL implementation and monitoring plan requirements. Results of the SCORE program will enable Chattanooga to establish guidelines for stream bank protection and water quality improvement.

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STREAM CORRIDOR ASSESSMENT SURVEY OF IMPAIRED WATERS IN A SMALL TENNESSEE MUNICIPALITY: IMPLEMENTATION OPTIONS AND APPROACHES

Matthew D. Smith, R.G.[1]*; Eric M. Solt, P.G.[2]; and William K. Barry, P.E., D.WRE[3]

Tennessee's Small Municipal Separate Storm Sewer Systems (MS4s) have authorization to discharge stormwater runoff into waters of the State of Tennessee under the National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges. According to this permit municipalities are responsible for a Stream Corridor Assessment (SCA) survey of impaired streams in their jurisdiction. The SCA survey is a component of the Total Maximum Daily Load (TMDL) program. The SCA provides a tool for identification of potential point and non-point source pollution sites, and prioritization of restoration areas which may help improve water quality in these "impaired" stream reaches.

S&ME recently completed a SCA survey for a small East Tennessee municipality, and is currently assisting several municipalities with benthic sampling and other NPDES related tasks. This presentation will outline several approaches for completing a SCA survey based on the needs of the municipality, available funding and technology, and the amount of stream length to be surveyed. Alternative methods for data collection and analysis depending on the capabilities of the MS4 will be discussed, along with trial and error experience from the recently completed survey.

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SESSION 3C

WATERSHED MODELING
8:30 a.m. – 10:00 a.m.

Use of AnnAGNPS (Annualized Agricultural Non-Point Source) Pollutant Loading Model for Prediction of Sediment Yields in a Mountainous Cumberland Plateau Region
M. Patrick Massey, John S. Schwartz, and Eric C. Drumm

Characterizing Spatial Variation in Nitrogen Delivery to Streams in the Tennessee River Basin
Anne B. Hoos and Gerard McMahon

Water Quality Impacts from Acidic Deposition in the Great Smoky Mountains: WINHSPF Model Simulations of Nitrogen and pH
Meijun Cai and John S. Schwartz

RISK ASSESSMENTS
10:30 a.m. – 12:00 p.m.

Development of a Spill Response and Water Quality Management Information System
Janey Smith, Eugene J. LeBoeuf, Mark D. Abkowitz, Edsel B. Daniel, and James P. Dobbins

Options for Sediment Ties-The State of the Science
Scott Hall

HEC-RAS Modeling of Hypothetical Outflows from Wappapello Dam, Missouri
Gregory H. Nail

USE OF ANNAGNPS (ANNUALIZED AGRICULTURAL NON-POINT SOURCE) POLLUTANT LOADING MODEL FOR PREDICTION OF SEDIMENT YIELDS IN A MOUNTAINOUS CUMBERLAND PLATEAU REGION

M. Patrick Massey[1]*, Dr. John S. Schwartz[2], and Dr. Eric C. Drumm[3]

This study attempts to develop a relationship with the predicted sediment yield fine particle size distribution (produced from the computer model) and the deposited sediment within the stream channel. By using specific hydrological parameters within a watershed, a calibrated AnnAGNPS pollutant loading model is created for four different sub-watersheds in the mountainous New River Basin of eastern Tennessee.

The fine particle size characteristics collected at specific bed deposition points are suspected to have a strong correlation with predicted sediment yield output from a calibrated Annualized Agricultural Non-Point Source (AnnAGNPS) pollutant loading model. The sites of the captured sediment are at locations just downstream of specific land use disturbances such as dirt roads, surface mining, and forest logging, all of which can be detrimental to the health of a stream environment and habitat if not properly managed. The sediment collected at the channel bed deposition points represent the distribution of different material sizes that have recently moved within the stream during large discharge events.

Currently, there are a limited amount of studies that analyze these collections of fine sediment deposited in areas of the stream that have interrupted velocity forces due to channel shape, objects, or formations. Through the combination of the AnnANGPS pollutant loading model and the collection/analyzation of specific fine sediment at depositional points in the stream, proper watershed management of a rural mountainous region can be better established.

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CHARACTERIZING SPATIAL VARIATION OF NITROGEN DELIVERY TO STREAMS IN THE TENNESSEE RIVER BASIN

Anne B. Hoos[1] and Gerard McMahon[2]

The SPARROW model (SPAtially-Referenced Regression on Watershed attributes) was used to investigate transport and fate of nitrogen on the landscape and in streams in river basins in the southeastern U.S., including the Tennessee River Basin. The SPARROW model integrates water-quality monitoring data with nitrogen source data to estimate mean-annual rates of combined overland and subsurface nitrogen transport from sources in a watershed to the adjacent stream channel. Delivery rates are characterized as functions of landscape factors such as soil permeability and depth. The model produces estimates of mean annual load and concentration of nitrogen for each stream reach in the model area, providing a tool for addressing several questions about stream nitrogen loads entering nutrient-sensitive water bodies in the Tennessee River Basin.

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WATER QUALITY IMPACTS FROM ACIDIC DEPOSITION IN THE GREAT SMOKY MOUNTAINS: WINHSPF MODEL SIMULATIONS OF NITROGEN AND pH

Meijun Cai[1] and John S. Schwartz[2]

Hydrological Simulation Program – FORTRAN (WinHSPF) from the BASINS 4.0 was used to simulate the stream response (nitrogen, pH) to acid deposition from 1999 to mid-2006 in Noland Divide Watershed, a small forested basin locating in southern Appalachian Mountains.

Hydrology calibration results were satisfactory showing model efficiency over 0.8 for yearly stream discharge and over 0.4 for daily flow. The greatest deviation occurred at peak flow, because of limitations in the precipitation records.

Nitrogen components, including nitrate and ammonia, were simulated by using program modules NITRX in PERLND, and NUTRX and PLANK in RCHRES. Through nitrification, 85 percent of deposited ammonia was converted to nitrate reducing ammonia concentration in the stream to about 0.05mg/L. Compared to the observed ammonia concentration near 0 mg/L in the stream, the model simulation could not commonly deplete ammonia as observed. The mean error between the simulated and measured stream nitrate concentration was -0.0254mg/L while the mean observed nitrate concentration was 0.5734mg/L. The model output for pH ranged from 5.7 to 6.0, which was similar the observed stream pH range of 5.5 to 6.5. However, these simulated pHs did not reflect the acidification process in the watershed because WinHSPF models pH values are simply based on the equilibrium of alkalinity and carbonate system in the stream. In addition, observed negative alkalinity from atmospheric deposition cannot be calculated from PERLND to RCHRES modules, resulting in the inaccuracy for pH calculation in low-alkalinity watershed.

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DEVELOPMENT OF A SPILL RESPONSE AND WATER QUALITY MANAGEMENT INFORMATION SYSTEM

Janey Smith[1]*, Eugene J. LeBoeuf[2]**, Mark D. Abkowitz[3], Edsel B. Daniel[4], and James P. Dobbins[5]

To assist in spill response efforts by local authorities, researchers at Vanderbilt University previously developed Spill Management Information System (SMIS 1.0) for predicting contaminant migration along inland waterbodies through use of geographic information systems (GIS) combined with water quality modeling. This initial system is presently used by the U.S. Army Corps of Engineers (USACE) and Nashville Metropolitan Water Services on the Cheatham Reach, Nashville, Tennessee. SMIS 1.0 combines ArcView 9.1, CE-QUAL-W2, a 2D water quality model from USACE, and a database management system. The efforts of the current research are to expand the capabilities of this technology through use of more advanced water quality models to create a more comprehensive system for both spill response and water quality management decision support. We will use advanced models such as the Environmental Fluid Dynamics Code (EFDC) and Water Quality Analysis Simulation Program (WASP), linked with GIS. Users of the system will have the ability to analyze changes in meteorological conditions and releases from dams and their impacts on downstream water quality including dissolved oxygen levels, temperature, etc., enabling river forecasting decision support and analysis of permit requirements. In addition, the system can be used as a tool to map and forecast the locations of contaminant plumes immediately following a chemical spill. Scenario analysis for boom deployment is another possibility. Incorporating model output of spill modeling results in a GIS environment enables visualization of contaminant plume concentrations as a function of space and time. Furthermore, the system can be used for pre-emergency planning and training exercises.

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OPTIONS FOR SEDIMENT TIES – THE STATE OF THE SCIENCE

Scott Hall[1]

In late 2007, the USEPA finalized its methodologies for conducting sediment Toxicity Identification Evaluation (TIE) studies. These laboratory-based studies are designed to characterize and identify the toxic constituent(s) in sediments. This can have application in risk assessments of contaminated sites, in decision-making for dredging operations, in site clean-up prioritization, and in assigning remediation liability. A key component of such assessments often involves determining the role of natural toxicants in the observed toxicity. USEPA TIE methodologies for effluents have been available since the late 1980s. However, TIE protocols for sediment-associated toxicants, particularly whole sediments, are much less established than TIE methods for effluents. This presentation will review the state-of-the-science in sediment toxicant identification, overview the newly-released EPA sediment TIE methodology, highlight notable research in this area, and discuss limitations of the new TIE methodology as well as study artifacts that must be considered in data interpretation.

Study Considerations – When designing a sediment TIE study, key considerations include:

- **Overall goal**
- **Test Organism(s)**
- **Whether to use whole-sediment or sediment interstitial water**
- **Suspected toxicants**
- **TIE treatments**

The primary toxicants addressed by the USEPA sediment TIE manual (USEPA, 2007) are:

- **Ammonia**
- **Metals**
- **Organics**

The role of these toxicants in causing sediment toxicity can be addressed using whole-sediment or sediment interstitial water, although the methodologies are different for each matrix. After conducting an initial toxicity test to document the general level of toxicity in the matrix (whole-sediment or interstitial water), a "baseline" test is used for comparison to treated samples. For freshwater sediments/waters, the following treatments can be used to implicate the toxicants indicated:

- **Zeolite: This natural resin removes ammonia from aqueous solutions, whether added to whole sediment to remove ammonia from waters between sediment particles or used to remove ammonia from interstitial waters after they are removed from the sediments. One must be aware, however, that zeolite serves as an ion exchange resin and can remove the toxicity due to toxicants other than ammonia (e.g., some metals). Likewise, water chemistry parameters (e.g., pH) should be monitored to account for other factors that may alter the form and hence toxicity of constituents in the sediment.**

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- **Cation Exchange Resins: These are used in whole-sediment additions, or to treat interstitial waters to remove heavy metals such as copper and zinc. Care must be taken to monitor pH as some resins use H^+ or OH^- exchange to remove metals and ions.**

- **Sulfide Addition: This is typically applied to whole-sediments to complex heavy metals, making them insoluble and non-toxic. The use of Acid Volatile Sulfide (AVS) analyses and metals analyses can determine *a-priori* whether it is possible for selected metals to be the source of toxicity. If, on a molar basis, the concentration of AVS exceeds the sum of the concentrations of the metals it complexes, such metals will not be toxic.**

- **Carbon Addition: Most commonly used on whole-sediments, addition of coconut charcoal, Powdered Activated Carbon (PAC), and Granular Activated Carbon (GAC) can be used to complex sorptive organics compounds such as pesticides.**

- **SPMDs: Semi-permeable Membrane Devices (SPMDs) can be placed in whole-sediments to remove low-solubility compounds that may be toxic. These devices contain lipid-like materials that allow partitioning of chemicals from the aqueous phase to the fat-like molecules that absorb such chemicals.**

In testing, appropriate treatment controls, and in some cases controls to account for dilution of the sediment by resin addition for example, should be included. Many of these treatments can be coupled with chemical analyses for comparison of levels before and after treatment, and to known toxic levels reported in the literature.

Conventional TIE methods applicable to interstitial waters to remove toxicants include:

- **EDTA Addition: Ethylene-di-amine-tetraacetic acid (EDTA) is a strong chelator of divalent cationic metals such as copper, zinc, and others. Although it does not remove metals, it renders them non-toxic, and decreased toxicity of EDTA-treated waters strongly implicates divalent cations as toxicants. Although not part of the USEPA sediment protocol, treatment of sediment interstitial waters with sodium thiosulfate for comparison to results of EDTA additions can implicate certain metals over others.**

- **Air stripping: pH 11 air stripping removes ammonia and other high-pH-volatile constituents. Coupled with the results of zeolite testing and/or ammonia analyses, strong indications as to the role of ammonia, a common sediment toxicant, can be achieved. Air stripping at various pH levels can implicate and rule out various toxicants.**

- **pH Adjustment, filtration: The toxicity of many constituents such as sulfide, ammonia, and various metals is a function of pH. A pH adjustment test, covering a range of pH values (e.g., 6.0 to 9.0 s.u.) can shed light on the role of such toxicants. Changing pH also alters the solubility of many constituents, most notably metals. Altering pH based on the solubility of suspect metals, then settling of filtering the test solution, also is a useful means of toxicant identification. Aqueous-phase tests under CO_2-enriched environments to suppress test solution pH are also useful to assess toxicity due to materials with known pH-dependant toxicity.**

- **Specialty Resins: Chromatography-grade resins such as C18 can be used to treat interstitial waters for removal of sorptive organics. The resins can then be eluted with solvents and subjected to chemical analyses to identify toxicants removed from solution.**

- **Other Tools available include:**

    - **Species sensitivity assessments - Some test species are known to be more sensitive to specific toxicants than other test species. Testing two or more species side-by-side, especially those with known differences in sensitivity to the suspect toxicants, and/or that have different modes of exposure (e.g., sediment ingestion in addition to direct body uptake) relevant to the toxic mode of the suspect chemical, can be used to further implicate various toxicants.**

    - **Spiking tests – In order to confirm that the suspect toxicants are bioavailable (toxic), they can be spiked into the sediment or water matrix to determine whether they increase toxicity**

REFERENCES

USEPA, 2007. *Sediment Toxicity Identification Evaluation (TIE) Phases I, II and III Guidance Document*. EPA/600/R-07/080. Office of Research and Development. Washington, DC.

HEC-RAS MODELING OF HYPOTHETICAL OUTFLOWS FROM WAPPAPELLO DAM, MISSOURI

Gregory H. Nail, Ph.D., PE[1]

The widely used Hydrologic Engineering Center – River Analysis System (HEC-RAS) software is sparsely documented in the published literature with regard to unsteady flow applications. This paper documents a successful utilization of HEC-RAS to model hypothetical steady and unsteady outflows from Wappapello Dam, Missouri. Wappapello Dam controls flow on the St. Francis River, which forms the boundary between the Missouri bootheel and Arkansas. The reach of the St. Francis below Wappello Dam is unusual in that previous steady and unsteady flow hydraulic modeling results are available for guidance and comparison. HEC-RAS results point to bridges at risk for overtopping, and overbank areas subject to flooding. Model predictions also quantify the timing of the downstream movement of the flood wave(s) generated by the hypothetical unsteady flow scenario(s).

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PROFESSIONAL POSTERS

All poster presenters will be available to discuss and answer questions about their displays beginning at 5:30 p.m. on Wednesday, April 16.

Tertiary Aquifer Recharge Area Mapping and Characterization in West Tennessee
Ryan Csontos and Brian Waldron

Multi-Trophic-Level Assessment of a Southeastern United States Stream
Tunishia Kuykindall and Scott Hall

Development of Multifunctional Heat Pulse Sensor for Measuring Soil and Water Properties
Jaehoon Lee, Andrew Sherfy, and John Tyner

A Community Collaborative Rain, Snow and Hail Network in Tennessee
Joanne Logan

Development of a Reservoir Embayment Characterization Process to Prioritize Water Quality Improvement Efforts
T. Shannon O'Quinn, Yongli Gao, and Jessica Buckles

Public Supply Water Use Trends and Drought in Tennessee, 2007
John A. Robinson

TERTIARY AQUIFER RECHARGE AREA MAPPING AND CHARACTERIZATION IN WEST TENNESSEE

Ryan Csontos[1] and Brian Waldron[2]

The hydrogeologic characterization of the recharge area to the Tertiary aquifers beneath West Tennessee is not well understood. This recharge area forms a large north-south band across West Tennessee, providing an avenue for direct recharge by precipitation and stream interaction to the aquifers. Previous investigations have delineated the outcrop boundaries of the primary Tertiary aquifers, Memphis and Fort Pillow – much of the mapping is based on well log information and stream downcutting. The availability of deep oil and gas wells from the TDEC Office of Geology along with shallow lignite borehole data from the North American Coal Company is enabling us to improve upon prior delineations as well as characterize each geologic unit as to the sand/clay composition, porosity, and depiction of facies changes within a three-dimensional context. This is made possible through the utilization of the oil industry standard mapping package, Petrel®. Additionally, topography (USGS 10-meter) along with detailed soils data from the NRCS and remote sensing evapo-transpiration data (MODIS) is being correlated to the Tertiary outcrops to determine the feasibility of spatially distributing potential recharge rate values across the landscape. Preliminary results are discussed.

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MULTI-TROPHIC-LEVEL ASSESSMENT OF A SOUTHEASTERN UNITED STATES STREAM

Tunishia Kuykindall*[1] and Scott Hall

A multi-trophic-level assessment was conducted to characterize the structure of key components of a small, effluent-dominated stream and reference stream in the southeastern United States. The periphyton, benthic macroinvertebrate, and fish communities were assessed. Periphyton community metrics (diatom and soft algae) and chlorophyll-a assessments were utilized, as were macroinvertebrate and fish community metrics specific to the region. Appropriate control sites were selected to account for stream sedimentation and habitat alteration. Chlorophyll-a data indicated the stream was of low-productivity, and were too imprecise to be a useful metric. The Siltation Index and taxa composition metrics were useful indicators of periphyton conditions, as were species-specific assessments that indicated the sites were dominated by silt-tolerant *Nitzchia* and *Navicula*. The seven benthic macroinvertebrate metrics applied were useful indicators of benthic community health, with the abundance of silt-tolerant organisms reflected by high percent oligochaete and chironomid values. Other macro invertebrate metrics indicated subtle differences between control and study sites. Fish tolerance ratings and taxa richness metrics were also shown to be useful community metrics. Study results indicated the importance of considering habitat conditions in data interpretation, and pointed to useful metrics to assess the effects of silt. The importance of reference sites incorporating local watershed effects and controlling for habitat variables was demonstrated by comparison of benthic macro invertebrate metrics for the study-specific reference stream to "ecoregion reference values" for minimally impacted streams.

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DEVELOPMENT OF MULTI-FUNCTIONAL HEAT PULSE SENSOR FOR MEASURING SOIL AND WATER PROPERTIES

Jaehoon Lee*[1], Andrew Sherfy, and John Tyner

A multi-functional heat pulse sensor (MFHPS) consists of a heater, four thermistors, and four electrodes which compose a Wenner array. The MFHPS emits a constant heat pulse (~8s) from a line heat source. Heat transfer in the thermal field near the heat source is quantified for simultaneous *in situ* measurements of soil heat capacity, thermal conductivity, thermal diffusivity, volumetric water content, soil bulk electrical conductivity, and saturated/unsaturated hydraulic conductivity. Two sensors were constructed and evaluated using repacked soil columns (sand and four soil types) in the laboratory. When calibrated for each soil, the standard errors between MFHPS measurements and directly measured values were less than 10% for most of the parameters. The new sensor technique has great potential for soil and water management.

Further research will be conducted to determine how these findings translate in various soil and water conditions.

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A COMMUNITY COLLABORATIVE RAIN, SNOW AND HAIL NETWORK IN TENNESSEE

Joanne Logan[1]

The Community Collaborative Rain, Snow and Hail Network (CoCoRAHS) is a non-profit network of volunteer weather observers. The network originated with the Colorado Climate Center at Colorado State University in 1998. Currently 26 states participate, and Tennessee joined in April 2007, under the direction of the National Weather Service Offices in Memphis, Nashville, and Morristown, and the University of Tennessee. Since that time, more than 800 volunteer observers in our state have agreed to take daily measurements of precipitation and record them on the CoCoRAHS website. The data are then displayed and organized in map and table formats for anyone to view. This study examines the distribution of the CoCoRAHS rain gauges, as well as the completeness and quality of the daily rain and snow data, using comparisons with NWS rain gauges and River Forecast Center Stage III rainfall estimates.

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DEVELOPMENT OF A RESERVOIR EMBAYMENT CHARACTERIZATION PROCESS TO PRIORITIZE WATER QUALITY IMPROVEMENT EFFORTS

*T. Shannon O'Quinn[1], Yongli Gao[2], and Jessica Buckles[2]

To simplify water quality improvement in reservoirs, it has been suggested that efforts should be focused on smaller and more manageable units such as reservoir embayment areas. Embayments are prime locations to locate marinas, parks, beaches, and residential homes. Current data and information on reservoir embayments in Tennessee will be assembled into a GIS-based database. GIS based data models will be developed to identify specific characteristics of embayments that influence water quality. Embayments of 11 main reservoirs have been mapped and digitized in ArcGIS. Initial characterization criteria include water quality, embayment area/watershed area ratio, embayment area/reservoir area ratio, flux between embayment and main reservoir, and stream influence on embayments. The characterization process will be applied to currently mapped reservoir embayments in Tennessee to identify and prioritize embayments that are most likely to be affected by watershed restoration efforts. If effective, this process can be used by resource agencies and stakeholders to prioritize water quality improvements in reservoir embayments.

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PUBLIC SUPPLY WATER USE TRENDS AND DROUGHT IN TENNESSEE, 2007

John A. Robinson[1]

Today, approximately 500 public water-supply systems in Tennessee serve the needs of domestic, commercial, industrial, and governmental users. As the population of Tennessee has grown from 3.3 million in 1950 to 5.9 million at present the amount of potable water supplied by public systems in Tennessee has increased from 160 to 906 million gallons per day. The upward trend in water demand and usage significantly increases the probability of water shortages occurring during drought periods.

Through the summer and fall of 2007, most of Tennessee experienced worsening drought conditions characterized by much lower than normal stream-flows and ground-water levels. Measurements by the U.S. Geological Survey show that historical lows for the period of record were set at many streamflow-gaging stations across the state. In September 2007, water-supply stresses resulting from the drought were reported by 63 public water-supply systems serving approximately 1.5 million people. Of these drought impacted systems, 33 systems serving about 0.6 million people requested voluntary water-use restrictions and 13 systems serving about 0.15 million people implemented mandatory water-use restrictions. Mandatory restrictions included surveillance, warnings, fines, and service cutoffs to enforce banned or restricted water uses. The potential exists for the drought to continue into the summer and fall of 2008.

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STUDENT POSTERS

Student poster presenters will be available to discuss and answer questions about their displays with the judges at 3:30 p.m., Wednesday, April 16. All poster presenters will be available to discuss and answer questions about their displays beginning at 5:30 p.m. on Wednesday, April 16.

Characterization of Bacteria and Geochemistry of Springs in Nashville, TN
Patrice Armstrong, Carlton Cobb, Brandon Cobb, Jennifer Stewart-Wright, and Tom Byl

Development of an Aquatic Plant Chemiluminescent Bioassay to Assess Water Quality
Chris Beals, Farida Forouzon, and Tom Byl

Using Geospatial Analysis Techniques to Assess the Impact of Riparian Forests on Stream Quality in Tennessee
Christopher A. Bridges

Are Aquifers at Greater Risk from Alternative Alcohol-Fuel Mixes Compared to Regular Gasoline?
Carlton Cobb, Loreal Spear, Keyshon Bachus, Baibai Kamara, Roger Painter, Lonnie Sharpe, and Tom Byl

Wetland Removal of Nutrients and Pollution from a Mixed Sewer and Karst Spring System in Nashville, Tennessee
Carlton Cobb, Brandon Cobb, Patrice Armstrong, Jameka Johnson, Lonnie Sharpe, and Tom Byl

CADDIS: Biological Results from a Case Study of Lower Falling Water River and Its Tributaries
Brooke Coffey and John Harwood

Water Surface Elevations for Bridge Design on Cane Creek Tributary, Martin, TN
David D. Highfield

A Chemical Fingerprinting Technique for Identifying the Sources of In-Stream Sediments
Robert A. Hull, Michael E. Essington, and Forbes R. Walker

Hydraulic Complexity and Model Peformance
Daniel H. Johnson

Use of Tanks-in-Series Method to Predict Nitrate Removal in Wetlands
Jameka Johnson, Carlton Cobb, Roger Painter, Lonnie Sharpe, and Tom Byl

Episodic Stream Acidification in Watersheds of the Great Smoky Mountains National Park
Keil J. Neff and John S. Schwartz

Effects of Hydrological Alteration on Brook Trout in the Great Smoky Mountains National Park
Joseph Parker, John S. Schwartz, and Keil J. Neff

Comparison of Video Mapping and Field Measurements of Stream Channel Substrate
Joshua Rogers and Ray Albright

CHARACTERIZATION OF BACTERIA AND GEOCHEMISTRY OF SPRINGS IN NASHVILLE, TN

Patrice Armstrong[1,2], Carlton Cobb[2,3], Brandon Cobb[2,3], Jennifer Stewart-Wright[4], Tom Byl[2,1]

ABSTRACT

The objective of the project was to evaluate the water quality of four limestone bedrock springs in an urban environment during a severe drought in the summer of 2007. Three of the springs were discovered on the Tennessee State University (TSU) campus in Nashville, TN in May, 2007. Two are located near a poultry research facility and a third near the TSU athletic center. An additional spring flowing from a cave in the Charlotte Park neighborhood of west Nashville (Carlos Cave) was also included in the study. The two TSU springs behind the poultry barns were sampled approximately every week from June through September, 2007. The cave and TSU athletic center springs were sampled less frequently. Water quality parameters included temperature, specific conductance, and dissolved oxygen, pH, sulfate, nitrogen, *E. coli*, and bacteria Biological Activity Reaction Tests (BART). Continuous water-quality monitoring devices were installed at two of the springs to measure changes associated with different weather patterns. Water temperatures were very stable, ranging from 16^{o}C in June to 19^{o}C in September. Sulfate concentrations were consistently higher in the spring water than the receiving surface waters. Conversely, nitrogen levels were lower in the spring water (< 10 mg/L) than the surface waters. Fecal bacteria levels fluctuated randomly with no discernable correlation to weather pattern. BART tests confirmed the presence of denitrifying, iron-reducing, sulfur-reducing, and slime-producing bacteria at each of the springs. Spring discharges decreased at all sites as the drought continued but never decreased below 10 gallons per minute. The data showed that each spring had unique water quality characteristics reflective of the different hydrologic recharge areas that replenish them.

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DEVELOPMENT OF AN AQUATIC PLANT CHEMILUMINESCENT BIOASSAY TO ASSESS WATER QUALITY

Chris Beals[1*], Farida Forouzon[2#], and Tom Byl[2,3]

ABSTRACT

Biomarkers such as enzyme activity from fauna exposed to chemicals in the water column and sediments have been widely used by environmental toxicologists to assess the quality of an environment. Biomarkers are especially useful indicators because they represent a direct biological response to toxicity. The objective of this research was to determine if chemiluminescence from selected plant oxidase enzymes could be used as a biomarker of water quality in aquatic systems. The initial phase of this study included lab determination of optimum pH followed by dose-response assays of various environmental toxins with oxidase enzymes extracted from potato. The optimum pH for the potato oxidase chemiluminescence reaction ranged from 5 to 7. Initial experiments using dissolved metals (Pb^{2+}, Ag^{2+}, Ni^{2+}) found that potato oxidase chemiluminescence was dose sensitive to metal concentrations above 500 mg/L and decreased proportionally with increasing metal concentrations. The chemiluminescent response of watercress collected near a relatively clean spring on Tennessee State University's campus was also investigated. Watercress stems and leaves were macerated with a mortar and pestle and the oxidase enzymes were extracted from the plant material. The crude enzyme extract did provide a chemiluminescent response upon addition of hydrogen peroxide to the assay mixture. The optimum pH for running the watercress chemiluminescence assay was pH of 4. Additional dose-response assays with whole-plant exposure will be needed before this bioassay can be used in water-quality assessments.

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USING GEOSPATIAL ANALYSIS TECHNIQUES TO ASSESS THE IMPACT OF RIPARIAN FORESTS ON STREAM QUALITY IN TENNESSEE

Christopher A. Bridges[1],[2]

Riparian forests play a major role in watershed protection by filtering runoff, stabilizing banks and providing aquatic habitat. While a great amount of literature has documented pollution removal, few projects have conducted landscape-level, empirical analyses of riparian forest contributions to water quality. This poster describes how precision conservation technologies were used to develop a spatially explicit inventory of Tennessee riparian forests, and to explore how this data relates to stream quality. National Land Cover Database tree canopy cover data was examined to quantify forest cover in riparian zones for 56,904 reaches. Comparisons were made between HUC-8 watersheds, HUC-12 sub-watersheds, and individual stream reaches based on status on the 2006 303(d) list. Preliminary statistical analysis indicates significant differences, most notably that fully supporting streams exhibited 14.4 % greater canopy cover in 30m riparian zones than impaired streams. Findings illustrate the need to target riparian restoration efforts in specific agricultural and urban catchments. The methodology employed in this study indicates applicability for natural resource policy analysis, soil and water conservation planning and the prioritization of streams for ecological restoration efforts. Future research will incorporate this baseline data into the development of more effective riparian forest conservation strategies that can help to ensure both the economic and ecological sustainability of Tennessee watersheds.

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ARE AQUIFERS AT GREATER RISK FROM ALTERNATIVE ALCOHOL-FUEL MIXES COMPARED TO REGULAR GASOLINE?

Carlton Cobb[1,2], Loreal Spear[1], Keyshon Bachus[1], Baibai Kamara[1], Roger Painter[1], Lonnie Sharpe[1], Tom Byl[1,2]

ABSTRACT

The United States government is promoting alternative fuels that reduce our dependency on foreign oil. Tennessee is promoting E-85, a fuel that consists of 85 percent ethanol and 15 percent gasoline. The environmental fate of gas-alcohol mixtures, however, has not been investigated. The consequences of an uncontrolled spill of E-85 or a related mixture would, therefore, be very difficult to predict. The objective of this research was to determine if a commercial grade E-85 mixture would dissolve more readily in water and move faster through water-saturated soil than regular gasoline. A better understanding of E-85 mobility in the subsurface is of practical importance if E-85 is to become widely used and stored in underground storage tanks like conventional fuels. Solubility-in-water studies comparing gasoline with E-85 found that the ethanol component in E-85 acted as a co-solvent and enabled aromatic compounds to dissolve five times more rapidly in water than regular gasoline. These enhanced solubility characteristics may allow the aromatic rings to move faster and further through water-saturated soils and karst conduits than regular gasoline. Additional experiments were conducted to determine if regolith soils would affect the dispersal rate of E-85 fuel compounds. Sterile soil-column studies using soils collected from karst regions of Middle Tennessee demonstrated that aromatic compounds, such as benzene, toluene or xylene (BTX), from the E-85 moved 3 to 4 times faster than BTX compounds in regular gasoline when transported by water through the soil. Additional work compared the biodegradation of E-85 with regular gasoline. Using static reactors with karst bacteria, E-85 biodegradation rates were almost 5 times greater than regular gasoline. This is in agreement with previous reports finding that dissolved-phase fuels were more bioavailable and degraded faster. Additional studies are needed to more thoroughly address issues concerning E-85 solubility and biodegradation.

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WETLAND REMOVAL OF NUTRIENTS AND POLLUTION FROM A MIXED SEWER AND KARST SPRING SYSTEM IN NASHVILLE, TENNESSEE

Carlton Cobb[1,3], Brandon Cobb[1,3], Patrice Armstrong[2,3], Jameka Johnson[1,3], Lonnie Sharpe[1],and Tom Byl[1,3]

ABSTRACT

Wetlands have been shown to attenuate suspended sediments and agricultural pollution in rural areas but little work has been conducted regarding the benefits of the wetlands in mitigating urban non-point source pollution (NPS). The objective of this project was to determine if an 80 acre natural wetland located down gradient of bedrock springs, parking lots, city streets and leaky sewer systems in Nashville, Tennessee helped to mitigate urban NPS runoff. Sampling points were selected by reconnaissance during rainfall events to determine general flow paths. Water samples were collected at these sampling points during base-flow and rain runoff events. Water-quality monitors were also placed in the springs and along the flow path during the 12 month period of study. Water samples were analyzed within 48 hours for turbidity, specific conductance, pH, and volatile organic compounds (VOC). Additional analyses were performed for sulfate (SO_4), nitrate (NO_3) ammonia (NH3) and chemical oxygen demand (COD). It was found that runoff from parking lots and roads during winter storms had relatively high VOC levels (62 µg/L benzene, 132 µg/L toluene, 106 µg/L xylenes, and a number of unidentified compounds). Water samples collected downstream of the wetland, however, had VOC concentrations below detection levels. Water samples collected at the most downstream site also had significantly lower levels of turbidity (90 % lower), NH_3 (99% lower), COD (95% lower), NO_3, (90% lower), and SO_4 (63% lower) on average for the year. The results indicated that routing water through the urban wetland resulted in significant water-quality improvements during the study period.

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CADDIS: BIOLOGICAL RESULTS FROM A CASE STUDY OF LOWER FALLING WATER RIVER AND ITS TRIBUTARIES

Brooke Coffey[1]*; John Harwood[1]

Causal Analysis/Diagnosis Decision Information System (CADDIS) is a five step process based on the stressor identification guidance. The process relies heavily on evaluation of benthic invertebrate, fish, and periphyton assemblages instead of simply considering physical and chemical parameters of the stream. Considering biological communities proves to be a beneficial approach to identifying impairment, since chemical and physical parameters mean little without integration of specific biological effects. After all, it is the biota that we are trying to protect.

In the case of lower Falling Water River, in Putnam and White Counties, three tributaries contribute to the impairment. Pigeon Roost Creek is the stream which has received the most attention in this study. Pigeon Roost Creek is most likely impaired from sediment, conductivity, and lack of suitable habitat. Sediment load and elevated conductivity are stressors which contribute to the impairment on Falling Water River downstream of the site where these streams merge. Our poster will focus on the biological evidence used to identify the stressors.

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WATER SURFACE ELEVATIONS FOR BRIDGE DESIGN ON CANE CREEK TRIBUTARY, MARTIN, TN

David D. Highfield[1]

A tributary of Cane Creek flows through the municipal boundaries of Martin, TN. Along this reach four bridges are to be redesigned as part of a Senior Capstone Design Project, involving undergraduate (senior) civil engineering students enrolled at The University of Tennessee at Martin. In support of the bridge redesign effort, water surface elevations corresponding to various storm scenarios were determined utilizing the Hydraulic Engineer Center – River Analysis System (HEC-RAS) software. Previous hydraulic modeling data, including an extensive set of surveyed ground elevations in the form of stream cross sections, were obtained from the Federal Emergency Management Agency (FEMA). In addition, a survey was conducted to obtain additional new stream cross sections, near the bridge locations. Because the bridges are in relatively close proximity, the existence of adequate hydraulic modeling data, and the desire to simulate unsteady flow events, several miles of the Cane Creek tributary were modeled – terminating at the confluence with the main stem of Cane Creek. Modeled storm scenarios include steady flow for a 100 year storm event, plus other hypothetical steady and unsteady flow cases. The poster depicts study and bridge location, HEC-RAS software, FEMA and other data, as well as modeling results.

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A CHEMICAL FINGERPRINTING TECHNIQUE FOR IDENTIFYING THE SOURCES OF IN-STREAM SEDIMENTS

Robert A. Hull[1]*, Michael E. Essington, and Forbes R. Walker

Developing and implementing total maximum daily loads (TMDL's) for point and non-point source pollutants identified on the Tennessee 303(d) list of impaired streams is an important component of Tennessee Department of Environment and Conservation's (TDEC's) strategy for improving water quality. In order to successfully implement management strategies to control sediment loss it is imperative to correctly identify the sources of the sediment. The objectives of this project were to evaluate methods of characterizing the elemental content of stream sediment and potential source materials, and to use the elemental data to identify sediment sources. The Pond Creek watershed is representative of agricultural watersheds that have been impacted by sediment in the ridge and valley physiographic region of east Tennessee. Furthermore, Pond Creek and two of its tributaries are listed on the Tennessee 303(d) list of impaired streams. Surface 1 to 2 cm samples were collected from locations throughout the watershed representing a variety of potential sediment sources. The silt plus clay fraction were isolated and subjected to total dissolution as well as to extraction procedures that used either nitric acid or the Mehlich 3 extractant. The resulting elemental fingerprints were then used to group source and stream sediment samples using a variety of multivariate statistical tools. Preliminary results, using a limited number of watershed samples, showed that the multi-elemental, multivariate statistical approach had significant discrimination power and potential for sourcing stream sediment. The preliminary result further illustrated that the discrimination of source samples could be attained using either the total or the Mehlich 3 extractable elemental compositions.

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HYDRAULIC COMPLEXITY AND MODEL PERFORMANCE

Daniel H. Johnson[1]

Watershed managements, stream restoration, and water quality regulations have created a demand for accurate and precise estimations of in-stream sediment and hydrodynamic processes, specifically sediment transport. Sediment transport for a channel reach is a function of upstream sediment supply, bed and bank roughness, sediment composition and flow hydraulics. The calculation of sediment transport requires data intensive model inputs, variables that are changing with space and time. Several numerical multi-dimensional models have been developed to quantify in-stream sediment transport and hydraulic characteristics; the computation ability and friendly graphical user interface have led to extensive application of both one and two dimensional models throughout the water resource industry. The application of these models without extensive model calibration and/or verification using detailed topographic data and accurate sampling of flow and sediment data during high flow events can lead to inaccurate results and estimations of sediment transport. In this study, two different models (CONCEPTS and CCHE2D) were executed on two streams with different hydraulic complexities. CONCEPTS (CONservational Channel Evolution and Pollutant Transport System) is a one dimensional model that simulates unsteady flow, graded-sediment transport, bed change, bank failure and channel widening. CCHE2D is a depth-averaged 2D model that solves for sediment transport, water quality, and flow. These models were implemented to determine the effect of hydraulic complexity on model performance and the application and accuracy of model results.

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USE OF TANKS-IN-SERIES METHOD TO PREDICT NITRATE REMOVAL IN WETLANDS

Jameka Johnson[1*], Carlton Cobb[1], Roger Painter[1], Lonnie Sharpe[1] and Tom Byl[1,2]

ABSTRACT

Quantitative tracer studies are frequently conducted to characterize hydrology through non-ideal flow systems and can provide very useful information, such as time of travel, discharge, residence-time distribution, advection and dispersion properties. The objective of this research was to determine if a tanks-in-series numerical model, incorporating residence-time distribution (RTD) coupled to a first-order rate of biodegradation (*k'*), could be used to predict contaminant removal in a series of small, natural, urban wetlands. The study site-wetland system consisted of an upper wetland (200 meters in length) and a lower wetland (400 meters in length) located on the campus of Tennessee State University and was modeled as two non-ideal flow, variable volume tanks-in-series. Flow characteristics used as input to the model were determined by quantitative tracer tests during base-flow and storm-flow conditions. Tracer data established there was an increase in mean residence time during storm-flow conditions due to rising water being diverted through cattails and other vegetation. Dispersion values were also observed to increase during storm-flow. A first-order nitrate removal rate (*k'*) of 0.1748 per hour was derived from a static mesocosm test. The tanks-in-series model using storm-flow conditions (mean residence time of 45 hours) and the *k'* value predicted 93% nitrate removal. Field data to test this model occurred when a leaking sewer provided nitrate-rich inflow to the wetland system during storm-flow conditions. Wetland discharge collected after 45 hours indicated an 83% reduction in nitrate. There was a 10% difference between the measured nitrate concentration and the nitrate concentration predicted using the non-ideal flow tanks-in-series model.

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EPISODIC STREAM ACIDIFICATION IN WATERSHEDS OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Keil J. Neff[1] and John S. Schwartz[2]

Atmospheric acid deposition has been shown to adversely impact stream acidification and have damaging effects on the health of aquatic biota and ecosystems. The Great Smoky Mountains National Park (GRSM) receives some of the highest rates of acid deposition in the U.S. Despite improvements in precipitation pH and sulfate, there has been little recovery in stream chemistry in the GRSM. In 2006, 67-km of 12 streams in the GRSM were listed on the 303d list as impaired due to low pH from atmospheric deposition and unknown sources. It is essential to determine if acid deposition is the dominant mechanism of stream acidification in the GRSM and relate how acid deposition impacts stream water chemistry differently among GRSM watersheds related to basin characteristics. Additionally, it is important to understand the connection between baseflow and stormflow, and identify spatial relationships of stream chemistry.

Ten to twelve sites will be selected in GRSM watersheds to monitor baseflow and stormflow water quality, and quantify the duration and extent of pH depressions during storm events considering physical, chemical and biological characterizations for watersheds including: 1) elevation, 2) trout distributions, 3) drainage area, 4) geology, 5) co-location with long-term baseflow stream water quality monitoring and fish sampling sites, 6) soils, 7) vegetation, 8) disturbance, and 9) slope. Regression and multivariate models will be developed to identify parameters controlling stream chemistry. Geostatistical techniques to interpolate baseflow and stormflow water quality data will be developed to model stream chemistry in GRSM watersheds.

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EFFECTS OF HYDROLOGICAL ALTERATION ON BROOK TROUT IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Joseph Parker[1], John S. Schwartz[2], and Keil J. Neff[3]

Indicators of hydrological alteration have been used to understand environmental change to watersheds. Flow patterns play a key role in sustaining aquatic life in rivers and streams. For example, extreme low flows during fish spawning periods can reduce fish population densities. Brook trout populations in the Great Smoky Mountains National Park (GRSM) have declined in some watersheds. It is believed that brook trout have primarily been impacted by episodic acidification; however, hydrological patterns may also impact brook trout populations in GRSM watersheds.

The Hydrological Simulation Program Fortran, WinHSPF, will be used to model flows of un-gauged streams in the GRSM. Model calibration will be accomplished using two USGS gauging stations in the GRSM. After model calibration, the model will be simulated for 20-25 selected stream sites. Brook trout population data has been accumulated at each of the selected sites since 1987. Historic hydrologic events such as floods and low flows seen in the model will be compared with the trout population data to identify correlations between certain hydrologic events and trout population data.

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COMPARISON OF VIDEO MAPPING AND FIELD MEASUREMENTS OF STREAM CHANNEL SUBSTRATE

Joshua Rogers[1] and Ray Albright[2]

Growing interest in the use of technology for water resources has developed new methods for assessing stream channel substrate. GPS videography is now being used to capture substrate data in a digital format with post-processing efforts being made to characterize stream-bed particles and their distributions. Advantages of this method include less field time, minimal stream bed disturbance, convenience of post-field processing, and digitally stored data. The question then arises in asking what the drawbacks of this method are and how accurate are the data. As far as the authors are aware, there have been no studies done to quantify digital video of stream channel substrate. For this study, we used current video mapping techniques to capture stream channel substrate footage on 3 stream reaches on Abrams Creek in the Great Smoky Mountains National Park. The post-processing of the data included a comparison of methods used to "retrieve" sample data from the video including the current method of visual estimation. We compared these data to the data gathered by 3 distinct pebble count methods to determine the accuracy and efficiency of both methods (video and field) by testing them against a frame method used as a control. ANOVA was used to test the hypothesis that the video mapping data and the pebble count data do not differ in their means by more than 15% for particle size, percent distribution, and diameter size class of the channel substrate.

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ILLUSTRATING HOW TO BUILD A WATER QUALITY STRUCTURE – A RAIN GARDEN-TO UNDERGRADUATE STUDENTS

Josh Thibodeaux, Dr. W. Anderson[1], and Mr. Larry Sizemore[2]
and MTSU undergraduate students enrolled in ABAS 3370 and 4370 from the fall 2005 through fall 2007

Drainage ditches can be essential management strategy for rural and urban land use. Surface ditches conduct excess water form crop production land or from an impermeable surface (parking lot) to a drain basin or waterway. Rain gardens can be used as bio-filter to remove soluble ions, petrochemical and trap sediments from runoff water before the water pools in a drain basin or enters a waterways. MTSU has built three gardens on campus since 2005. The rain gardens on the campus filter storm runoff water from some of the 20,000 + parking stalls before it pools in a drain basin. This presentation will present insight learned about building rain gardens in middle Tennessee.

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MODELING EPISODIC STREAM ACIDITY DURING STORMFLOW IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Guy Thomas Zimmerman[1], J.S. Schwartz, R.B. Robinson, and K.J. Neff

This study characterizes water quality in Great Smoky Mountains National Park watersheds examining differences in mass transport of ions between baseflow and stormflow periods. Three water quality monitoring study sites have been located in the Middle Prong of the Little Pigeon River. These remote sites have been equipped with YSI 6920 multi-parameter sonde to record continuous 15-min data of pH, depth, conductivity, turbidity, and temperature. Additionally, ISCO 6712 composite samplers were used to collect stream samples during storm events. Baseflow conditions were determined through grab samples prior to storm events. Precipitation samples are collected after storm events. The three sites have been positioned for comparison of native trout habitat, and one site still has a population of native trout while the other two sites have experienced extirpation. All samples were analyzed for pH, ANC, and conductivity using an autotitrator. Inductively coupled plasma spectrometer and ion chromatography are used to determine major cations, trace metals, and anions (Ca^{2+}, Na^+, K^+, Mg^{2+}, Al^{n+}, Cu, Fe, Mn, Si, Zn, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+). A mass balance is performed for the ions. Discharge during stormflow events are modeled using the computer program RIVER2D and verified with field measurements. This information will help resource managers at the Great Smoky Mountains National Park ascertain a clearer picture of how pH is affected as ions are transported through the system during a stormflow.

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