Proceedings of

the Twentieth Tennessee Water Resources Symposium

April 13-15, 2010

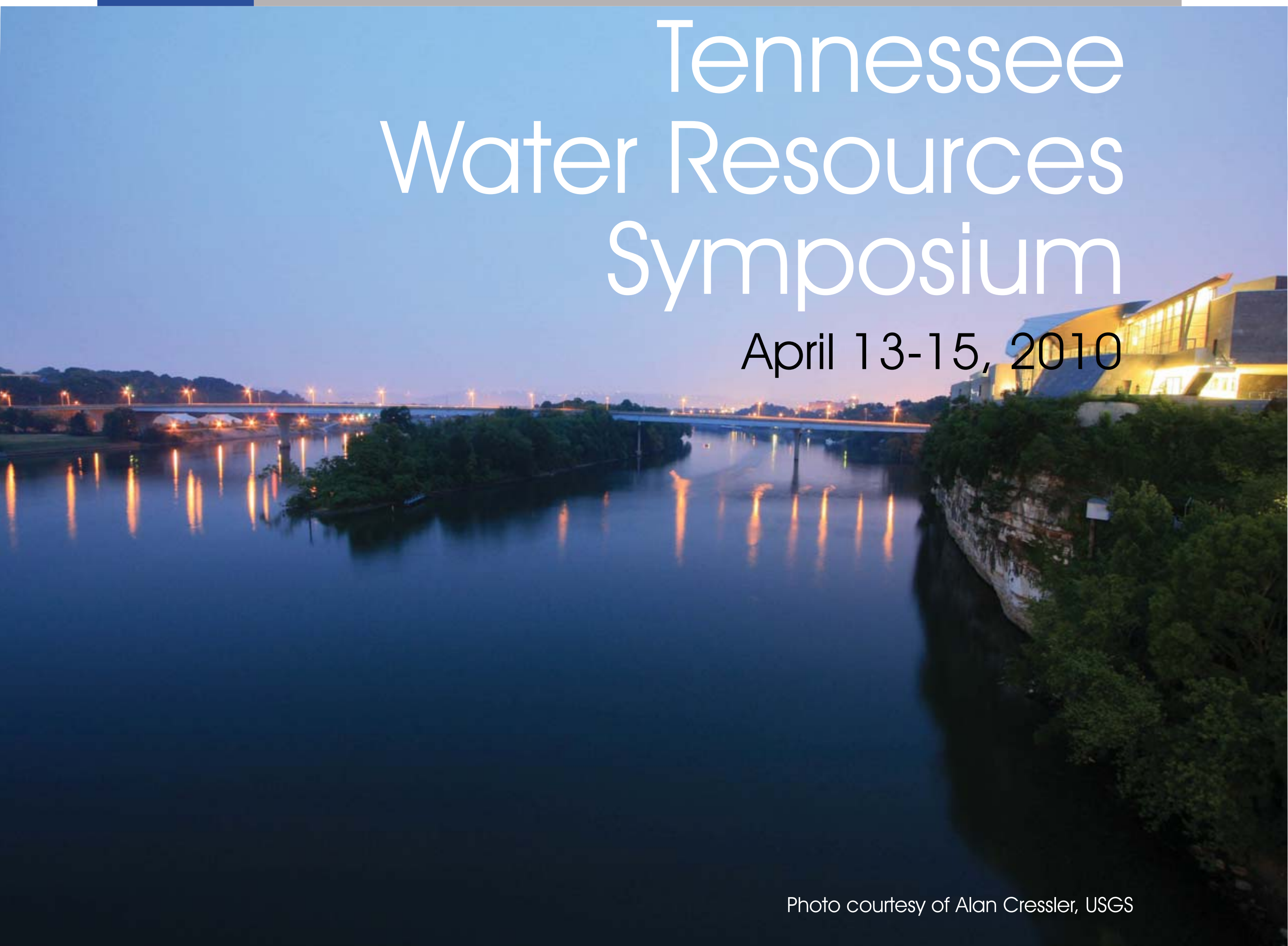


Photo courtesy of Alan Cressler, USGS

Proceedings from the

Twentieth Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 13-15, 2010

Sponsored by

Tennessee Section of the American Water Resources Association

In cooperation with

Barge, Waggoner, Sumner & Cannon, Inc.
City of Chattanooga
City of Memphis
Cumberland River Compact
Harpeth River Watershed Association
Nashville Metro Water Services
Tennessee Association of Utility Districts
Tennessee Department of Environment and Conservation
Tennessee Technological University
Tennessee Valley Authority
University of Tennessee
U.S. Geological Survey, Water Resources
Water Quality Matters!

Also Sponsored By

- AquaShield™, Inc.
- Barge Waggoner Sumner & Cannon, Inc.
- CDM
- Center for the Management, Utilization & Protection of Water Resources, TTU
- City of Memphis
- Civil and Environmental Consultants, Inc.
- EnSafe, Inc.
- Fulghum, MacIndoe & Associates, Inc.
- Ground Water Institute, University of Memphis
- Hach Hydromet
- John McFadden, Aquatic Restoration Service and Supplies
- Neel-Schaffer, Inc.
- Sutron Corporation
- American Society of Civil Engineers, Tennessee Section
- Tennessee Stream Mitigation Program
- UT, Tennessee Water Resources Research Center/ISSE

Exhibitors

- AMEC Earth & Environmental
- Architectural Wall Solutions
- City of Memphis
- Crawford Hydrology Lab
- Hach Hydromet
- Jen-Hill Construction Materials
- Microbac Laboratories, Inc.
- P.E. LaMoreaux and Associates, Inc. (PELA)
- Roper Laser Co.
- Sherman Dixie & Terre Hill
- S&ME, Inc.
- Stevens Water Monitoring
- Suntree Technologies
- Sutron Corporation
- Tennessee Environmental Council
- Tennessee Stream Mitigation Program
- U.S. Geological Survey
- UT, Tennessee Water Resources Research Center/ISSE
- Water Quality Matters!
- YSI, Inc.

Cover Design by Amy Knox, Center for the Management, Utilization & Protection of Water Resources, Tennessee Technological University, with photo courtesy of U.S. Geological Survey
Guess the Picture Question: What's the name of the island in the middle of this river?

PREFACE

Welcome to the Twentieth Tennessee Water Resource Symposium at Montgomery Bell State Park sponsored by the Tennessee Section of the American Water Resource Association and, this year, by the Tennessee Section of the American Society of Civil Engineers. We hope that you are inspired and professionally motivated by this year's symposium and that these Proceedings will serve as a reference for your professional library and a reminder of the symposium.

The TN AWRA is and always has been a unique collection of water professionals. We come from very diverse backgrounds; state, federal and municipal agencies, manufacturers and vendors, academic institutions and consortia, contractors, non-profit organizations, consulting engineering and scientific firms. We are looking for new ideas and new ways to collaborate on old problems; we are looking for a snapshot of where the waters of Tennessee stack up today versus where we were last year; we are looking for successes to emulate and failures to avoid; we are looking to be encouraged by bright young minds and to see the wisdom of experience; we are looking for the direction of science, craft, regulations, policy and how each is influencing the other and our water. Each symposium for the greater part of two decades has met those expectations and objectives. The organizing committee who selected the presentations and solicited the panelists and pulled the details together hopes you will be no less inspired by this symposium than in past years.

This year's theme is that increasingly important topic: storm water. The expansion of the program to a full first day allowed us to offer a workshop on the Soil, Water Assessment computational Tool (SWAT). Afterwards we are fortunate to hear a keynote address by Andy Reese, a local Tennesseean, who has been in the eye of the storm water storm for a number of years. We are going to follow Andy's picture of the direction of storm water regulation and practice with sessions particularly tailored for civil engineers, whose work has a tremendous impact on storm water quality and who will, in practice, provide for the measures to be taken to mitigate construction and facilities' impacts on the waters of the state. Major construction projects will soon be faced with stringent standards for run-off and objective measurements of the degree of sediment control attainment. It is indeed a brave new world for storm water! A world that, we hope, will see less sediment impaired streams in Tennessee.

Once again contributors have filled over a day and a half of enticing presentations divided into three tracks. That's the good news; the bad news is that most of us are limited to one room at a time and we will have to choose where to go. That's where the Proceedings come in. You can still get the gist of what you missed with the papers and extended abstracts published for you. This is a good time to thank Tennessee Tech's Water Center for dedicating Amy Knox to the task of pulling the Proceedings together once again this year. It is an important role and one that in many ways sets the TWRS apart from other professional society meetings.

The third day of the symposium in recent years has turned into the opportunity to address current issues of interest to the water resources community. We follow emphases in the past few years on "energy and water", "drought" and "climate change" with panels addressing this year: "The New Stream Delineation Rules", "Dam Operations and Safety", and a report on regional water sourcing that we are entitling, "Meeting Future Water Needs through Sustainable Supplies." If you get a chance to thank the organizing committee and those working the registration table this week for their hard work on the program, please do so. Remember that the organizations that they work for also contributed to their time and effort including the travel to and from Memphis or Chattanooga or Knoxville to Nashville numerous times.

To put it bluntly, I'm not sure we could have a conference without the work of Scott Gain and the USGS support for this effort. Far and away the most important contribution that Scott makes is continuing to make Lori Weir available. Absent Lori, we would be at best reinventing the wheel every year; at worst, floundering badly. She is the brain trust; the hub of the organization; the traffic cop and director. Her experience, attention to detail, and just plain hard work is why this symposium for so many years has remained one of the best organized (despite me this year!) Thanks, Lori.

I want to thank the sponsors and exhibitors. Ken Barry, P.E. gets the complete credit for bringing additional ASCE participation to the conference and challenging the organizing committee to consider how we should be sharing resources with professional groups of like mind and interests. Thanks to ASCE and the companies, agencies, manufacturers and vendors, public and private educational institutions and non-profits whose literal contributions have kept this conference extremely affordable.

And, lastly, but NOT LEAST, THANK YOU for your participation. You wrote the abstracts and made the presentations. You filled the rooms and thanked the speakers with your applause. You encouraged the student presenters and quizzed them about their posters. You asked your organizations to send you to this conference. You moderated the sessions. You ran, jogged, or walked the "fun run" (or at least a few of you did!) You ate the food, paid your dues, and recycled the conference materials that were left over. Your presence was an encouragement to those who worked to put the symposium together for another year. AND, we hope, you WILL take your renewed enthusiasm and new ideas back to your organizations and coworkers that we may professionally continue to fulfill our mandate to protect and manage this important resource. Do something this year you can tell us about next year!

George Garden, President, Tennessee Section AWRA, 2010 Conference Chair

2009-2010 TN AWRA OFFICERS

President and Symposium Chair:
George Garden
Barge Waggoner Sumner & Cannon, Inc.
211 Commerce Street, Suite 600
Nashville, TN 37201
Phone: (615) 252-4255
E-mail: gcgarden@bwsc.net

President-Elect:
Michael Hunt
Nashville Metro Water Services
1607 County Hospital Road
Nashville, TN 37218
Phone: (615) 880-2425
E-mail: michael.hunt@nashville.gov

Past President:
Scott Gain
U.S. Geological Survey
640 Grassmere Park, Suite 100
Nashville, TN 37211
Phone: (615) 837-4701
E-mail: wsgain@usgs.gov

Treasurer:
David Duhl
TDEC, Water Pollution Control
401 Church Street, 7th Floor Annex
Nashville, TN 37243
Phone: (615) 532-0438
E-mail: david.duhl@tn.gov

Secretary:
Tiffany Foster
Tennessee Valley Authority
260 Interchange Park Drive
Lenoir City, TN 37772
Phone: (865) 632-8106
E-mail: tlfoster@tva.gov

Membership Chair:
Lori Weir
U.S. Geological Survey
640 Grassmere Park, Suite 100
Nashville, TN 37211
Phone: (615) 837-4720
E-mail: lrweir@usgs.gov

PLANNING COMMITTEE FOR THE TWENTIETH TENNESSEE WATER RESOURCES SYMPOSIUM

- George Garden, Barge Waggoner Sumner & Cannon, Inc.
- Michael Hunt, Nashville Metro Water Services
- Scott Gain, U.S. Geological Survey
- David Duhl, TDEC, Water Pollution Control
- Tiffany Foster, Tennessee Valley Authority
- Lori Weir, U.S. Geological Survey
- Michael Cain, Harpeth River Watershed Association
- Paul Davis, TDEC, Water Pollution Control
- Dennis George, Center for the Management, Utilization and Protection of Water Resources-TTU
- Sharon Gordon, City of Memphis
- Don Green, City of Chattanooga
- Vena Jones, Cumberland River Compact
- Amy Knox, Center for the Management, Utilization and Protection of Water Resources-TTU
- Tom Lawrence, Water Quality Matters!
- Larry Lewis, Tennessee Association of Utility Districts
- Forbes Walker, University of Tennessee
- Sherry Wang, Tennessee Department of Environment and Conservation
- Derek Willis, City of Memphis

1:30 – 3:00 p.m.
Tuesday, April 13
Keynote Address *by* Andrew J. Reese, P.E., LEED AP, D WRE,
Vice President AMEC Earth and Environmental
Stormwater: Back to the Future

Andrew J. Reese, principal engineer and vice president, AMEC Earth and Environmental Inc., is one of the most experienced stormwater management specialists in the United States. He has a master's degree in business management from Boston University and another in water resource engineering from Colorado State University. Over 30 years' experience in a wide variety of stormwater management, water resources, hydraulic and hydrologic engineering, and management roles has earned him recognition as a national expert. His reponsibilities have included supervision of large and complex municipal stormwater program developments, implementing stormwater NPDES permits, performing financial studies for development of stormwater utilities, developing ordinances and regulations, facilitating stakeholder discussions, developing and executing public awareness programs, software development, hydraulic engineering research, and computer modeling and design. He has assisted several Federal agencies, counties in 35 states, and over 100 cities in addition to private sector clients. He has performed work in a wide variety of environmental and physical settings.

Mr. Reese has special skills and experience in the assessment of municipal stormwater programs, development of program growth and improvement strategies, costs of service analyses, facilitation of citizen groups, and development and implementation of public education and involvement programs. He is adept at public speaking, dealing with the press, handling public and stakeholder meetings, and making technical concepts easy to understand by the layman. Mr. Reese has been a popular speaker at over 200 conferences and meetings including the keynote for the first annual STORMCON conference, Association of State Floodplain Managers, National Association of Flood and Stormwater Management Agency and National League of Cities national conferences, and a number of state organizations. He teaches short courses across the United States on Municipal Stormwater Management and Stormwater Utility Development. He has published over 45 articles and papers nationally and internationally on subjects such as stormwater utilities, public awareness, hydraulic research, urban stormwater management, regulatory compliance, and stormwater quality. He also has co-authored an authoritative and best-selling, 1400 page textbook on Municipal Storm Water Management, now in its second edition.

ABSTRACT

Nature has a certain way of handling the array of storms that occur on an annual basis. Much of it is infiltrated or returned to the atmosphere through evapotranspiration. The rest collects in small depressions and pools and slowly makes it sway to freshets, creeks, and finally rivers. As urban development has transformed landscapes from forest to field to urbanized areas engineers have also transformed the way that urban stormwater design should be done – the prevailing accepted practice.

One hundred years ago the "right" way to do stormwater design was to combine it with sewer systems. The solution to pollution was dilution and rivers were the right place to send sewage. This is reflected in downtown Nashville's combined sewer system. Over the last hundred years the paradigm of stormwater management has shifted from efficient drainage, to detention, to master planning, to BMP design, to Low Impact Development.

But today there is a sea change in how stormwater management is approached – volume is the new pollutant. Regulatory approaches are rapidly transforming into volume-control requirements and Green Infrastructure rules the day. The requirement to try to mimic the days of forests takes us back… to the future. It is emerging in Federal regulations, TMDL requirements, new MS4 stormwater permits, CSO long term control plans, and in the minds and hearts of local leaders who want to be "green."

We will look at some of the ins and outs of this approach and what it may mean to local governments and designers.

12:30 – 1:30 p.m.
Wednesday, April 14
Luncheon Presentation *by* Lena Beth Carmichael, UT Extension
Days of My Life as a Watershed Coordinator (A.K.A. Was This in My Job Description?)

Ms. Carmichael has a B.S. and M.S. from UT Knoxville in agriculture and 12 years' experience with the UT Extension. At the UT Extension Office, Carmichael has served in three positions, for a total of five counties, and taught for eight years at Hiwassee College in Madisonville, Tennessee.

SESSION 1A

STORMWATER BEST MANAGEMENT PRACTICES

HYDRAULICS

SESSION 1B

WATER QUALITY

STORMWATER I

SESSION 1C

ENGINEERS WITHOUT BORDERS

STORMWATER PRODUCTS

SESSION 2A

PATHOGENS AND PUBLIC HEALTH

ECOLOGY I

ECOLOGY II

ECOLOGY III

SESSION 2B

STREAM MORPHOLOGY I

STREAM MORPHOLOGY II

STREAM MORPHOLOGY III

TDEC WATER QUALITY

SESSION 2C

WATER QUALITY

GROUNDWATER I

GROUNDWATER II

GIS & DATA MANAGEMENT

SESSION 3A

NEW STREAM DELINEATION RULES

MEETING FUTURE WATER NEEDS THROUGH SUSTAINABLE SUPPLIES-PANEL

SESSION 3B

DAM OPERATIONS AND SAFETY PANEL

SESSION 3C

STORMWATER II

PROFESSIONAL POSTERS

STUDENT POSTERS

SESSION 1A

STORMWATER BEST MANAGEMENT PRACTICES
1:30 p.m. – 3:00 p.m.

How Combining LID Practices Can Eliminate/Reduce Detention Ponds and Improve Water Quality
Pete A. Shack

Turbidity Monitoring for Compliance with New Federal Rules
Timothy H. Diehl

Field vs. Laboratory Testing of Manufactured Stormwater BMPs: "You Can't Always Get What You Want"
Mark B. Miller

HYDRAULICS
3:30 p.m. – 5:00 p.m.

Hydrologic Modeling and Flood Assessment Using Coincident Frequency Analysis for Interior and Exterior Levee Systems in Wichita, Kansas
Kelsey Piech and Masoud Meshkat

Predicting Sinkhole Flooding in Cookeville
Peter Li, Evan Hart, Hugh Mills, Derrick Ho, and Martin Kimbrell

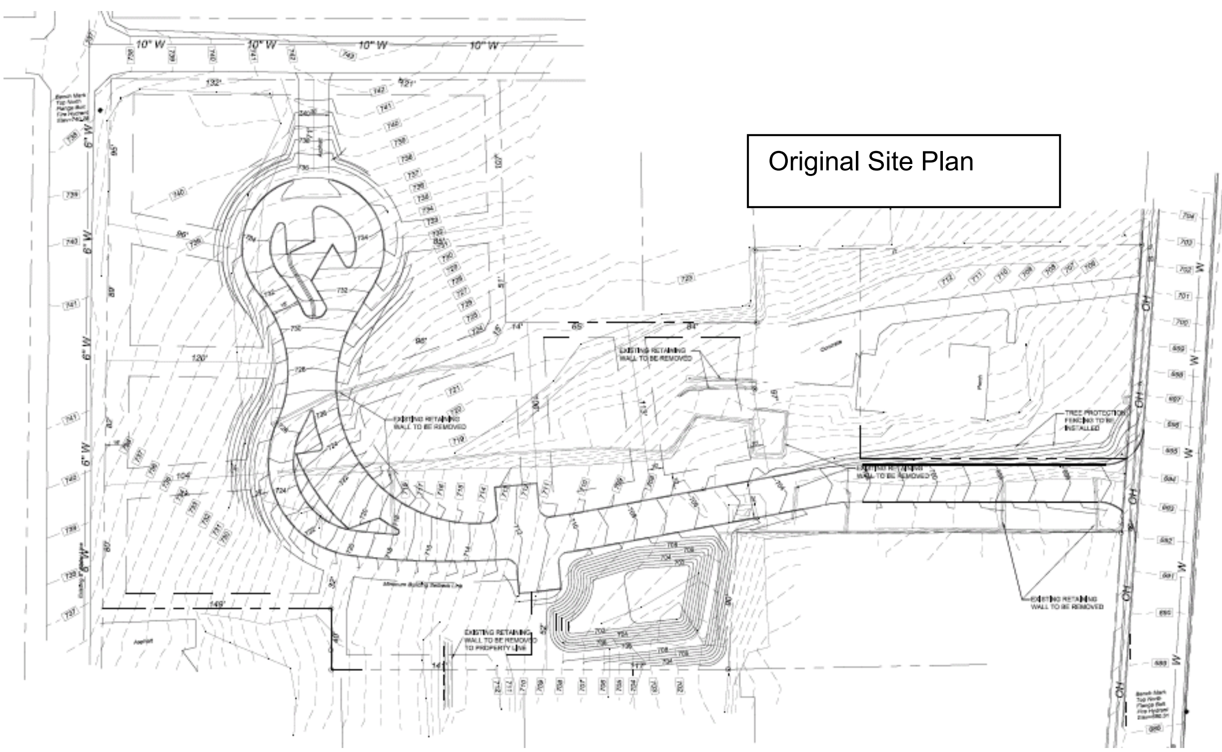
Tennessee DOT Monitoring Program for Scour Critical and Unknown Foundation Bridges
Jon Zirkle

HOW COMBINING LID PRACTICES CAN ELIMINATE/REDUCE DETENTION PONDS AND IMPROVE WATER QUALITY

Pete A. Shack[1]*

Although detention ponds have long been used to reduce the volume and improve the quality of stormwater runoff from developed sites, incorporating low impact development (LID) practices such as rain gardens, pervious pavement, bioswales, and soft infrastructure can provide reductions in peak runoff and improvements in water quality comparable to conventional detention ponds. In this case for an upscale single-family home development, it was demonstrated that LID practices were equivalent to detention in a pond.

The site is located in the Duck River watershed of Middle Tennessee. The Duck River is one of the most biodiverse streams in the world as recently recognized in *National Geographic* magazine. Given this vibrant ecology, the developer wanted to minimize the development's impact on the environment. The 2.2 acre site was laid out with 10 lots. The original site drainage plan was designed using conventional detention sized for a 25-year, 24-hour storm with curb and gutter lined streets. This resulted in a detention pond covering 0.13 acres that contained 26,100 cf of storage and consumed one full lot.



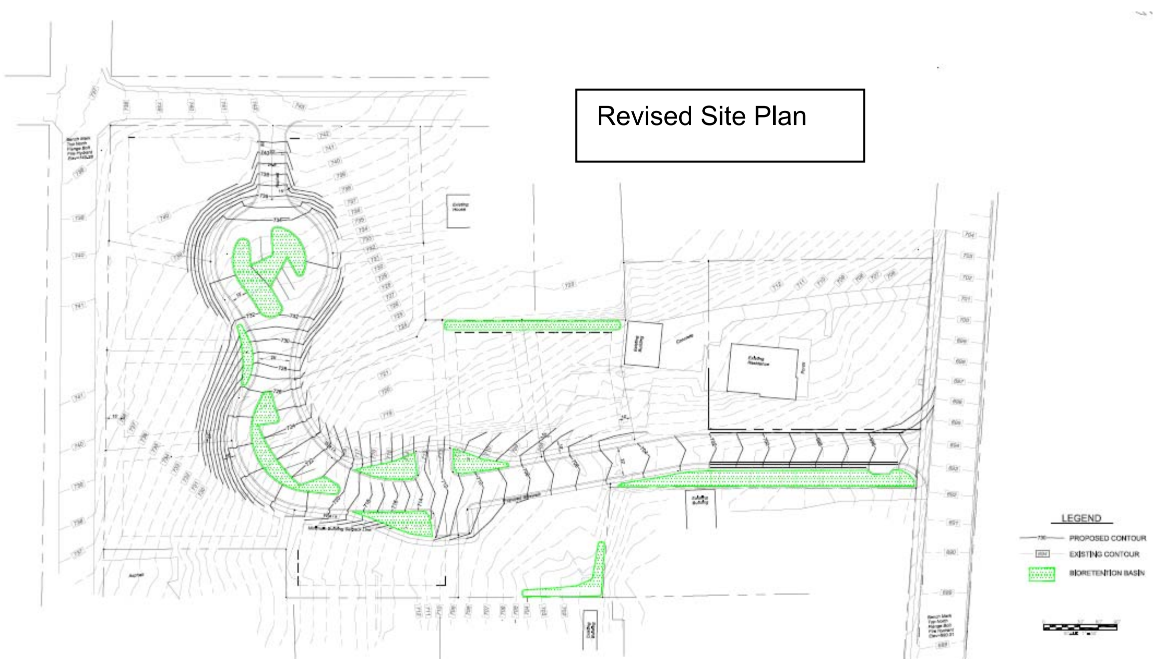
The site was redesigned to eliminate the pond and instead incorporate LID practices increasing the number of lots from 10 to 11 (9 percent). The drainage area was approximately 4.6 acres. The 100 year storm peak discharge prior to development was estimated at 26.4 cfs and had a total stormwater discharge volume of 86,000 cf.

---

[1] PE

Redesign of the site's hydrology began with narrower roadways, flat curbs, and no gutters. In addition, approximately 21,300 sf of permeable pavement was used in lieu of impervious pavement making about 80 percent of the asphalt paving pervious. Offsite runoff was routed around the project area to the extent possible. A total of five Bioretention areas and four Bioswales were strategically located to maximize their functionality while minimizing their impact on building sites. The ground area consumed by the Bioretention and Bioswales was almost twice that of the original pond, but by locating them advantageously, no lots or building sites were compromised. Bridges were built over the Bioretention areas where sidewalks crossed them to further increase the aesthetics. The result was a softer site with more landscaping, better aesthetics, the same functionality, and better discharge water quality.

In terms of infrastructure, five curb inlet structures, four concrete drainage structures (headwalls, pond outlet, manholes) and approximately 50 LF of piping were eliminated.



The impact of the LID improvements on site hydrology was estimated. The post-development 100 year peak runoff was reduced by 3.5 percent while the stormwater volume was reduced by over 20 percent when compared to pre-development conditions. Table 1 below compares the pre- to post- development storm estimates for a variety of storms.

Table 1 - Comparison of Pre-Development to Post-Development Using LID for Multiple Storm Frequencies

Storm Return Period	Peak Flow			Peak Volume		
	PRE (cfs)	POST (cfs)	Change	PRE (cf)	POST (cf)	Change
2	7.7	2.9	-63%	25,271	11,494	-55%
5	12.5	8.5	-32%	40,435	24,932	-38%
10	15.8	12.4	-21%	50,944	34,864	-32%
25	20.0	18.6	-7%	64,891	47,944	-26%
50	23.2	22.0	-5%	75,440	57,873	-23%
100	26.4	25.5	-3%	85,988	67,800	-21%

When compared to the conventional detention pond design for the site, the LID approach had lower peak flows up to the 25 year storm. At 25 years and beyond, the peak flows were actually greater because the Bioretention areas do not provide any outlet flow control as a detention pond does. The volume of water discharged was less in all categories for the LID approach, because in any size storm water is being captured and infiltrated. Table 2 illustrates these results.

Table 2 – Comparison of Detention Pond to LID Practices for Multiple Storm Frequencies

Storm Return Period	Peak Flow			Peak Volume		
	POND (cfs)	LID (cfs)	Change	POND (cf)	LID (cf)	Change
2	6.7	2.9	-57%	23,681	11,494	-51%
5	10.6	8.5	-20%	36,963	24,932	-33%
10	13.2	12.4	-6%	46,116	34,864	-24%
25	16.5	18.6	13%	58,088	47,944	-17%
50	19.1	22.0	15%	67,136	57,873	-14%
100	21.5	25.5	19%	76,157	67,800	-11%

In summary, the LID approach improved the site's hydrologic footprint by reducing the amount of water discharged from the site, treating the majority of the stormwater from the site (which comes from storms of 2 year frequency or less, and controlling the peak discharge. At the same time the number of lots was increased, the drainage infrastructure was reduced, and the aesthetics of the site were improved.

TURBIDITY MONITORING FOR COMPLIANCE WITH NEW FEDERAL RULES

Timothy H. Diehl[1]*

The USEPA has issued a new rule regulating the turbidity of stormwater runoff from construction sites. Construction permit holders are required to monitor turbidity at least three times daily while runoff is flowing. If the daily average turbidity exceeds 280 NTU the permit will be violated unless rainfall for that day exceeds the 2-year, 24-hour rainfall. Current USEPA guidance on monitoring leaves several questions to be resolved at the state level, including how much bias in turbidity measurements will be tolerated and how monitoring sites will be selected. A range of approaches to site selection and monitoring for compliance with the new rule will be described, and their implications for the detection of daily average turbidity above the new standard will be discussed.

[1] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211 thdiehl@usgs.gov

FIELD VS. LABORATORY TESTING OF MANUFACTURED STORMWATER BMPS: "YOU CAN'T ALWAYS GET WHAT YOU WANT"

Mark B. Miller[1]

A growing number of manufactured stormwater best management practices (BMPs) have been implemented in recent years. This has led to a spirited debate whether field or laboratory testing conditions better portray the performance level of a given BMP. Convincing arguments can be made to support either approach. This presentation considers the variety of pitfalls and benefits associated with field and laboratory testing programs with respect to BMP performance evaluation. A preference for field data is a logical progression from that of initial laboratory investigations since it provides "real world" performance data within a natural dynamic setting. Supporters of field testing assert that site-specific stormwater runoff conditions cannot possibly be duplicated in the laboratory. Those that favor laboratory studies maintain that a range of controlled and repeatable parameters are simulated for those conditions most likely to be encountered by a BMP. Thus, a defensible laboratory performance test would not require that subsequent field testing be implemented for essentially random influent conditions. Field tests fail to allow for side by side BMP performance comparisons, while laboratory testing allows for side by side comparisons when using the same protocol (e.g. New Jersey's TARP). Field programs provide an effective means to evaluate long term performance, structural integrity, maintenance issues and overall BMP functionality. Laboratory programs provide a defensible and cost-effective means of performance verification within a short period of time.

It is important to consider that long term field results may not represent actual BMP performance levels due to a number of factors such as: (a) particle size bias by autosamplers, (b) methods of flow measurement, (c) instrument precision, (d) laboratory analytical methods (TSS vs. SSC), (e) pollutant load stratification, and (f) seasonal variations. It is important to consider that a complete field testing program requires a considerable investment of time and financial resources. These programs can span one to two years; and, considerable cost can be incurred due to the use of independent consultants, laboratories and sampling equipment. For example, one storm event can result in outside costs of thousands of dollars in consultant and analytical fees. The length of time required to complete a field test can be affected not only by weather patterns, but also by the number of storms required for a protocol (minimum of 12). Site characterization should be performed prior to implementation of full scale field testing. Influent parameters of concern typically include sediment concentrations, particle size distribution and flow rates Characterization better ensures that influent parameters are conducive to testing since most sites do not meet testing criteria. Additional factors that can affect test site selection include: site stability, approval from stakeholders, accessibility, security, reliable power supply, destructive animals, organic material and debris in runoff, and overall logistical considerations.

Stormwater BMP evaluation methods will continue to develop as the industry progresses. Unfortunately, no direct performance comparison can be made between the results of field and laboratory testing programs. Although field testing provides actual storm data, direct side by side BMP comparisons cannot be made given that no two test sites can produce identical conditions. Laboratory testing allows for direct side by side when following the same protocol, but complex storm variables cannot be duplicated. Data interpretation and BMP performance evaluation should be considered within the context of both approaches.

HYDROLOGIC MODELING AND FLOOD ASSESSMENT USING COINCIDENT FREQUENCY ANALYSIS FOR INTERIOR AND EXTERIOR LEVEE SYSTEMS IN WICHITA, KANSAS

Kelsey Piech[1] and Masoud Meshkat[1]

INTRODUCTION

The City of Wichita is currently conducting an analysis of nearly 100 miles of levees with a complex conveyance system including flap gates, diversion structures and pump stations. A notable challenge of this study is not only estimating the peak water surface elevations within the levee (exterior), but also determining the flooding extent on the dry side (interior) of the levee; therefore, tailwater conditions within the levee are critical. The nature of coincidental occurrences of storms in addition to the degree of closures of the gated gravity drains through the levees makes the interior analysis unique. Some systems are highly correlated and interdependent which can be treated in a single hydrologic model while others are independent but can be evaluated using coincidental probability analysis.

APPROACH

This presentation examines two ways of conducting these analyses: (1) using combined interior and exterior hydrology models for a closed system which inherently predicts the correct water surface elevation of the exterior while adjusting the degree of gate closure for interior stage determination, and (2) conducting coincidental probability analysis with historical gage records that are used in conjunction with the interior model to calculate the probability of interior flooding stages.

RESULTS

Both methods have been used in Wichita. The first method is more efficient as it uses the time-stamped stage data inside the levee as a tailwater condition. The second method is subjective and dependent on the availability of gages, length of records and proximity to the location of the interior drainage outlet structure.

[1] AMEC Earth and Environmental, Nashville, Tennessee

PREDICTING SINKHOLE FLOODING IN COOKEVILLE

Peter Li[1], Evan Hart[1], Hugh Mills[1], Derrick Ho[1], and Martin Kimbrell[1]

Lower drainage density in Cookeville was verified by cave density. Such unique hydrology features occurring in karst region poses the danger of ignoring potential flood in Cookeville. SCS method was used to find volume of 3 hour, and 24 hour 100-year return flood. GIS functions were carried out to delineate flooded basins. The results indicate that 2.1% of Cookeville urban growth boundary will be inundated. A 7% of public housing in Cookeville is under flood zones, compared to 1% of residential flooded structures. This has posed the question of environmental justice issue in a small city like Cookeville. Rational method was also applied to delineate the flood zones. The Coefficient of Areal Correspondence shows a 51% spatial correlation between SCS and Rational Method. A recent storm validates the flood zones generated from this study.

[1] Earth Sciences, Tennessee Technological University

Power Point File of Presentation

TENNESSEE DOT MONITORING PROGRAM FOR SCOUR CRITICAL AND UNKNOWN FOUNDATION BRIDGES

Jon Zirkle[1]*

INTRODUCTION

Monitoring of scour critical and unknown foundation bridges in Tennessee was traditionally done with the two year inspection cycle and cursory inspections if problems were found during regular inspections or brought to our attention by citizens or other government entities.

In August of 2004, the Tennessee Department of Transportation (TDOT) contracted with US Engineering Solutions (USES)[2] for use of their Scourwatch™ program to aid in monitoring 1015 scour critical bridges across the state, three fourths of which are located in west Tennessee. Currently the program has been renamed Bridgewatch™ since functionality has been added over time and monitors close to 900 scour critical bridges and now around 1200 unknown foundation bridges across the state.

RESULTS AND DISCUSSION

The program fortifies the TDOT monitoring program by tying data sources such as USGS stream gages, NOAA weather radar, and any scour monitoring equipment, if available, to notification software that contains TDOT bridge data and GIS information for each scour critical and unknown foundation bridge in the state and is triggered by TDOT set thresholds. These flood frequency thresholds are set so that a flood event that may cause scour critical to the stability of the bridge triggers the software to call out TDOT or local official personnel by phone, fax, email, beeper, etc. The official personnel can then perform an on site inspection as described in the Plan of Action (POA) as a crucial flood event occurs. This site visit will allow official personnel whether state or local to make timely decisions on whether to close a bridge or not before the safety of the traveling public is compromised.

---

[1] PE

SESSION 1B

WATER QUALITY
1:30 p.m. – 3:00 p.m.

Metro Nashville's Watershed Group Thermography Program Enhancements and Findings
Mary Garmon

Root Cause Analysis of Kingston Ash Pond Failure TVA Kingston Fossil Plant, Roane County, Tennessee
William H. Walton, William Butler, and Gonzalo Castro

Denitrification and Eutrophication Potential in Land Application of Sewer Effluents from Small Step/Recirculating Sand Filter Systems in Middle Tennessee
Michael Cain

STORMWATER I
3:30 p.m. – 5:00 p.m.

State-of-the-Art Microbial Source Tracking Toolkit for Analysis of Stormwater Discharges
Candice A. Owen and Dustin G. Bambic

Using an NCAA Sports Facility as a Regional Stormwater Detention Basin
Michael Clay and Brad Davis

Effect of Effluent Limitations Guidelines on TDOT's EPSC Design Toolbox
Jeffrey B. Shaver

METRO NASHVILLE'S WATERSHED GROUP THERMOGRAPHY PROGRAM ENHANCEMENTS AND FINDINGS

Mary Garmon[1]*

The Thermograph program within Metro Water Services' Watershed Group began operations in 2003, successfully completing five seasons of flights. The Metro Nashville Police Department assists by providing use of their helicopter services and infrared camera equipment for detection of illicit discharges, which are shown through differences in surface water temperatures. When flying over a stream, an anomaly on the camera will signify that there is a discharge of some sort to that stream. Often times this can be groundwater seepage or a tributary with warmer ambient temperatures. However, sometimes it shows illicit discharges that would not be seen with the naked eye. Some of the Watershed Group Thermography findings have been water line breaks, sewer overflows or seepages, missing manholes, faulty sediment basins, etc.

Mary Garmon, a Watershed Group member resumed responsibility for the Thermograph program in 2007 and in that time has enhanced the program with changes which optimize time management and efficiency. One change is to fly at night to eliminate reflections from the sun and therefore produce fewer false positives. In addition, temperatures are generally colder when the sun goes down; the lower the temperature of the creek that is being flown, the easier it is to see discharges. Another change within the program is to geocode every anomaly during the review process using GIS, which proves to be a very useful tool for the thermograph program. Comparing thermograph layers from previous years with current data on GIS eliminates unnecessary field work. The focus of this presentation will be to provide a detailed look at the improvements made by Metro Water Services' Watershed Group to improve the Thermograph program and analyze 2010 data.

[1] Metro Water Services – Watershed Group, 1607 County Hospital Rd, Nashville, TN 37218
mary.garmon@nashville.gov

ROOT CAUSE ANALYSIS OF KINGSTON ASH POND FAILURE
TVA KINGSTON FOSSIL PLANT, ROANE COUNTY, TENNESSEE

William H. Walton[1]*, William Butler[2], and Gonzalo Castro[3]

The Kingston ash disposal cells in Harriman, Tennessee, were engineered structures used since 1954 to store wet flyash and bottom ash, ultimately within stacked cellular embankments constructed over former Swan Pond Creek flood plain, a back water slough of the Emory River, now part of the Watts Bar Reservoir. The north and central portion of the vertical stacked cell structure (Cell 2) suddenly failed toward the north just after midnight on December 22, 2008. An estimated 5.4 million cubic yards of ash and dikes built 90 feet high failed rapidly northward in a progressive manner. As evidenced by soil borings and instrumentation, the flow slide was located along the bottom of ash through a weak layer of silt and ash slime deposited early on over the native flood plane clayey soils. The liquefied ash moved rapidly over the old flood plane 4,600 feet inundating several sloughs and discharged to the Watts Bar Reservoir, and had an angle of repose after flow failure of less than 1/2 degree.

The Tennessee Valley Authority (TVA) retained AECOM in early January 2009 to conduct a Root Cause Analysis (RCA) to determine the probable failure mode(s) which contributed to the failure. AECOM performed an extensive subsurface exploration, laboratory testing program, seepage and stability analysis and record review for the RCA Report. This paper discusses the RCA investigation, findings, and conclusions.

[1] P.E., S.E., F.ASCE, AECOM, 750 Corporate Woods Parkway, Vernon Hills, Illinois 60061, 847-226-7694, Bill.Walton@AECOM.com
[2] P.E., AECOM, 1035 Kepler Drive, Green Bay, Wisconsin 54311, 920-406-3168, William.Butler@AECOM.com
[3] Ph. D., P.E., Consultant, 1 Muster Court, Lexington, Massachusetts 02421, Gv.castro@verizon.net

DENITRIFICATION AND EUTROPHICATION POTENTIAL IN LAND APPLICATION OF SEWER EFFLUENTS FROM SMALL STEP/RECIRCULATING SAND FILTER SYSTEMS IN MIDDLE TENNESSEE

Michael Cain*

The purpose of this research is to improve function and effectiveness of drip irrigation wastewater disposal to reduce eutrophication potential and to develop a model for engineers and system designers to use to specify treatments that will maximize the effectiveness of a system for a particular location. This research will use in-labs soil columns for experimental treatment of various concentrations of organic carbon to test the carbon's effect on denitrification, and test wells in existing drip irrigation fields for comparative analysis. Redox potential will be measured to map changes over time of the aerobic and anaerobic zones to help in the understanding of the process of nitrification, denitrification and carbon utilization.

STATE-OF-THE-ART MICROBIAL SOURCE TRACKING TOOLKIT FOR ANALYSIS OF STORMWATER DISCHARGES

Candice A. Owen[1]* and Dustin G. Bambic

An astonishing number of the nation's waterways are impaired by bacteria discharges, which can pose health risks to recreational users and shellfish consumers. Control of bacteria discharges poses an immense challenge to public agencies. Identification of sources of fecal pollution in stormwater is a critical first step for NPDES and TMDL compliance efforts. Microbial source tracking (MST) is a continually evolving area of research for water quality assessment in the U.S. In recent years, source trackers have migrated toward "library-independent" methods that include analysis of the enteric bacteria group *Bacteriodales* with quantitative polymerase chain reaction (qPCR). These methods not only identify host-specific fecal sources, but also quantify amounts of those sources. Quantitative *Bacteriodales* analyses are available to identify a variety of hosts (including: human, horse, cow, dog, and bird) while by-passing many of the downfalls associated with traditional indicators. For instance, unlike *E. coli*, *Bacteroidales* cannot grow and persist in the environment because they are anaerobic. This presentation discusses the efficacy of a state-of-the-art microbial source tracking toolkit to assess discharges from the non-CAFO area of a horse race track. The toolkit utilized included *Bacteriodales* assays for universal and human which have been more widely published, but also employed recently-developed horse, cow, and bird *Bacteriodales* assays. In addition to *Bacteriodales*, traditional indicators (*E. coli*, *Enterococcus*, and total coliform) and other environmental parameters were also monitored for comparison. Our study design included two separate laboratories with independently developed assays to validate MST results. This allowed for the "head-to-head" comparison of results of individual samples from each storm event. This redundancy of design allowed for testing of the efficacy of each laboratory's *Bacteriodales* assays based on water samples and fecal samples with known amounts of fecal contamination. Overall, our results highlight the pros and cons of applying MST to stormwater discharges, demonstrate the importance of using a weight-of-evidence approach, and should be useful for a variety of agencies faced with the challenge of reducing bacteria discharges.

[1] Candice Owen is a Water Resources Engineer with AMEC Earth & Environmental, Inc. Her current work involves microbial source tracking studies and assisting stormwater agencies with NPDES permit compliance. Her educational background includes a B.S. in Civil Engineering and a M.S. in Environmental Engineering from the University of Tennessee, Knoxville.

AMEC Earth & Environmental, Inc., 3800 Ezell Road, Nashville, TN 37211

USING AN NCAA SPORTS FACILITY AS A REGIONAL STORMWATER DETENTION BASIN

Michael Clay[1*], Brad Davis[1]

ABSTRACT

The drainage system in the City of Memphis' historic midtown area regularly surcharges during intense rain events causing extensive flooding. The City studied a 1,457 hectare (3,600 acre) area and the underlying drainage system to analyze the existing conditions and possible solutions. The analysis provided multiple improvement options including a regional stormwater detention basin on the site of an existing NCAA soccer field at Christian Brothers University. The study area was fully developed, so adequate open space was not available for construction of a detention project. The soccer field provided the needed open area without demolition of existing structures and provided flood relief for downstream areas. The cooperation between Christian Brothers University and the City of Memphis provided a mutually beneficial outcome for both parties. The City gained a regional detention facility without purchasing an expensive tract of land, and the University gained an aesthetically and functionally improved soccer complex.

KEYWORDS: Regional detention, multi-use basin, stormwater, flood mitigation.

INTRODUCTION

The historic Midtown area of Memphis, Tennessee has drainage infrastructure designed and constructed in the early 1900's. With rapid urbanization and increased impervious areas (See Figure 1. Urbanized Study Area), the city has faced numerous flooding issues resulting from over-stressed storm sewers and open channels. An array of factors contributes to the severity of the flooding and complexity of possible solutions, including:

- Undersized storm sewers for current runoff
    - Much of the area's storm sewers have 1/3 the capacity needed to convey the design storm
- Open and Closed Conduit drainage networks
    - Storm Sewers flow from culverts to open channels and back into culverts throughout the study area.
- Developments in low, flood-prone areas
    - Houses built atop large box culverts.

[1] Smith Seckman Reid, Inc.
*To whom correspondence should be addressed. Email: mclay@ssr-inc.com.

Figure 1. Urbanized Study Area

Based on record grading and drainage plans, culverts in some areas were designed for a capacity of 0.70 cubic meters/second/hectare (1 cubic foot/second/acre). This minimal capacity requirement may have been sufficient for certain culverts with wooded, swampy upstream drainage areas; but upstream areas were later developed into high-density residential and commercial zones. Current design standards would require certain culverts to provide a capacity of up to 4.20 cubic meters/second/hectare (6 cubic foot/second/acre), far greater than the existing infrastructure's capabilities (Anderson, et al., 1986). The undersized drainage system surcharges frequently during intense rain events, flooding intersections, underpasses, yards, and finished floor elevations.

The current drainage system is severely undersized, and existing drainage easements would not provide adequate area for an improved drainage system. Furthermore, increasing the capacity of one section of the drainage system would necessitate improvements for miles downstream; otherwise, flooding issues would simply be transferred to the location where improvements cease. Detention could provide flood relief, but the structure would need to be large (at least 1.2-2.02 hectares or 3-5 acres) for a substantial benefit. The basin is extremely urbanized, making it nearly impossible to find a large, undeveloped piece of property in a location that would hydraulically benefit the study area.

METHODOLOGY

Study Approach

The City of Memphis has adopted a Regional Detention approach to address the widespread flooding issues in fully developed areas of the city. This approach necessitates the analysis of the entire watershed that is contributing to the frequently flooded areas in order to formulate solution alternatives that would optimize available resources and provide the least detrimental effects to nearby areas. Utilizing a combination of GIS and a state of the art storm water modeling program, a highly urbanized 3800 acre study area was analyzed. Thanks to the availability of GIS data from the City, survey information, and the capabilities of the storm water modeling software, the complexity of the drainage network was accurately modeled for the entire study area.

Solution Evaluation

The formulation of solution alternatives was complicated by the lack of open space available for detention and the density of homes and businesses throughout the study area. Having a detailed, composite model allowed for the evaluation of solution alternatives based on the resources and locations that were available for storm water management. The modeling software was able to quickly evaluate mitigation measures such as above and below ground detention and enlarged culvert sections. Also, the effects of a particular solution alternative could be observed across the entire study area to ensure that recommended improvements would not harmfully affect any location within the study area either upstream or downstream.

RESULTS

Site Selection and Approval

The Lick Creek Drainage Study was completed in the summer of 2006. Results from this study provided the City with the information necessary to confidently allocate funds for stormwater management in the entire study area. The use of GIS exhibits, Urban Floodplain Mapping, and animated drainage profiles provided the public with a clear understanding of the impact provided by the proposed drainage improvements. The modeling results and GIS exhibits were crucial to the successful design and implementation of multiple projects including a regional stormwater multi-use basin. Figure 2. Existing Flooded Area and Figure 3. Improved Flooded Area display the estimated improvement afforded by the construction of the multi-use basin.

Due to the lack of undeveloped land, the NCAA soccer field on the Christian Brothers University campus was cited as the only hydraulically beneficial and spatially feasible construction site for a large detention area. With the use of innovative and progressive design ideas and materials, a large-scale stormwater detention basin was designed that maintained all the functionality of the existing soccer complex. The design addressed issues related to field inundation frequency, drying time, trash accumulation, stadium seating, aesthetic/architectural improvements, and access agreements. Construction on the multi-use basin began in November 2008 and was originally estimated to be completed in July 2009, but is now estimated to be completed in the fall.

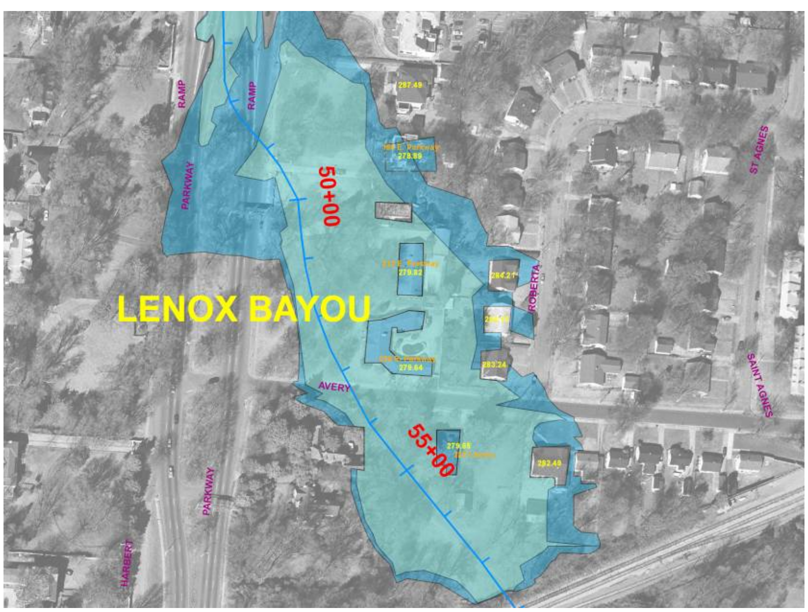


Figure 2. Existing Flooded Area

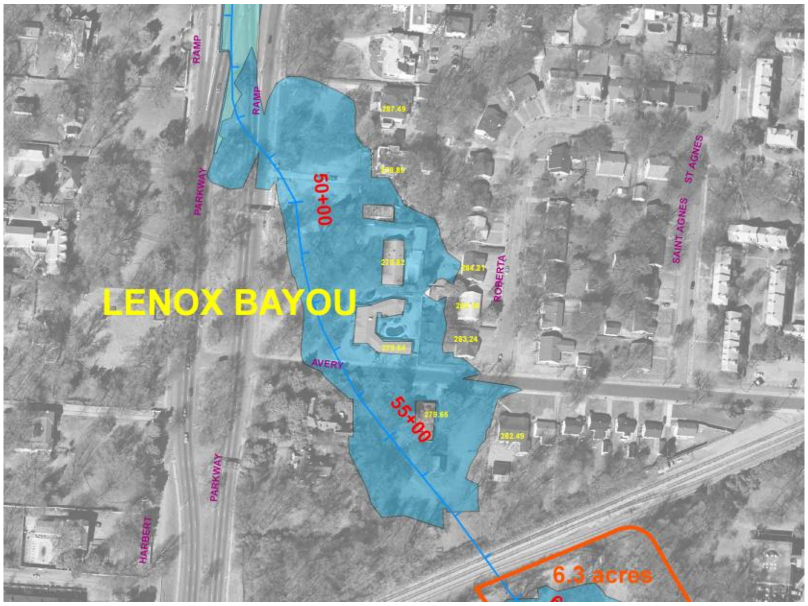


Figure 3. Improved Flooded Area

Functional Design Features

The manner in which stormwater would flow onto the field, or into the basin, was strategically planned. An oversized, box culvert with a side discharging weir was designed to provide the primary mode for stormwater to enter and leave the detention basin; See Figure 4. Oversized box culvert with side discharging weir. Figure 4 provides a section view of the box culvert running along the edge of the detention basin/soccer field. At the upstream end of the box culvert is the incoming drainage. At the downstream end of the box culvert is the outlet control structure for the basin. Notice in Figure 4 that

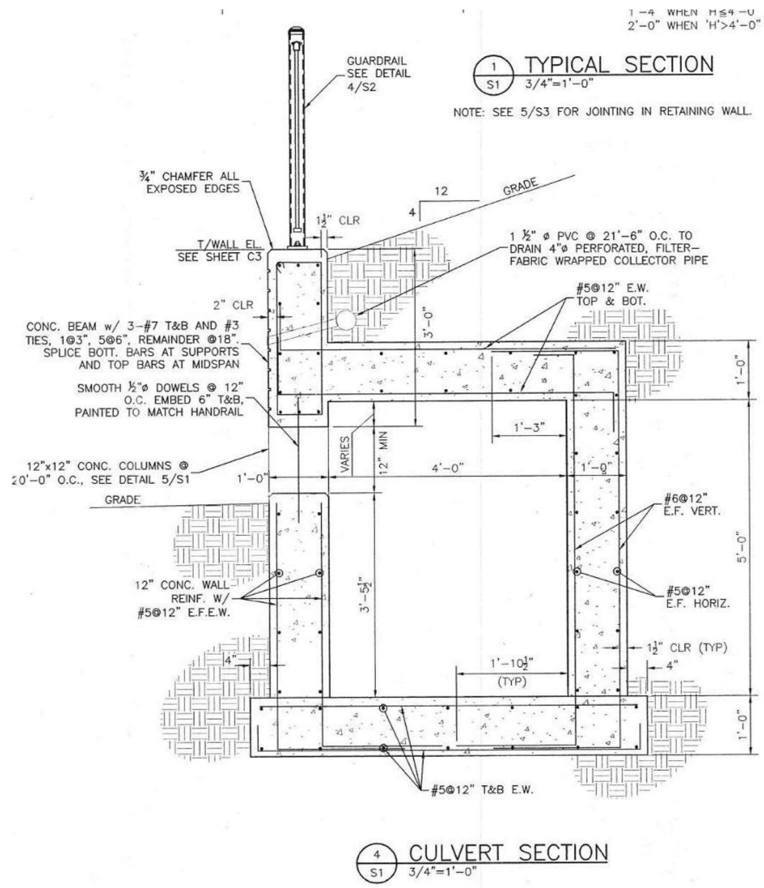


Figure 4. Oversized box culvert with side discharging weir

there is an opening in the side of box culvert. This opening runs approximately 150 feet in length and allows water to enter and exit the detention basin. The opening is approximately three feet above the invert of the box culvert, allowing flow generated from frequent rain events to flow under the opening and not discharge onto the field. This will allow the field to remain dryer for longer durations, and serve as a first flush volume to wash the majority of floatables and trash through system, rather than onto the field.

The outlet control structure consisted of junction box with the oversized box culvert penetrating one wall, and the outlet pipe on an adjacent wall; see Figure 5. Outlet Structure. As shown in Figure 5, a steel plate with an 18" orifice is mounted at the opening to the outlet pipe. This single plate controls the stage-storage-discharge relationship for the entire detention facility. The outlet pipe is an oversized, 42" reinforced concrete pipe. The oversized outlet pipe allows the entire storage characteristics of the detention basin to be modulated by simply replacing the steel plate. If the City would like to detain stormwater more often, a plate with a smaller orifice could be installed. Conversely, if the City would like to detain stormwater less often, a plate with a larger orifice could be installed.

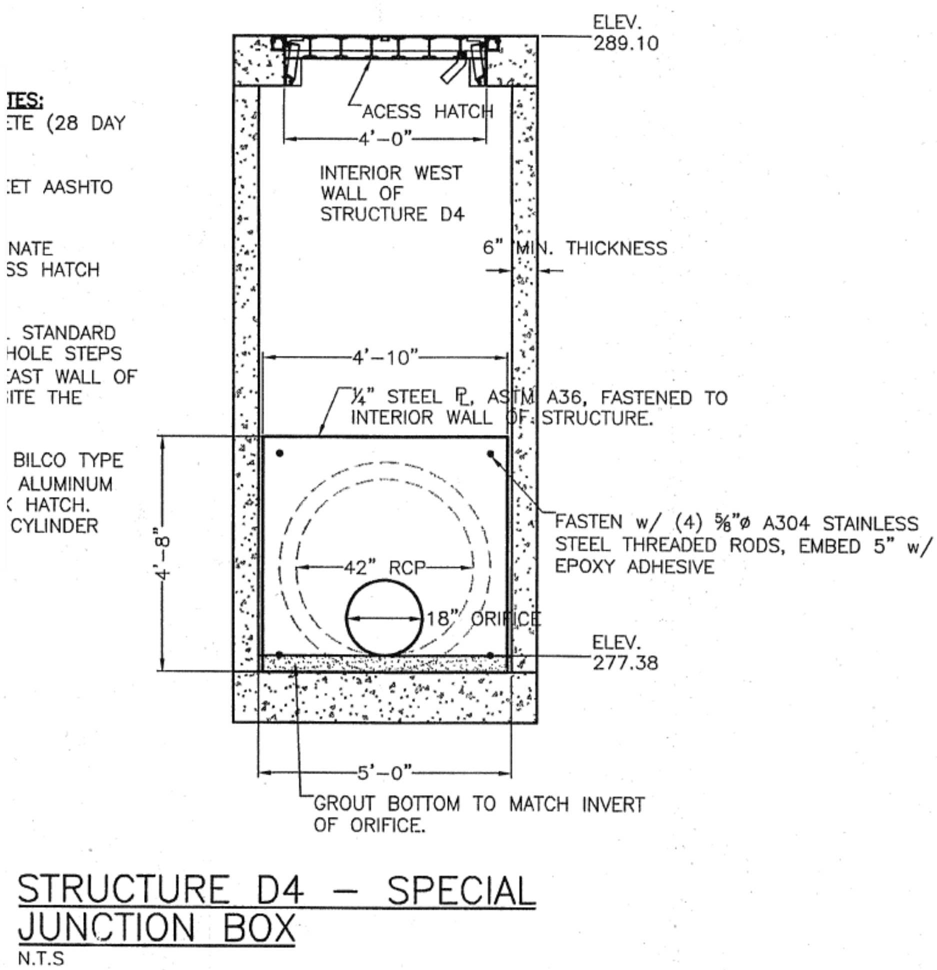


Figure 5. Outlet Structure

The outlet structure also has a Bilco access hatch with a clear opening of 4' x 6' instead of a standard manhole frame and lid. This enlarged opening will facilitate changing the orifice plate and removing large debris that collects at the outlet structure. The large opening will also allow the use of a back hoe or bobcat for removal of heavy pieces of debris.

Laying out an NCAA regulation sized soccer field, players' box, spectator seating, and walkways within the project site proved difficult. Retaining walls were utilized to minimize the footprint without diminishing the required freeboard within the basin. Christian Brothers University was very concerned with the appearance of concrete retaining walls and requested a surface treatment that would match the existing campus. Most of the existing campus buildings have brick façades with similar color patterns. A brick façade was avoided on the detention project because brick would be susceptible to failure caused by the moisture conditions that were expected in the project area. In order to provide an aesthetically pleasing treatment that would stand up to site conditions better than brick, a concrete formliner was used. A formliner is a thin, reusable form placed on the exterior surface of poured in place concrete formwork. The concrete is poured in behind the formliner, leaving the imprint of the form after curing. Figure 6. Formlined Concrete, displays concrete surface treated with the formliner specified for the detention project. The formliner specified was produced by Custom Rock in their Running Bond Used Brick pattern. This pattern matched the existing campus' brick pattern and could be stained to match. A formlined and stained concrete retaining wall will provide the structural integrity, weather resistance, and aesthetic appearance required by the University and City.

Figure 6. Formlined Concrete (photo courtesy of Custom Rock Formliner)

DISCUSSION/CONCLUSIONS

The implementation of a multi-use basin has, thus far, proven to be a success. The City of Memphis was able to provide regional stormwater detention in an area that would have otherwise necessitated the purchase of four to five acres. Even with the added construction expense associated with making the facility a functional soccer complex, the total cost was far less than a traditional, earthen basin on purchased property. Furthermore, the agreement between the City and the University relieves the City of certain maintenance procedures, such as mowing.

The University has gained a completely renovated soccer field with improved field drainage, spectator seating, and intra-campus circulation. The new formlined retaining walls and path lighting will dramatically improve the aesthetic continuity with the existing campus, and provide a safer walkway for pedestrians at night. The existing field has no ADA accessibility routes, but a new ramp will provide ADA compliant slopes. The construction of a regional detention basin on campus has allowed the University to expand and develop their property without having to lose valuable land to a site detention basin or adding to flooding issues downstream.

ACKNOWLEDGMENTS

Smith Seckman Reid, Inc. would like to thank their valued client, the City of Memphis, and especially Hugh Teaford in the City's Engineering Division; also, many thanks to Mr. Dan Wortham with Christian Brothers University.

REFERENCES

Anderson, J. L., Beasley, M.L., and Smith, J. W. (1986). *City of Memphis Drainage Design Manual*. Department of Engineering. Memphis, Tennessee.

Custom Rock Formliner. http://custom-rock.com (accessed July 7, 2009).

Bilco. http://bilco.com (accessed July 7, 2009).

EFFECT OF EFFLUENT LIMITATIONS GUIDELINES ON TDOT'S EPSC DESIGN TOOLBOX

Jeffrey B. Shaver[1]*

A general overview of current best management practices (BMP) used to design erosion prevention and sediment control (EPSC) plans for TDOT roadway projects. This overview will include the standard BMPs that have been available to designers as well as new BMPs that have recently been added to TDOT's EPSC Design Toolbox. A discussion is also included on how proprietary EPSC products are added to TDOT's Qualified Products List for use in lieu of a standard BMP called for in the EPSC plans for a roadway project.

An overview of EPA's "Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category" and how they will have an effect on TDOT's EPSC Design Toolbox. This overview will include the basic requirements listing the EPA's "Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category". A discussion is also included on how these requirements will affect the implantation of the BMPs in TDOT's EPSC Design Toolbox. Anticipated additions and/or deletions to the BMPs in TDOT's EPSC Design Toolbox are also included.

[1] Suite 1300, James K. Polk Bldg, 505 Deaderick Street, Nashville, TN 37243, Jeffrey.B.Shaver@tn.gov

SESSION 1C

ENGINEERS WITHOUT BORDERS
1:30 p.m. – 3:00 p.m.

Lessons Learned from Low Cost Water Improvement Projects in Rural Guatemala
Forbes Walker, John Schwartz, and Neal Eash

Assessing Water Needs in a Developing Country, Nashville Engineers Without Borders, Chapelton, Jamaica
Candice A. Owen

Lessons Learned from TSMP
J. Woodard (Abstract Not Available)

STORMWATER PRODUCTS
3:30 p.m. – 5:00 p.m.

Incorporating Innovative Stormwater Management Technologies into a Sustainable Integrated Use System
Mark B. Miller

Treating Stormwater with an Upflow Filtration System that Incorporates Hydro-Variant Technology
Tom Happel

Polymer Enhanced System Provides Flow-Through Treatment for a Dredging Operation on Kentucky Lake
Jason Painter

Stabilizing and Vegetating Extreme Slopes Using High Performance Hydraulic Mulches
Shannon Martin

LESSONS LEARNED FROM LOW COST WATER IMPROVEMENT PROJECTS IN RURAL GUATEMALA

Forbes Walker[1], John Schwartz[2] and Neal Eash[3]

Since 2007, the Engineers Without Borders (EWB) student chapter at the University of Tennessee (UT) has being working with the community of La Fortuna, a rural community in western Guatemala to implement sustainable water supply projects. In May 2007, EWB members traveled to Guatemala to construct three prototype rainwater storage tanks. These systems collected rainwater from the roofs of the villager's homes during the rain season (May to October), and provide clean, safe water for each household during the dry season (November to April). A follow-up visit was conducted in March 2008. Water tests showed that the water was still clean (no detectable *E. coli*) compared with a nearby well (> 10^6 cfu *E. coli* per 100 ml).

In May 2009 a follow-up visit was conducted. During this trip several projects were initiated including a spring-protection project. During this presentation we will share our experiences with leading groups of students on international service learning projects.

1 Associate Professor, Biosystems Engineering & Soil Science, The University of Tennessee, 2506 E.J. Chapman Dr., Knoxville, TN, 37996-4531, frwalker@utk.edu
2 Associate Professor, Civil and Environmental Engineering, The University of Tennessee, Knoxville, TN, 37996-4531 jschwart@utk.edu
3 Associate Professor, Biosystems Engineering & Soil Science, The University of Tennessee, 2506 E.J. Chapman Dr., Knoxville, TN, 37996-4531, eash@utk.edu

ASSESSING WATER NEEDS IN A DEVELOPING COUNTRY
NASHVILLE ENGINEERS WITHOUT BORDERS – CHAPELTON, JAMAICA

Candice A. Owen[1]*

A team from the Nashville Professional Chapter of Engineers Without Borders-USA (EWB) recently traveled on a project assessment trip to the small community of Chapelton, Jamaica. EWB-USA is a national organization (www.ewb-usa.org) established to partner with developing communities worldwide to improve quality of life through sustainable engineering projects. The Chapelton partnership is the first international project for the Nashville chapter and focuses primarily on improving the water supply and distribution system for the community. As an initial step in the process of designing and implementing multiple projects in Chapelton over the next few years, five Nashville professionals spent a week in Jamaica assessing problems facing the community.

This presentation discusses multiple aspects of the Jamaica assessment trip including: initial planning, interaction with the Chapelton community, evaluating problems of the community (engineering and otherwise), dealing with government agencies on a local, regional and national level, data collection, moving toward implementation and lessons learned. A brief introduction to EWB-USA and the activities of the Nashville Professional Chapter is also provided.

[1] Candice Owen is a Water Resources Engineer with AMEC Earth & Environmental, Inc. Her current work involves microbial source tracking studies and assisting stormwater agencies with NPDES permit compliance. Her educational background includes a B.S. in Civil Engineering and a M.S. in Environmental Engineering from the University of Tennessee, Knoxville. Candice is a LEED Accredited Professional.

AMEC Earth & Environmental, Inc., 3800 Ezell Road, Nashville, TN 37211

INCORPORATING INNOVATIVE STORMWATER MANAGEMENT TECHNOLOGIES INTO A SUSTAINABLE INTEGRATED USE SYSTEM

Mark B. Miller[1]

A sustainable approach to water management has been implemented in association with the LEED inspired construction of a new 12,500 square foot corporate headquarters building in Chattanooga, TN. The integration of stormwater management technologies serve to reduce pollution from stormwater runoff, limit the disruption to the natural site hydrology by reducing impervious cover, increase infiltration, utilize water that would otherwise have been lost, reduce wastewater generation, and minimize potable water use. Innovative, cost-effective technologies designed to capture, treat, harvest and reuse waters derived from both stormwater and roof runoff are described.

Stormwater and roof runoff are captured and piped to an underground treatment train system constructed of HDPE. This system provides treatment by hydrodynamic separation and filtration technologies. The hydrodynamic separator removes debris, coarse sediment and free floating oil; while filtration provides simultaneous removal of fine-grained sediment, residual oil and waterborne pathogens using a proprietary antimicrobial technology. Harmful microorganisms are destroyed on contact with the media at stormwater flow rates. The treated, non-toxic water is subsequently harvested within a 13,000 gallon (100 year storm volume equivalent) underground modular and lined polypropylene storage unit. Stored water is then used for non-potable property applications including landscape irrigation, an outdoor fountain, and a variety of other building processes. Elsewhere on the property, infiltration is enhanced through the use of a combination of load-supporting drivable grass and gravel paving technologies in the vehicle parking areas. These unique features also serve to reduce the urban heat island effect caused by traditional paving materials; and, enhance the viewscape of the area.

The incorporation of these stormwater technologies into a sustainable integrated use system requires advanced design planning compared to traditional water management practices. The benefits of their implementation can be realized in terms of practical uses and operational costs of water usage. As witnessed during the drought of 2007 in the southeastern states, their implementation would have addressed environmental health, used water that otherwise would have been lost, and reduced potable water demand.

[1] P.G., Research Scientist, AquaShield™, Inc., 2705 Kanasita Drive, Chattanooga, TN 37343, (888) 344-9044, mmiller@aquashieldinc.com

TREATING STORMWATER WITH AN UPFLOW FILTRATION SYSTEM THAT INCORPORATES HYDRO-VARIANT TECHNOLOGY

Tom Happel[1]

Since its inception, the idea of treating stormwater with media filtration has meant that the stormwater quality unit has been placed off-line. During this presentation, participants will learn about an Upflow Filtration System that incorporates Hydro-Variant Technology which offers a method of bringing media filtration online without the significant headloss associated with traditional media filtration systems. In addition, the participants will be introduced to a variety of media types which enables customizing the treatment to more precisely address particular pollutants of concern.

[1] President Company, Suntree Technologies, 798 Clearlake Rd, Suite 2 Cocoa, FL 32922, (321) 637-7552

POLYMER ENHANCED SYSTEM PROVIDES FLOW-THROUGH TREATMENT FOR A DREDGING OPERATION ON KENTUCKY LAKE

Jason Painter[1]

The EPA has recently changed the effluent guidelines for the construction and development industry. As a result of these higher standards, the local regulatory agencies and the development community must educate themselves on environmentally safe erosion & sediment control techniques. During this case study review, participants will learn about different polymer types, applications, and how to implement them into their projects.

[1] East/West Tennessee Sales Manager, Jen-Hill Construction Materials, 145 Old Shackle Island Rd., Hendersonville, TN 37075, (615) 824-1200

STABILIZING AND VEGETATING EXTREME SLOPES USING HIGH PERFORMANCE HYDRAULIC MULCHES

Shannon Martin[1]

During this case study review, participants will be introduced to the Walden's Ridge Paragliding Club on Signal Mountain near Chattanooga. Sitting high on the Cumberland Plateau, this site is recognized as one of the best paragliding sites in the Southeast. In recent years, the activity on the ridge coupled with the steep slope face and high winds have increased erosion at this site. The presentation will detail specifics related to the BMP selection process, the selected high performance hydraulic mulch, and the industry testing that supports the spectacular results.

[1] Regional Sales Manager Company: North American Green

SESSION 2A

PATHOGENS AND PUBLIC HEALTH
8:30 a.m. – 10:00 a.m.

Public Perception and Possible Health Effects of a Large Water Utility Cross Connection Event
Judy Manners and Rand Carpenter

Identifying and Detecting Waterborne Pathogens in Tennessee
Alice Layton, Dan Williams, Larry McKay, and James Farmer

Nonpoint Sources of E. coli *in the Sequatchie River Watershed: Building a Case for Clean Water in a Rural Watershed*
Nicholas Hollingshead and Daniel Carter

ECOLOGY I
10:30 a.m. – 12:00 p.m.

Survey of Stressor Identification in State Water Management
John Harwood

Predicting Environmental Flow Metrics at Ungaged Basins in the Tennessee and Cumberland River Valleys
Rodney R. Knight, W. Scott Gain, and William J. Wolfe

Is It Safe to Swim? A New WERF-Funded Study of Pathogen Discharges
Dustin Bambic, Stefan Wuertz, Graham McBride, and Woutrina Miller

ECOLOGY II
1:30 p.m. – 3:00 p.m.

Water Qualty and Mussel Populations in the Clinch River in Tennessee and Virginia
Greg Johnson, Jennifer Krstolic, and Brett Ostby

Application of ASTM Mussel Toxicity Testing Guidance to Conducting a USEPA Toxicity Identification or Reduction Evaluation
Richard Lockwood and Robin L. Garibay

Recent Developments in Understanding the Effects of Ions on Aquatic Life
Scott Hall

ECOLOGY III
3:30 p.m. – 5:00 p.m.

Assessing the Relationship Between Whole Effluent Toxicity and In-Stream Biological Communities
Scott Hall

Evaluating Macroinvertebrate Community Diversity in Ponds Utilizing Two Sampling Techniques
Laura Ashlie Farmer and Steven W. Hamilton

Practical Implementation Factors for Green Infrastructure in Tennessee
Curt Jawdy

PUBLIC PERCEPTION AND POSSIBLE HEALTH EFFECTS OF A LARGE WATER UTILITY CROSS CONNECTION EVENT

Judy Manners, M.S.[1], and Rand Carpenter, DVM[1]

SUMMARY

In fall 2008, water utility personnel identified a household sewage outlet accidentally connected to the water main supplying a small Tennessee community. This cohort study of 1,047 affected households demonstrate that households in the affected area were more likely to report having diarrhea among persons living in the home during April through August or the month of August alone than households in the nonaffected area (OR= 1.89; 95% CI: 1.51-2.3). Those households in the affected area reporting greater quantities of water consumed were more likely to report illness than those in the affected area where smaller quantities were consumed (OR= 3.4; 95% CI: 2.26-5.13). Ninety-seven percent of the 354 affected households were aware of the event. Fifty-six (56%) percent reported first hearing of the event by direct communication with the water utility; 34% by letter and 22% by telephone. Media notification accounted for 31.6% of the households being aware, 26% by television news and 5.6% by newspaper. First notifications by word of mouth accounted for 9.3% of households in the affected area. Fifty-three percent of the 337 of the non-affected households were aware of the event. Results demonstrating greater illness among households reporting greater water consumption add validity to the risk of illness in affected households.

INTRODUCTION

Public water system maintenance events, line breaks, and cross connections can have adverse health effects on exposed households (Nygard, et al 2007). Understanding customer perception and possible health effects of water supply events facilitates communication and response to these type of events. Complaints regarding water quality have led to the discovery of the cross connection events (Fernandes, et al 2007).

In September 2008, water utility personnel identified a household sewage outlet accidentally connected to the water main supplying a small community. In response to the improper cross connection to the water main supplying the community, the Tennessee Department of Health conducted a survey of residents' knowledge, attitudes, and perceptions of the event as well as their response to the event and any health effects they perceived as possibly caused by the cross connection.

METHODS

Utility personnel and water supply regulators defined the affected area and a comparably populated unaffected area served by the same utility. A self-administered paper questionnaire and a stamped addressed envelope were mailed to all identified households with the customer water bills. Residents' knowledge, attitudes, and perceptions of the event as well as their response to the event and any health effects they perceived as possibly caused by the cross connection were studied.

[1] Tennessee Department of Health Communicable and Environmental Disease Services

Cohort Study

Study Population

A list of the 1,047 possibly exposed household addresses was provided by the water system personnel (Area 1). A list of 1,800 unexposed household addresses was provided to serve as a control group (Area 2). All households were served by the same water system.

Case Definition

"Perceived health effects" were defined as a household from Area 1 or Area 2 in which at least one person reported having diarrhea during April through August 2008 or during the month of August 2008.

Exposure Definition

An exposed household was one belonging to the list of possibly exposed households provided by the water system (Area 1). Daily water consumption was determined by survey response based on the following categorized volumes consumed: None, 1-2, 3-4, or 5 or more 8 ounce glasses per day.

Data Collection

For both areas, information collected through standardized questionnaires included: number of people in the household; type of water generally used for drinking in the home; for those consuming tapwater, methods of treatment; amount of water consumed; occurrence of diarrhea during April through August 2008; occurrence of diarrhea in August 2008; number of people in the household with diarrhea; pressure changes and water quality issues; method of notification of the cross connection.

The questionnaires were delivered with utility bills to the households during October 2008, within one month following the discovery of the cross connection.

Data Handling and Analyses

All questionnaires that were returned were included in the analysis. Data were entered into Statistical Analysis Software (SAS). Odds Ratios (OR) and corresponding 95% confidence intervals (CI) were computed between Area 1 and Area 2 for households reporting health effect symptoms.

RESULTS

Cohort Study

Respondent Population

Of the 1,047 affected households, 354 (34%) responded. Of the 1,800 nonaffected households, 337 (19%) responded.

Adverse Health Effects

Households in the affected area were more likely to report having diarrhea among persons living in the home during April through August or during August alone than households in the nonaffected area (OR= 1.89; 95% CI: 1.51-2.3). Those households in the affected area reporting greater quantities of water consumed were more likely to report illness than those in the affected area where smaller quantities were consumed (OR= 3.4; 95% CI: 2.26-5.13)

Water Consumption

The reported water consumption was similar in the two studied cohorts with the largest proportions drinking 5 or more eight ounce glasses per day.

Method of Notification

Ninety-seven percent of the 354 affected households were aware of the event. First hearing of the event by direct communication with the water utility was reported by 55.8% of the respondents; 34% by letter and 21.8% by telephone. Media notification accounted for 31.6% of the households being aware, 26% by television news and 5.6% by newspaper. First notifications by word of mouth accounted for 9.3% of households in the affected area. Fifty-three percent of the 337 of the non-affected households were aware of the event.

DISCUSSION

Households served by the water main affected by this improper cross connection reported high rates of illness. Effective public notification by the water utility and wide media coverage led to increased public awareness and potential response bias. Results demonstrating greater illness among households reporting greater water consumption add validity to the risk of illness in affected households.

Persons affected by adverse water supply events are effectively contacted via a variety of media. These findings can help water systems quickly and confidently notify customers during emergencies.

REFERENCES

Fernandes, T.M. A., C. Schout, A.M. DeRoda, Husman, A. Eilander, H. Vennema and Y. T. H. P. Van Duynhoven. Gastroenteritis associated with accidental contamination of drinking water with partially treated water, *Epidemiology and Infection* 2007; 135: 818–826

Nygard, Karin, Erik Whal, Truls Krogh, Odd Atle Tveit, Erik Bohleng, Aage Tverdal, and Preben Aavitsland. Breaks and maintenance work in the water distribution systems and gastrointestinal illness: a cohort study, *International Journal of Epidemiology* 2007; 36:873-880

IDENTIFYING AND DETECTING WATERBORNE PATHOGENS IN TENNESSEE

Alice Layton[1]*, Dan Williams[2], Larry McKay[3] and James Farmer[4]

WATER QUALITY MONITORING AND ASSESSMENTS

The measurement of *E. coli* concentrations using commercially available kits forms the basis for determining whether surface waters meet acceptable "pathogen" water-quality limits and ultimately whether a particular watershed is considered impaired. *E. coli* and/or fecal coliforms were chosen more than 2 decades ago as indicator organisms of potential disease risk based on a limited number of epidemiological studies. These studies suggested that people swimming in waters with high *E. coli* concentrations had higher incidences of water-borne illnesses than those swimming in water with low *E. coli* concentrations. Thus the basic philosophy in using *E. coli* as fecal indicator organisms was, and still is, that water with fecal contamination has high *E. coli* and thus may have other water-borne pathogens. However, a growing number of studies have noted that *E. coli* concentrations alone may not be predictive of the likelihood of finding pathogens in an individual water sample. In Tennessee, little is currently known about the probability of finding human pathogens in surface waters or what types of pathogens are more likely to be found. In this talk, we will review the types of pathogens typically found in different animal wastes including, poultry, dairy, and sewage, and discuss the design and application of molecular methods to identify pathogens and the occurrence of pathogens from a limited number of water samples collected in Tennessee.

* speaker presenting the paper

[1] Research Associate Professor, Center for Environmental Biotechnology and Department of Microbiology, The University of Tennessee, 676 Dabney Hall, Knoxville, TN, 37996. alayton@utk.edu
[2] Research Associate, Center for Environmental Biotechnology, The University of Tennessee, 676 Dabney Hall, Knoxville, TN, 37996.
[3]Professor and Head, Dept. of Earth and Planetary Sciences, The University of Tennessee, Knoxville, TN 37996 lmckay@utk.edu
[4]Hydrologist, U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211

NONPOINT SOURCES OF *E. COLI* IN THE SEQUATCHIE RIVER WATERSHED: BUILDING A CASE FOR CLEAN WATER IN A RURAL WATERSHED

Nicholas Hollingshead[1] and Daniel Carter[1]

The Sequatchie River Watershed (HUC 0602004) is located in southeast Tennessee and includes both the predominantly agricultural Sequatchie Valley and portions of the Cumberland Plateau and Walden Ridge. Elevated levels of *E. coli* have been found in some streams of the Watershed. In 2008, the Tennessee Department of Environment and Conservation set a Total Maximum Daily Load (TMDL) for *E. coli* for the watershed, and identified nonpoint sources as probable causes of these elevated levels. The Landscape Analysis Lab at the University of the South, Sewanee, TN, working with the Southeast Tennessee Development District has completed a study to support the implementation of the TMDL through the development of a geographic information system that characterizes potential nonpoint sources of *E. coli* in the watershed.

In addition to supporting future water quality sampling efforts and the implementation of the TMDL, the geospatial data resources could be useful for regional growth planning that considers water quality protection at the watershed scale. Near the headwaters of the Sequatchie River watershed on the surface of the Cumberland Plateau, the potential development of large subdivisions may have significant impacts on future water quality in the watershed. We present the process of developing these novel geospatial data resources for the region, the challenges of working in a rural watershed, and the relationship between water quality, development, and current local and state laws. Different growth scenarios and potential opportunities for regional planning for the watershed are discussed.

[1] Landscape Analysis Lab, University of the South, Sewanee, TN

SURVEY OF STRESSOR IDENTIFICATION IN STATE WATER MANAGEMENT

John Harwood[1*]

INTRODUCTION

We are completing our evaluation of the usefulness of the Web-based EPA Causal Analysis/Diagnosis Decision Information System (CADDIS; http://cfpub.epa.gov/caddis/) in identifying stressors causing impairment of waters of Tennessee. The research is funded by TDEC Division of Water Pollution Control, TMDL Program. The intended use of CADDIS in Tennessee is to inform the TMDL process. We are determing what data sources are readily available in stressor identification in Tennessee. Also, we are testing varying levels of stakeholder involvement in the different test cases. To gain insight from the experience of others, we distributed a survey to regulators in other states who employ CADDIS or other stressor identification in their work. Thirteen states were sent surveys, identified by EPA as employing stressor identification (SI); ten of the states responded.

The survey addresses three aspects of implementing stressor analysis: guidelines as to what impairment scenarios to approach with CADDIS / SI, information needed to apply CADDIS / SI, and the stakeholder role in applying CADDIS / SI.

RESULTS

Survey responses include:

- *What processes are the SI analyses you perform intended to inform? To what types of impairments do you find it most useful to apply CADDIS / SI?*

TMDL program	11
303(d) listing	6
305(b) preparation	3
regulatory actions	5
agency research	6

- Summary of responses to the question: *To what types of impairments do you find it most useful to apply CADDIS / SI?*

"Multiple stressors" - 4, plus 1 "unknown and/or multiple stressors"
"Urban impairments" - 1
"mostly ... non-point source pollution" - 1
"unknown stressors" – 5
"SI process has been most effective in biological impairment studies where multiple stressors are involved. Our biological standards do little to diagnose the cause of impairment. SI has enabled us to organize the necessary data, eliminate some candidate causes using strength of evidence, and ultimately, diagnose stressors to bring forward into TMDL development."

[1] Department of Chemistry and EVS Ph.D. Program, Tennessee Technological University, Cookeville, TN, 38505 jharwood@tntech.edu. Project administration by the Center for the Management, Utilization and Protection of Water Resources, Tennessee Technological University, Cookeville, TN, 38505

"EPA SI approach is required in [...] for all benthic impairments. Due to the nature of benthic impairments (... it is rarely obvious as to what is causing the community shift), a consistent, organized approach is imperative."

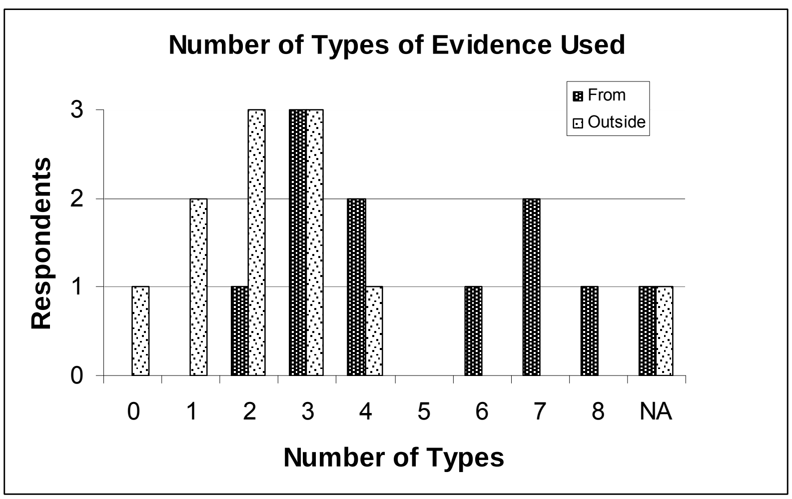
- *Which among the CADDIS / SI types of evidence have you used in analyzing your cases?*

a. Evidence from the Case:

__9__ Spatial/Temporal co-occurrence
__4__ Evidence of Exposure or Biological Mechanism
__9__ Causal Pathway
__9__ Stressor Response Relationships from the field
__2__ Manipulation of Exposure
__3__ Laboratory Tests of Site Media
__6__ Temporal Sequence
__2__ Verified Predictions
__3__ Symptoms

b. Outside the case:

__8__ Stressor Response Relationships from Other Field Studies
__5__ Stressor Response Relationships from the Laboratory
__0__ Stressor Response Relationships from Ecological Simulation Models
__4__ Mechanistically Plausible Cause
__2__ Manipulation of Exposure at Other Sites
__2__ Analogous Stressors



- *How have you engaged stakeholders in CADDIS / SI analyses?*

__1__ a) only individually
__2__ b) meetings of stakeholder teams
__4__ c) not at all
__3__ d) depends on the case

- *Have stakeholders been generally supportive of CADDIS / SI analysis processes they participate in?*

__6__ Yes __1__ No __3__ NA

- *Have stakeholders been generally supportive of the conclusions of CADDIS / SI analysis processes they participate in?*

__7__ Yes __1__ No __2__ NA

- *Does CADDIS / SI assist in formulating TMDL allocations or other regulatory products in your state?*
_ _5_ _ Yes __4__ No

- Summary of responses to the question: *What changes in your state water monitoring procedures would be helpful in making CADDIS / SI analyses more efficient and/or effective?*

Monitoring suggestions:

"Flow or stage monitoring in conjunction with routine sampling." "Storm flow sampling at select stations." "Habitat Assessments." "More biological monitoring stations."

Integrating monitoring:

Three note need to plan integrated monitoring for SI: "Data collection that better links biology, water chemistry and hydrological function, geomorphology, and land-use analyses. ...with the adoption of biotic impairments and the SI process, we are starting to see the benefits of applying many of these tools to the same impairment at the same time." "Identification of impaired sites well in advance of SI analyses in order to incorporate additional supporting data collection (WQ, LULC ground truthing) early in the process to reduce data gaps." "Better planning for stressor analysis in terms of water quality sampling (what parameters to collect) prior to the beginning of the TMDL development/SI process." also, "...incorporation of the reference communities utilized in stressor designations."

One respondent suggests need for increased resources to apply SI: "The process is data intensive and time consuming and we other don't have the luxury to commit enough resource to complete many SID studies."

CONCLUSION

The results of our survey show that EPA web-based CADDIS stressor identification is being used effectively in state water regulation. This analysis is found most useful in approaching cases of multiple stressors or unknown stressors. Use of CADDIS can help structure more efficient and effective monitoring to determine causes of biological impairment. Stakeholders are generally very supportive of the results of stressor identification analyses.

PREDICTING ENVIRONMENTAL FLOW METRICS AT UNGAGED BASINS IN THE TENNESSEE AND CUMBERLAND RIVER VALLEYS

Rodney R. Knight[1], W. Scott Gain[1], and William J. Wolfe[1]

The increased need to understand the implications of water management decisions of stream ecology has given cause to predict a new class of streamflow metrics - environmental flow metrics. Environmental flow metrics represent a different aspect of the streamflow hydrograph than do traditional metrics such as low-flow or flood-frequency metrics. Environmental flow metrics represent not only streamflow frequency and duration, but also timing, rates of change, and magnitude of certain aspects of the annual hydrograph. Prediction of environmental flow metrics presents a challenge due to the broad and varied nature of the metrics. This presents the opportunity and need to investigate different descriptive explanatory variables for use in streamflow metric prediction. We propose that four general groups of descriptive explanatory variables can be used to adequately predict environmental flow variables as well as describe the hydrologic processes that govern the delivery of water from land-surface to streams in the Tennessee and Cumberland River valleys. These four groups include climate, regional, physical, and land-use characteristics. Climate variables include annual precipitation and differences between average annual/monthly temperatures. Regional descriptors include percentages in Ridge and Valley or Blue Ridge Level 3 ecoregion, as well as geologic factors reflecting recession rates. Physical descriptors include soil factors, basin elevation, and rock depth. The final group is land-use factors, which is described by percentages of forest and agricultural uses in each watershed. Of these, the climate and the land-use factors are subject to some change over time. This presentation represents the second of a three phrase project between the U.S. Geological Survey, Tennessee Wildlife Resources Agency, Tennessee Department of Conservation, and The Nature Conservancy aimed to identify environmental flow metrics critical to fish in the Tennessee River valley, develop predictive tools to estimate flow metrics at ungaged locations, and finally to test the applicability of the metrics at estimating fish community health as well as identifying other intervening factors governing fish community structure.

[1] Hydrologist, U.S. Geological Survey Tennessee Water Science Center, 640 Grassmere Park, Suite 100, Nashville, Tennessee, 37211

IS IT SAFE TO SWIM? A NEW WERF-FUNDED STUDY OF PATHOGEN DISCHARGES

Dustin Bambic [1], Stefan Wuertz[2], Graham McBride[3], Woutrina Miller[4]

Each year, millions of people recreate in waters of the United States, yet many of these waters are categorized as unsafe for water contact. Swimming and other water contact activities in the U.S. are protected with recreational water quality (REC) criteria based on measurements of bacteria (e.g., *E. coli*). Estimates of health risks associated with swimming in contaminated waters are generally inaccurate because a small number of epidemiological studies were used by USEPA to develop existing REC criteria, and thus there are many types of watersheds and hydrological conditions that are poorly characterized by available epidemiological data. For instance, while beaches subject to point source discharges (municipal wastewater) were used to develop the existing REC criteria, most beaches today are dominated by diffuse, non-point sources (e.g., municipal stormwater). USEPA has undertaken a *Critical Science Plan* and *Criteria Development Plan* to update existing recreational water quality criteria, including additional, more sophisticated epidemiological studies. However, epidemiological studies cannot be performed in all watersheds or even all regions of the U.S., and thus an alternative approach to risk prediction – quantitative microbial risk assessment (QMRA) – is considered an important component of REC criteria development, and perhaps more importantly, criteria implementation.

This presentation describes an ongoing Water Environment Research Foundation (WERF)-funded project designed to support future applications of QMRA to better understand and assist with management of pathogen-impacted discharges to recreational waters. Developing robust QMRA requires capturing and quantifying data for many variables including contributing fecal sources, types of pathogens, individual exposure levels, and dose-response relationships. Potential inputs for QMRA were both compiled from existing literature and will be collected with an extensive sampling program of sources including municipal stormwater, wastewater, agricultural runoff, and natural runoff. The analytical “toolkit” is one of the most comprehensive to date, including *Salmonella*, *Campylobacter jejuni, Vibrio cholerae*, *Cryptosporidium, Giardia, Toxoplasma gondii*, adenoviruses, enteroviruses, noroviruses, rotaviruses, *Bacteroidales, Enterococcus,* and *Escherichia coli*. An important consideration of this project is the role of QMRA for development of site-specific criteria for recreational waters that are not well-represented by “default” USEPA recreational water quality criteria (i.e., criteria based on *E. coli* and/or *Enterococcus*). The approach developed by this WERF project will allow stakeholders and agencies involved in implementing and complying with REC criteria to more accurately predict health risks and mitigate waterborne sources of pathogen pollution.

1 Presenter, from AMEC Earth & Environmental, 3800 Ezell Road Suite 100, Nashville, Tennessee
2 Department of Civil and Environmental Engineering, University of California, Davis, 2001 Engineering III, One Shields Ave., Davis, California
3 NIWA (National Institute of Water and Atmospheric Research), P.O. Box 11-115, Hamilton 3251, New Zealand
4 Department of Pathology, Microbiology & Immunology, School of Veterinary Medicine, University of California, One Shields Avenue, Davis, California

WATER QUALITY AND MUSSEL POPULATIONS IN THE CLINCH RIVER IN TENNESSEE AND VIRGINIA

Greg Johnson[1], Jennifer Krstolic[2], and Brett Ostby[3]

The Clinch River supports more threatened and endangered freshwater mussel species than any river in North America. Dramatic declines in mussel diversity and density have been documented for more than twenty years in the middle reach of the upper Clinch River in Virginia, where coal production has been active and increasing. Mussel populations in the Tennessee reaches of the upper Clinch River, 40-50 miles downstream of concentrated coal mining, have remained healthy. The striking difference in mussel health along the 40-mile stretch of river between Dungannon, VA and Horton Ford, TN presents an opportunity to study and understand subtle interactions among land use, water chemistry and sediment effects on aquatic ecology.

The U.S. Geological Survey (USGS) is working to establish a scientific framework to understand the effects of increasing energy extraction, intensifying land use, and changes in climatic variability on endangered populations of freshwater mussels in the Clinch River. A time-of-travel dye study was conducted on a portion of the Clinch in 2009 to better characterize constituent transport conditions. Continuous water-quality monitors, measuring specific conductivity, pH, temperature, and turbidity, were operated at Dungannon, VA (USGS station 03524740) and Looney's Gap (Horton Ford) TN (USGS station 03527220) in 2009. Five paired storm samples and two paired base flow samples were collected at both sites and analyzed for sediment, metal, nutrient, and organic constituents. Constituent concentrations were similar between sites during large storm events, with unfiltered concentrations of metals (Fe, Al, Ni, Pb, Zn) at least a ten times higher in storms than at base flow. However, the upstream site at Dungannon—where mussel populations are degraded—showed significantly higher concentrations of metals and major ions in base-flow samples. Continuous turbidity and specific conductance were also higher at Dungannon than at Looney's Gap.

Quantitative and semi-qualitative mussel surveys done at seven sites on the Clinch River showed a clear pattern of increasing mussel density from upstream (1–5 mussels/square meter) to downstream (7 - 43 mussels per square meter). Species richness was also less than 15 species/site upstream and greater than 15 species/site downstream, which is consistent with other recent mussel surveys on this reach. Eight mussel silos with juvenile mussels were deployed at each of four study sites and monitored for survival and growth. These showed little variation in survival, ranging from 93.8 percent to 97.9 percent at all sites, but clear differences in juvenile mussel growth rates. Juvenile mussels in silos at Looney's Gap, for instance, grew at a rate of 55 percent between July and August 2009. Juveniles at the other three sites studied grew at only 33 to 37 percent during the same period. These initial findings suggest that one or more chronic stressor may contribute to a loss of mussel health.

[1] U.S. Geological Survey, Tennessee Water Science Center, Knoxville, TN
[2] U.S. Geological Survey, Virginia Water Science Center, Richmond VA
[3] U.S. Geological Survey, Biological Resources Discipline, Virginia Tech

Power Point File of Presentation

APPLICATION OF ASTM MUSSEL TOXICITY TESTING GUIDANCE TO CONDUCTING A USEPA TOXICITY IDENTIFICATION OR REDUCTION EVALUATION

Richard Lockwood[1]* and Robin L. Garibay[2]

In summer of 2005 a mussel die off was discovered downstream of a new NPDES discharge in Oklahoma. This event prompted an investigation that included a Toxicity Identification Evaluation and Toxicity Reduction Evaluation (TIE/TRE) to identify and control freshwater mussel toxicants in the effluent. The TIE/TRE was initiated in January 2007, with mussel testing methods taken from the recently approved ASTM Method E2455 – 06 *Standard Guide for Conducting Laboratory Toxicity Tests with Freshwater Mussels*. The fatmucket (*Lampsilis siliquoidea*) was selected due to the proximity of its natural range to the discharge site, a prior testing history with the development of the ASTM guidance, and standardized culturing methods that ensured year round availability of reliable test organisms. The mussel testing methods were applied to elements of USEPA protocols for conducting a TIE/TRE. The TIE/TRE methods were taken from:

EPA/600/6-91/003. *Methods for Aquatic Toxicity Identification Evaluations Phase I Toxicity Characterization Procedures.*
EPA/600/R-92/080. *Methods for Aquatic Toxicity Identification Evaluations Phase II Toxicity Identification Procedures for Samples Exhibiting Acute and Chronic Toxicity*.
EPA/600/R-92/081. *Methods for Aquatic Toxicity Identification Evaluations Phase III Toxicity Confirmation Procedures for Samples Exhibiting Acute and Chronic Toxicity*.
EPA/600/2-88/062. *Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants*.

Due to the high levels of Total Dissolved Solids (TDS) in the effluent, conventional TIE "fractionation" methods were not applicable, and a "mock effluent" and effluent-spiking approach were the primary methods employed. Results of the TIE/TRE investigation revealed that potassium was the primary toxicant with elevated alkalinity levels causing secondary effects. It was also determined that the levels of ammonia typically observed in the effluent were not a concern for the mussels. Choice of test vessel size, dilution water chemistry, reference toxicant tests, and mortality endpoints were components of the mussel test methods that were refined for application to the TIE/TRE.

[1] Project Manager, ENVIRON International Corporation, 201 Summit View Drive, Brentwood, TN 37027, 615-377-4775 ext. 155, Rlockwood@environcorp.com
[2] Principle, ENVIRON International Corporation, 4350 North Fairfax Dr, Ste. 300, Arlington, VA 22203, 703-522-9662, Rgaribay@environcorp.com

Power Point File of Presentation

RECENT DEVELOPMENTS IN UNDERSTANDING THE EFFECTS OF IONS ON AQUATIC LIFE

Scott Hall[1]

The potential aquatic life effects of major ions released as a result of the use of road salts and with salts in industrial discharges have been receiving increased attention in the United States and Canada. Interest in these areas, and review of water quality criteria for chloride and sulfate in the U.S., have resulted in sharp increases in the knowledge related to salt toxicity, ion interactions, water quality parameters altering salt toxicity, and ways to identify salts as toxicants in aquatic systems. Some states have recently released ambient water quality criteria for ions such as chloride and sulfate that are a function of water quality parameters. Key among parameters known to alter ion toxicity are total hardness and chloride. Iowa recently developed chloride criteria dependant on hardness and sulfate concentrations, and Illinois has sulfate criteria dependant on hardness and chloride concentrations. In addition to the salinity toxicity relationship (STR) model to predict acute ion toxicity, predictive models for chronic anion toxicity have just been developed. The recent literature indicates that potassium is a highly toxic cation, while bicarbonate may be the most toxic anion. In addition to confirmation that cladocerans are highly sensitive to salts/ions, recent data indicate that freshwater mussels may be highly sensitive to ions such as chloride.

[1] Manager, Ecotoxicology. ENVIRON International Corporation. Nashville, Tennessee, USA.
shall@environcorp.com

Power Point File of Presentation

ASSESSING THE RELATIONSHIP BETWEEN WHOLE EFFLUENT TOXICITY AND IN-STREAM BIOLOGICAL COMMUNITIES

Scott Hall[1]

The potential aquatic life effects of major ions released as a result of the use of road salts and with salts in industrial discharges have been receiving increased attention in the United States and Canada. Interest in these areas, and review of water quality criteria for chloride and sulfate in the U.S., have resulted in sharp increases in the knowledge related to salt toxicity, ion interactions, water quality parameters altering salt toxicity, and ways to identify salts as toxicants in aquatic systems. Some states have recently released ambient water quality criteria for ions such as chloride and sulfate that are a function of water quality parameters. Key among parameters known to alter ion toxicity are total hardness and chloride. Iowa recently developed chloride criteria dependant on hardness and sulfate concentrations, and Illinois has sulfate criteria dependant on hardness and chloride concentrations. In addition to the salinity toxicity relationship (STR) model to predict acute ion toxicity, predictive models for chronic anion toxicity have just been developed. The recent literature indicates that potassium is a highly toxic cation, while bicarbonate may be the most toxic anion. In addition to confirmation that cladocerans are highly sensitive to salts/ions, recent data indicate that freshwater mussels may be highly sensitive to ions such as chloride.

[1] Manager, Ecotoxicology, ENVIRON International Corporation. Nashville, Tennessee, USA. shall@environcorp.com.

EVALUATING MACROINVERTEBRATE COMMUNITY DIVERSITY IN PONDS UTILIZING TWO SAMPLING TECHNIQUES

Laura Ashlie Farmer[1]*, Steven W. Hamilton[2]

Milan Army Ammunition Plant (MLAAP), located in Gibson and Carroll counties, Tennessee, is a munitions production facility comprising 90.48 km^2 of hardwood forest interspersed with grazing and row crop agricultural. In 1987 MLAAP was placed on the Environmental Protection Agency's National Priority List for groundwater contamination. MLAAP has established the Integrated Natural Resources Management Plan in which previous research is coupled with ongoing studies to develop a long-term sustainable natural resources management plan for MLAAP, in part to deal with past environmental contamination. Macroinvertebrates, often used in water quality monitoring, are among the taxa being studied. June 2009 began a research project to compare the efficacy of two different sampling techniques in accessing macroinvertebrate diversity in pond communities at MLAAP. Both funnel-trap and dip-net sampling methods were employed in 10 ponds. Four funnel-traps were set in each pond and left for two consecutive 48-hour periods between June 18 and 22 and December 8 and 12. On June 29 and November 11 dip-net samples were collected with two collectors sampling simultaneously for 30 minutes in each pond. Taxonomic analysis is incomplete; however, to date 4,981 individuals in 121 taxa have been collected. Statistical analysis comparing the sampling methods shows no significant difference in taxa richness or Shannon-Weaver diversity. Jaccard's Similarity Coefficient values are low indicating collection of very different sets of taxa. Dip-net sampling required fewer people and person-hours to complete saving time and money. Additionally, dip-net samples could add to taxa richness, particularly in the orders Coleoptera, Hemiptera and Odonata.

1 Center of Excellence for Field Biology, Austin Peay State University, Clarksville, TN 37044, farmerl@apsu.edu
2 Center of Excellence for Field Biology, Austin Peay State University, Clarksville, TN 37044, hamiltonsw@apsu.edu

PRACTICAL IMPLEMENTATION FACTORS FOR GREEN INFRASTRUCTURE IN TENNESSEE

Curt Jawdy[1]

Federal stormwater guidance has begun to require the use of green infrastructure practices on Federal facilities, and similar regulations are proposed for municipal implementation throughout Tennessee. The design methodologies require the site to meet predevelopment hydrologic conditions or handle 1" of rainfall on site through infiltration, evapotranspiration or reuse. This talk will describe several long term models performed for Tennessee localities examining the implications a green infrastructure requirement would have on local designs and land use.

Implementation of such policies requires difficult technical decisions such as whether to allow credit for disconnecting impervious areas, how to ensure that water captured by cisterns is actually used, and how to define long-term "pre-development" hydrologic budgets. The impacts of green infrastructure facilities on downstream ecological health will be discussed.

Green infrastructure facilities provide much of their environmental benefit during frequent small storms. However, most current municipal stormwater policies deal primarily with the hydrology and hydraulics of large storms, utilizing rule-of-thumb techniques for green infrastructure design. The pros and cons of continuous modelling vs. rule-of-thumb design techniques will be discussed.

[1] P.E., Water Resources Engineer, AMEC Earth and Environmental, 10239 Technology Drive, Knoxville, TN 37932
curt.jawdy@amec.com; (865) 671-6774 (office); (865) 671-6254 (fax)

SESSION 2B

STREAM MORPHOLOGY I
8:30 a.m. – 10:00 a.m.

A Modeling Approach to Restoring Pool-Riffle Structure in an Incised, Straightened Channel of an Urban Stream
Keil Neff, Andrew Dodson, and Michael Hamrick

Introduction to TDOT Natural Stream Design Guidelines
A. Hangul

Stream Restoration Design, Bid, and Build: Key Considerations for Project Success
Michael K. Pannell and William K. Barry

STREAM MORPHOLOGY II
10:30 a.m. – 12:00 p.m.

Applications of Bedrock Stream Restoration Techniques in Two Middle Tennessee Streams
J. Case Davis

Channel Units, Bed Material, and Channel Slope of Two Middle Tennessee Flat-Rock Streams
William J. Wolfe, Timothy H. Diehl, and Michael W. Bradley

BAGS Application for Channel Design
William K. Barry, John S. Schwartz, Brent C. Wood, and Patrick McMahon

STREAM MORPHOLOGY III
1:30 p.m. – 3:00 p.m.

Integrating Stream and Weltand Restoration through an Innovative Approach
Joe Berg, Suzanne Hoehne, and Keith Underwood

Determining River Bank and Soil Erosion Rates from Exposed Tree Roots and the Potential Uses of Dendrochronology in Water Resources Management
Brian Dick, Ian Jewell, Ilona Peszlen, and Peter Simon

Development of Assessment and Modeling Guidance on Estimating Reliable Bed-Material Transport Rates for Gravel-Bed Streams in Tennessee
Patrick McMahon, John Schwartz, and Greg Babbit

TDEC WATER QUALITY
3:30 p.m. – 5:00 p.m.

2010 Tennessee Water Quality Assessment
Gregory M. Denton

Tennessee Headwater Reference Stream Project
Deborah H. Arnwine

Probabilistic Periphtyon Study of Wadeable Streams in Tennessee
Michael H. Graf

A MODELING APPROACH TO RESTORING POOL-RIFFLE STRUCTURE IN AN INCISED, STRAIGHTENED CHANNEL OF AN URBAN STREAM

Keil Neff[1], Andrew Dodson[2], and Michael Hamrick[3]

Urbanization impacts watershed hydrology, in-stream hydraulics, and channel geomorphology causing geomorphic and ecological disturbances in natural stream systems. Pool-riffle structure, capable of supporting diverse biological ecosystems, is frequently disturbed in urban streams because of channel incision and the loss of channel-scale helical flow patterns, which are responsible for initiating and maintaining pool-riffle sequences. The objective of the current study was to restore pool-riffle bedform and channel hydraulics to maintain pool-riffle structure in an incised, straightened 300-m reach of Beaver Creek (Knox County, Tennessee). Property boundaries laterally constrained restoration design thereby limiting extensive planform alterations (i.e. macro-sinuosity). A computational fluid dynamic (CFD) model was used to design bed, bank, and in-stream features to support maintenance of velocity acceleration/deceleration sequencing, energy dissipation and complex flow patterns, and bed and bank stability. FLOW-3D®, a three-dimensional CFD model was used as a preliminary tool to evaluate in-stream velocities, hydraulic roughness and boundary shear stresses critical for designing pool-riffle structures. Pool-riffle sequencing design included spacing of 5-7 bankfull channel widths while working with existing natural constrictions and expansions. At each riffle location, bank material (1-2 m by 15-20 m) was removed to dissipate energy and create hydraulic macro-eddies; gravel substrate was imported. Flow patterns at multiple flow conditions (from baseflow to bankfull) for both the current condition and the design channel were characterized by modeling with River2D®, a two dimensional depth averaged finite element hydrodynamic model customized to evaluate aquatic habitat. The design channel was manipulated in ESRI's ArcMap® using the Interactive TIN Editing Tools, and modeled in River2D® to develop a sustainable design by altering bed and channel form to create self-regulating pool-riffle sequences, rather than relying solely on natural channel design structures. Boundary shear stresses were calculated from model output to size substrate, design stable in-stream features to augment flow structure, and evaluate bank and bed stability. This work illustrates the utility of using GIS and CFD models for stream restoration in urban watersheds whereby channels in disequilibrium with poor in-stream habitat can be rehabilitated without a reference stream. Model development and a description of construction will be presented.

[1] Research Assistant, Department of Civil and Environmental Engineering, University of Tennessee
[2] Stormwater Engineer, Knox County Stormwater Management
[3] GIS Analyst, Knox County Stormwater Mangement

INTRODUCTION TO TDOT NATURAL STREAM DESIGN GUIDELINES

A. Hangul

SECTION -01 NATURAL STREAM DESIGN

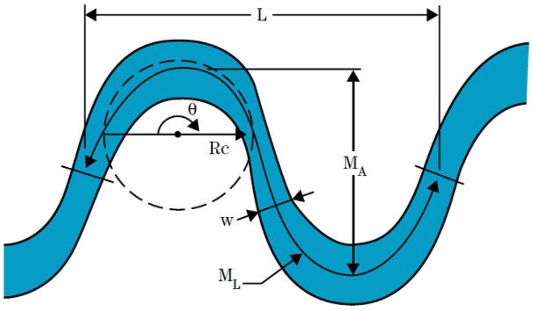
These guidelines present the procedures, methods, and available mitigation measures to be used by the Tennessee Department of Transportation (TDOT) Design Division for the proper design of a stream relocation plan using natural stream design and construction methods. The information is presented with the assumption that the designer is familiar with road and bridge design and understands the basic principles of hydrology, hydraulics, and stormwater runoff typically encountered on a roadway project.

The primary purpose and intent of a stream relocation design that incorporates natural design and mitigation measures is to minimize impacts to the stream that will be affected by a roadway project by mimicking the environmental features of the stream reach; thereby reducing the potential for adverse effects to the physical, biological, chemical, or habitat present in the existing water resource. The goal of this chapter is to assist the designer in formulating a stream relocation plan that will achieve the intended purpose and project goals at a reasonable cost.

Toward that end, this chapter will provide information and guidance on:
• The fundamentals of natural stream relocation and channel design
• Guidelines and criteria for the project designer to meet project goals
• Mitigation practices available for use as part of a natural stream design plan
• The development of a sound and effective stream relocation plan
• Stream relocation plan requirements for TDOT projects

SECTION 02 – DOCUMENTATION PROCEDURES

SECTION 03 – FUNDAMENTALS OF NATURAL STREAM DESIGN



L Meander wavelength
M_L Meander arc length
w Average width at bankfull discharge
M_A Meander amplitude
Rc Radius of curvature
θ Arc angle

03.4.2 Existing Channel Cross Sections
03.4.3 Existing Channel Profile
03.4.4 Tailwater Conditions
03.4.5 Channel Stability
03.4.6 Existing Riparian Vegetation
03.4.7 Hydraulic Roughness
03.4.8 Stream Structure and Habitat

03.5 NATURAL STREAM DESIGN PROCESS

	Threshold channel	Alluvial channel
Channel boundary	Immobile at design discharge	Mobile
Design discharges	Flood event (e.g. – Q_{50})	Flood event (e.g. – Q_{50}) Channel forming discharge Flow duration curve Long-term flow record
Bed-material sediment inflow	Usually small or negligible	Significant
Given Information	Design discharge Channel roughness	Design hydrograph Channel-forming discharge Bed-material sediment inflow Bed material Streambank characteristics
Design Parameters	Width Depth Slope (Roughness, if there is a choice of lining materials)	Width Depth Slope Planform Bank roughness
Design equations	Hydraulic conveyance	Hydraulic conveyance Sediment transport
Design goal with respect to channel stability	Pass the design discharge at an acceptable elevation without eroding the channel	Pass the incoming sediment load without aggradation or degradation or significant planform change

Table 11-X
Summary of the Natural Stream Design Process
Reference: Adapted from NEH 654

FUNDAMENTALS OF NATURAL STREAM DESIGN

When environmental issues will necessitate natural stream design for the relocation of an existing natural stream or river in order to ensure that the relocated stream will provide the same function and benefits which were available in the original stream. The designer's primary role in this process is to determine the physical characteristics of the relocated channel in terms of four basic elements:

- cross sectional shape and dimensions
- vertical profile of the stream flow line (or thalwag)
- horizontal planform of the channel
- mitigation practices

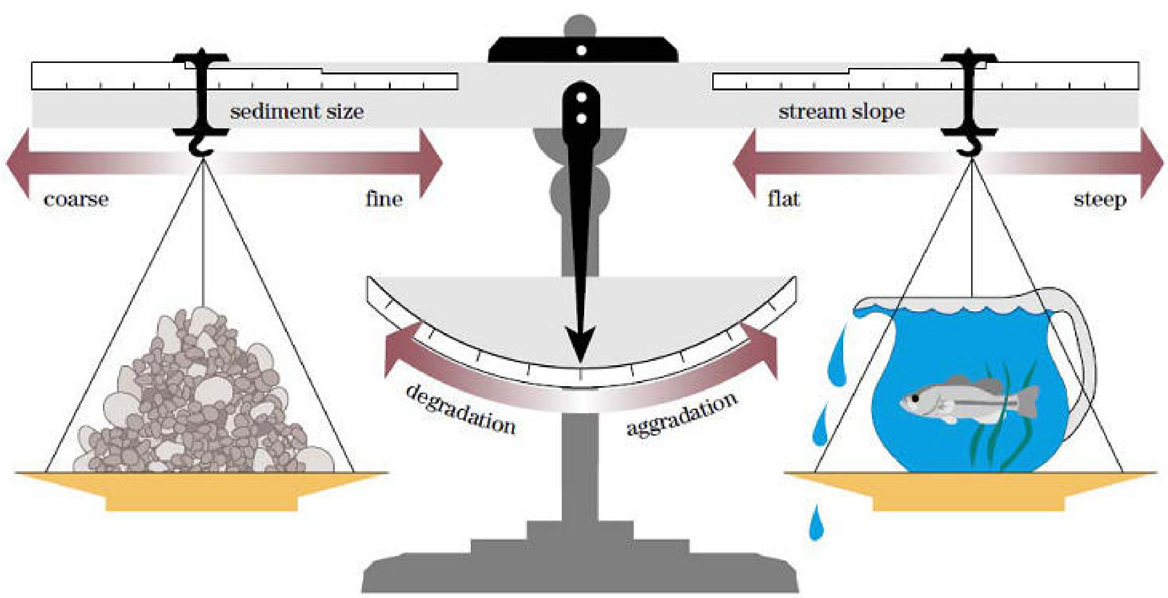
CHANNEL TYPES

One of the most basic ways to classify a channel is to examine the nature of the interaction between the sediments within the channel and the flows which pass over them. This classification is very important because it will determine the approach used to design a relocated channel. Under this method of classification, the two general categories for channels are *threshold* and *alluvial*.

FACTORS AFFECTING ALLUVIAL CHANNEL STABILITY

E. W. Lane proposed a conceptual model that can be used as an aid to qualitatively assess stream responses to changes in flow, slope, and sediment load. This model is known as Lane's Balance and is based on the general theory that if the force applied by the flowing water on an alluvial channel boundary is balanced with strength of the channel boundary and the delivered sediment load, the channel will be stable and neither aggrade nor degrade. This equilibrium condition can be expressed as a balance of four basic factors:

- sediment discharge, Qs
- median grain size of bed material, D50
- dominant discharge such as the channel forming flow, Qcf
- thalweg slope or energy slope, S



SECTION 04 – GUIDELINES AND CRITERIA

04 GUIDELINES AND CRITERIA
04.1 NATURAL STREAM DESIGN GUIDELINES
04.1.1 Minimizing or Avoiding Impacts to Streams
04.1.2 Limitations on Stream Relocations
04.2 GOALS OF NATURAL STREAM DESIGN
04.2.1 Preserve Existing Stream Function and Habitat
04.2.2 Re-establish Stream Plan Form (Length and Sinuosity)
04.2.3 Re-establish Stream Vertical Profile
04.2.4 Maintain Existing Floodplains
04.2.5 Stable Channel Design for Alluvial Streams
04.2.6 Effects of Relocation on Overall Stream Corridor
04.2.7 Approaches for an Unstable Stream Reach
04.3 STORM FREQUENCIES FOR STREAM RELOCATION DESIGNS
04.3.1 Channel Forming Discharge

Bankfull Discharge is determined based on the depth below which it appears that most of the fluvial activity is taking place in the channel. This bankfull depth is usually determined by examining the site to look for typical indicators of fluvial activity.

Effective Discharge is conceptually a combination of both the magnitude of a flow event and its frequency of occurrence. Essentially, the flow duration curve (as described in the following section) is divided up into increments, and the increment that transports the largest fraction of the annual sediment load is considered the effective discharge.

04.3.2 Flow Duration Curves
04.3.3 Flood Discharges
04.4 DATA REQUIREMENTS
04.5 HYDRAULIC CONSIDERATIONS
04.5.1 Curved Channel Alignments
04.5.2 Channel Transitions
04.6 MITIGATION PRACTICES FOR NATURAL STREAM DESIGN
04.6.1 Selection of Mitigation Practices
04.6.1.1 Role of Mitigation Practices in Habitat Preservation
04.6.1.2 Temporary Practices
04.6.1.3 Permanent Practices
04.6.2 Revetment Types for Curved Alignments
04.6.2.1 Preference for Revetment Materials
04.6.2.1.1 Vegetation
04.6.2.1.2 Machined Riprap
04.6.2.1.3 Precast Concrete Forms
04.6.2.1.4 Revetment Types To Be Avoided
04.6.2.2 Longitudinal Extent of Protection
04.6.2.3 Vertical Extent of Protection
04.7 PERMIT REQUIREMENTS
04.8 RIGHT-OF-WAY AND EASEMENTS
04.9 SAFETY AND MAINTENANCE CONSIDERATIONS
04.10 CONSTRUCTION CONSIDERATIONS
04.11 SPECIAL CONSIDERATIONS FOR URBAN STREAMS
04.12 SPECIAL CONSIDERATIONS FOR FEMA STUDIED REACHES

SECTION 05 – DESIGN PROCEDURES

05 DESIGN PROCEDURES

Because of the complexities often involved in natural stream design for channel realignment projects, it is not possible to provide a single step-by-step design procedure that may be applied in all cases. The specific procedure used to design a channel relocation will depend heavily on site specific conditions, especially whether the existing stream channel is threshold or alluvial. This section provides separate step by step procedures for threshold and alluvial channels. However, the designer should bear in mind that these procedures may require some adjustment based on site specific conditions.

05.1 INITIAL PLANNING
05.1.1 Determining Begin and End Points for the Relocation Project
05.1.2 Determining Existing Bed Materials
05.1.3 Determining Existing Channel Type
05.1.4 Assessing Existing Channel Stability
05.1.5 Hydraulic Analysis of the Existing Stream

05.2 DESIGN PROCEDURES FOR THRESHOLD CHANNELS

Once the supporting data have been collected and the initial steps have been completed, the actual natural stream design process can be carried out for the relocated channel.
Because the boundary materials in a threshold channel should be immobile for the design discharge, the concept of channel-forming discharge does not apply to the design procedure, since natural fluvial processes do not affect the channel dimensions. Thus, the design process consists of determining cross sections, horizontal planform and vertical profile for the relocated channel, and then performing a hydraulic analysis to check the stability and hydraulic performance of the proposed stream design.
The general procedure is as follows:
Step 1: Determine characteristics of the existing stream, including:
Step 2: Determine design discharges
Step 3: Determine the cross section,
Step 4: Perform a hydraulic analysis of the relocated channel for the design discharge
Step 5: Select appropriate mitigation measures
Step 6: If the mitigation measures selected in Step 5 will affect the hydraulic roughness

05.3 DESIGN PROCEDURES FOR ALLUVIAL CHANNELS

Once the supporting data have been collected and the initial steps have been completed, the actual natural stream design process can be carried out for the relocated channel. Because a stable alluvial channel is subject to fluvial processes which can alter its cross section or planform, the natural stream design process will require both hydraulic and sediment transport analyses. Although the procedure in this section is presented as a series of linear steps, the actual design process may turn out to be iterative, since the hydraulic and sediment transport characteristics of a channel are interrelated. Thus, an initial design for the channel may require adjustments based the results of one analysis or another. In this manner, the process will typically progress from the preliminary design to the final result.

The general natural stream design procedure for alluvial channels is described in the following steps. Because this is a general procedure, it contains very little detail as to how each step will be accomplished.

Step 1: Determine characteristics of the existing stream,
Step 2: Determine the discharge data needed to support the design,
Step 3: Conduct a hydraulic analysis of the existing channel
Step 4: Determine sediment inflows for the project
Step 5: Determine the bankfull discharge and effective discharge.
Step 6: Develop a stability curve based on the channel forming discharge and the sediment inflow rating curve developed in the previous steps.
Step 7: Check the slope and width of the existing channel against the stability curve developed in the previous step.
Step 8: Determine the cross section, planform and vertical profile of the relocated channel.
Step 9: Conduct a sediment impact analysis using the channel dimensions proposed for the relocated channel.
Step 10: Conduct a hydraulic analysis of the proposed relocated stream channel
Step 11: Select appropriate mitigation measures

05.4 NATURAL STREAM DESIGN PROCEDURES

05.4.1 Roughness Coefficient Determination by Cowan's Method

05.4.2 Computing Sinuosity

05.4.3 Measuring Meander Characteristics

05.4.4 Estimating a Flow Duration Curve

05.4.5 Estimating Sediment Flows

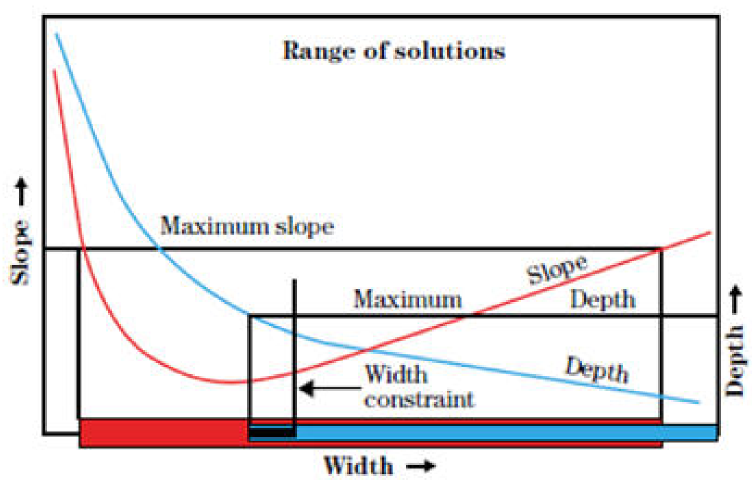
05.4.5.1 Brownlie Sediment Transport Function

05.4.5.2 Meyer-Peter and Muller Sediment Transport Function

05.4.6 Estimating Channel Forming Discharge

Channel forming discharge is required only for natural stream design for the relocation of an alluvial stream. The channel forming discharge should be evaluated based on a comparison between the bankfull discharge and the effective discharge

05.4.7 Developing a Stability Curve for an Alluvial Channel



05.4.8 Sediment Impact Analysis

The procedure in the previous section is useful for the stability design of a stream relocation project, but is based on a single discharge. Once the proposed alignment and cross section for the relocated channel have been established, the stability of the new channel should be assessed for the full range of discharges which could occur at the site. This assessment is called a sediment impact analysis.

SECTION 06 – THE NATURAL STREAM DESIGN PLAN

06 THE NATURAL STREAM DESIGN PLAN

The natural stream design process for stream relocation begins early in the development of a roadway project and continues until well after the construction of the roadway itself has been completed. The need for a stream relocation project is usually identified in the early planning phases of a roadway project.

06.1 NATURAL STREAM DESIGN PLAN DEVELOPMENT PROCESS
06.1.1 The Environmental Boundaries Document
06.1.2 Design of the Relocated Stream
06.1.3 Stream Mitigation Practices
06.1.4 Planting Schedule and Plant List
06.1.5 Permits
06.2 PLAN REQUIREMENTS FOR NATURAL STREAM DESIGN
06.2.1 Development of the Stream Relocation Plan
06.2.2 Relocation Plan Information by Plan Sheet
06.2.3 EPSC Plans for Stream Relocation

SECTION 07 – ACCEPTABLE SOFTWARE

07 ACCEPTABLE SOFTWARE
07.1 HEC-RAS
07.2 RIVERMORPHTM
07.3 ANOTHER SOFTWARE

SECTION08 – MITIGATION PRACTICES FOR NATURAL STREAM DESIGNS

08 MITIGATION PRACTICES FOR NATURAL STREAM DESIGNS
08.1 LONGITUDINAL MITIGATION PRACTICES
08.1.1 Coconut Fiber (COIR) Rolls
08.1.2 Vegetated Riprap
08.1.3 Willow Cuttings (Post and Poles)
08.1.4 Live Fascines
08.1.5 Live Siltation
08.1.6 Longitudinal Stone Toe
08.1.7 Vegetated Gabions
08.1.8 Vegetated Mechanically Stabilized Earth (MSE) Walls
08.1.9 Articulated Concrete Blocks
08.1.10 Brush Mattresses
08.2 IN-STREAM MITIGATION PRACTICES
08.2.1 Boulder Clusters
08.2.2 Log Deflectors and Vanes
08.2.3 Log Drop
08.2.4 Step Pool
08.2.5 Rock Vane
08.2.6 Spur Dikes
08.2.7 Constructed Riffles
08.2.8 Large Woody Debris
08.3 OPTIONAL MITIGATION MEASURES TO CONSIDER
08.3.1 Maintaining Riparian Buffer Zone

STREAM RESTORATION DESIGN, BID, AND BUILD: KEY CONSIDERATIONS FOR PROJECT SUCCESS

Michael K. Pannell[1], William K. Barry[1], P.E., D. WRE

Implementing effective stream restoration is a challenging and complex undertaking requiring extensive knowledge and experience. Natural channel design is common method used for stream restoration design which uses a reference reach to develop design criteria (i.e. dimensionless ratios). The design criteria then must be incorporated into contract documents (e.g., drawings, technical specifications, and contract language) the contractor will use for construction. Whether evaluating existing site conditions, collecting data, designing, bidding the project, or construction, each stage is critical for implementing a successful restoration project. Problems experienced in any one of these areas can have an adverse effect on the project outcome. Client expectations are also a critical component of the process. This presentation discusses key considerations during each phase of the project from conception, through design and bidding, to construction.

[1] S&ME, Inc. – Knoxville, Tenn.

APPLICATIONS OF BEDROCK STREAM RESTORATION TECHNIQUES IN TWO MIDDLE TENNESSEE STREAMS

J. Case Davis, PE
President, Beaver Creek Hydrology, LLC

Natural channel design methodologies combined with sediment transport and ecohydraulic studies were used to design/build two impaired bedrock streams in Middle Tennessee. These restoration sites were subject to frequent design flows during and immediately after construction, allowing for observations of channel adjustment in a small time frame. This presentation will describe flood-tested applications of bankfull channels, cross-vanes, and other hydraulic/habitat structures and design/build techniques in bedrock channels.

Figure 1. Application of natural channel design methodology in the restoration of Mill Creek, Nolensville, Tennessee.

CHANNEL UNITS, BED MATERIAL, AND CHANNEL SLOPE OF TWO MIDDLE TENNESSEE FLAT-ROCK STREAMS

William J. Wolfe[1]*, Timothy H. Diehl[2], and Michael W. Bradley[3]

Channel units (pools, riffles, runs, cascades, and steps) bed material, and channel slope were documented along more than 2.5 miles of the channels of Copperas Branch and Greens Hollow Branch in Williamson County, Tennessee, and additional field observation were collected along South Garrison Branch, also in Williamson County. The observations were made as part of a joint study by the U.S. Geological Survey and the Tennessee Department of Transportation. The primary goal of the study is to better understand effect of highway construction on receiving streams and aquatic ecosystems, but it also provides an opportunity to examine in some detail the geomorphic character of Middle Tennessee headwater streams. All three channels are characterized by a mixture of bedrock- and cobble-dominated streambeds. Cobbles form the highest quality invertebrate habitat, and the distribution of cobble-dominated bed material is a crucial determinant of biological diversity. The overall distribution of channel units generally, cobble-dominated beds in particular, and the longitudinal profiles of these streams integrate numerous factors, notably coarse-sediment supply, lithology, and geologic structure.

[1] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211, wjwolfe@usgs.gov
[2] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211, thdiehl@usgs.gov
[3] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211, mbradley@usgs.gov

BAGS APPLICATION FOR CHANNEL DESIGN

William K. Barry[1], John S. Schwartz[2], Brent C. Wood[3], Patrick McMahon[4]

The ability to predict and design stream restoration projects for sediment characteristics with easily gathered field data has been lacking. Earlier work (Cantrell, William R., Unpublished Thesis, University of Tennessee, Knoxville, 2009) provided some indication that the use of bed depositional patchiness to assess supply or transport limited sediment regimes may be of practical importance. The current effort investigated the application of the Bedload Assessment in Gravel-bedded Streams (BAGS) software to stream design efforts to assess patchiness and design a restored channel with appropriate sediment characteristics. On-going research on bedload transport measurement will also be presented.

[1] PE, D. WRE, S&ME, Inc. – Knoxville, Tennessee
[2] Ph. D, PE, University of Tennessee at Knoxville, Dept. of Civil and Environmental Engineering
[3] PE, S&ME, Inc. – Knoxville, Tennessee
[4] PE, University of Tennessee at Knoxville, Dept. of Civil and Environmental Engineering

INTEGRATING STREAM AND WETLAND RESTORATION THROUGH AN INNOVATIVE APPROACH

Joe Berg[1], Suzanne Hoehne[2*], and Keith Underwood[3]

Naturally occurring and undisturbed aquatic, wetland, and upland habitats work together to recharge groundwater, maintain baseflow, process sediments and nutrients, and attenuate flood flow by retaining water on the landscape. Changes in landuse patterns have impacted the riparian and stream ecosystem through a spiraling effect of changes which eventually leads to degradation of the ecosystem's population composition and distribution, eutrophication of downstream receiving water bodies, and lower water tables. Traditional approaches to handle the increase in stormwater runoff often look at only part of the picture, such as moving the water off the site, stabilizing the channel structure, and or moving the sediment through the site. These methodologies have often harmed the ecosystem more than healing it. A design approach has been developed based on the idea that the longer the water is retained on the landscape the greater the ecological and social benefits. This approach, Regenerative Stream Conveyance or RSC, involves reconnecting a stream baseflow channel with the surrounding landscape through the construction of a series of pools and riffle/weir grade control structures, along with shallow floodplain pools behind low sand and wood chip berms. Water is retained on the floodplain behind the sand and wood chip berms, through which it must seep to be returned to the baseflow channel or groundwater flow. By retaining water longer on the floodplain, surrounding wetland features are rehydrated, hydric soil chemistry is supported, and groundwater/surface water interactions are prolonged. Other research has documented that greater denitrification occurs in restoration projects that integrate stream and wetland features over unrestored streams or streams restored using other channel design methodologies. Also, research has indicated that a base flow channel connected with the surrounding riparian floodplain ecosystem is comparable to the geological record based on work focusing on legacy sediments where transects excavated across stream valleys show the presettlement conditions. The RSC methodology has numerous applications ranging from wetland creation to stormwater BMPS.

Figure 1. Incised stream before construction.

Figure 2. Stream restored using the RSC Methodology.

[1] Biohabitats, Inc. Chesapeake/Delaware Bays Bioregion, Baltimore, Maryland
[2] Biohabitats, Inc. Ohio River Bioregion, Louisville, Kentucky
[3] Underwood & Associates, 1753 Ebling Trail, Annapolis, MD 21401

Regenerative Stream Conveyance is a holistic approach to restoration whereby the natural regeneration of stream and wetland ecosystems is the driving performance standard, rather than the presumption that designing for a designated storm event will be of benefit to the downstream water bodies. Installation of these systems has multiple benefits including: less area of disturbance, lower costs, and opportunities for stakeholder stewardship and participation. The last of these benefits has been shown to be invaluable in terms of raising community awareness and helping to foster the important and often overlooked connection between humans and nature.

DETERMINING RIVER BANK AND SOIL EROSION RATES FROM EXPOSED TREE ROOTS AND THE POTENTIAL USES OF DENDROCHRONOLOGY IN WATER RESOURCES MANAGEMENT

Bryan Dick[1], Ian Jewell[1], Ilona Peszlen[2], and Peter Simon[3]

Exposed tree roots offer a means of determining erosion rates for specific sites of concern across the southeast. Dendrogeomorphology is a well established field, yet little has been done in the continental U.S. using this tool and no current literature exists on the use of this tool for many species found in the Eastern U.S. The exposed roots of sugar maple (*Acer saccharinum*), slippery elm (*Ulmus rubra*) and common hackberry (*Celtis occidentalis*) were analyzed to determine annual stream bank erosion rates. The method establishes erosion rates accurately and in a more cost effective manner than they can be determined either by bank pins or by resurveying bank profiles, which only determine erosion rates from the date of the last survey. Additionally, as bank pin and survey studies can take years to determine stream bank erodability, they often exceed contractual and decision critical time lines.

Findings of the dendrochronological study are presented. Macroscopic and microscopic indicators of the date or root exposure include; the occurrence of eccentricity in growth rings, a transition of diffuse to ring porous arrangements of vessels, a decrease in the size of vessels and fibers, the occurrence of gelatinous fibers in tension wood and the occurrence of pith flecks (scarring and wound tissue).

This application provides a viable means of determining lateral and vertical erosion rates for sites possess angiosperms with root exposure due to erosive fluvial forces. Methods for lateral erosion rate determination and potential uses for water quality modeling, remediation site prioritization and risk assessment are presented

Contact Information:
Bryan M. Dick, PE, PH, 701 Corporate Center Dr., Suite 475, Raleigh, NC, 27607
Ph: 919-854-6252
E-mail: bryan.dick@aecom.com

[1] AECOM, Raleigh, NC, USA
[2] Wood and Paper Science Department, North Carolina State University, Raleigh, NC, USA
[3] Birmingham University, Birmingham, UK; Ann Arbor Technical Services, Ann Arbor, MI, USA

DEVELOPMENT OF ASSESSMENT AND MODELING GUIDANCE ON ESTIMATING RELIABLE BED-MATERIAL TRANSPORT RATES FOR GRAVEL-BED STREAMS IN TENNESSEE

Patrick McMahon[1], John S. Schwartz[2], and Greg Babbit[3]

Geomorphic success of stream restoration projects is largely dependent on reach-scale hydraulic geometry that provides a long-term balance between bed-material sediment supply and transport capacity. In gravel-bed streams with changing land use conditions, obtaining this balance is likely the most difficult aspect of restoration design. This proposed project focuses on improving the restoration design process by evaluating practical solutions for assessment of sediment supply and transport capacity relations. Outcomes of this project, a work-in progress, will provide restoration design practitioners detailed guidelines for estimating bed material transport.

Sediment capacity relations will be explored using the Bedload Assessment in Gravel-bedded Streams (BAGS) model (Wilcock *et al*. 2008; Pitlick *et al*. 2008). Evaluation of the BAGS model will be based on a comparison of uncertainty between uncalibrated and calibrated models. The uncalibrated model uses input data collected from low-cost monitoring devices that practitioners would use (i.e., bed-material pit trap or net trap, and crest gauges upstream and downstream of the trap). The calibrated model is adjusted by a reference shear stress (τ_r) and hydraulic roughness (n_D) computed by in-field transport measurements. It uses research-level collection devices for bed material transport to obtain reasonable estimates of "known" transport rates (i.e., full channel width use of Sear (2000) pit traps with load cells, and stage-height pressure transducers upstream and downstream of the trap; both equipped with data loggers). The study site to be assessed is Friar Branch in Chattanooga, Tennessee which is a fully alluvial, gravel-bed reach.

Bed-material sediment supply from watershed will also be assessed as part of this project by deploying scour chains, bank pins, and bank profiles in strategic locations based on channel conditions in the supply reach. Bed materials in the supply reach will be characterized by pebble counts and bulk/bar samples. Bank stability (BEHI) assessment, or other acceptable channel stability assessment techniques, and hillslope estimating protocols will be applied (Reid and Dunne 1996), and compared to measured annual sediment yields.

This presentation describes the overall project objectives, and illustrates the design and construction of the bed-material sediment collection station. Any data collected to date will also be presented.

[1] Ph.D. Candidate, University of Tennessee, Department of Civil and Environmental Engineering, 67 Perkins Hall, Knoxville, TN 37996-2010, pmcmahon@utk.edu

[2] Associate Professor, University of Tennessee, Department of Civil and Environmental Engineering, 63 Perkins Hall, Knoxville, TN 37996-2010, jschwart@utk.edu

[3] TSMP Project Manager, 300 Walker Blvd, Maryville, TN 37803, greg.babbit@tsmp.us

2010 TENNESSEE WATER QUALITY ASSESSMENT

Gregory M. Denton[1]*

The *Clean Water Act*, Section 305(b) (U.S. Congress, 2002) and the *Tennessee Water Quality Control Act* (Tennessee Secretary of State, 1999) both require a biennial report about the status of water quality in the state. The Division of Water Pollution Control (WPC) is entrusted with protecting the people's right to enjoy clean water. In order to reach this goal, WPC works to establish clean water objectives, monitor surface water, and determine if the waters of the state support their intended uses.

Water Quality Standards

There are seven designated uses for the waterways of the state. Those uses are defined in Rules of Tennessee Department of Environment and Conservation, Division of Water Pollution Control Chapter 1200-4-4. Chapter 1200-4-3 of those rules defines specific water quality standards, both numeric and narrative, and delineates the state's antidegradation policy, which deals with prevention of future damage to water quality.

Monitoring Programs

Tennessee has an abundance of water resources with over 60,000 miles of rivers and streams and over 570,000 lake and reservoir acres. However, this vast system of streams, rivers, reservoirs and wetlands requires efficient use of Tennessee's monitoring resources.

TDEC's watershed approach serves as an organizational framework for systematic assessment of the state's water quality problems. By viewing the entire drainage area or watershed as a whole, the department is better able to address water quality monitoring, assessment, permitting, and stream restoration efforts. This unified approach affords a more in-depth study of each watershed and encourages coordination of public and governmental organizations. The watersheds are addressed on a five-year cycle that coincides with permit issuance.

In addition to systematic watershed monitoring, waterbodies are sampled to fulfill other information needs within the division. Some of these other needs include continuation of the ecoregion reference stream monitoring, Total Maximum Daily Load (TMDL) generation, complaint investigation, antidegradation evaluations, trend investigations, compliance monitoring, and special studies.

[1] Water Pollution Control, Tennessee Department of Environment and Conservation, 7th Floor L&C Annex, 401 Church Street, Nashville, TN 37243. Gregory.Denton@tn.gov

TENNESSEE HEADWATER REFERENCE STREAM PROJECT

Deborah H. Arnwine[1]*

Tennessee has established macroinvertebrate and nutrient guidelines for narrative criteria for assessing wadeable streams throughout the state based on reference stream monitoring in each of 25 ecoregions. The reference streams were generally 3rd order or larger and are not appropriate for comparison to headwater streams. In 2008, the division began a 7 year study to identify and monitor first and second order reference streams in 13 Tennessee bioregions to aid in development of biological and nutrient criteria guidelines in headwater streams.

Headwater streams are an important component of every watershed. They comprise the highest percentage of stream miles in the state. The health of larger streams and rivers depend upon an intact primary headwater stream network. These small streams nourish downstream segments with essential supplies of water and food materials. Headwater streams with vegetated buffers assist in reducing sediment delivery to larger streams. They also increase biodiversity in a watershed by offering unique habitat niches and by providing refugia from competitors, predators, and exotic species.

These guidelines will be used to assess headwater streams for the 305(b) and 303(d) reports, locate exceptional headwater streams through the anti-degradation process, provide information for point-source discharge and aquatic resource alteration permits as well as provide information for TMDL studies. The study will also help Tennessee achieve three of its nutrient criteria workplan goals (develop nutrient criteria guidelines for headwater streams, develop associated biological criteria for headwater streams, add a second biological indicator group (periphyton) to nutrient and biological criteria.

Project Goals

1. Establish a minimum of 77 headwater reference streams in 13 Tennessee bioregions over a five-year period.
2. Collect and analyze nutrient, habitat, dissolved oxygen, pH, temperature, conductivity, flow, macroinvertebrate during two seasons at each station in accordance with the five year watershed cycle. Collect and analyze periphyton data once during the growing season.
3. Determine appropriate sampling seasons for headwater streams in various bioregions.
4. Determine appropriate biological metrics for assessment of headwater streams.
5. Develop macroinvertebrate and periphyton indices appropriate for assessment of headwater streams, thereby achieving two of the state's nutrient criteria development workplan goals.

[1] Water Pollution Control, Tennessee Department of Environment and Conservation, 7th Floor L&C Annex, 401 Church Street, Nashville, TN 37243. Debbie.Arnwine@tn.gov

PROBABILISTIC PERIPHTYON STUDY OF WADEABLE STREAMS IN TENNESSEE

Michael H. Graf[1]*

The periphyton community is comprised of sessile algae that inhabit the surfaces of underwater rocks and other stable surfaces. They are the primary producers in the stream ecosystem turning nutrients into food for aquatic macroinvertebrates and fish. They are good indicators of nutrient enrichment as elevated nutrients in the absence of shade at warm temperatures will result in excessive algal growth. This can reduce stream biodiversity by making rock habitat unsuitable for benthic organisms and by altering diurnal dissolved oxygen patterns.

In 2008, the division began analysis of samples collected at ecoregion reference sites and at 90 probabilistic monitoring streams that were collected in 2007. The results from the probabilistic study will be used to compare to nutrient and macroinvertebrate samples that were collected at the same time. The data from reference streams will begin the process of developing a second biological index, which is sensitive to nutrient enrichment in accordance with the state's nutrient criteria development plan.

Project Objectives:

1. Initiate development of a second biological index for determination of nutrient impairment in wadeable streams.
2. Identify baseline periphyton assemblages at 34 established, 3rd order or larger, reference sites.
3. Use probabilistic monitoring based on 90 randomly selected sites to determine statewide and aggregated ecoregion periphyton assemblages and compare to nutrient data.
4. Establish randomly selected periphyton stations for use in trend analysis and 305(b) assessments.
5. Use study data to help refine existing narrative nutrient and biological criteria.
6. Begin incorporation of periphyton data into state nutrient assessment process.

[1] Water Pollution Control, Tennessee Department of Environmenta and Conservation, 7th Floor L&C Annex, 401 Church Street, Nashville, TN 37243. Michael.Graf@tn.gov

SESSION 2C

WATER QUALITY
8:30 a.m. – 10:00 a.m.

Relational Database Design 101: Designing a Database for Water Quality Data
Gerald A. Burnette

Modeling Episodic Stream Acidity During Stormflow in the Great Smoky Mountains National Park
Guy Thomas Zimmerman, J.S. Schwartz, R.B. Robinson, and K.J. Neff

Export of Carbon, Nutrients, and Microbiological Indicators in Beaver Creek Watershed, Tennessee
Si Chen

GROUNDWATER I
10:30 a.m. – 12:00 p.m.

Evaluation of Statistical Assumptions for Groundwater Contamination Near Landfills Overlying Karst/Sand Aquifers in Tennessee
Randy M. Curtis

Hydrologic and Geologic Controls on Contaminant Transport at the Hardeman County Landfill
Michael W. Bradley and Thomas D. Byl

Reconnaissance Evaluation of the Hardeman County Landfill for Natural Attenuation
Thomas D. Byl and Michael W. Bradley

GROUNDWATER II
1:30 p.m. – 3:00 p.m.

Water Prospecting via Non-Intrusive Geophysical Methods
Laura S. Weir

Previously Undescribed Half-Kilometer-Wide Structural Basin Along Lytle Creek, Murfreesboro, Central Tennessee
Mark Abolins

Fluorescent Dye Interactions with Groundwater Contaminants and Remediation Chemicals
Priscilla Baker, Laura Kreitzer, and Katherine Rush

GIS & DATA MANAGEMENT
3:30 p.m. – 5:00 p.m.

Using Geographic Information System Techniques to Analyze Karst Terrain in Selected Red River Sub-Watersheds, Tennessee and Kentucky
David E. Ladd

Urban Growth 2001-2009 Near Puckett and Overall Creeks, Stones River Watershed, Rutherford County, Tennessee
Mark Abolins, Jordan Graw, Christina Nicholas, Erica Cathey, and Taylor Bailey

How to Retrieve USGS Hydrologic Data from NWISWEB
Rodney R. Knight

Power Point File of Presentation

RELATIONAL DATABASE DESIGN 101:
DESIGNING A DATABASE FOR WATER QUALITY DATA

Gerald A. Burnette[1]

INTRODUCTION

When you're tasked with managing data, it's easy to fall into the trap of using the most familiar tool even if it's not the appropriate one. A lot of people make this mistake, especially if they start out with only a small amount of data. In this paper we will try to use a spreadsheet to manage some water quality data, and we'll see why it doesn't work so well. Then we'll switch the data to a database management system and discover how that approach improves our data quality. We will see what happens as our data needs expand, and we will learn some fundamental concepts of database design along the way.

THE INITIAL DATA

Suppose we work for an organization that monitors water quality at a small local lake and the surrounding area (as depicted in Figure 1). We sample water quality at several locations in the lake. We also sample at selected stream locations and wells from time to time. When we sample, we make in situ observations of water temperature and secchi depth (lake stations only), and we field test for values of dissolved oxygen, pH, and total alkalinity. We take a grab sample and ship it to a contract laboratory for analysis of certain nutrients and a few metals. We've been doing this for three years now, and all the results are recorded on field data sheets and lab analysis hardcopy reports. It's high time we started doing some analysis on these data, so we have determined we will start managing the data electronically. Since we know how to use Excel, we construct a spreadsheet like the one depicted in Figure 2.

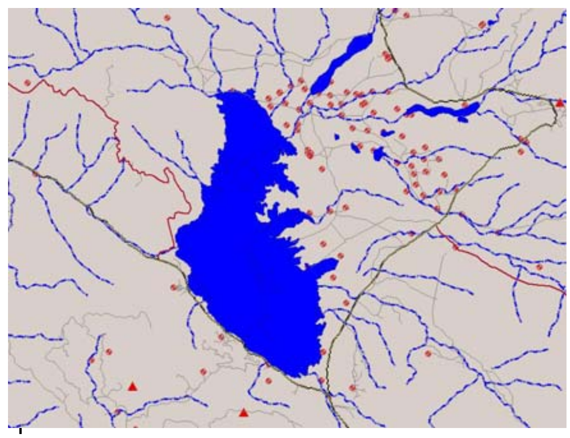


Figure 3

	A	B	C	D	E	F	G	H	I	J
1			Water Temp deg	Secchi	DO	pH	Alkalinity, Tot	Ammonia, Tot	Kjeldahl, Tot	NO2+NO3
2	Date	Location	deg C	m	mg/l	units	mg/l	mg/l	mg/L	mg/L
3	5/7/2005	Well 3	26.7		5.4	7.8	88	0.2309	0.5178	[illegible]
4	5/7/2005	Well 6	19.8		3.6	7.6	108	0.0916	0.689	[illegible]
5	5/15/2005	Stream Station 2	27.1		5.3	8	74	0.176	0.7084	[illegible]
6	5/15/2005	Stream Station 3	20.3		5.8	7.8	76	0.0997	0.233	[illegible]
7	5/17/2005	Lake Station 1	21	1.2	9.2	8.5	68	0.0348	0.485	[illegible]
8	5/17/2005	Lake Station 3	22.4	1	12.2	8.9	94	<0.025	0.634	[illegible]
9	6/15/2005	Stream Station 5	27.2		5.3	7.6	84	0.1964	0.3575	[illegible]
10	9/12/2005	Stream Station 3	26.8		5.1	7.6	70	0.2259	0.4436	[illegible]
11	9/15/2005	Well 3	27.8		6.3	7.8	84	0.2048	0.3055	[illegible]

Figure 4

2

[1] HydroGeoLogic, Inc., gburnette@hgl.com, 865-995-9953

PROBLEMS WITH THIS APPROACH

There are a number of problems with using this spreadsheet to manage these data. Among the more important problems are these:

- Some data (e.g., the sampling location) are repeated in multiple rows. This is a problem if we need to change one of these values because we have to change it in multiple instances. Also, if we have a typographical error in one row, it makes it more difficult to group the results for that item together.

- The sampling location names are unique, but the use of sequence numbers within each station type can lead to confusion. For instance, if we come across a field data sheet that is simply labeled "Location 1," there is no easy way to distinguish if it refers to Lake Station 1, Stream Station 1, or Well 1.

- There is no space for recording relevant metadata about the sampling events. These metadata are important in evaluating the quality of the data, and include information such as who collected the sample, the collection method, the preservation method, etc.

- There is also no space for recording metadata about the results. Relevant metadata includes analysis test method, value qualifiers, the lab that performed the analysis, date of the analysis, etc.

- Samples are identified by date only. What happens if we need to take two samples on the same day from a single station? What if we need to perform a vertical profile on one of the lake stations? These activities would require a sample time and a sample depth respectively.

THE SOLUTION: USE A DATABASE

We could alleviate some of these problems by keeping different spreadsheets for different aspects of the data – say, one for sampling locations, one for sampling events, and one for sampling results. While this might resolve some of the issues, it would introduce the need for a lot of data manipulation and cross-checking when performing an analysis. A better approach is to use a database.

Conceptually, a spreadsheet is a 2-dimensional matrix. A database, by contrast, can have as many dimensions as required to adequately model the real world situation. To get a better understanding of how databases work, we need to define some terms.

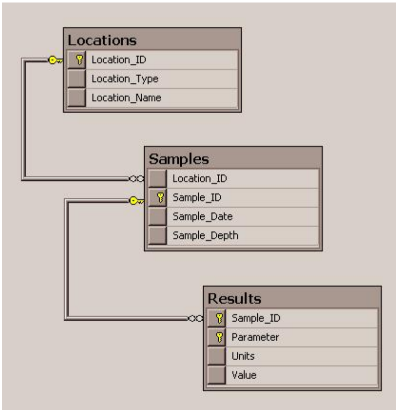


Figure 5

- A **Relation** is a collection of attributes. A good analog of the term "relation" can be found in the world of language – a relation is a group of nouns and adjectives that describe them.

- An **Atomic Element** is a data element that cannot be broken down into smaller pieces without losing its meaning. In our analogy with language, these are just the nouns. For instance "white dog" is not an atomic element, but "dog" is.

- **Decomposition** is the act of breaking a relation down into a collection of other relations.

It is this last item – decomposition – that lies at the heart of designing an efficient and effective database. The key to database design is the identification of the atomic elements and an understanding of how they relate to one another. In our example, we might start by segregating the sampling locations, the sampling events, and the sample results. The database design now starts to look like the diagram in Figure 3. We have broken the relation in the spreadsheet into three separate relations. (Note that we have addressed some of the problems we discussed, but not all.) The justification for decomposition is found in another term: **Normalization**. It's a little harder to cite a single definition of normalization, though, because there are different levels of normalization. Normalization is best defined in terms of goals – the goal of normalization is to avoid potential data anomalies that might otherwise result from inserting, editing, or deleting data.

There are three additional important database concepts depicted in Figure 3. The first is that of a primary key. A key is any set of attributes that uniquely identifies a row in a table. A candidate key is a key that is also non-redundant. That is, no attribute of a candidate key can be removed without destroying the property of unique identification. A **primary key** is simply the candidate key that is selected for use. Basically, the primary key is a field or combination of fields in the table that uniquely identify a row. We have created location ID and sample ID fields in the locations and samples tables respectively. These will be sequential numbers – or any combination of letters, numbers, and symbols we choose to enter – assigned to each record, and those will be our primary keys for those tables. The results table has a composite primary key. Once a primary key is identified, the database will not let you enter a value for the key into a new record if the primary key already exists in another record. The second concept is that of a **foreign key**. A foreign key is an attribute that appears as a primary key in one table and as a non-key in another table. The pairing of one table's primary key with another table's foreign key defines the last term: a **relationship**. Relationships are very powerful tools in a database because they enforce rules regarding how the data are connected. The collection of relationships and keys (and a few other things that we won't be discussing in this paper) together produce what is probably the most compelling reason to use a database: **relational integrity**. Relational integrity is the database's way of keeping you from making careless mistakes.

MORE ENHANCEMENTS

We've created a better way to manage our water quality data, but there are still some glaring problems. Of particular note, the location type in the locations table and the parameter field in the results table will contain repeated values. We can address these problems by further decomposing the relations as depicted in Figure 4. These new table additions are examples of another powerful tool in the database arena: lookup tables. A **lookup table** is nothing more than a table that contains values that replace other entries in another table for reporting purposes. In Figure 4, note that we have created a parameters table, and assigned a code to each parameter name. The code (as opposed to the parameter name) is stored in the results table, and the lookup table is used to retrieve the name in reports and queries. The other lookup table we added was for location types, but it is actually a variation on the standard lookup table: a **domain table**. A domain table is like a lookup table, except the value entries are not coded. The domain table is used to define the valid values allowed for the related column in the other table. How do you know when to use a domain table instead of a lookup table? That's a matter of personal taste really. In our example, we chose to use a standard lookup table for parameters because parameter names can get

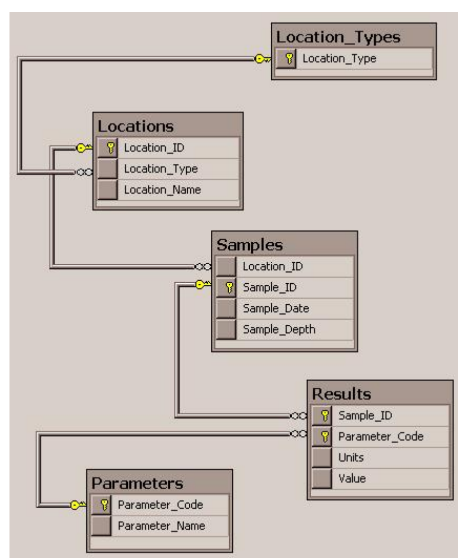


Figure 6

quite long. If we allow, say, 250 characters for parameter names, then we would have a 250-character field in our results table for every record. But we can define the parameter codes any way we want, so if we choose, say, a 5-digit number for the parameter codes, then our results table will take up considerably less room. On the other hand, the location types are relatively short. So there is not as much wasted space by using a domain table for this purpose. The other consideration is the time required to resolve the lookup table references during data retrieval. Best performance is obtained by balancing the two types rather than relying strictly on lookups.

COMPLETING THE STRUCTURE

With this basic understanding of some relatively simple concepts, we can continue to refine our database so that it stores more and more information that will be useful in our analysis. Our completed structure might look something like Figure 5. We've made some interesting additions that are noteworthy. For example, we've created a table that stores the maximum time allowed between sample collection and analysis for each parameter. The purpose of this table is to work with the analysis date field we added to the results table to give us feedback on whether the lab did the analysis in a timely manner. Why add a separate table instead of just adding a column for hold time to the existing parameters table? In this simple case it probably doesn't make much difference, but what if we were dealing with thousands of parameters and the hold time was important in only a few cases? In that event, having a separate table for hold times makes sense because it doesn't waste a lot of storage space in the parameters table on empty entries. [3] Another table worth noting is the test methods table. It looks up valid entries for parameter code in the parameters table, but then is itself a lookup table for the test method in the results table.

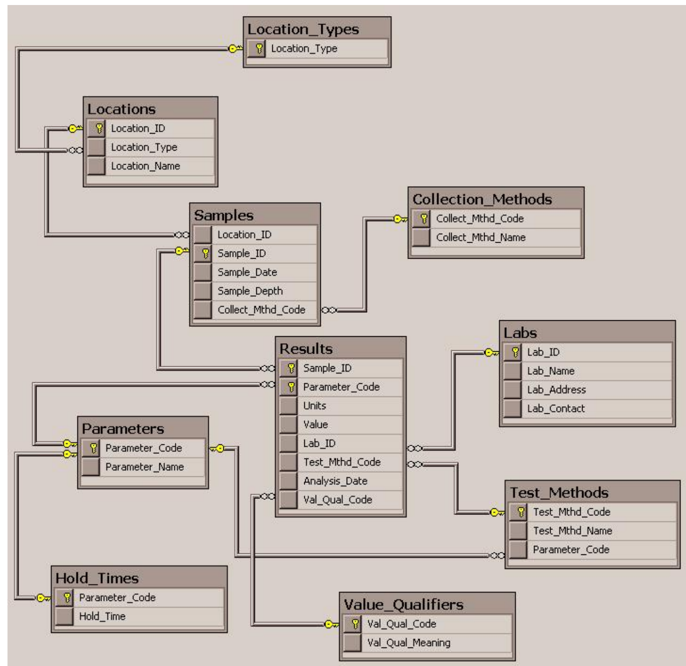


Figure 7

MORE DATABASE CONCEPTS

So far we've managed to decompose our water quality data needs into a set of normalized tables. Each table focuses on one data element, so the management of those entries is centralized in one place. But the drawback to this decomposition is that a simple query of the data in one of our primary tables produces a somewhat cryptic view. Let's say we want to look at the results for one sample. The results table might look like this:

Sample ID	Parameter Code	Units	Value	Lab ID	Test Method Code	Analysis Date	Value Qualifier Code
25	100	mg/L	<0.05	NTL	22	5/15/2005	U
25	307	mg/L	1.02	NTL	14	5/15/2005	
25	14237	deg. C	12.6	X	200	5/12/2005	
25	94	units	6.8	X	201	5/12/2005	

The data are all there, but the details are obscured by all these coded values. Fortunately, the database offers an inherent way to make this more readable. The concept is called a **Join**, and essentially all it does is to pair up values from related tables. You can then determine which of the pair of entries has meaning. (There are all sorts of joins, but we'll confine our discussion to the simplest one – called an inner join.) Using the magic of table joining, our results query can now look like this:

Sample ID	Parameter Name	Units	Value	Lab Name	Test Method Name	Analysis Date	Value Qualifier Meaning
25	Copper	mg/L	<0.05	National Test Labs	Flame Analyzation	5/15/2005	Estimated Value
25	Nitrite	mg/L	1.02	National Test Labs	Colorimetry	5/15/2005	
25	Water Temp	deg. C	12.6	Field Data	Probe	5/12/2005	
25	pH	units	6.8	Field Data	Electrometric	5/12/2005	

Using additional joins we could modify the query to also include the location from which the sample was taken, the sample depth, and other details.

The last database concept we will discuss is related to performance. As your database grows, you may find that queries take longer than usual to return results. The reason for this is that data in its raw form in the database may be scattered all over the place. Records in a given table are typically stored in the order in which they were entered. A typical query doesn't return all the records, though, and the order specified by the query is almost never the order in which they were entered. When you issue a query, the database must read all the data in your table (or tables in the case of a join) to determine which rows meet your selection criteria. That can take awhile if the database is large. Fortunately, databases offer a solution to this problem: indexes. An **index** is like a snapshot of a table, except the snapshot only includes the fields you specify. This provides a mechanism that the database can use to much more quickly identify the rows that should be returned. A table can have as many indexes as needed (although data insertion performance will suffer if you have too many). As a general rule of thumb, you should create indexes on the fields that are most often used for querying. In our example, let's say we often want to retrieve all the samples within a given date range. By indexing the samples table on the sample date field, we gain faster performance for that query.

CONCLUSION

We've learned that even a relatively simple data model such as a minimal one for managing water quality data is better implemented using a database instead of other tools. We've learned some fundamental database design principles along the way.

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. Two 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 two sites have been positioned for comparison of native trout habitat, and one site still has a population of native trout while the other site has 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^{+}). Discharge during stormflow events are modeled using the computer program RIVER2D and verified with field measurements. A stage-discharge curve is created to model ion transport. 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.

[1] Guy Thomas Zimmerman, Graduate Research Assistant, University of Tennessee, Knoxville, Department of Civil and Environmental Engineering, 706 Science and Engineering Research Facility, Knoxville, TN 37996, gzimmer1@utk.edu

EXPORT OF CARBON, NUTRIENTS, AND MICROBIOLOGICAL INDICATORS IN BEAVER CREEK WATERSHED, TENNESSEE

Si Chen

INTRODUCTION

The Beaver Creek Watershed (HUC TN-06010207-011) is located in the Lower Clinch River Watershed of East Tennessee, entirely within the northern portion of Knox County. The 44 mile main stem plus seven main tributaries passes through five different communities before emptying into the Clinch River. Suffering from the common issue of the water body pollution due to the rapid urbanization and development, the water quality in Beaver Creek has declined and the Tennessee Department of Environment and Conservation (TDEC) has included Beaver Creek on the 303(d) list of impaired waterways in 2006 due to nutrients, pathogens, sediment, and biotic integrity. In order to develop sustainable and effective management strategies to protect Beaver Creek for drinking water supply, recreational use, and natural ecological functions, this study investigated the potential sources and transport mechanisms of carbon, nutrients, and pathogen indicators which are of great importance to the management of water quality in the Beaver Creak Watershed.

A few studies focused on the carbon, nutrients and microbial exports from various types of watersheds under base flow conditions (Bernal et al., 2005; Billen et al., 2007; Brooks and Lemon, 2007). However, the estimate of annual contaminant loading may not be accurate without considering the impacts of the storms. Net annual exports of contaminants could be highly underestimated without considering the dynamics of pollutants transport under wet conditions.

Because storms have strong influence on contaminant release and considerably affect the mobilization of contaminants during a relatively short time period comparing with base flow conditions (Buffam et al., 2001; Clark et al., 2007; Hinton et al., 1997), the evaluation of contaminant transport during storm events in Beaver Creek watershed is important for determining how urbanization potentially influences stream water quality. The impact of storm events on stream water quality has been studied at the watershed scale, with a particular focus on watersheds of forest, agricultural or mixed land use (Dalzell et al., 2007; David et al., 1999; Olyphant et al., 2003; Rusjan et al., 2008; Salvia-Castellví et al., 2005). However, water quality dynamics during storm events is less understood with no clear trend. Furthermore, discrepancies are present regarding the mechanisms controlling the transport of contaminants during storms. In order to develop a rationale management strategy for Beaver Creek watershed, a detailed investigation of the flow-dependent export patterns of C, N. P, and *Escherichia coli* is needed.

Therefore, this study focused on the monitoring of transport dynamics of carbon, nutrients, and pathogens during a number of storm events in the Beaver Creek Watershed. The water resources management implications of the impact of storm flow on water quality were also discussed. Results of this study are organized into three independent but related topics: (1) The impact of storm events on dissolved organic carbon export; (2) Intra-storm nitrogen and phosphorous export; and (3) Intra-storm export of microbiological indicator *Escherichia coli*.

APPROACH

Water Sampling

The discrete water samples during the storm events were collected by an ISCO automatic sampler (Model 3700) equipped with Teflon sampling tubing and silicone peristaltic pump tubing from the site. Beaver Creek, Powell (USGS 03535200) (36°1' 6''N; 84°3'6''W), which are nearby the USGS gage established to detect the flow rate every 15 min. For each of the storms, weather reports were checked for the estimation of the starting time and the duration of the storms. Then the ISCO sampler was programmed and set on the site described above before the storms. The water samples during storms were collected at either 3 or 4 hours interval based on the period of the storms. After collection, the pH and conductivity of water samples both from base flow and storm events were measured immediately on the field and then transferred them to laboratory with icebox.

Water Pretreatment

After sampling, each of the water samples were filtered by glass fiber filter (0.7um, Waterman GF-F, baked at 450°C for 4 hours before use) acidified to pH 2 by high concentrated HCl (6N).
DOC and SUVA Measurement

After preparation, the water samples were kept at 4°C and analyzed as soon as possible. The UV_{254nm} (at wavelength of 254nm) (Thurman, 1985) of each sample was measured by UV-visible spectrophotometer (Beckman DU-600) using two side clear quartz cell with 1cm length. All the spectra of the samples were referenced to a blank spectrum of deionized water.

The DOC concentrations were measured on already acidified (pH 2) water samples by a Shimadzu TOC-V_{CHS} high temperature (680 or 720°C) catalytic oxidation analyzer combined with an ASI auto-sampler. After DOC concentrations of the samples were measured, the commonly used optical parameter, SUVA with unit, L $mgC^{-1}m^{-1}$, indicating the aromatic characteristics of the water samplers was calculated by the ratio of UV_{254nm} to DOC concentration (mg C/L) and then timed by 100 (Fabris et al., 2008; Hernes et al., 2008; Imai et al., 2001; Sachse et al., 2001; Westerhoff and Anning, 2000).

DOC Fractionation

The DOC fractionation of the water samples can be fulfilled by resin absorption with 3 kinds of macro-porous resin adsorbents to fractionize the DOC into 5 parts, defined and categorized by many researchers (Imai et al., 2002; Imai et al., 2001; Leenheer, 1981): AHS (aquatic humic substances including humic and fulvic acid), HoN (hydrophobic neutral substances), HoA (hydrophobic acid), BaS (base substances), HiA (hydrophilic acid). The storm water samples taken from the peak flow for each of storm events were analyzed by DOC fractionation method.

Nitrate, and Soluble Reactive Phosphorous (SRP) Measurement

The concentration of Nitrate (NO_3^-) samples were decided by the UV spectrophotometric screening method (Standard Methods 4500 B, APHA, 2005) (Karlsson et al., 1995). Soluble reactive phosphorus (P-SRP) of the water were decided colorimetrically by molybdate-antimony blue method (Murphy and Riley, 1962).

Calcium and Magnesium Measurement

The basic cations, Ca^{2+} and Mg^{2+} were measured by ICP-AES instrument (Intrepid II XSP, Thermo). Before measurement, the samples should be acidified (pH<2) by concentrated nitric acid (1:1). In order to avoid the over range of the standard curves due to the high concentrations, the original samples were diluted by DI water by the ratio 1:10 first. The calibration, detection control were applied for each sample's measurement.

Total Suspended Solid (TSS) Measurement

TSS concentrations for the storm water samples collected during summer, 2009 were analyzed by the standard method 2540D (APHA, 2005). 50ml volume of samples was chosen to filtrate through glass fiber filter, with 0.7μm pore size (Waterman GF-F).

E. coli Enumeration

All of the storm water samples were processed for the *E. coli* enumeration by membrane filtration method within 24hr collection, following the EPA procedures (USEPA, 2002). The MI agar plates were applied. After 4hr incubation, the blue dots on the plate were counted for *E. coli* under normal/ ambient light and the colony-forming unites (CFU) per 100ml for each of the water samples were applied to indicate the colony concentration.

Microbial Partitioning

For the microbial partitioning experiment, a Sorvall RC-5B$^+$ centrifuge (Kendro, US) with a F15-8×50C rotor (Fiber Lite, Piramoon Technologies Inc) was used for solid–liquid separation to separate the ''settleable'' particles (and associated microbes) from the free phase organisms and less dense particles. Based on the similar previous studies (Characklis et al., 2005; Krometis et al., 2007), the speed of spinning the samples was at 1164g (3000-3500 rpm) for 10 min with a brake of 4 min, while holding temperature constant at 4^{o}C. Following the centrifuge, the supernatant for each of the water samples was removed for the analysis of the *E. coli* enumeration based on the same procedures mentioned above. Then the quantity of the microbes associated with settable particles can be decided by the difference between the CFU values of raw water and supernatant samples.

Carbon and Nutrient Flux Estimation

Due to the high frequency of sample collection (usually 3-4 hour time interval or even less) (Clark et al., 2007; Walling and Webb, 1985) during storms in this study, the flux can be calculated by the product of the nutrient concentration and the average flow discharge and then convert it to flux by dividing the product by the catchment area (mass of nutrient exported per unit of time and per unit of area, kg yr^{-1} ha^{-1}, generally applied). The average of the flow discharge was estimated by integrating the instantaneous 15 min discharge obtained from USGS gage over the time interval between the two samples collected in order to best estimate the actual carbon or nutrient export by stream during this time period.

Hydrological Subdividing

The criterion used to distinguish three hydrological periods was the hydrograph separation method proposed by (Hewlett and Hibbert, 1967). The start of the storm flow period is defined by an increase in stream discharge; the end of the period is defined by adding 0.0055 L/s to the stream base flow for each hectare of catchment area for each hour (0.05 $ft^3/s/mi^2/hr$) (Hinton et al., 1997). So, the hydrological graph under each storm event was divided into two main periods: rising limb (from base flow to the peak flow), and recession flow (after the peak until the end of the storm flow). The peak flow was defined as the 10-15% of the whole storm period around the highest flow rate.

Data Analysis

The linear correlations/regressions between the parameters in each of the storm events were analyzed. Additionally, to be able to estimate the impacts of the pre-event hydrological state of the watershed, on the nutrient exports, the 7-day antecedent precipitation was introduced (Wagner et al., 2008).

On the other hand, in order to group these total nine storms events into typical categories, the cluster analysis (Eulclidean distance and Ward's aggregation method) was applied to test the significance of the overall difference between group variations (Piscart et al., 2009) based on the parameters of the storms including the rainfall amount, intensity, the 7-day antecedent precipitation.

In order to compare the parameter variation patterns caused by storms and their differences among different types or stages of rainfall events, ANOVA test was applied to compare the differences of the DOC fractions and SUVA under different categories. Each Pair Student's method was applied to decide the significant differences between the two categories.

In this study, the statistical software, JMP (version 7, SASS Institute Inc) was applied to process the data analysis. By controlling the level of significance at α=0.05 and 95% confidence interval, $p<0.05$ means the correlations or the differences between the two variables or categories are statistically significant.

RESULTS AND DISCUSSION

THE IMPACT OF STORM EVENTS ON NUTRIENTS EXPORT

DOC

Based on the characteristics of 9 storm events from October 2008 to February 2009, three categories, small, moderate and heavy storms were grouped by cluster analysis. The linear relationships between DOC concentration or flux and the flow rate, 'Q' indicate that the positive correlation between DOC flux and storm discharge was significant only during heavy storms ($R^2>0.7$, $p<0.0001^{**}$). The SUVA showed more obvious fluctuations (from 2.5 to 7) under heavy storms conditions than it under other two storm types (ranged from 2.5 to 4). Consistent with the patterns of the SUVA values under three storm categories, the results of the DOC fractionations of peak flow for three storm categories indicated that: (1) Aquatic humic substances (AHS) and the hydrophilic acids (HiA) together under peak flow were basically 70-90% of the DOC concentration averagely, and the AHS parts were always comprised most; (2) there is the significant increase trend of the AHS part among three storm categories, from small to heavy rainfall ($p=0.01^{*}$) (3) The ratio of AHS/ HiA reflecting the compositions of DOC showed the similar patterns that the average ratio under heavy storm is bigger. (4) The relatively constant percentages of HiA part, 20-30% had no apparent patterns of variations under different storm types. These indicated that the increase of DOC flux during high flows could be attributed to the greater inputs of allochthonous organic carbon facilitated by the formation of preferential flow path of precipitation through the upper soil horizon during intense storm events, while flow path under light precipitation may origin from the deeper soil layer.

Nitrates and SRP

The nitrate and SRP releasing influenced by four spring storm events, from middle March to early May, 2009, had also been evaluated. The declining trends of the concentrations of nitrate and cations (Ca^{2+} and Mg^{2+}) during storms and their highly correlated linear relationships with the flow rate ($r=-0.7$, $p<0.05^*$ for nitrate; $r=-0.9$, $p<0.05^*$ for Ca^{2+} and Mg^{2+}, respectively) indicated they followed the similar flow path and they were diluted by the storm water on the nitrate and cations coming from groundwater mainly especially when the ratio of the input water from groundwater or the deep soli layer to the rainfall decreased at peak flow conditions. The high order increase of SRP concentrations during storm flow, approximately 4-20 times of that under base flow and the sharp decrease during the declining limbs demonstrated that the flushing effects of overland flow can mobilize the P resources in surface or sub-surface layers near the stream. However, the patterns of the SRP for these four events didn't perform constant. The peak concentration occurred on the rising, falling limb of the hydrograph or the peak flow period, which may involve in various transport processes from P sources to stream water courses.

Pathogen Indicator (*E. coli*)

The intra-storm export of *E. coli* from Beaver Creek during 6 summer storm events (from May to August, 2009) indicated that *E. coli* export and flow rate or DOC during early periods of storm events had relative strong correlation, which demonstrated that landscape runoff could be an important source contributing to the sharp increase in *E. coli* export during storms (20~100 fold). The strong correlations ($R^2=0.5-0.8$, $p<0.05^*$) between *E. coli* and TSS throughout all storms demonstrate that the transport of *E. coli* into the stream during storms is particle related, and it may come from sediment re-suspension. On the other hand, the intra-storm *E. coli* partitioning patterns revealed that suspended *E. coli* levels rose significantly during the recession limbs by 5% to 20% averagely ($p=0.011^*$). Although pathogens such as *E. coli* might be present as freely suspended populations, those attached to particulate matter are still the main form as the storms progressed.

REFERENCES

Billen, G. et al., 2007. A long-term view of nutrient transfers through the Seine river continuum. Science of The Total Environment. 375 (1-3): 80-97.

Brenner, K.P., Rankin, C.C., Roybal, Y.R., Jr, G.N.S., Scarpino, P.V., Dufour, A.P., 1993. New medium for the simultaneous detection of total coliforms and Escherichia coli in water. Applied Environmental Microbiology. 59 (11), 3534-3544.

Brooks, P.D. and Lemon, M.M., 2007. Spatial variability in dissolved organic matter and inorganic nitrogen concentrations in a semiarid stream, San Pedro River, Arizona. Journal of Geophysical Research-Biogeosciences. 112 (G3): 11.

Buffam, I., Galloway, J.N., Blum, L.K., McGlathery, K.J., 2001. A stormflow/baseflow comparison of dissolved organic matter concentrations and bioavailability in an Appalachian stream. Biogeochemistry. 53 (3), 269-306.

Characklis, G.W., Dilts, M.J., Simmons Iii, O.D., Likirdopulos, C.A., Krometis, L.-A.H., Sobsey, M.D., 2005. Microbial partitioning to settleable particles in stormwater. Water Research. 39 (9), 1773-1782.

Clark, J.M., Lane, S.N., Chapman, P.J., Adamson, J.K., 2007. Export of dissolved organic carbon from an upland peatland during storm events: Implications for flux estimates. Journal of Hydrology. 347 (3-4), 438-447.

Dalzell, B.J., Filley, T.R., Harbor, J.M., 2007. The role of hydrology in annual organic carbon loads and terrestrial organic matter export from a midwestern agricultural watershed. Geochimica Et Cosmochimica Acta. 71 (6), 1448-1462.
David, M., Vance, G., Kahl, J., 1999. Chemistry of dissolved organic carbon at Bear Brook Watershed, Maine: Stream water response to $(NH_4)_2SO_4$ additions. Environmental Monitoring and Assessment. 55 (1), 149-163.
Fabris, R., Chowa, C.W.K., Drikas, M., Eikebrokk, B., 2008. Comparison of NOM character in selected Australian and Norwegian drinking waters. Water Research. 42 (15), 4188-4196.
Hernes, P.J., Spencer, R.G.M., Dyda, R.Y., Pellerin, B.A., Bachand, P.A.M., Bergamaschi, B.A., 2008. The role of hydrologic regimes on dissolved organic carbon composition in an agricultural watershed. Geochimica Et Cosmochimica Acta. 72 (21), 5266-5277.
Hewlett, J.D., Hibbert, A.R., 1967. Factors affecting the response of small watersheds to precipitation in humid areas. In: Forest hydrology. Proc. Intern. Symp. on Forest Hydrol., Penn State. Pergammon Press, NY, 275–290 pp.
Hinton, M.J., Schiff, S.L., English, M.C., 1997. The significance of storms for the concentration and export of dissolved organic carbon from two Precambrian Shield catchments. Biogeochemistry. 36 (1), 67-88.
Imai, A., Fukushima, T., Matsushige, K., Kim, Y.-H., Choi, K., 2002. Characterization of dissolved organic matter in effluents from wastewater treatment plants. Water Research. 36 (4), 859-870.
Imai, A., Fukushima, T., Matsushige, K., Kim, Y.H., 2001. Fractionation and characterization of dissolved organic matter in a shallow eutrophic lake, its inflowing rivers, and other organic matter sources. Water Research. 35 (17), 4019-4028.
Karlsson, M., Karlberg, B., Olsson, R.J.O., 1995. Determination of nitrate in municipal waste water by UV spectroscopy. Analytica Chimica Acta. 312 (1), 107-113.
Krometis, L.-A.H., Characklis, G.W., Simmons Iii, O.D., Dilts, M.J., Likirdopulos, C.A., Sobsey, M.D., 2007. Intra-storm variability in microbial partitioning and microbial loading rates. Water Research. 41 (2), 506-516.
Leenheer, J.A., 1981. Comprehensive approach to preparative isolation and fractionation of dissolved organic carbon from natural waters and wastewaters. Environmental Science & Technology. 15 (5), 578-587.
Murphy, J., Riley, J.P., 1962. A modfied single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta. 27, 31-36.
Olyphant, G.A., Thomas, J., Whitman, R.L., Harper, D., 2003. Characterization and Statistical Modeling of Bacterial (Escherichia Coli) Outflows from Watersheds that Discharge into Southern Lake Michigan. Environmental Monitoring and Assessment. 81 (1), 289-300.
Piscart, C., Genoel, R., Doledec, S., Chauvet, E., Marmonier, P., 2009. Effects of intense agricultural practices on heterotrophic processes in streams. Environmental Pollution. 157 (3), 1011-1018.
Rusjan, S., Brilly, M., Mikos, M., 2008. Flushing of nitrate from a forested watershed: An insight into hydrological nitrate mobilization mechanisms through seasonal high-frequency stream nitrate dynamics. Journal of Hydrology. 354 (1-4), 187-202.
Salvia-Castellví, M., François Iffly, J., Vander Borght, P., Hoffmann, L., 2005. Dissolved and particulate nutrient export from rural catchments: A case study from Luxembourg. Science of The Total Environment. 344 (1-3), 51-65.
Sachse, A., Babenzien, D., Ginzel, G., Gelbrecht, J., Steinberg, C.E.W., 2001. Characterization of dissolved organic carbon (DOC) in a dystrophic lake and an adjacent fen. Biogeochemistry. 54 (3), 279-296.
Thurman, E.M., 1985. Organic Geochemistry of Natural Waters. Martinus Nijhoff/Dr W. Junk Pub, Dordrecht.
USEPA, 2002. Total Coliform and Escherichia coli in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium). EPA 821-R-02-024. In: USEPA (Editor), Washington, DC.

Westerhoff, P., Anning, D., 2000. Concentrations and characteristics of organic carbon in surface water in Arizona: influence of urbanization. Journal of Hydrology. 236 (3-4), 202-222.
Walling, D.E., Webb, B.W., 1985. Estimating the discharge of contaminants to coastal waters by rivers: some cautionary comments. Marine Pollution Bulletin. 16 (12), 488-492.
Wagner, L.E., Vidon, P., Tedesco, L.P., Gray, M., 2008. Stream nitrate and DOC dynamics during three spring storms across land uses in glaciated landscapes of the Midwest. Journal of Hydrology. 362 (3-4), 177-190.

Power Point File of Presentation

EVALUATION OF STATISTICAL ASSUMPTIONS FOR GROUNDWATER CONTAMINATION NEAR LANDFILLS OVERLYING KARST/SAND AQUIFERS IN TENNESSEE

Randy M. Curtis[1]*

The Tennessee Solid Waste Regulations require an owner / operator to select and report a statistical method to be used in evaluating the groundwater monitoring data for a landfill. The choice of a statistical evaluation procedure should be guided by the distribution, variation, and number of samples in the data set, as well as the method(s) to account for sample results below the detection limit, seasonal and spatial variability, and potential temporal correlation in the data. Eight to ten years of sample results from two landfills with known groundwater contamination were compiled into electronic spreadsheets to allow calculation of descriptive statistics and to check basic assumptions in areas of known groundwater contamination. One landfill was over a dual porosity karstic aquifer in East Tennessee and one was over a multiple sand aquifer system in West Tennessee. All detections of sample parameters found on the standard monitoring list (trace metals, fluoride, and volatile organic compounds) were evaluated to determine how the actual groundwater data compared to the statistical underpinnings of the tracking methods allowed under the Tennessee Solid Waste Regulations. No single statistical choice consistently covered the range of conditons encountered at the two landfill sites. Tracking the movement of contaminanted groundwater, beyond the initial detection, would require a flexible approach in the use of statistics to track the rate and extent of effects in aquifers affected by release of solid wate constituents from landfills.

Statisitcal evaluations are intended to be a method to prevent bias with regard to a sensitive and polarizing issue. At one extreme, environmental activism treats any shift in groundwater monitoring data as a potential risk to the public health or the environment. The landfill business operations are sanctioned by permit, and are geared towards responses to risks if the landfill is clearly implicated as the source of a release. In the simplest terms, a statistical procedure uses math to reduce expectations down to a simple number. Under the permit and guidance requirments for landfills in Tennessee, standard detection monitoring versus more extensive and expensive assessment monitoring or corrective action procedures hinges on the phrase "statistically significant difference" for groundwater results.

DATA SELECTION

Multi-year groundwater monitoring data sets from two landfills, one over a regional sand aquifer in West Tennessee and one over a karstic limestone/dolomite aquifer in East Tennessee, were examined to determine the basic characteristics of groundwater results collected in assessment monitoring programs. Each landfill had known groundwater contamination issues and multiple well groundwater monitoring systems. The well locations were evaluated for consistency in their positions relative to the uppermost aquifer and historical similarities in their data. Wells with consistent volatile organic contamination, near the waste disposal area, were assumed to represent groundwater affected by the site. Obviously perched water levels or differeing bedrock types were also considered in the selection of wells to exclude from this evaluation. The goal was to select a group of wells from each site where the only obvious difference was spatial position inside a long-term plume of contamination. This resulted in a six well/ten year core

[1] Environmental Compliance Section, Gresham Smith and Partners, Suite 1400, 511 Union Street, Nashville, TN 37219 randy_curtis@gspnet.com

data group for the West Tennessee site and a seven well / eight year core data group for the East Tennessee site.

ASSUMPTIONS

The most basic question for groundwater monitoring data is whether a specific value from a specific well is different from background, and, if it is different, is it unexpected? The Regulations governing Solid Waste processing and Disposal Operations in Tennessee lists the basic groundwater monitoring parameters to be used for landfills (Tennessee Department of Environment & Conservation November 2008, Appendix I). This list names fluoride, sixteen common metals, and forty-seven volatile organic compounds that are to be used to detect contamination via comparison between upgradient wells unaffected by leakage from the facility and downgradient wells placed to intercept leakage before it travels more than one hundred and fifty meters from the waste boundary. Statistics are to be used to detect if leakage has occurred, to assess the extent of leakage known to have occurred, and to track the effectiveness of corrective action if statistics show that risk is present ("…statistically significant level exceeding the groundwater protection standard…").

Compliance with the regulations is fairly straightforward if data is collected from new wells screened in the same aquifer before waste disposal operations begin. A statistical method may be chosen based on the number of samples, variance, normality, and independence characteristics in the observed data. The underlying assumptions behind the initial choice of a statistical method are fundamentally affected by leakage of either landfill gas or leachate. The emphasis of this study is on groundwater deduced to be affected in order to highlight the range of methods needed to comply with the most basic assumtions of normality, independence, and equality of variance.

DETECTIONS

The site in east Tennessee is in a headland area of the Valley and Ridge physiographic province. It has a fill area of about thirty acres with a maximum waste depth of about one hundred feet. The fill is predominantly in residual clay cuts over an aquifer in the Conococheague Formation. It has a twelve well monitoring system, with occassional volatile detections in all but one downgradient well and mercury and volatile detections in the intended upgradient well. The west Tennessee site also has a twelve well system, with two background wells to account for upgradient conditions in a local perched aquifer over a clay body of several acres extent as well as the deeper regional aquifer system. The waste area is also about thirty acres, with a maximum waste depth of up to fifty feet. There is some evidence of increased carbon dioxide effects in the subsurface near the upgradient wells. Both landfill sites have been closed for many years, and both are in groundwater assessment due to detection of volatile compounds over groundwater protection standards. Table 1 lists the percentage of detections for Appendix I inorganics at both sites for downgradient wells near the waste assumed to be in the plume of contamination.

TABLE 1: DETECTION RATE OF APPENDIX I INORGANICS

PARAMETER	WEST TN SAND	EAST TN KARST
Antimony	9.3%	11.2%
Arsenic	4.3%	20.6%
Barium	100.0%	97.2%
Beryllium	11.4%	5.6%
Cadmium	23.6%	5.6%
Chromium	70.0%	29.0%
Cobalt	100.0%	57.0%
Copper	45.0%	24.3%
Fluoride	43.6%	46.7%
Lead	49.3%	40.2%
Mercury	27.1%	10.3%
Nickel	92.9%	28.0%
Selenium	28.6%	29.9%
Silver	12.9%	2.8%
Thallium	0.0%	2.8%
Vanadium	60.7%	9.3%
Zinc	88.6%	69.2%

The lack of thallium detections in ten years of data in the west Tennessee site is notable (zero detections in 140 possible samples). The number of samples at the east Tennessee site varied from 104 to 111, owing to sample collection and well access issues, but some thallium values were detected. Both sites detected barium, cobalt, and zinc at high enough rates to allow some flexibility in the choice of evaluation procedures. The west Tennessee site had relatively higher detection rates for chromium, nickel, and vanadium. The detection rates of eleven of the seventeen parameters in the west Tennessee site favor nonparametric methods. Only three of the parameters in the east Tennessee site have detection rates indicating the need for further evaluation of the data distributions.

The forty-seven volatile organic compounds found on the Appendix I list are expected to be absent in the initial, detection monitoring phases for a new landfill. Even though the core data for both sites in this study were chosen based on known volatile contamination, most of the volatile compounds found on the Appendix I list were still non-detect at both sites. The detected volatiles are listed in Table 2 to contrast the types and relative rates of detections for volatiles in the different geologic settings.

TABLE 2: DETECTION RATE OF APPENDIX I VOLATILES

PARAMETER	WEST TN SAND	EAST TN KARST
Tetrachloroethene	50.0%	8.1%
Trichloroethene	61.4%	11.7%
1,1-Dichloroethane	76.4%	93.7%
Cis-1,2-Dichloroethylene	67.1%	68.5%
Vinyl Chloride	55.7%	55.0%
Benzene	27.9%	62.2%
1,4-Dichlorobenzene	25.0%	49.5%
Chlorobenzene	2.1%	24.3%
Chloroethane	9.3%	33.3%
Ethylbenzene	12.9%	10.8%
Xylene	25.0%	8.1%
1,2-Dichloropropane	2.9%	39.6%
Acetone	6.4%	0.0%
Methyl Chloride	0.7%	0.0%
Methylene Chloride	42.1%	0.0%
Methyl Ethyl Ketone	3.6%	0.0%
Dichlorodifluoromethane	0.7%	0.0%
1,3-Dichlorobenzene	0.7%	0.0%
1,2,4-Trimethylbenzene	13.6%	0.0%
Trans-1,2-Dichloroethylene	0.0%	20.7%
1,1-Dichloroethene	0.0%	1.8%
1,2-Dichloroethane	0.0%	4.5%
Toluene	0.0%	6.3%
Carbon Disulfide	0.0%	2.7%
Vinyl Acetate	0.0%	0.9%
Chloroform	0.0%	0.9%
1,2-Dibromoethane (EDB)	0.0%	2.7%
Number of Detected Compounds	19	20

The rate of detection of vinyl chloride and cis-1,2-dichloroethylene in both sites was remarkably similar. The presence of 1,1-dichloroethane was nearly ubiquitous in east Tennessee, and relatively highest in west Tennessee. Of the nineteen volatile compounds with at least one detection in the west Tennessee site, fourteen had detection rates <50%; of the twenty volatiles with at least one detection in east Tennessee, sixteen had overall detection rates less than 50%.

DISTRIBUTIONS/NORMALITY ASSUMPTIONS

One of the basic assumptions for parametric hypothesis tests is that the observations follow a normal distribution. Observations that fit a log normal distribution may be transformed to allow some of the same tests as the normal distribution. The data from the two sites in this study were grouped according to the criteria of contamination. The grouped data detection rates were then examined to see which parameters were detected most frequently in the area of unambiguous contamination. Of the thirty seven Appendix I parameters detected in groundwater near the waste at the east Tennessee site, seven were detected frequently enough to merit evaluation of the distribution of the observations; of the thirty five parameters detected at least once at the west Tennessee site, eleven were detected at rates above 50%. Table 3 lists the parameters detected, whether the observations fit a normal or lognormal distribution, and, whether other distributions were a better fit.

TABLE 3: DISTRIBUTIONS OF APPENDIX I PARAMETERS (>50% DETECTIONS)

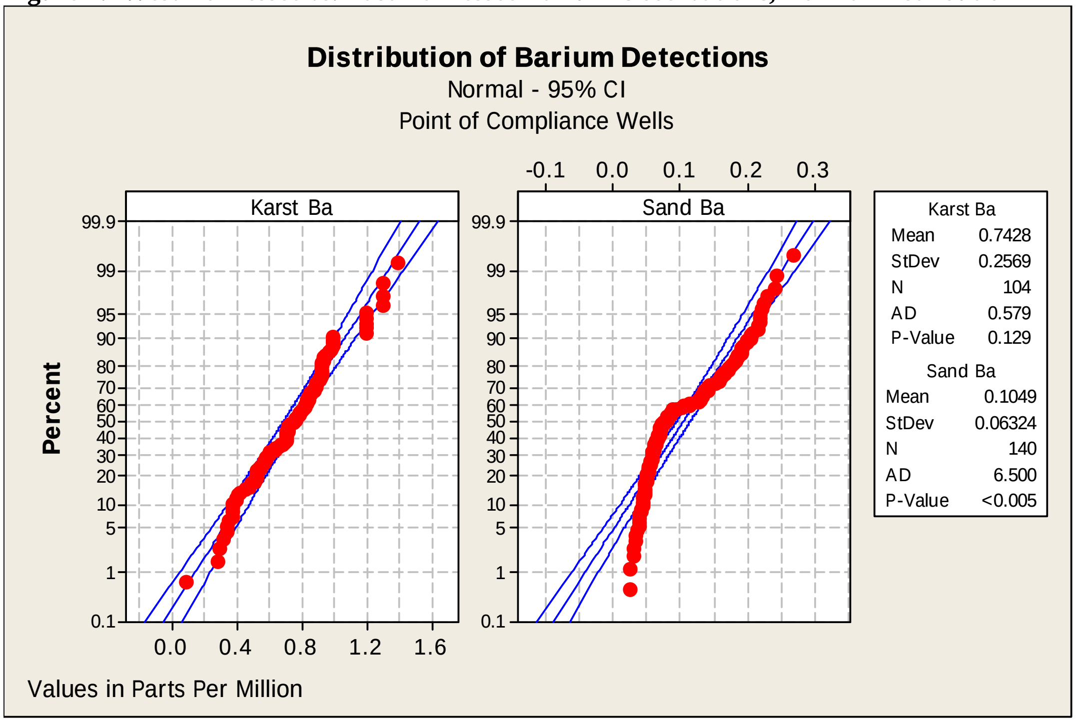
PARAMETER	NORMAL?	LOG NORMAL?	BEST FIT*
West Barium	N	N	3 parameter loglogistic
East Barium	Y	N	logistic
West Cobalt	N	Y	3 parameter loglogistic
East Cobalt	Y	Y	lognormal
West Zinc	N	N	3 parameter loglogistic
East Zinc	N	Y	3 parameter loglogistic
West 1,1-Dichloroethane	N	Y	loglogistic
East 1,1-Dichloroethane	N	Y	3 parameter lognormal
West cis-1,2- Dichloroethylene	N	Y	3 parameter Weibull
East cis-1,2- Dichloroethylene	N	N	3 parameter loglogistic
West Vinyl Chloride	N	Y	3 parameter Weibull
East Vinyl Chloride	Y	Y	3 parameter gamma
West Chromium	N	Y	3 parameter lognormal
West Nickel	N	Y	3 parameter loglogistic
West Vanadium	N	Y	3 parameter Weibull
West Trichloroethene	Y	Y	3 parameter Weibull
West Tetachloroethene	Y	Y	3 parameter gamma
East Benzene	N	Y	3 parameter lognormal

*Best Fit based on value of Anderson Darling goodness-of-fit test statistic

Of the parameters with more than a 50% detection rate in the contaminant plume area, only five had an approximately normal distribution appropriate for a parametric test method. Of the remaining thirteen, ten could be transformed with a relatively common procedure, while three would require more intensive transformation procedures.

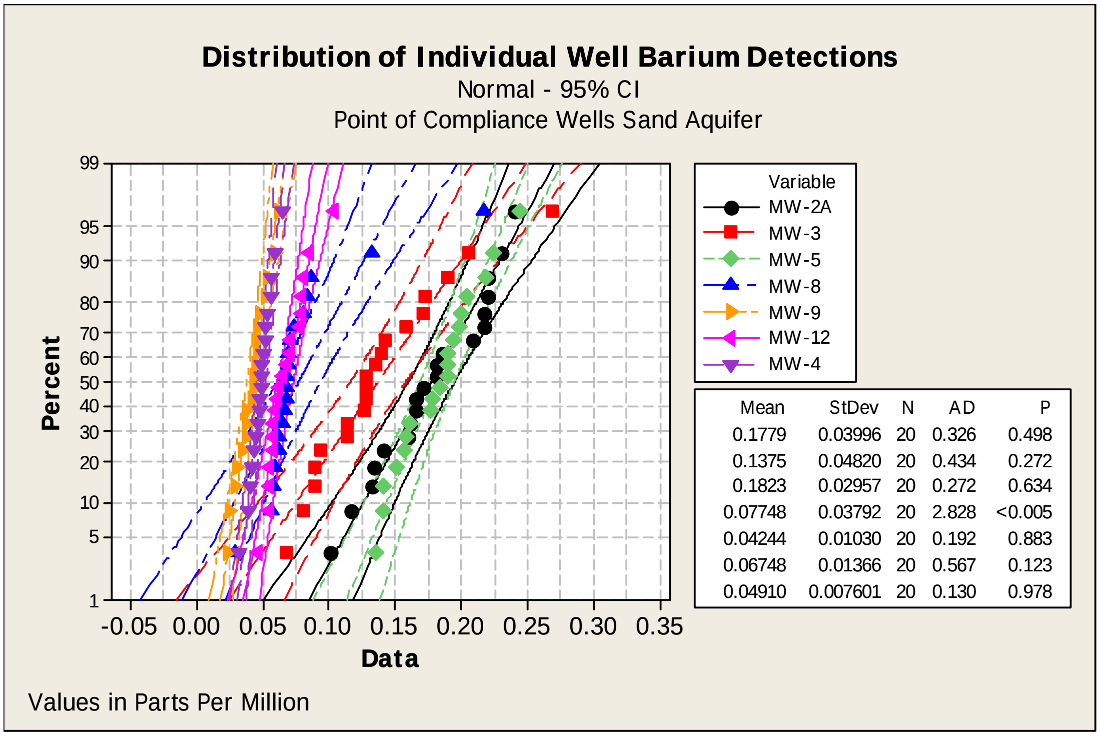
The west Tennessee sand barium values were examined in more detail to see if there were some indications as to why the grouped data would not be amenable to log transform protocols. Figure 1 illustrates the east and west barium (karst vs. sand) observations, and Figure 2 breaks the observations in the west out into individual well/point distributions.

Figure 1: West Tennessee vs. East Tennessee Barium Observations, Normal Distribution



The west Tennessee wells, although all within the same aquifer in a relatively small geographic area, appear to break out into small groups in terms of their distribution pattern, with one well transitioning between the groups with similar barium values. The assumption of normality for individual well data generally holds for individual wells, but not for the plume area as a whole. The same wells were evaluated for equality of variance between individual well pairs.

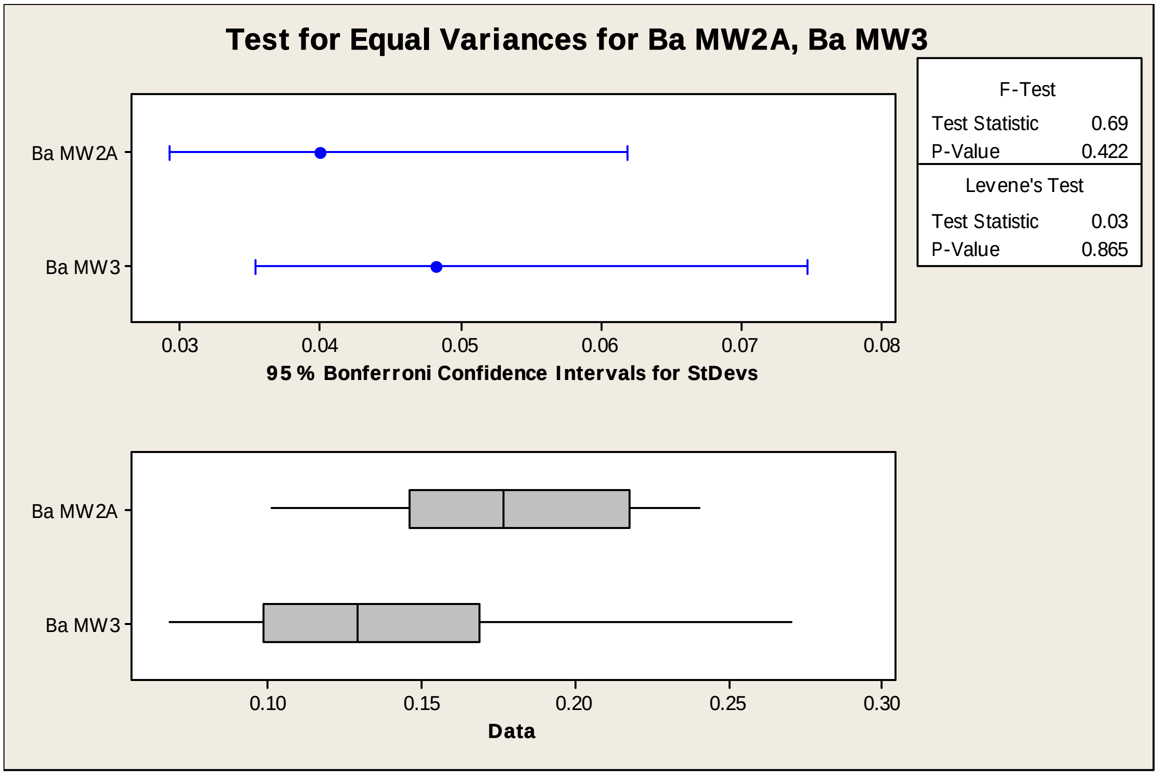
Figure 2: West Tennessee Barium Group Observations Broken out by Well

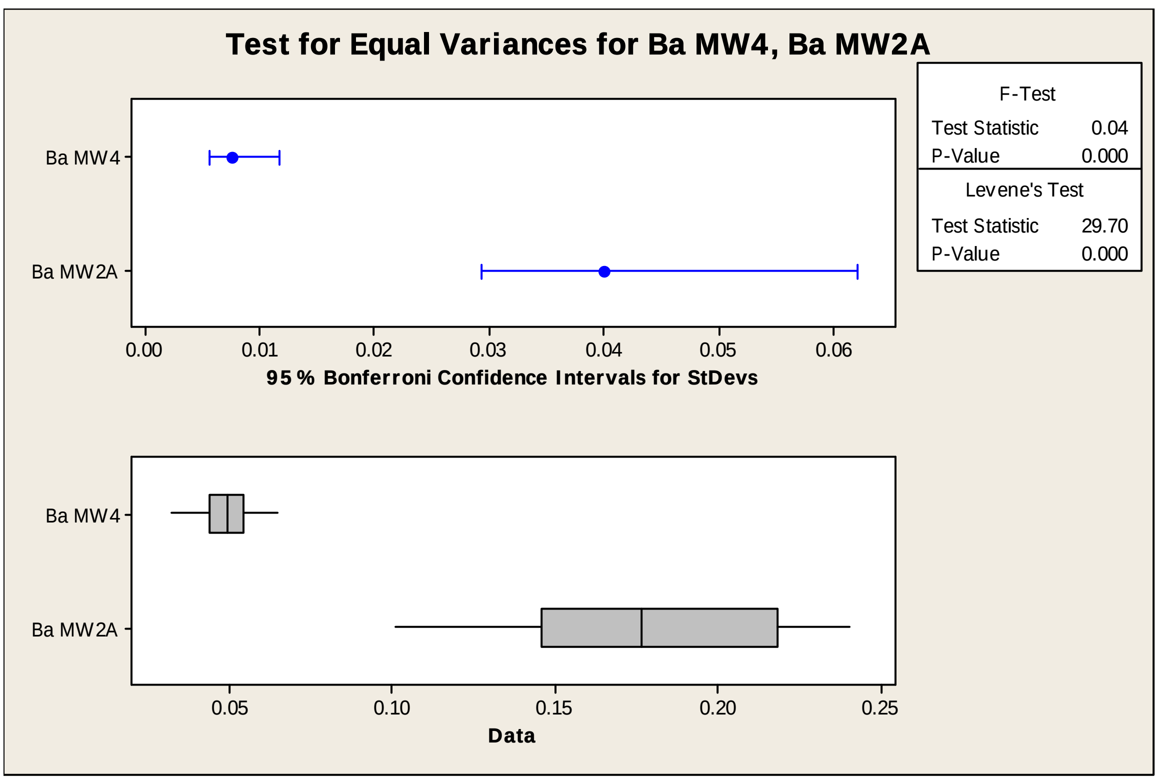


EQUAL VARIANCES

The west Tennessee sand site's grouped data for barium indicated a non-normal distribution. This may reflect barium interaction with sulfides, carbonates, or other factors within the contaminant plume. The same core group wells were tested against each other to determine whether their variances were similar. The variance test procedures used were F-test and Levene's test in the computer software program ®Minitab to check the validity of this assumption. Figure 4 illustrates the situation when wells have similar variances (barium in MW 2A and MW3, vs. wells with different variances MW2A and MW4). Many statistical procedures, including the two sample t-test procedures, assume that the two samples are from populations with equal variance.

Figure 4: Test of Equal Variances for West Tennessee Barium in Sand Site Wells





Another way to evaluate variances is to note the degree of separation between the values for individual wells' for a specific parameter group of observations. The core groups which showed detection rates greater than fifty percent at each of the study sites were split back into individual well observations for the parameters where parametric statistics might be attempted. Vinyl chloride and nickel were the only parameter groups for wells at the west Tennessee sand site that did not vary by more than two orders of magnitude. For the east Tennessee karst site, vinyl chloride, benzene, and barium had variance values with two orders of magnitude in the variance calculations.

OTHER FACTORS

Classical hypothesis tests assume the observations come from a population with the same variance, are nearly normal in their distribution of potential values, and are independent. Independence in the hydrogeologic system the samples are taken from is not as straightforward as in the classical statistical systems, e.g., the probability throwing a six with an unaltered six-sided die is not affected by the previous result.

> *"The problem of correlated data over time and/or space is one of the most serious facing the data analyst. Highly correlated data can seriously affect statistical tests and can give misleading results when estimating the variance of estimated means, computing confidence limits on means, or determining the number of measurements needed to estimate a mean."*
> (Gilbert, 1987, p.2-3).

The fundamental dynamics of subsurface water movement impart some self-ordering of groundwater data. In the sand aquifer setting for this study, a local perched zone catches and organizes a multi-acre segment of recharge, before delivering the stacked/collected recharge back into the vertical flow path towards the deeper regional aquifer at the edges of the perched clay layer. The dual porosity of the karst aquifer has collecting solution conduits surrounded by diffusing fractures that will either disperse or concentrate contaminants, depending on local bedrock structural geometry.

The physics of the water pathway from recharge to uppermost aquifer has natural chemical variation as well as the potential contaminant imprint. At landfills, where the release of contaminants can be liquid or gaseous, the contaminant overprint can impact recharge pathways before the groundwater flow rates and directions get involved in contaminant dispersion or alteration.

The most fundamental influence for statistical considerations is the how well the sampling process represents actual aquifer conditions. Potential risk to the public health or the environment is based on aquifer water quality. The location, depth, and construction of the wells, as well as the pumping / bailing procedures, sample rate, preservation and handling protocols, and actual analysis in the lab are all potential opportunities to introduce dependences and autocorrelation into the observations used to define water quality. The first question for any system, under these conditions, is whether the background well is unaffected. Finally, cost and effort become involved in that a relatively small number of sampling points (wells) are used to represent many acres of surface area and hundreds of vertical feet of subsurface two or four times a year.

CONCLUSIONS

The solid waste regulations imply that an informed choice of statistical evaluation will be used to track groundwater quality in areas of permitted landfills. The list of potential contaminants and the range of regulation (detection, assessment, and corrective action) are tracked by statistical methods. The complexity of the environmental changes and groundwater quality shifts induced by leakage from a landfill make the choice of one method of statistical evaluation a contradiction. Many statistical methods in the regulations assume high detection rates that are not present in the sample data. The stringent protection standards for some parameters do not allow even one detection to be ignored. From a regulatory standpoint, three years of sample data with water quality under a maximum containment level could be obviated by one new detection of a previously absent volatile at a level over the standard.

This study looked at grouped water quality observations from multiple wells in order to check some of the assumptions for statistical evaluations. Multi-year data from two common aquifer types indicate that the variation in detection rates, distributions, variance ranges, and other factors in the affected water of a contaminant plume make errors inevitable if a single statistical evaluation method is adhered to. The opportunity to assess attainment in multiple wells or for multiple chemicals as performance criteria does not exist in the current Tennessee regulations. Regulatory pathways exist that could allow as many choices or methods as the operator could afford and obtain permission for, but increasing complexity does not necessarily inspire public confidence when it comes to choices by landfill operators regarding water quality evaluations. Ideally, adjustment of the regulatory language regarding what constitutes a plume of contamination could allow simple indicator parameters to define and track the extent of landfill impact to local aquifers, while allowing risk to be tracked by separate statistical protocols geared towards changes or trends in existing contamination from specific metals or volatiles. This would allow the public access to understandable information on where groundwater is affected, while allowing flexibility in the sampling for known contamination for assessment or corrective action.

REFERENCE MATERIAL

American Society for Testing and Materials, 1996, Provisional Standards for Ground-Water Detection Monitoring Programs, ASTM PS 64-96

Federal Register: October 11, 1988, Part 2. 40 CFR Part 264. Statistical Methods for Evaluating Groundwater Monitoring from Hazardous Waste Facilities, Final rule

Gilbert, Richard O., 1987, Statistical methods for Environmental Pollution Monitoring, by Van Nostrand Reinhold, New York, New York, USA

Tennessee Department of Environment and Conservation, Division of Solid Waste Management, 2008, CHAPTER 1200-1-7 SOLID WASTE PROCESSING AND DISPOSAL RULES

United States Environmental Protection Agency, 1992, Addendum to Final Guidance, Statistical Analysis of Ground-water Monitoring Data at RCRA Facilities.

United States Environmental Protection Agency, 1992, Methods for Evaluating the Attainment of Cleanup Standards, vol.2: Groundwater. EPA 230-R-92-104.

HYDROLOGIC AND GEOLOGIC CONTROLS ON CONTAMINANT TRANSPORT AT THE HARDEMAN COUNTY LANDFILL

Michael W. Bradley[1] and Thomas D. Byl[2]

The Hardeman County landfill was used as a disposal site for chlorinated solvents and other toxic organic compounds from 1964 to 1973. Continued release of these materials to surrounding aquifers and surface-water bodies is an ongoing problem and issue of concern. In 2009, the U.S. Geological Survey, in cooperation with the Tennessee Division of Remediation, conducted a preliminary investigation to evaluate conditions along the adjacent Clover Creek wetland and to identify the potential for natural attenuation of organic contaminants. That investigation included the collection of water-quality samples for geochemical and bacterial conditions and an evaluation of hydrologic and geologic controls on contaminant transport. Two sources of surface-water contamination were identified during this evaluation: seeps at gaining reaches of major tributaries of Clover Creek and seeps along the edge of the Clover Creek wetland. An improved understanding of the hydrologic and geologic controls on contaminant transport at this site will aid in the identification and selection of appropriate remedial actions.

A series of discharge measurements along Clover and Pugh Creeks were used to identify gaining stream reaches. Stream and spring discharge were measured at 25 sites during high base-flow conditions in March of 2009. Discharge measurements on Clover Creek indicated a gain of about 10 cubic feet per second (cfs) from upstream to downstream along this reach. Unit-area discharge for this same reach of Clover Creek was 0.74 cubic feet per second per square mile (cfsm) which was relatively higher than that observed for the rest of the drainage area—indicating possible flow augmentation (seepage). Stream flow in Pugh Creek increased from 0 to 2.29 cfs and the largest relative increase in flow was found along a reach where the unconfined aquifer (Claiborne Formation) thins and a clay layer intersects the stream bed.

The increases in discharge along Pugh Creek and other tributaries are likely related to the intersection of streams with discontinuous clay layers within the Claiborne Formation and at the boundary of the Claiborne Formation and underlying Wilcox Formation. Contaminants from the landfill may be migrating laterally in dissolved phase through the Claiborne Formation and then discharging in seeps along tributaries where the stream bed has eroded into the clay layers.

A series of seeps was identified along the edge of the Clover Creek wetland and near the base of a bluff formed by the Claiborne Formation and undifferentiated terrace deposits. Water from two of these seeps was sampled and found to contain detectable concentrations of carbon tetrachloride and chloroform. The dissolved phase of these contaminants was probably also migrating laterally through local aquifers and discharging with groundwater along a seepage front at the edge of the wetland.

[1] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211, mbradley@usgs.gov
[2] U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211, tdbyl@usgs.gov

RECONNAISSANCE EVALUATION OF THE HARDEMAN COUNTY LANDFILL FOR NATURAL ATTENUATION

Thomas D. Byl[2] and Michael W. Bradley[1]

The Hardeman County landfill was used to dispose of industrial waste from 1964 to 1973. Continued seepage of contamination from this waste into surface-water and groundwater systems has been a source of concern for many years. Recently, the U.S. Geological Survey, in cooperation with the Tennessee Division of Remediation, began an investigation into conditions within nearby Clover Creek wetland and the potential for natural attenuation of carbon tetrachloride and chloroform. Water samples were collected in June, 2009 from two background sites, two sites north of the landfill and along the edge of the Clover Creek wetland, and a reach of Pugh creek—a tributary in the wetland. Samples came from surface-water, groundwater, seeps, and several drive-point samplers. Surface-water samples were found to be in the range of 36 to 60 microsiemens per centimeter (uS/cm) for specific conductance and contained dissolved oxygen concentrations of 3 to 5.7 milligrams per liter. Subsurface and ground-water samples were in the range of 107 to 320 uS/cm specific conductance and contained dissolved oxygen concentrations of less than 0.1 to 0.5 mg/L. No volatile organic compounds were detected in a background sample taken from a spring, or in water from a deep aquifer well, a surface-water sample from the north tributary, or in water from drive-point samplers collected near the north tributary. Along the edge of the wetland, water from one seep contained concentrations of 310 micrograms per liter (ug/L) carbon tetrachloride and 230 ug/L chloroform. Surface water collected from the middle tributary and along Pugh Creek contained 110 to 210 ug/L carbon tetrachloride and 38 to 93 ug/L chloroform. Samples from Pugh Creek also had 7.9 – 9.2 ug/L (estimated) methylene chloride. Water collected from the drive-point samplers at both areas had lower concentrations with non-detect to 1.1 ug/L carbon tetrachloride, non-detect to 0.70 ug/L (estimated) chloroform, and 0.21 ug/L (estimated) to 0.31 ug/L cis-1,2-dichloroethene.

Tree-cores were collected from 6 sites near the Hardeman County landfill in June 2009 to evaluate the use of volatile organic compound headspace analysis to characterize the areal extent of contaminants. The tree-core sample with the fewest and weakest detects was collected near a background spring east of Pugh Creek. Samples collected near contaminated seeps at Pugh Creek had more and stronger detects. Overall, VOCs in tree-cores collected down gradient of the landfill appear to be related to contamination from the landfill, but tree-cores from north of Clover Creek, a background area, show gas chromatography peaks similar to cores from some contaminated sites. Additional analyses will be required to determine if these results represent contamination from the landfill or some other source.

1 U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211 mbradley@usgs.gov
2 U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211 tdbyl@usgs.gov

WATER PROSPECTING VIA NON-INTRUSIVE GEOPHYSICAL METHODS

Laura S. Weir[1]*

Water is an essential and valuable resource. Well drilling is a common method of accessing this valuable resource, with drilling locations generally chosen at random. A random well drilling program can be very costly with all too often disappointing results. This is especially true for regions where water is seemingly hidden within bedrock fractures; where a few feet of distance on the surface means the difference between a “dry hole” and a high-yielding well. Technological advancements with geophysical instrumentation have dramatically increased the success of well placement for locating significant sources of potable water, specifically with the use of very low frequency (VLF) imaging.

Geophysical investigations are non-intrusive and can provide a method of imaging the subsurface utilizing real electrical, magnetic, or electromagnetic fields. A VLF survey utilizes very low frequency electromagnetic energy to locate fractures in bedrock, a potential source of water, since fractures tend to improve the permeability of bedrock. Data is collected in transects along the surface to provide a profile of the subsurface beneath each transect; several transects can be collected in an orthogonal pattern to provide a three-dimensional survey. Three-dimensional VLF surveys can be used to locate large fractures or fracture zones for placement of potable water production wells or environmental water quality monitoring wells.

Case studies have shown that VLF surveys can eliminate the guesswork in finding groundwater and help bring this valuable resource to within our reach.

[1] Project Manager, Civil & Environmental Consultants, Inc., 333 Baldwin Road, Pittsburgh, Pennsylvania 15205, lweir@cecinc.com

PREVIOUSLY-UNDESCRIBED HALF-KILOMETER-WIDE STRUCTURAL BASIN ALONG LYTLE CREEK, MURFREESBORO, CENTRAL TENNESSEE

Mark Abolins[1]

ABSTRACT

The investigator examined bedrock aquifers and aquitards of the Ordovician Stones River Group along a NW-SE traverse through western Murfreesboro, TN during August, 2009. The traverse extends upstream along Lytle Creek for a distance of 3.45 km from the confluence between Lytle Creek and the West Fork of the Stones River. The traverse crosses the upper ~14.3 m (~47 ft) of the Murfreesboro Limestone aquifer, the Pierce Limestone aquitard (~6.4 m or ~21 ft thick), and the lower ~17.4 m (~57 ft) of the Ridley Limestone (including aquifer and aquitard units). Along this traverse, the investigator recorded 82 structural attitudes with an average spacing of 48 m between observations. Bedding plane dips ranged from 0.3° to 8.8° and averaged 3.2°. The investigator also recorded the width of fissures and the spacing of bedding plane fractures. In combination, these observations revealed a previously-unrecognized basin measuring at least 520 m along the line of the traverse. The basin outcrops within an area previously-mapped as a homocline. The findings show that new surface geologic observations and, in particular, a high density of attitudes can reveal previously-unrecognized structures in the gently-dipping strata of central Tennessee.

INTRODUCTION

Gently-folded Ordovician platform carbonates underlie central Tennessee. Sub-surface investigations (Farmer and Hollyday, 1999) have revealed large inaccuracies in existing geologic maps (Galloway, 1919; Wilson, 1965) of three formations: the Murfreesboro Limestone (stratigraphically lowest), the Pierce Limestone, and the Ridley Limestone (highest). Previous investigators probably made mistakes because of the similar lithologies in these formations, poor exposure, gentle but complex folding, low topographic relief, and lack of topographic detail on base maps. Accurate surface geologic maps are of hydrogeologic interest because much of the Murfreesboro Limestone is an aquifer, the Pierce Limestone is an aquitard, and the Ridley Limestone includes a lowermost aquifer unit ("lower Ridley karst aquifer" of Crawford, 1988), an aquitard ("lower Ridley confining layer" of Crawford, 1988), and the upper Ridley Limestone aquifer.

The investigator has used novel techniques, GPS, and the Rutherford County, TN base map (1 foot contour interval) to map a 0.3 sq. km area near the confluence between Lytle Creek and the West Fork of the Stones River in Murfreesboro, TN (Abolins, 2008). In this report, the investigator describes new results from an area where the Galloway (1919) and Wilson (1965) maps disagree. The investigator made observations along a traverse (Figure 1) extending southeast from the confluence for 3.45 km along Lytle Creek. According to Wilson (1965), the Murfreesboro and Pierce Limestones underlie the entire traverse, and they strike a relatively uniform N5°W-N20°W and dip less than 1°SW according to a structure contour map based on the Wilson map (Moore and others, 1969). In contrast, Galloway (1919) shows Ridley Limestone beneath the center of the traverse implying greater structural complexity.

[1] Associate Professor, Department of Geosciences, Middle Tennessee State University, Murfreesboro, TN 37132
mabolins@mtsu.edu

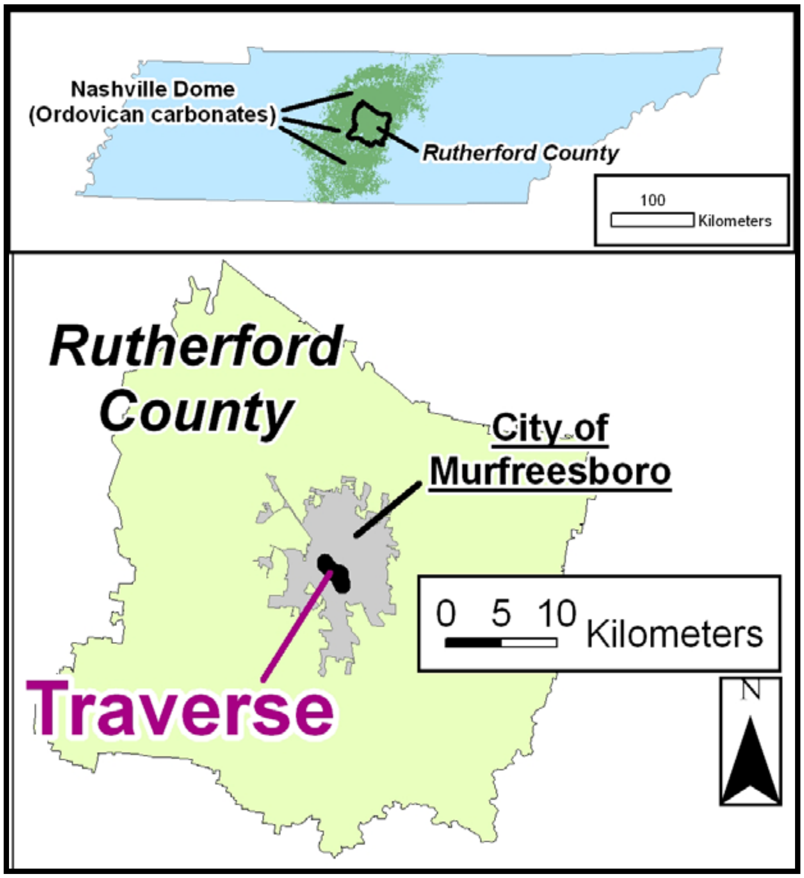


Figure 1. Location of Rutherford County within Tennessee (top) and of the traverse within the City of Murfreesboro (bottom).

To accurately describe structures along the traverse, the investigator measured 82 bedding plane attitudes with an average spacing of 48 m between stations. The investigator measured the attitudes during August, 2009 at a time of low flow and, consequently, extensive bedrock exposure in the channel and along the banks of Lytle Creek. At each observation station, the investigator placed a wooden board on a bed top and used a Macklanburg-Duncan SmartTool 24 inch digital level to identify a strike line (line of 0.0^{o} dip) on the board. He then used a Brunton pocket transit to measure the azimuth of the strike line, and he used the digital level to measure the dip of the board. The investigator obtained the topographic elevation of each station from the county base map (1 ft contour interval). He observed the width and spacing of any fissures because fissures are mostly developed within the aquifer units of the Murfreesboro and Ridley Limestones. Finally, he measured the spacing of bedding plane fractures because the fractures are generally more closely spaced in stratigraphic intervals which contain more clastic sediment (i.e., the Pierce Limestone aquitard and the lower Ridley confining layer). Observations are described below, and, in the Interpretation section, the investigator relates these observations to a previously-undescribed basin containing Ridley Limestone. As described in the Discussion section, the preceding interpretation suggests that the Wilson (1965) map is grossly inaccurate along part of the traverse.

OBSERVATIONS

Strata in the center of the traverse (1,352 m – 2,002 m from the northwest end) differ in mean dip and dip direction from strata at the ends (Figure 2). As shown on Figure 2, the traverse crosses ten structural domains and Domains 3, 4, and 5 are in the center ("central traverse"). Strike and dip are relatively constant within each domain but are different in adjacent domains. Specifically, within each domain 85% of strike measurements are within two standard deviations of the mean strike for that domain and 85% of dip measurements are within two standard deviations of mean dip. As recorded in Table 1, adjacent domains differ in strike, dip, dip azimuth, or some combination of the three:

- the mean strike of each domain differs from that of adjacent domains by at least 1.5 standard deviations,
- the mean dip differs from that of adjacent domains by at least 1 standard deviation,
- the dip azimuth differs by more than 135^o,
- or some combination of the above.

The central traverse has a higher mean dip (5.0^o as opposed to 3.2^o for the whole traverse) and the only dips greater than 7.0^o were measured in Domains 4 and 5 (Figure 3). In addition, Domains 3 and 4 dip to the southeast and northeast, respectively, differing in dip direction from all other domains, and Domain 5 and Domains 6-8 (immediately southeast of the central traverse) dip to the northwest unlike any other domains. Large differences in dip and dip direction between Domains 3 and 4 and Domains 4 and 5 define a pair of synclines which plunge more steeply and have smaller interlimb angles than the other seven folds along the traverse (Figures 4 and 5).

Because of the folding described in the preceding paragraph, the central traverse probably contains the youngest strata along the traverse: two carbonate aquifer units and an intervening aquitard unit (Figure 6). In the aquifer units, fissures are more than 10 cm wide and bedding plane fractures are more than 10 cm apart. In contrast, the aquitard generally lacks fissures and bedding plane fractures are less than 10 cm apart in places. Because the same lithologies are present in different units, formations are not easy to identify by direct observation, but, in the Interpretation section, the aquifer units are interpreted as the lower Ridley carbonate aquifer and upper Ridley Limestone and the intervening aquitard is interpreted as the lower Ridley confining layer.

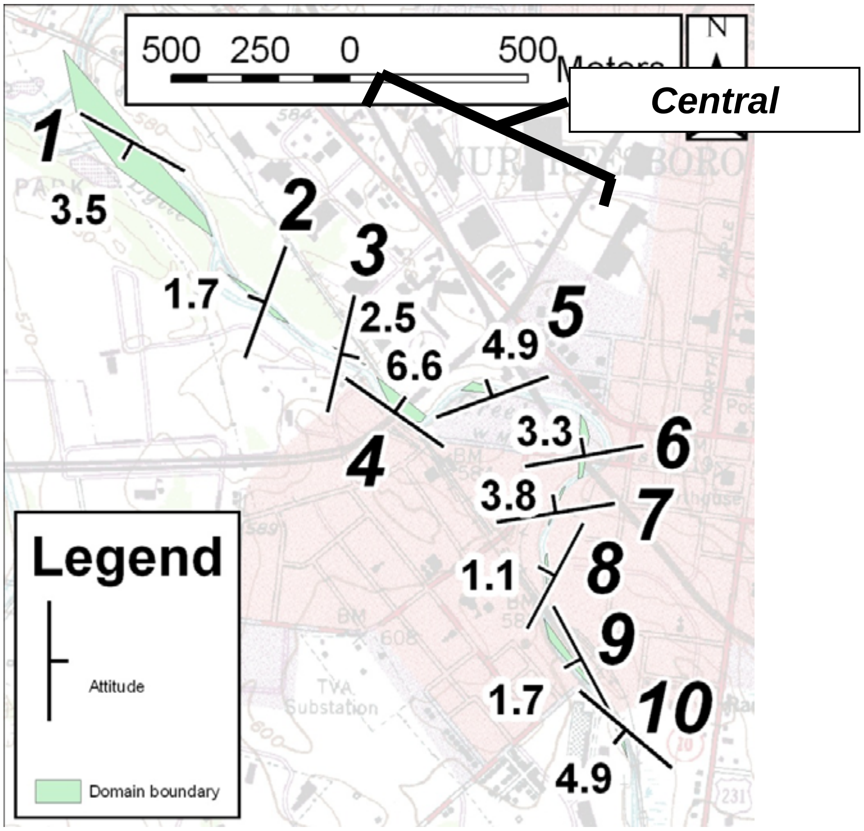


Figure 2. Mean strike and dip within each structural domain. See Figure 1 for location.

Domains	Differ in strike	Differ in dip	Differ in dip azimuth
1 and 2	X	X	
2 and 3			X
3 and 4	X	X	
4 and 5	X	X	
5 and 6		X	
6 and 7		X	
7 and 8	X	X	
8 and 9	X	X	
9 and 10		X	

Table 1. Differences between adjacent structural domains. See text for definitions of “differ in strike,” “differ in dip,” and “differ in dip azimuth.”

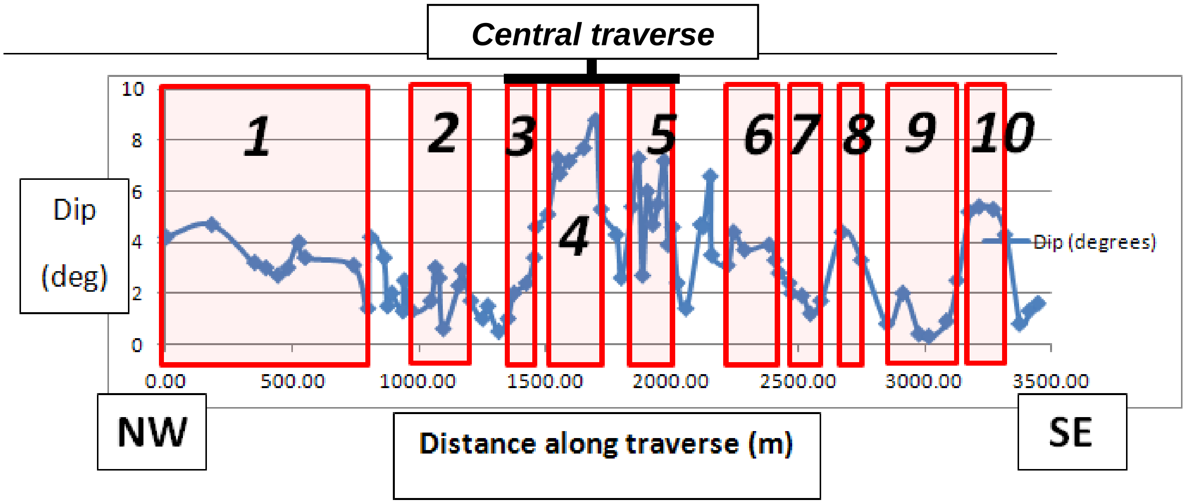


Figure 3. Dip of bedding in Domains 1-10. See Figure 2 for location of "central traverse."

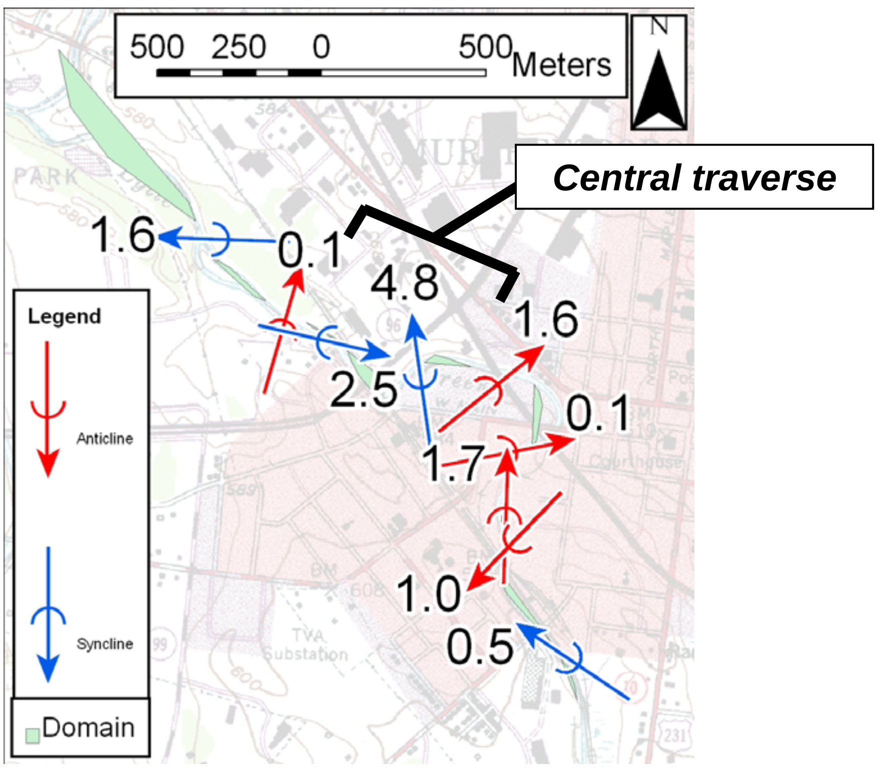


Figure 4. Fold axis orientation as calculated from domain means. See Figure 1 for location.

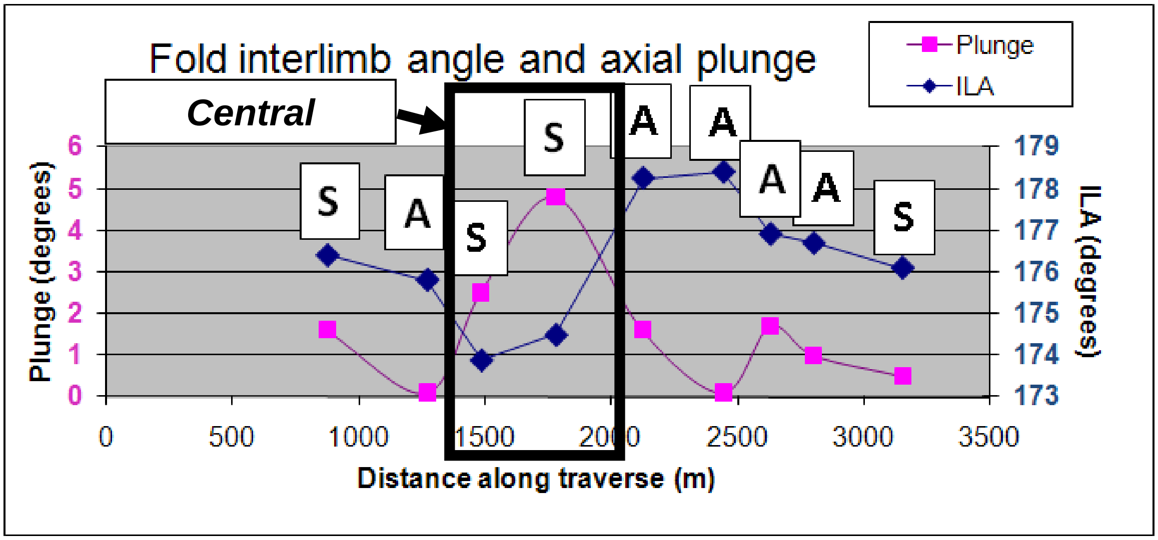


Figure 5. Plunge of fold axis and fold interlimb angle. Values calculated from domain means. S=syncline, A=anticline.

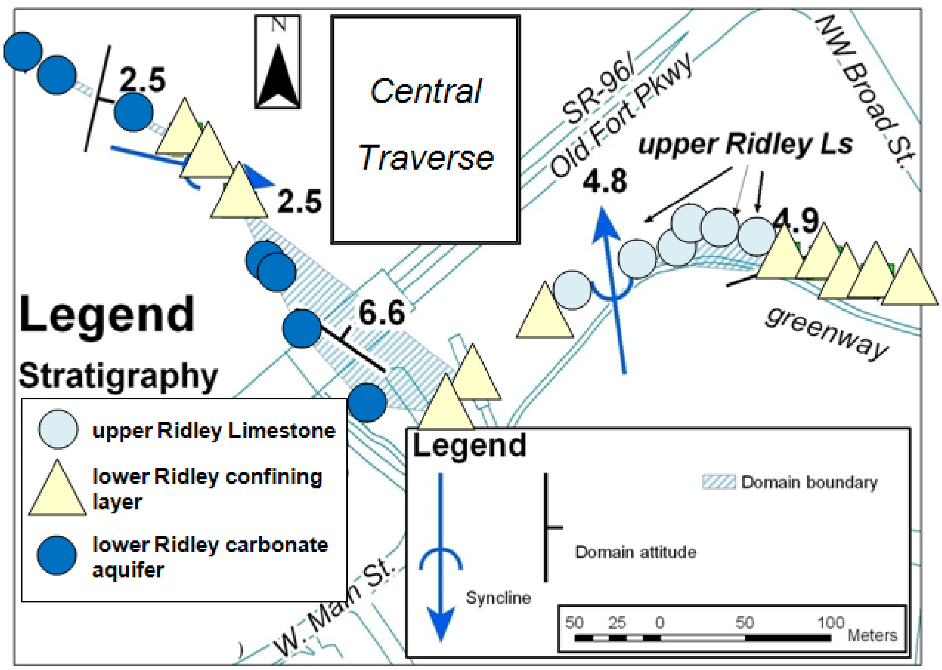


Figure 6. Geology of structure stations in the central traverse. See Figures 2 and 4 for location.

INTERPRETATIONS

Mean domain attitudes and fold orientations in the central traverse and dip directions in Domains 6-8 define either a part of a structural basin or a plunging syncline. Based on existing data, a basin is the preferred interpretation because existing maps (Wilson, 1965; Moore and others, 1969) suggest that strata dip southwest in areas northeast of the traverse. In the vicinity of the traverse, the basin is at least 520 m wide based on the straight line distance between Domains 3 and 7.

The basin contains two carbonate aquifer units and an intervening aquitard and these units are interpreted here as the lower Ridley carbonate aquifer (on the stratigraphic bottom), lower Ridley confining layer, and upper Ridley Limestone (on the top). The preceding interpretation is based on the stratigraphic elevation of the central traverse relative to the base of the Ridley Limestone. The Ridley, Pierce, and Murfreesboro Limestones outcrop along and near the northwest end of the traverse (0-550 m from the northwestern end) according to both Galloway (1919) and Wilson (1965), and the two maps show contacts in essentially the same places. Abolins (2008) confirmed the overall map pattern at the northwest end of the traverse (although he suggested that at least one contact on the Wilson map was mislocated by perhaps 40 m). Simple trigonometric calculations suggest that the stratigraphic elevation of outcrops in the central traverse are 4.0-17.4 m (13-57 ft) above the base of the Ridley Limestone, and the preceding stratigraphic elevations are typical of the upper part of the lower Ridley carbonate aquifer, lower Ridley confining layer, and the lower part of the upper Ridley Limestone (Crawford, 1988; Farmer and Hollyday, 1999). Figure 7 depicts the stratigraphic elevation of structure stations in the central traverse and elsewhere along the traverse.

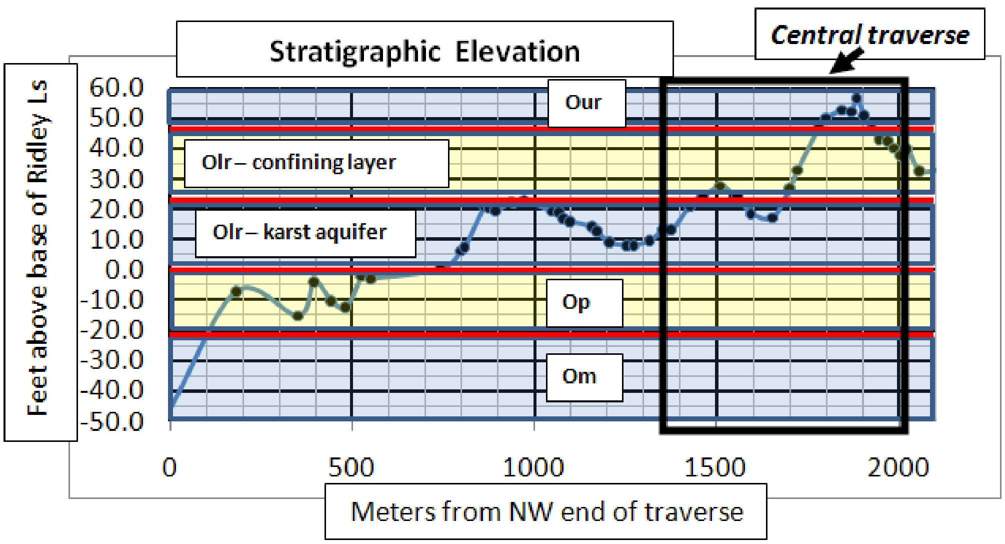


Figure 7. Stratigraphic elevation in feet above the base of the Ridley Limestone based on strike and dip measurements at stations (black dots) and the distance between stations. Om=Murfreesboro Limestone, Op=Pierce Limestone, Olr=lower Ridley Limestone, Our=upper Ridley Limestone.

DISCUSSION AND CONCLUSION

The structure of the central traverse and Domains 6 and 7 differs from the structure depicted on Wilson (1965) and the related Moore and others (1969) structure contour map. As described in the Observation section, strata dip to the northwest, northeast, and southeast in the preceding areas (see, for example, Figure 2) while the above mentioned maps depict a west-southwest dipping homocline. In contrast, the investigator only observed southwest dipping domains at the ends of the traverse. According to the Interpretation section, the geology of the central traverse differs from the geology depicted on the Wilson map. Simple trigonometric calculations suggest that the Ridley Limestone (including the lowermost upper Ridley Limestone) outcrops in and adjacent to the central traverse (see Figure 7), while Wilson shows the Murfreesboro and Pierce Limestones along the entire traverse. The observations and interpretations described in this report are more consistent with the Galloway (1919) map in so far as the Galloway map shows Ridley Limestone along Lytle Creek in the vicinity of the central traverse. However, direct comparison with the Galloway map is difficult because it lacks detail. This report shows how new surface geologic observations and, in particular, a high density of attitudes can reveal previously-unrecognized structures in the gently-dipping strata of central Tennessee.

ACKNOWLEDGEMENTS

This research was supported by a Middle Tennessee State University Faculty Research and Creative Activity Summer 2009 Grant to Mark Abolins.

REFERENCES CITED

Abolins, M., 2008, Improved surface geologic mapping of two carbonate aquifers and an aquitard within the Stones River Group, Murfreesboro, Tennessee, Proceedings of the Tennessee Section Meeting of the American Water Resources Association, p. 2C-3 – 2C-10.

Crawford, N.C., 1988, Karst hydrology investigation in the vicinity of the Campus-Injector Complex for the proposed middle Tennessee site for the Superconducting Super Collider, Tennessee Div. of Geology, 27 p., 7 plates.

Galloway, J.J., 1919, Geology and natural resources of Rutherford Co., TN, Tennessee Div. of Geology, Bull. 22, 81 p.

Farmer, J.J. and Hollyday, E.F.P., 1999, Regional Subsurface Correlation of the Pierce Limestone and Adjacent Limestones of Middle Tennessee, Tennessee Div. of Geology Report of Investigations 47, 21 p.

Moore, G.K., Burchett, C.R., and Bingham, R.H., 1969, Limestone hydrology in the upper Stones River Basin Central Tennessee, Tennessee Dept. of Cons., Tennessee Div. of Water Res. And the USGS, Nashville, TN, 58 p., 3 plates.

Wilson, Jr., C.W., 1965, Geologic Map and Mineral Resources Summary of the Murfreesboro Quadrangle, TN: Tennessee Div. of Geology, Nashville, TN.

Power Point File of Presentation

FLUORESCENT DYE INTERACTIONS WITH GROUNDWATER CONTAMINANTS AND REMEDIATION CHEMICALS

Priscilla Baker[1], Laura Kreitzer, and Katherine Rush

Fluorescent dye tracing is the standard practice for mapping groundwater flows in karst terrane. Often dye tracing is carried out in areas of groundwater contamination, where it is used to determine contamination sources and impacted areas, and used to develop remediation plans. While dyes used in groundwater tracing are largely non-reactive, remediation chemicals and compounds in contaminated water have infrequently been suspected of degrading dyes.

Crawford Hydrology Laboratory tested the interactions of fluorescent dyes with common groundwater contaminants and remediation compounds. Fluorescein (FL), eosine (EO) and sulphorhodamine B (SRB) dyes were tested against trichloroethylene (TCE), a groundwater contaminant, and the remediation compounds hydrogen peroxide (H_2O_2) and potassium permanganate ($KMnO_4$).

EO and SRB exhibited significant degradation over time when in contact with hydrogen peroxide, though SRB experienced less degradation. TCE had no significant effect on either EO or SRB. FL and SRB exhibited significant degradation in the presence of potassium permanganate, though SRB demonstrated more tolerance to the remediation compound.

Based on these results, the presence of potassium permanganate and hydrogen peroxide during a dye trace may compromise the results of the trace. Therefore, dye tracing should be carried out before the introduction of these remediation compounds. TCE should not negatively impact the ability to conduct a successful dye trace.

[1] Crawford Hydrology Laboratory, Western Kentucky University

USING GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES TO ANALYZE KARST TERRAIN IN SELECTED RED RIVER SUB-WATERSHEDS, TENNESSEE AND KENTUCKY

David E. Ladd[1]

Karst features, such as closed depressions and their catchments, present challenges to natural-resources management and topographic analysis. Diversion and collection of surface-water runoff by these features can complicate analyses of stream and groundwater flow, recharge, and contaminant transport. In karst areas, some component of runoff is diverted to closed depressions that drain to and recharge groundwater at various rates, affecting the amount of runoff reaching streams and providing potential pathways for contaminant entry to a groundwater system.

Much of the Red River watershed in north-central Tennessee and south-central Kentucky is characterized by karst terrain. Little is known about the number, catchment area, storage capacity, and drainage rate of closed depressions that occur in the Red River watershed. Only a small part of the Red River watershed has been dye-traced to map subsurface flowpaths. Additional study in the area could aid in water-resources protection by helping to identify sources of impairment to streams and improving definition of the groundwater/surface-water interaction. Crucial components of water-resources protection in karst areas such as the Red River watershed include the delineation of features such as depressions and depression catchments, understanding of the potential storage and contaminant-transport capacities of depressions, understanding of the rate of contaminant transport through karst features to groundwater, and determining the fate of contaminants once they enter a groundwater system.

Geographic Information System (GIS) techniques applied to digital elevation data provide oa means to automate the identification of karst features at local and regional scales. The spatial distribution, storage characteristics, and contaminant-transport potential of karst features derived from GIS analysis of digital elevation data can be used to evaluate the possible influences of these features on the hydrologic response and contamination of streams. If the amount of runoff diverted into a depression during a storm event exceeds the depression drainage rate, flooding may occur. A flooded depression that can no longer accept water may divert storm flow back to runoff. Calculations of depression storage volume and catchment area provide an estimate of the rainfall required to fill a closed depression. Depressions with low storage capacity will flood and spill quickly where connections to groundwater systems are poor; thus, these depressions are less likely to transmit significant amounts of water and potential contaminants from runoff to groundwater during storm events. Depressions with high storage capacity are less likely to spill regardless of their ability to transmit runoff to a groundwater system. These depressions have the potential to collect more runoff than low-storage capacity depressions, and they can rapidly recharge a groundwater system if well connected hydraulically. GIS techniques to define which depressions are most likely to transmit substantial runoff to groundwater can be applied to prioritize areas needing further study. These techniques might then reduce the number of dye-tracer tests necessary to establish predominant subsurface flowpaths. When applied at a statewide or regional scale, they might also help define groundwater basins and surface-water/groundwater interactions at lower cost.

Although much can be learned by applying GIS techniques to study karst systems, analysis of digital elevation data will not provide all of the information necessary to determine the influences that closed depressions have on stream flow and groundwater recharge. Field work is required to determine

[1] Hydrologist, U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211; email: deladd@usgs.gov

depression drainage rates and depression/discharge-point connections. To this end, the U.S. Geological Survey (USGS), in cooperation with the Tennessee Department of Environment and Conservation (TDEC), is applying GIS terrain analysis and field methods to identify karst features, to characterize the surface-water/groundwater connectivity and contaminant-transport potential of these features, and to determine the fate of contaminants that enter these features in support of water-resources protection in selected sub-watersheds of the Red River in Tennessee and Kentucky.

URBAN GROWTH 2001-2009 NEAR PUCKETT AND OVERALL CREEKS, STONES RIVER WATERSHED, RUTHERFORD COUNTY, TN

Mark Abolins*[1], Ph.D.; Jordan Graw[1]; Christina Nicholas[2]; Erica Cathey[3]; and Taylor Bailey[4]

ABSTRACT

A Middle Tennessee State University Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP-MT) faculty/undergraduate/high school team created a new land cover/land use map of a ~10 sq. km area in Rutherford County, TN during an eight week interval in the summer of 2009. The new map has a 30 m cell size and includes areas surrounding Puckett and Overall Creeks where they flow through the Blackman area in and adjacent to the northwestern part of the City of Murfreesboro. Map classes include high intensity developed, low intensity developed, agricultural, forest, bare earth, and quarry. The map is based entirely on a May 31, 2009 Landsat 5 image and a June 2009 county roadmap. July 2009 field investigations and air photo observations at 519 randomly-located sites show that the new map has an accuracy of 73%-82%. The new map shows that developed land increased from ~21% in 2001 to 46%-57% in 2009. At that rate of growth, the study area would likely be at least 76% developed and probably >90% developed by 2020.

INTRODUCTION

The Blackman area in and adjacent to northwestern Murfreesboro, TN is of hydrologic interest because Puckett and Overall Creeks, two tributaries of the Stones River, flow through it. Both had relatively good water quality as of 2002 (Goodhue and others, 2002), but the area has developed rapidly since then and the potential for urban impacts is much greater now. How much of the area was covered by developed land in 2009 and by what year might developed land cover the entire area? A Middle Tennessee State University Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP-MT) team investigated the preceding questions during the Summer of 2009. The team included the first author (a Geosciences professor), a Geosciences undergraduate, a Physics and Astronomy undergraduate, a high school biology teacher, and a high school student. The National Science Foundation funds STEP-MT and the budget, overall organization, and timeline were set by STEP-MT administrators, but the team had considerable freedom in choosing the research topic and study area and developing a methodology. During an eight week interval, the team made a land cover/land use (LCLU) map of an approximately 10 square kilometer area and verified its accuracy at 519 randomly-located sites. The study area, map-making methodology, and results (including accuracy assessment) are described in separate sections below. Then, in the discussion section, the authors briefly compare the results with two year 2020 growth scenarios developed by Portland, OR-based planners Fregonese, Calthorpe, and Associates (FCA) around 2001 (Cumberland Region Tomorrow, 2003).

[1] Department of Geosciences, Middle Tennessee State University, Murfreesboro, TN
[2] Siegel High School, Murfreesboro, TN
[3] Department of Physics and Astronomy, Middle Tennessee State University, Murfreesboro, TN
[4] Blackman High School, Murfreesboro, TN

STUDY AREA

The study area (Figure 1) includes approximately 10 sq. km in the general vicinity of Blackman High School in and adjacent to the City of Murfreesboro, Rutherford County, Tennessee. The northwestern part of the study area includes a forest and abandoned quarry north of State Route 840 and the eastern part of the study area includes The Avenue lifestyle center although these areas are regarded by many as outside Blackman. The preceding were included because some LCLU classification methods work best if the study area contains substantial amounts of every major LCLU type including forest and high intensity developed land. Politically, the study area is inside an urban growth boundary and it is currently a patchwork of city and county.

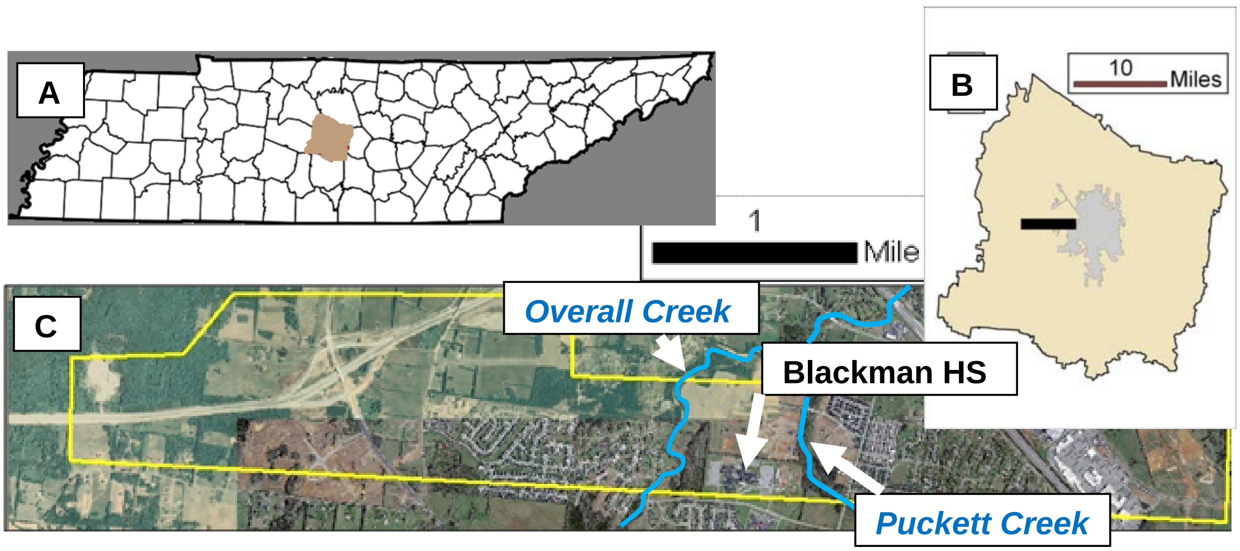


Figure 1. A. Location of Rutherford Cou nty (brown) within Tennessee. **B.** Within Rutherford County, location of the study area (black rectangle) in and adjacent to northwestern Murfreesboro (gray). **C.** Map accuracy was assessed inside the yellow polygon.

METHODOLOGY

The LCLU map is based entirely on a May 31, 2009 Landsat 5 scene (30 m cell size) and a June, 2009 Rutherford County, TN road map. The authors developed an original map-making protocol, but their protocol incorporates many methods (e.g., the tasseled cap transform) used to create the National Landcover Dataset 2001 (Homer and others, 2004). The map-making details are mostly beyond the scope of this report and involved unsupervised, supervised, and fuzzy classification of the Landsat scene as well as the calculation of a road density map, a normalized difference vegetation index (NDVI) image, band ratio images, and the greenness component of the tasseled cap transform. Of the preceding, unsupervised classification was the primary classification method and the other classification methods and images improved classification accuracy. For example, the cells with the highest NDVI were (with almost no exceptions) forest and the preceding was true even if the cells did not cluster with other forest cells in the unsupervised classification. Similarly, cells having a high road density and meeting other criteria (e.g., clustering with agricultural land in the unsupervised classification) were classified as low intensity developed with little error. The LCLU map and its accuracy are described in the next section.

RESULTS

The LCLU map (Figure 2) depicts six classes: high intensity developed, low intensity developed, agricultural, forest, bare earth, and quarry. Developed land covers the largest area (roughly half of the entire study area) and most of the developed land is low intensity. In contrast, bare earth and quarry (bare rock) cover only small areas and quarry is almost entirely confined to the abandoned quarry in the northwestern part of the study area. The LCLU classes are described briefly below.

- High intensity developed land includes commercial development (e.g., The Avenue), parts of school sites, wide roads (e.g., Interstate 24 and State Route 840) and, probably, some medium intensity developed land (i.e., developed areas having 50-79% impervious cover).
- Low intensity developed land is primarily residential, developed open space (e.g., large lawns), and two lane roads (e.g., Beesley Road), but probably includes some medium intensity developed land.
- Agricultural land includes cropland and pasture.
- Bare earth is mostly at construction sites.
- Quarry is bare rock and is almost entirely confined to the abandoned quarry in the northwestern part of the study area.
- Forest areas are those in which trees comprise greater than 20% of vegetative cover.

Air photo and field observations show that the LCLU map is 73-82% accurate. Accuracy was assessed at 519 randomly-located 90 m X 90 m sites by two independent interpreters. The interpreters examined all of the sites on digital orthophotos. (Most of the photos were acquired in April, 2009 although photos of the northwestern part of the area were acquired in 2007.) The interpreters also visited almost all of the sites on the ground during early July, 2009. For accuracy assessment, bare earth and quarry were included in the developed high intensity class because the areas covered by these two classes were too small to contribute meaningful statistics. Finally, the bootstrap method was used to calculate 95 percent confidence intervals. One interpreter found that the map is 73-80% accurate and the other found that the map is 75-82% accurate, indicating an overall accuracy of roughly 73-82%.

Developed land covered 46-57% of the study area in 2009 (Figure 3 - top). In contrast, developed land covered only 21% of the study area in 2001 (Figure 3 - bottom) according to the National Landcover Dataset 2001 (NLCD 2001). If NLCD 2001 is approximately 73% accurate within the study area – a reasonable assumption based on its accuracy at other locations (Homer and others, 2004) – then the study area was 18-24% developed in 2001 and low and high estimates for growth between 2001 and 2009 are (46%-24%)/(8 years) = 2.8%/year and (57%-18%)/(8 years) = 4.9%/year. The preceding growth rates suggest that developed land will completely cover the study area sometime between 2009+(100%-57%)/4.9% = 2018 and 2009+(100%-46%)/2.8% = 2029. A middle growth rate [(52%-21%)/(8 years) = 3.9%/year] suggests that all of the land will be developed by roughly 2009+(100%-52%)/3.9%) = 2021.

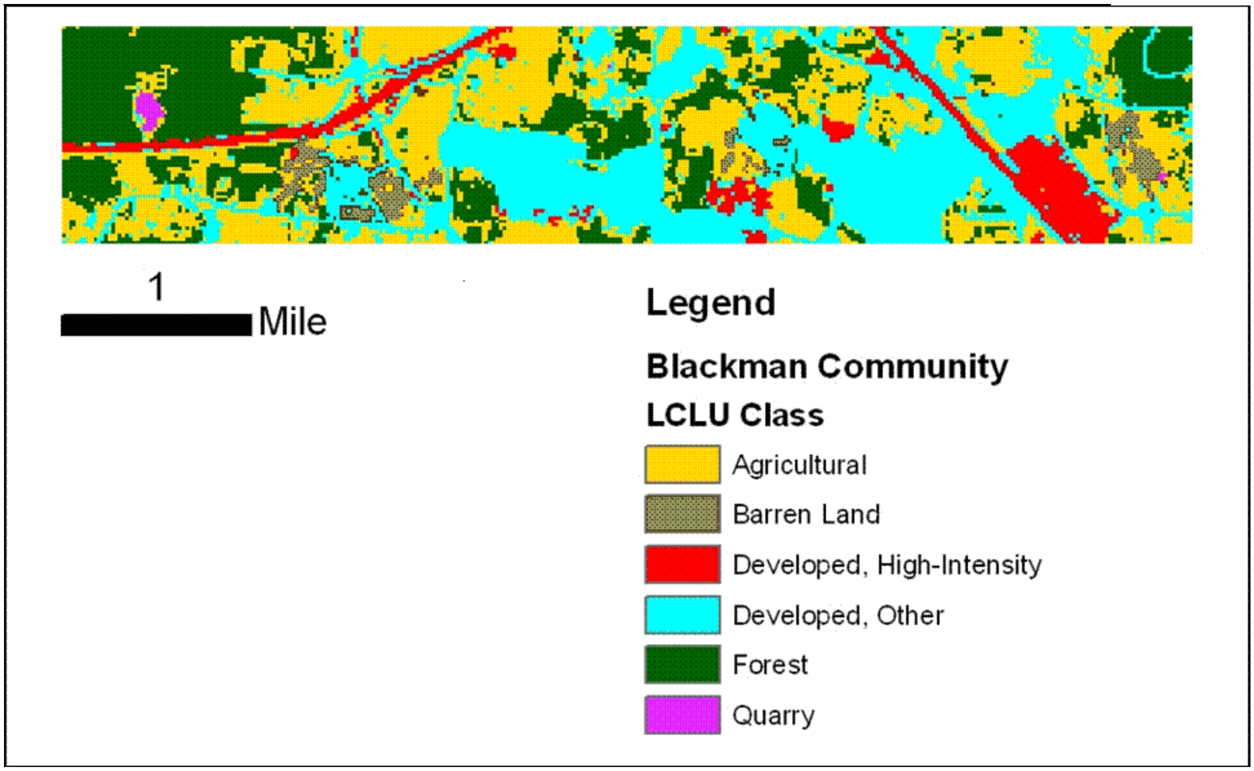


Figure 2. Land cover/land use map of parts of the Blackman community and adjacent areas. See Figure 1 for location. Note that "Developed, Other" is mostly low intensity developed land. North is at the top of the map.

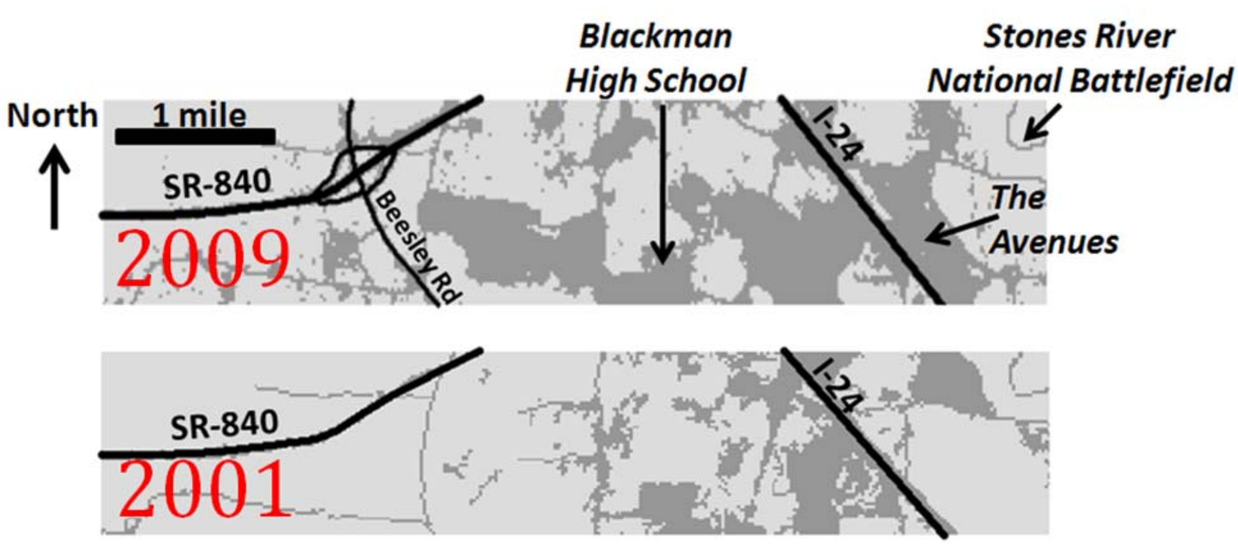


Figure 3. Developed land (all developed classes) in 2009 (top) and 2001 (bottom).

DISCUSSION

The early (2018) and middle (2021) estimates for complete development of the study area agree with predictions made around 2001 by Portland, OR-based planners Fregonese, Calthorpe, and Associates (FCA). Under a contract with non-profit Cumberland Region Tomorrow, FCA developed maps of growth in the ten-county area including and surrounding Nashville-Davidson County, TN (Cumberland Region Tomorrow, 2003). FCA analyzed public and proprietary geospatial data and consulted with area growth experts to develop a “Base Case” year 2020 scenario based on then-existing trends, and they predicted that almost all of the land in the study area would be developed by that date. Although the data and methods described in this paper cannot preclude a later date (2029) for complete development, the study area would still be 46%+(2.8%/year)(11 years) = 76% developed in 2020. While all of the calculations in this paper are simplistic and linear, they suggest that the study area has grown considerably between 2001 and 2009 and that the area will be largely developed by 2020 as predicted by FCA.

Could less development happen during the years ahead? In public workshops held by FCA around 2000, many participants opposed further development within the study area. On an “Alternative Case” year 2020 map based on their preferences, FCA depicted almost no development in the study area except for a little “rural residential,” “conservation rural,” and, in roughly the area where The Avenue lifestyle center now exists, a little industrial development. According to the results described in this paper, more growth has already happened than was shown on the Alternative Case map, but the preferences embodied by that map could still shape future growth.

CONCLUSION

Much urban growth happened near Puckett and Overall Creeks in the Blackman area in and adjacent to northwestern Murfreesboro, TN between 2001 and 2009. The amount of developed land grew from approximately 21% in 2001 to 46-57% in 2009. Simple linear extrapolation suggests that the study area will be at least 76% developed and quite likely >90% developed by 2020. These findings show that, while Puckett and Overall creeks had relatively good water quality in 2002, the potential for urban impacts has increased and will likely continue to increase unless growth slows.

ACKNOWLEDGEMENTS

This investigation was supported by STEP-MT through a grant from the National Science Foundation to Middle Tennessee State University.

REFERENCES CITED

Cumberland Region Tomorrow, 2003, A report to the region, Nashville, TN, http://www.cumberlandregiontomorrow.org/getdoc/08f1759c-a9f8-48ab-b724-336dfd6fab48/CRT_03 (accessed 13 March, 2010)

Goodhue, A., Holland, J.E., Smith, J.R., Cochran, R.E., Duhl, D., Fathi, S., Vann, A., and Wang, S., 2002, Stones River Watershed (05130203) of the Tennessee River Basin Water Quality Management Plan, Nashville, TN, Division of Water Pollution Control, Tennessee Department of Environment and Conservation, http : / / www.state.tn.us/ environment/ wpc/ watershed/wsmplans/ stones/ (accessed 13 March, 2010)

Homer, C., Huang, C., Yang, L., Wylie, B., and Coan, M., 2004, Development of a 2001 National Land-Cover Database for the United States, Photogrammetric Engineering and Remote Sensing, v. 70, p. 829-840.

HOW TO RETRIEVE USGS HYDROLOGIC DATA FROM NWISWEB

Rodney R. Knight[1]

This presentation will show how to retrieve water-resources data from the U.S. Geological Survey's NWISWeb internet site (http://waterdata.usgs.gov/nwis). Several types of retrievals will be demonstrated. Examples will include (1) how to locate sites with specific data types of interest, (2) how to download a dataset of streamflow information, (3) how to download water-quality data for specific parameters, (4) how to import data directly into Microsoft Excel, and (5) how to automate web retrievals for multiple sites.

[1] Hydrologist, U.S. Geological Survey Tennessee Water Science Center, 640 Grassmere Park, Suite 100, Nashville, Tennessee, 37211

SESSION 3A

NEW STREAM DELINEATION RULES
8:30 a.m. – 10:00 a.m.

Legal Aspects
E. Yao (Abstract Not Available)

Training and Certification of Stream Delineators in Tennessee
Dan Eagar

Development of Stream Identification Protocols in Tennessee
Jimmy R. Smith

MEETING FUTURE WATER NEEDS THROUGH SUSTAINABLE SUPPLIES -- PANEL
10:30 a.m. – 12:30 p.m.

Tennessee's Approach to Regional Water Resource Planning: Meeting Future Water Needs Through Sustainable Supplies
Tom Moss and Paul Davis

Balancing Competing Uses for Comprehensive Regional Water Supply Plan in Central Tennessee
Thomas Dumm, George Rest, Doug Murphy, Joe Bishop, and Brian McCrodden

TRAINING AND CERTIFICATION OF STREAM DELINEATORS IN TENNESSEE

Dan Eagar

Last year's amendment to the *Tennessee Water Quality Control Act* charges the Department of Environment and Conservation (department) with developing a certification program for department staff and other persons who wish to become certified hydrologic professionals. Under the Act, Hydrologic Professionals are individuals who determine if a watercourse is classified as either a stream or wet weather conveyance for state regulatory purposes. The statute establishes that a hydrologic professional is a person holding a bachelors degree in biology, geology, ecology, engineering or related sciences, having at least five years of relevant experience in making hydrologic determinations, and having obtained certification from the department. Draft rules to establish a Hydrologic Professional certification program have been distributed to the public for comment, and the department is currently evaluating comments and revising the rules for submission to the Tennessee Water Quality Control Board for their consideration. The department is also developing a training program that will be a necessary part of the certification process. In certain circumstances, when a Certified Hydrologic Professional submits a determination to the department that a watercourse has been determined to be a wet weather conveyance, there is a presumption that the determination is correct unless it is challenged and refuted by the department within a specified time frame.

DEVELOPMENT OF STREAM IDENTIFICATION PROTOCOLS IN TENNESSEE

Jimmy R. Smith[1]

The Division of Water Pollution Control's (WPC) need to characterize the hydrologic status of watercourses has its roots in the early days of establishing the NPDES program in Tennessee in the late 1970's. With the development of the Aquatic Resource Alteration Permit program in the 1980's, and the promulgation of state and local stormwater regulations in the early 2000's, the need to accurately and consistently characterize watercourses became even more important. Whether a watercourse flowed perennially, intermittently, or only carried storm runoff was important in making regulatory decisions involving discharging into, altering, or establishing buffers on Waters of the State.

Throughout this time period, the Division's methodologies and guidance on how to make these hydrologic determinations (HDs) continued to evolve, until in 2009, the General Assembly enacted *Public Chapter 464*. This new law largely codified the regulatory treatment of wet weather conveyances, and instructed the Division to develop new rules and guidance concerning the standard technical procedures used in making hydrologic determinations. This presentation will briefly examine some of the issues surrounding making field HDs using the standard TDEC protocols, as currently proposed.

Although there are many legal and scientific definitions and concepts involved in making jurisdictional HDs for regulatory purposes, the following three are perhaps the most important:

"*Waters of the State*" means any and all water, public or private, on or beneath the surface of the ground, that are contained within, flow through, or border upon Tennessee or any portion thereof, except those bodies of water confined to and retained within the limits of private property in single ownership that do not combine or effect a junction with natural surface or underground waters [T. C. A. § 69-3-103]
"Wet Weather Conveyances" are man-made or natural watercourses, including natural watercourses that have been modified by channelization: that flow only in direct response to precipitation runoff in their immediate locality; whose channels are at all times above the groundwater table; that are not suitable for drinking water supplies; and in which hydrological and biological analyses indicate that, under normal weather conditions, due to naturally occurring ephemeral or low flow there is not sufficient water to support fish, or multiple populations of obligate lotic aquatic organisms whose life cycle includes an aquatic phase of at least two months. [Section 1 of P. Ch. 464 of the Acts of 2009]
"Stream" means a surface water that is not a wet weather conveyance. [Section 1 of P. Ch. 464 of the Acts of 2009]

For linear watercourses, the core WPC jurisdictional distinction is "stream" vs. "wet weather conveyance" (WWC). The standard procedures involved in HDs are geared toward determining if a watercourse fits the WWC definition or not. The definition of a "stream" is an inverse one – that is, all surface watercourses that are <u>not</u> WWCs are streams. The definition of a WWC has 4 characteristics, and all must be met to be considered a WWC. If any one of the characteristics is not met, the watercourse must be considered a stream.

The developed HD protocols are based on the scientific fields that inform our understanding of the natural processes that create, maintain, and shape surface water features, as well as the applicable regulatory language involved in jurisdictional status. They also reflect the fact that, due to the nature of the overall

[1] TNDEC, Water Pollution Control

WPC regulatory program, an HD evaluation may be restricted to a single field investigation, and may be conducted under inopportune climate conditions.

Much of the field HD investigative process relies on the underlying scientific principle that, in general, watercourses that in a normal year carry surface flow for extended periods of time are more likely to develop certain physical, hydrological, or ecological characteristics than are WWCs that flow only in direct response to precipitation. Although a WWC may exhibit some degree of these indicators, in general, indicators will be stronger and more prevalent the more persistent the in-channel flow. Some specific combinations of indicators may rise to the level of being considered definitive in all but the most anomalous situations.

Core portions of the HD guidance and standard protocols are reflected in the *Hydrologic Determination Field Data Sheet (HD Field Sheet)*, reproduced below. It outlines the many field indicators that will inform an HD, and breaks them into primary and secondary categories. Much of the design of the *HD Field Sheet* and the protocol as a whole is based upon concepts and methodologies originally developed and revised by the North Carolina Division of Water Quality since 1997, which have been currently adopted whole or in part by many other regulatory agencies. In particular, the scoring index and much of the guidance language concerning the Secondary Field Indicators is taken directly from the *NC DWQ Identification Methods for the Origins of Intermittent and Perennial streams, Version 3.1*.

Hydrologic Determination Field Data Sheet
Tennessee Division of Water Pollution Control, Version 1.0

County:	Named Waterbody:	Date/Time:
Assessors/Affiliation:		Project ID :
Site Name/Description:		
Site Location:		
USGS quad:	HUC (12 digit):	Lat/Long:
Previous Rainfall (7-days) :		
Precipitation this Season vs. Normal : very wet wet average dry drought unknown		
Watershed Size :	Photos: Y or N (circle) Number :	
Soil Type(s) / Geology :		
Surrounding Land Use :		
Degree of historical alteration to natural channel morphology & hydrology (circle one & describe fully in Notes) : Severe Moderate Slight Absent		

Primary Field Indicators Observed

Primary Indicators	**NO**	**YES**
1. Hydrologic feature exists solely due to a process discharge		WWC
2. Defined bed and bank absent, dominated by upland vegetation / grass		WWC
3. Flow absent anytime during February through April, under normal precipitation / groundwater conditions		WWC
4. Substantial evidence that feature only flows in direct response to rainfall		WWC
5. Presence of lotic benthic organisms with ≥ 2 months aquatic phase		Stream
6. Presence of fish (use caution if only *Gambusia* is present)		Stream
7. Obvious presence of naturally occurring groundwater connections (springs)		Stream
8. Flowing water in channel and 7 days since last precipitation in local watershed		Stream

NOTE : If any Primary Indicators 1-8 = "Yes", then STOP; determination is complete.

In the absence of a Primary Indicator, or other definitive evidence, complete the Secondary Indicator table on page 2 of this sheet, and provide score below.

Guidance for the interpretation and scoring of both the Primary & Secondary Indicators is provided in: *TDEC-WPC Standard Procedures for the Identification of Wet Weather Conveyances and Streams, Version 1.0*

Overall Hydrologic Determination =

Secondary Indicator Score (if applicable) =

Justification / Notes :

Secondary Field Indicators

A. Geomorphology (Subtotal =)	**Absent**	**Weak**	**Moderate**	**Strong**
1. Continuous bed and bank	0	1	2	3
2. Sinuous channel	0	1	2	3
3. In-channel structure: riffle-pool sequences	0	1	2	3
4. Sorting of soil textures or other substrate	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9. Natural levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley or drainageway	0	0.5	1	1.5
13. At least second order channel on existing USGS or NRCS map	No = 0		Yes = 3	

B. Hydrology (Subtotal =)	**Absent**	**Weak**	**Moderate**	**Strong**
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and >48 hours since rain	0	1	2	3
16. Leaf litter in channel (January – September)	1.5	1	0.5	0
17. Sediment on plants or on debris	0	0.5	1	1.5
18. Organic debris lines or piles (wrack lines)	0	0.5	1	1.5
19. Hydric soils in stream bed or sides of channel	No = 0		Yes = 1.5	

C. Biology (Subtotal =)	**Absent**	**Weak**	**Moderate**	**Strong**
20. Fibrous roots in channel [1]	3	2	1	0
21. Rooted plants in channel [1]	3	2	1	0
22. Crayfish in stream (exclude in floodplain)	0	0.5	1	1.5
23. Bivalves/mussels	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
26. Macrobenthos (record type & abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus	0	0.5	1	1.5
29.Wetland plants in channel [2]	FAC = 0.5; FACW = 0.75; OBL = 1.5; SAV =2.0; Other = 1			

[1] Focus is on the presence of upland plants. [2] Focus is on the presence of aquatic or wetland plants.

Total Points = ____________
Watercourse is a Wet Weather Conveyance if Secondary Indicator Score < 19 points

Notes :

The indicators included on the Field Sheet are broken into two categories – Primary and Secondary. Primary Indicators are individual or combinations of field characteristics that under normal circumstances and in the absence of any directly contradictory evidence are considered to be definitive for jurisdictional determination purposes. Primary Indicators are typically very conclusive evidence, and allow for an immediate HD end-point to be reached, without further evaluation of Secondary Indicators.

If none of the Primary Indicators are present at the time of the investigation, the investigator must then evaluate the overall strength of evidence provided by the Secondary Indicators along the watercourse in question in order to make a determination. This process is again based on the principle that over the long-term, the longer the duration of continuous stream flow in a stream channel, the stronger the corresponding observed field indicators are likely to be. All stream systems are characterized by interactions among hydrologic, geomorphic (physical) and biological processes, and attributes of these three processes are used to produce a numeric score. Secondary Indicator scores less than 19.0 indicate the channel carries only stormflow ephemerally, and is therefore a wet weather conveyance, whereas scores 19.0 or greater indicate that the channel is at least an intermittent stream. Detailed guidance describing the individual primary and secondary indicators, and how to evaluate each one, along with specific examples and photographs is contained in the proposed TDEC standard protocol manual.

Prior to conducting a field evaluation, the investigator should always review the recent precipitation patterns for the local area, the longer-term seasonal precipitation trends, and any other available information such as historic land-use, regional geology and soil types, or previous HDs near the site. Because of longitudinal variability, HDs should not be made on a single point without first looking upstream and downstream for indicators available along the watercourse. In general, several hundred feet of channel should be evaluated before making a determination.

Given the wide range of stream types, physiographic regions, land uses, and natural diversity found across Tennessee, it would be impossible to create detailed written policy that would cover every possible site-specific scenario that may be encountered when making HDs. However, certain confounding issues are more commonly encountered, and require more frequent jurisdictional interpretation. General guidelines on how to deal with several of the more commonly encountered variants are provided in the proposed guidance, including : sinking / losing stream reaches; delineating stream origins / transition breakpoints; wetland-stream interconnection; impoundments / ponds; historic & recent alterations; and exposed groundwater.

TENNESSEE'S APPROACH TO REGIONAL WATER RESOURCE PLANNING: MEETING FUTURE WATER NEEDS THROUGH SUSTAINABLE SUPPLIES

Tom Moss[1] and Paul Davis[2]

INTRODUCTION

The Tennessee Department of Environment and Conservation is partnering with the U.S. Army Corps of Engineers, the Tennessee Advisory Commission on Intergovernmental Relations, the USGS, The Nature Conservancy and others to develop a water resources regional pilot plan in each of two areas of the state. The study will assess the existing water resources for the two specific areas and project the preferred alternative for water supply to meet future needs.

The purpose of this paper will be to present and discuss the two pilots, and more broadly to discuss the model for regional water resource planning in Tennessee that is being developed through this process. It is anticipated that this paper could be presented as part of series, with companion presentations from others who are also involved in the development of the pilot plans, such as USGS, The Nature Conservancy, modeling consultant Hydrologics, USACOE, or TACIR.

MODEL REGIONAL WATER RESOURCE PLANS

The benefits of a regional water plan have been discussed and recommended by the department's Water Resources Technical Advisory Committee. See http://tn.gov/environment/boards/wrtac/. In order to develop a process and demonstrate the utility of regional planning, two pilot areas were selected for initial planning efforts. Those two pilot areas are North Central Tennessee, including Portland, Gallatin, Castalian Springs, Bethpage, White House and Westmoreland and the South Cumberland Plateau consisting of portions of Franklin, Grundy, Marion and Sequatchie counties and the towns of Tracy City, Sewanee, Altamont and Monteagle.

At this point, the Corps of Engineers has completed Phase I of the pilot, which focused on the collection of existing background data for the study area. A series of meetings was held over the summer and early fall 2009 to introduce these communities to the regional planning process and to provide participants with the opportunity to ask questions about the information presented. In addition to the general public, mayors, water department management, planners, county commissioners and other local elected officials attended these meetings.

We continue to work on the next phases of the pilot that will include the steps required for us to recommend a preferred alternative for meeting the future water supply needs of the region. The current focus is on developing the water availability data and water demand projections, using baseline data from the utilities and some modeling. We are gathering input from the public on alternatives to be considered.

It is anticipated that actual compilation and writing of the pilot plans, a task that is being undertaken by the Tennessee Advisory Commission on Intergovernmental Relations, will be well underway by the date of presentation.

[1] Tom Moss, Acting Director, TDEC, Division of Water Supply, 615-523-0170, tom.moss@tn.gov
[2] Paul Davis, Director, TDEC, Division of Water Pollution Control, 615-532-0632, paul.estill.davis@tn.gov

BALANCING COMPETING USES FOR COMPREHENSIVE REGIONAL WATER SUPPLY PLAN IN CENTRAL TENNESSEE

Thomas Dumm[1], PE, George Rest[1], PE, Doug Murphy[2], Joe Bishop[3], PE, and Brian McCrodden[4], PE

ABSTRACT

Droughts and competing uses for existing water supplies in recent years have fostered creative approaches to water supply planning in the eastern United States. In central Tennessee, O'Brien & Gere, CTI Engineers, and HydroLogics have been working with the Tennessee Duck River Development Agency to address the potable water needs of a five-County region through 2060. Normandy Reservoir is located in the upper portion of the Duck River watershed and reached record low water levels during the 2007 drought. This drought highlighted the complicated balance of the competing uses for the Duck River which include wasteload assimilation, environmental flow for threatened and endangered species, municipal and industrial water supply, irrigation, and recreation. The Duck River is nationally recognized as one of the most biologically diverse rivers in the United States. The key study objectives include development of a plan for water supply that is environmentally sustatinable (i.e., maintains or improves biodiversity) and socially beneficial by recognizing basic human needs and the benefits for the region.

This presentation will include a chronology of the challenges and findings from the comprehensive regional water supply plan including:

- Defining water demands and available water supplies based on reservoir/river constraints (i.e., instream flows for protection of a multitude of uses) over a 50-year period.
- Evaluating over 40 water supply alternatives using decision-making tools to address the following factors: reliable capacity, water quality, cost, potential delays due to permitting, flexibility, environmental benefits, and recreation.
- Addressing equity issues among several water utilites.
- Conducting highly-effective workshops and making critical decisions with the public and agencies personnel present.

INTRODUCTION

The Tennessee General Assembly created the Tennessee Duck River Development Agency (DRA) in 1965 as a comprehensive regional development agency. Its broad powers include the "control and development of the water resources" of those portions of the Duck River Watershed lying in Bedford, Coffee, Hickman, Marshall and Maury Counties. Any county or municipality in the Duck River Basin or any governmental entity from which flows any tributary stream of the river, or any county adjoining the river basin may become a sponsoring and participating entity. In 1998, the DRA Board of Directors adopted the following mission statement:

"To develop, protect, and sustain a clean and dependable water resource for all citizens of the Duck River region."

The DRA represents seven water utilities that serve approximately 250,000 people and industries that include car manufacturers, food processing plants, and other businesses utilizing water for production. In

[1] O'Brien & Gere, 8401 Corporate Drive, Landover, MD 20785
[2] Tennessee Duck River Development Agency, 210 E. Depot Street, Shelbyville, TN 37160
[3] CTI Engineers, 3354 Perimeter Hill Drive, Suite 140, Nashville, TN 37211
[4] HydroLogics, 811 Mordecia Drive, Raleigh, NC 27604

November 1999, the DRA/Water System partnership was further strengthened with the establishment of the Duck River Agency Technical Advisory Committee (DRATAC) which includes the water system managers. DRATAC provides advice, guidance and assistance to the DRA Board.

The DRA sponsored the formation of the Duck River Watershed Water Resources Council (WRC) in May 2002. The WRC is a voluntary group of over 25 federal, state and local agencies and private organizations working on water supply quantity and quality issues in the watershed. Its purpose is to foster cooperation and coordination of member's activities as they attempt to fulfill their missions relating to ground and surface water resources.

The DRA has undertaken a Comprehensive Regional Water Supply Plan for Bedford, Coffee, Marshall, Maury, and southern Williamson Counties (shown at left) to meet future water demands and address concerns with possible water shortages brought on by drought conditions. The goal is to develop a plan with a 50-year projection (through 2060) and a 100-year planning horizon that will provide direction to the DRA for the management of available water resources, including the implementation of specific water supply infrastructure projects. The plan will include specific recommendations, including budgets and implementation timelines, for water supply and water management projects.

The drought of 2007 highlighted the issue that in extended dry weather conditions the citizens of the Duck River Region primarily depend on the water stored in Normandy Reservoir to meet multiple uses, including drinking water, wastewater dilution, recreation and natural resource protection. The dramatic decrease in rainfall in 2007, combined with multiple uses of the reservoir and river, caused record low levels in Normandy Reservoir that resulted in temporary dam operational changes to protect all water uses. Weather patterns and growth have created the need for a comprehensive regional water supply plan for the Duck River Region.

STRATEGIC PLANNING TEAM

The DRA has assembled a Strategic Planning Team to develop a Comprehensive Regional Water Supply Plan. The Team consists of O'Brien & Gere (Prime Consultant), CTI Engineers, Inc. (Subconsultant), HydroLogics (Hydrologic Modeling), BDY Environmental, LLC (Environmental), and Trauger & Tuke (Legal). The Plan will provide direction to the DRA regarding the management of available water resources, including the implementation of specific water supply infrastructure projects.

NEEDS ASSESSMENT

The first step in the Comprehensive Regional Water Supply Plan is the assessment of the need for additional water supply. The needs assessment combines an estimate of public water use (demand) and an assessment of the availability of water supply.

Water demands were projected using studies by USGS and TVA, and population projections developed by the University of Tennessee Center for Business and Economic Research (CBER) which is viewed as an authoritative, independent source for demographic information. The demand projections use CBER data to estimate future water use assuming that the current mix of domestic, commercial and industrial water use continues. The potential impacts of water conservation, improved water efficiency, and drought-based restrictions are addressed in the alternatives evaluation.

The HydroLogics OASIS computer model is being used to estimate how much supply is available from Normandy Reservoir (shown at left) and the Duck River for the period of record (1921-2008) as well as the frequency and duration of shortages. The yield of the reservoir was computed under current and future conditions using the existing operating constraints which include maintaining a minimum instantaneous release of 40 cfs below the dam and a minimum instantaneous flow of 120 cfs (December – May) and 155 cfs (June – November) at Shelbyville (approximately 27 river miles downstream of the dam). The available supply for the river users was computed based on a minimum instantaneous flow constraint of 100 cfs at Columbia (approximately 116 miles downstream of Normandy Dam) which is not a release requirement for Normandy Reservoir.

Under 2060 demand conditions, the model shows that the surplus yield available in Normandy Reservoir is approximately 15 mgd (2007 drought of record). For the river system, the OASIS model shows that the 1999 drought is critical and the deficits increases from 4 mgd in 2010 to 32 mgd in 2060.

ALTERNATIVES ANALYSIS

A list of 40 potential water supply alternatives identified in previous studies was reduced to 26 unique alternatives which were considered worthy of further consideration. Alternatives included a wide array of non-structural and structural measures such as:

- Implementing additional water efficiency measures
- Implementing a regional drought management plan
- Changing operation of Normandy Reservoir
- Modifying river constraints
- Raising Normandy Dam
- Constructing tributary reservoirs (Fountain Creek Reservoir)
- Building offstream storage reservoirs (pumped storage)
- Utilizing quarries
- Constructing pipelines from reservoirs, rivers or other water systems

A summary matrix was developed which described each of the alternatives and documented key aspects of the alternative related to seven criteria: reliable capacity, raw water quality, cost, implementability (permitting), flexibility (phasing), environmental benefits, and recreation. During public work sessions with stakeholders, the alternatives were discussed and sorted into four categories:

- Baseline (water efficiency, drought management, etc.)
- Fatally Flawed or Highly Unlikely (unreliable, variation of alternative is preferred, costly, permitting obstacles, etc.)
- Backup (alternative which may be suitable for implementation with a cornerstone alternative)

- Cornerstone (alternatives capable of satisfying entire river deficit in 2060)

More detailed investigations are currently being conducted and implementation plans are being generated on four candidate cornerstone alternatives to assist with identification of a recommended alternative.

EXTENSIVE PUBLIC INVOLVEMENT

The Comprehensive Regional Water Supply Plan is being conducted using a uniquely open process, with extensive opportunities for input from the public, elected officials, and governmental agencies through the use of public workshops and informational meetings, routine updates via our website, agency briefings and press coverage. The DRA is conducting six public workshops and several public meetings to obtain input from the public. Among the many stakeholders are the public water systems, represented by the Duck River Agency Technical Advisory Committee (DRATAC), and the DRA's Water Resources Council, which includes over 25 governmental and non-governmental organizations.

For more information on the Study Approach, a listing of Stakeholder agencies, workshop materials and more, please visit the project website at: www.duckriveragency.org.

SESSION 3B

DAM OPERATIONS AND SAFETY PANEL
8:30 a.m. – 10:00 a.m.

TN Safe Dam Site
L. Bentley (Abstract Not Available)

TVA
L. Groce (Abstract Not Available)

USACE
D. Hendrix (Abstract Not Available)

SESSION 3C

STORMWATER II
8:30 a.m. – 10:00 a.m.

The Status of and a Vision for Sustainable Water Management in Tennessee
D. Galbreath

Developing a Successful Watershed Project: Lessons from the Oostanaula Creek Watershed Restoration Project
Forbes Walker, Shawn Hawkins, Lena Beth Carmichael, and Shawn Lindsey

An Analysis of Construction and Development Point-Source Category Regulations and Their Sociological Influences in the Southeastern United States
Melissa A. Harris

THE STATUS OF AND A VISION FOR SUSTAINABLE WATER MANAGEMENT IN TENNESSEE

D. Galbreath

Human designed, sustainable water systems can succeed when they simply "mimic" the endemic nature, structure and function of natural climate, hydrology, geology, pedology, botany and the natural hydro-geomorphology that exist in a given geographical region. Prior to the overwhelming alteration of natural systems by human existence and modern development, sustainable water management existed successfully because of millions of years of tested experience.

In fact, evidence shows that sustainable systems as a whole continue to be successful, with unforseen benefits. In addition to water management, the Michigan Department of Highways realized cost saving and safety enhancing right-of-way management in its roadside prairie restoration program. David Rosgen's fluvial geormorphology classification system and river restoration practices have realigned modern river management practices with sustainable design approaches. Jane Benyus' biomimicry concepts connect nature's design lessons with high tech design specialists to inspire more efficient and longer lasting technological solutions.

In sustainable water management, some communities in the Northeast, Midwest and Northwest have at least one and sometime three decades of experience adopting naturally derived, common sense, economical proven water systems. Although Tennessee has less than one decade of experience, some significant examples of sustainable water management exist in documented private and public projects. The presentation will showcase sustainable water management applications in Tennessee, highlight their holistic benefits and values, and offer a vision for a future that could accelerate progress and will generate continued and broader prosperity for the state.

DEVELOPING A SUCCESSFUL WATERSHED PROJECT: LESSONS FROM THE OOSTANAULA CREEK WATERSHED RESTORATION PROJECT

Forbes Walker[1], Shawn Hawkins[2], Lena Beth Carmichael[3] and Shawn Lindsey[4]

In recent years funding priority has been given to watershed projects that demonstrate effective broad based partnerships. The Oostanaula Creek (HUC TN06020002083) is an urbanizing agricultural watershed in eastern Tennessee, typical of the Ridge-and-Valley region occupying much of the eastern United. The issues facing this watershed are common throughout the ridge and valley region (urbanization, water quality degradation, etc.). Since 2006 a watershed partnership has been working to cooperatively address both agricultural and urban components of the restoration plan. Partners include the City of Athens, Athens Utility Board, McMinn County, Monroe County, McMinn County Soil and Water Conservation District, Monroe County Soil and Water Conservation District, Tennessee Department of Agriculture, Tennessee Department of Environment and Conservation, University of Tennessee Extension, Tennessee Valley Authority, Environmental Protection Agency, USDA Natural Resources Conservation Service and Tennessee Stream Mitigation Program.

The partnership has been successful in developing a watershed restoration plan that was approved by the state in 2007. During 2008, partnership members reached out to local decision makers in McMinn and Meigs Counties, inviting them to join forces by co-hosting a Growth Readiness Workshop Series. A final report on the Growth Readiness workshops and recommendation on model ordinances was shared with local decision makers and planning commission members in early 2009. In 2009 the partnership was successful in attracting funding from several sources to implement parts of the restoration plan, develop demonstration sites throughout the watershed and use the best available science to identify sources of water quality degradation in the watershed and to encourage agricultural producers and other stakeholders.

[1] Associate Professor, Biosystems Engineering & Soil Science, The University of Tennessee, 2506 E.J. Chapman Dr., Knoxville, TN, 37996-4531, frwalker@utk.edu
[2] Assistant Professor, Biosystems Engineering & Soil Science, The University of Tennessee, 2506 E.J. Chapman Dr., Knoxville, TN, 37996-4531, shawkins@utk.edu
[3] University of Tennessee, Extension Area Specialist II, McMinn county, Athens, TN, lbcarmichael@utk.edu
[4] Public Works Director, City of Athens TN, slindsey@cityofathenstn.com

AN ANALYSIS OF CONSTRUCTION AND DEVELOPMENT POINT-SOURCE CATEGORY REGULATIONS AND THEIR SOCIOLOGICAL INFLUENCES IN THE SOUTHEASTERN UNITED STATES

Melissa A. Harris

The objectives of the Clean Water Act (CWA) include, among others, eliminating the discharge of pollutants into navigable waterways and attaining a level of water quality that protects public health as well as the health of aquatic and terrestrial wildlife. The National Pollutant Discharge Elimination System (NPDES) stormwater permit program was established to help attain those objectives. However, there is indication that NPDES is not effectively fulfilling the mission of the CWA (Coyne & Imus, 2003; U.S. General Accounting Office, 1983; U.S. Government Accountability Office, 2009). Sociological factors such as culture, economics, and politics have strongly influenced how environmental policies have been developed, implemented, and enforced. This study researches the sociological characteristics that possibly influence NPDES stormwater regulations in the southeastern U.S., specifically for the construction and development (C & D) point-source category, in order to better understand the current regulatory environment. Construction and development contribute to water quality degradation by exacerbating soil erosion and sediment fluxes. Accordingly, the NPDES program sets standards to prevent pollution from C & D stormwater discharges. However, each state has the right to authority under the CWA to establish their own NPDES stormwater program as long as it is at least as stringent as the standards set by the EPA. This study, therefore, compares southeastern NPDES stormwater regulations to determine similarities and differences among the states, a potential reason for the diminished effectiveness of the NPDES stormwater program. The policies are ranked on the stringency of implementation and enforcement regulations and then compared with the sociological data. Correlations will be examined to determine associations between the stringency of regulations and the influence of sociological factors. To date, the data are being compiled and analyzed. Conclusions will discuss the policy implications of C & D regulatory variations.

REFERENCES

Coyne, W., & Imus, B. (2003). *Clean water enforcement report card: how nine states' regulations measure up.* Ann Arbor: Public Interest Research Group in Michigan Education Fund.

U.S. General Accounting Office. (1983). *Report to the administrator, Environmental Protection Agency: wasterwater dischargers are not complying with EPA pollution control permits.* Washington, D.C.: U.S. General Accounting Office.

U.S. Government Accountability Office. (2009). *Testimony before the Committee on Transportation and Infrastructure, U.S. House of Representatives: Clean Water Act, longstanding issues impact EPA's and states' enforcement efforts.* Washington, D.C.: U.S. Government Accountability Office.

PROFESSIONAL POSTERS

Total Coliform in Automated Storm Water Sampling for the Tennessee Department of Transportation's Best Management Practice Research
Jill M. Kovalchik

Water Demand Projections in North Central, Tennessee and Southern Cumberland Plateau, Tennessee, 2010-2030
John A. Robinson

TOTAL COLIFORM IN AUTOMATED STORM WATER SAMPLING FOR THE TENNESSEE DEPARTMENT OF TRANSPORTATION'S BEST MANAGEMENT PRACTICE RESEARCH

Jill M. Kovalchik[1]*

INTRODUCTION

Tennessee Department of Environment and Conservation issued an individual Municipal Storm Sewer System Permit (No. TNS077585) to Tennessee Department of Transportation (TDOT) on April 2006. Among the unique regulatory requirements contained within this permit, Section 2.1.5 requires that TDOT develop, implement and enforce a program to reduce pollutants in stormwater from its post-construction facilities including roadways, right-of–ways and appurtenants subject to stormwater runoff. During the permit application process, TDOT conducted a study on stormwater runoff from mature highways in urban areas. The researchers for this study came up with four classifications of Tennessee highway segments: multiple lane roadways with a center concrete divider; divided highways with grass medians; multiple lane roadways with curbs and storm sewer systems; and multiple lane roadways from which stormwwater runoff drains to the shoulder(s) (TDOT, 2001). In 2007, four mature highway sites were selected in Central and East Tennessee where BMPs will be implemented on a semi-permanent basis for research evaluation of stormwater run-off quality after BMP implementation (TDOT, 2007). In preparation for BMP selection and implementation, TDOT has begun conducting stormwater sampling at each site to determine background levels of pollutants. This document describes the approach and results of stormwater sampling conducted at East Tennessee sites from December 2008 through December 2009. Stormwater sampling at the selected Central Tennessee locations has been delayed and is expected to begin in 2010.

APPROACH

Locations selected for stormwater sampling and eventual implementation of post-construction BMPs in compliance with the Section 2.1.5 are as follows:

East Tennessee
I-75 in Knox County at the Merchants Road Interchange, between the south end of Exit 108 and mile marker 109.4. This highway segment consists of a 6-lane interstate, a concrete median wall with drop inlets at its base, and drop inlets along the shoulder. Grass areas within the interchange drain via concrete ditches into catch basins before discharging to nearby Second Creek.
SR-61 in Anderson County, within the City of Clinton. This roadway section includes an elevated section above a commerical district; drainage flows to curb inlets that discharge through a storm sewer outfall above the Clinch River.

Central Tennessee
SR-386 in Sumner County, at mile marker 6.0. This site is near Hendersonville, TN off Exit 6 of the Vietnam Veterans Parkway. Runoff from the divided highway drains to the median or to concrete or grass-lined roadside ditches.
SR-52 in Sumner County near the town of Oak Grove, TN. Two paved lanes with paved shoulders drain to side ditches.

[1] Science Applications International Corporation (SAIC), 151 LaFayette Drive, Oak Ridge, TN 37830 jill.m.kovalchik@saic.com

Characteristics of each selected highway segment are summarized in Table 1 below.

Table 1. Characteristics of Locations Selected for the BMP Research Study

Roadway Parameter	I-75 in Knoxville	SR-386 in Hendersonville	SR-61 in Clinton	SR-52 in Oak Grove
Type of Road Segment	**Interstate with concrete barrier -always high ADT**	**Divided highway with grass median - high ADT**	**Four lane highway curb and gutter - moderate ADT**	**Two lane highway - low ADT**
ADT Volume (2006)	72506	57350	26678	10831
Length of Segment (ft)	7400	2700	994	3510
Average width of ROW (ft)	300	300	65	100
Number of lanes	6	4	4	2
Width of each lane (ft)	12	12	12	12
Average width of all impervious surface (ft)	120	76	65	36
Average width of grass median (ft)	none	48	none	none
Total Drainage Area (ac)	62.5	22.3	1.5	9.8
Impervious Surface Area (ac)	57.0	3.2	1.43	3.9
Pervious Surface Area (ac)	5.5	19.1	0.07	5.9
Estimated C for Total Area	0.90	0.39	0.94	0.56
Drainage Area Within TDOT ROW (%)	100	100	95	88
Predominant drainage conveyance	RCP storm sewer to concrete lined ditch	Grass swales	Curb and gutter to RCP storm sewer	Curb and gutter to grass shoulder
Receiving stream	Second Creek	Tributary of Drakes Branch Creek	Clinch River	Tributary of Caney Fork Creek

ADT = Average Daily Traffic
RCP = Reinforced Concrete Pipe
ac = acre
ft = feet

Three automated samplers were installed at roadside locations in East Tennessee in Fall 2008: a storm sewer outfall discharging runoff from an elevated section of SR-61 in Anderson County, within the City of Clinton ("Clinton"); a culvert conveying runoff from the northwestern quadrant of the interchange at I-75 and Merchants Road in Knoxville to Second Creek ("75 South"); and culvert conveying runoff from the southwestern quadrant of the interchange at I-75 and Merchants Road off right-of-way ("75 North"). Automated samplers were programmed to collect first-flush grab and flow composite samples during qualifying storm events. Qualifying events were defined as those yielding greater than 0.10" of precipitation and occurring more than 72 hours after the previously measured storm event exceeding 0.10" of precipitation. Stormwater samples were analyzed for the following list of parameters: total metals by EPA Method 200.7 (cadmium, calcium, copper, lead, magnesium, and zinc); dissolved metals by EPA Method 200.7 (cadmium, copper, lead, and zinc); hardness (calculated) by SM2340B; extractable petroleum hydrocarbons; general chemistry parameters - ammonia (as nitrogen), chemical oxygen demand, chloride, nitrate/nitrite (as nitrogen), phosphorus, total dissolved solids, total suspended solids, orthophosphate (as Phosphorus), and total Kjeldahl nitrogen; and total coliform. Selection of parameters was based upon previous monitoring studies requiring estimates of pollutant loads and concentrations (Federal Highway Administration, 2001).

RESULTS AND DISCUSSION

Twenty-nine sample sets (fifteen grab and fourteen composite) were collected and analyzed for the full-range of parameters. Seven samples (four grab and three composite samples from four storm events) were collected from Clinton. Of the remaining twenty-two samples, only two (one grab and one composite from a single storm event) were collected from the sampler at 75 South. Twenty samples from the sampler at 75 North were collected during thirteen separate storm events. With the exception of total coliform, all detected concentrations fell within anticipated results.

Detected concentrations of total coliform in samples taken from the Clinton site ranged from 13,000 colonies per 100 ml (February 2009) to 2.2 million colonies per 100 ml (May 2009). 75 South yielded detected concentrations of 480,000 and 580,000 total coliform colonies per 100 ml in the single storm event sampled (December 2009). Concentrations of total coliform at 75 North ranged from 6,600 colonies per 100 ml (March 2009) to "Too Numerous To Count" (December 2008 and January 2009).

Manual grab samples were taken from the storm sewer culvert at Merchants North and other locations at the interchange concurrently with samples obtained through the automated sampler in both April and December 2009. All locations yielded similar results, indicating that the high numbers of total coliform were not caused by sampler contamination and truly reflect conditions throughout the interchange, not just the location of the automated sampler. Options for additional future analysis include fecal coliform, fecal streptococcus, and DNA analysis to distinguish the type and possible source of coliform contamination.

Sampling continues at East Tennessee locations and is expected to begin at Central Tennessee locations in 2010. Once baseline parameters have been established, post-construction BMPs targeting identified pollutants will be selected for implementation. After installation, stormwater sampling will continue to determine the efficiency of each BMP in reducing pollutant loads in stormwater runoff leaving TDOT right-of-way.

REFERENCES

Federal Highway Administraion, 2001, Guidance Manual for Monitoring Highway Runoff Water Quality Report, No. FHWA- EP-01-022: Federal Highway Administration Office of Natural Environment.

Tennessee Department of Transportation (TDOT), 2001. Part 2 Stormwater NPDES Permit Application. With preparation assistance by EnSafe and subcontractor K.S. Ware & Associates, Nashville, TN.

TDOT, 2007. TDOT Best Management Practice Study Plan. Prepared for the TDOT Environmental Compliance Office by Science Applications International Corporation, Oak Ridge, TN.

WATER DEMAND PROJECTIONS IN NORTH CENTRAL, TENNESSEE AND SOUTHERN CUMBERLAND PLATEAU, TENNESSEE, 2010-2030

John A. Robinson[1]

Public concern about water use in Tennessee has grown in recent years, driven by growing awareness of fresh water as a finite resource. That awareness has been spurred by increasing current and projected demands for water, a series of notable droughts, and competing claims to water resources among and within Tennessee and surrounding states. A critical planning need is the integration of current and projected demands for water with scientific understanding of its physical availability under varying assumptions regarding climate and population growth.

The U.S. Geological Survey, in cooperation with the Tennessee Department of Environment and Conservation, has undertaken to develop water demand projections supported by existing population projections for periods 10 and 20 years into the future for each two pilot areas in Tennessee. These focus areas are North Central region including the towns of Portland, Westmoreland, Gallatin, White House and Castalian Springs/Bethpage, and the Southern Cumberland Plateau region including the towns of Monteagle, and Sewanee, and the utilities of Big Creek, Cagle/Fredonia, Griffith Creek, and Foster Falls. Three growth scenarios are being evaluated, reflecting anticipated growth and uncertainty in growth predictions. Local economic development goals, existing land use patterns, and official land use plans will form the basis for the projections of future commercial and industrial water use. This information will be used in an assessment of the likely timeframe within which projected water demand will exceed existing water source yields for each utility and region. The future water-supply needs for each region will be evaluated and used to guide the selection of alternative sources and regional solutions to ensure safe and sustainable water supplies for the future.

[1] Hydrologist, U.S. Geological Survey, 640 Grassmere Park, Suite 100, Nashville, TN 37211 jarobin@usgs.gov

STUDENT POSTERS

Correlations Between Groundwater Bacteria Types and Geochemistry of Springs in Nashville, Tennessee
Patrice Armstrong

Characterizing Hydraulic Gradients and Groundwater Flow near the Cumberland River, Nashville, Tennessee
Aras Barzanji, Mike Bradley, and Tom Byl

Use of a Luminometer and Watercress Bioassay to Analyze Abiotic Environmental Stress
Chris Beals and Tom Byl

Indications of Oil Biodegradation at a Crude Oil Spill on Clear Creek, Obed Wild and Scenic River National Park
Jaala Brooks, Carlton Cobb, Brandon Cobb, Marquan Martin, Patrice Armstrong, Mike Bradley, and Tom Byl

Interpreting a Spring's Chemographs to Estimate Groundwater Recharge in an Urban, Karst Terrain
Carlton Cobb, Lonnie Sharpe, Patrice Armstrong, Dafeng Hui, and Tom Byl

The Implications of Concentrations of Elements in the Nashville Basin Area with Regards to Magnesium (MG), Iron (FE), Manganese (MN), and Phosphorus (P)
S. Hovis, M. Graves, C. Shannon, W. Cribb, and W. Anderson

Comparing the Tanks-in-Series and Continuous-Stirred Flow Reactor Models to Predict Contaminant Removal in a Wetland
Jameka Johnson, Carlton Cobb, Lonnie Sharpe, and Tom Byl

Increased Risk of Groundwater Contamination with Et-85 Fuels
Baibai Kamara, Loreal Spear, Christin Staples, Lonnie Sharpe, and Tom Byl

Improving the Residence-Time Distribution Model to Accurately Describe Contaminant Flow in Non-Ideal Flow Systems
Marquan Martin, Roger Painter, and Tom Byl

Concentration-Discharge Relationships in a Mine Impacted Catchment, New River, Tennessee
Jenny Murphy

AQUATOX Modeling in Stressor Identification of Water Quality Impacts on Tennessee Streams
Cynthia Torres, Jessica Murillo, and Adam Stroud

Calibration of HSPF Model Simulated Flow
Nicholas B. Vergatos

Protecting the Unique Ecosystem from Contaminated Storm Runoff at Mammoth Cave, KY
Ashley West, Carlton Cobb, Brandon Cobb, Marquan Martin, Jaala Brooks, Rickard Toomey, and Tom Byl

CORRELATIONS BETWEEN GROUNDWATER BACTERIA TYPES AND GEOCHEMISTRY OF SPRINGS IN NASHVILLE, TENNESSEE

Patrice Armstrong

The objective of the project was to evaluate the water quality of two limestone bedrock springs in an urban environment from the summer of 2007 to spring of 2009. These springs, Tumbling Rock springs and Trough Springs are located near a poultry research facility and were discovered on the campus of Tennessee State University (TSU) in Nashville, TN in May, 2007. The two TSU springs behind the poultry barns were sampled approximately every week from June 2007 through March, 2009.
During this study period there were episodic events such as the drought that occurred in the summer of 2007 as well as an unexpected leak from our poultry waste container. Water quality parameters include: temperature, specific conductance, dissolved oxygen, pH, sulfate, nitrogen, iron, and bacteria types. Continuous water-quality monitoring devices were installed at the springs to measure changes associated with different weather patterns. The ph levels were normal for this type of environment setting between 6.5 and 8. Water temperatures were very stable, ranging from 16^{o}C in June to 19^{o}C, as well as during the time of the drought. The specific conductance readings displayed an annual pattern with spikes from where storm water mixed in. Sulfate concentrations were consistently higher in the spring water than the receiving surface waters, suggesting that surface vegetation may have removed the sulfate. Conversely, nitrogen levels were lower in the spring water (<10 mg/L) than the surface waters, suggesting denitrification by bacteria in the subsurface. BART tests confirmed the presence of denitrifying, nitrifying, iron-reducing, sulfur-reducing, and heterotophic aerobic bacteria at each of the springs.
There were several correlations examined with relation to the water quality parameters between the geochemistry, bacteria, as well as episodic and seasonal events. Spring discharges decreased at all sites, and has risen back up 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.

CHARACTERIZING HYDRAULIC GRADIENTS AND GROUNDWATER FLOW NEAR THE CUMBERLAND RIVER, NASHVILLE TENNESSEE

Aras Barzanji[1*], Mike Bradley[2], and Tom Byl[1,2]

Groundwater flow patterns are difficult to predict in karst terrains due to the anisotropic openings in the subsurface. However, using three or more wells one can calculate the magnitude and direction of hydraulic gradients using the triangulation method. The objective of this research was to monitor changes in hydraulic gradient within a limestone-bedrock aquifer approximately 0.5 mile east of the Cumberland River near Tennessee State University (TSU; about river mile 185) to infer the likely direction of groundwater flow. Three deep (200-250 feet below land surface) wells located along the Cumberland River floodplain on TSU's research farm were used for this study. Geophysical logging placed the top-of-bedrock at approximately 40 to 60 feet below ground surface and revealed two openings in the bedrock at approximately 72- and 108-feet below land surface. Water levels were measured under different weather conditions using an electric tape. Also, continuous water levels were monitored in one of the wells using a pressure transducer and data recorder. Over the period of observation, water levels ranged from 6 to 22 feet below land surface depending on the well and recent rainfall. Results indicate that rain rapidly influenced the hydraulic gradient and the likely direction of groundwater flow. For example, within 24 hours of a 1.5 inch rain event, groundwater levels rose between 1 and 3 feet in each of the three wells; the hydraulic gradient rose about 11 percent; and the inferred direction of groundwater flow appeared to shift from north to north-west. Additional work is needed to determine the extent to which the Cumberland River may affect water levels and gradients.

1 Civil & Environmental Engineering, Tennessee State University, Nashville, TN, arasali2005@yahoo.com
2 U.S. Geological Survey, Nashville, TN

USE OF A LUMINOMETER AND WATERCRESS BIOASSAY TO ANALYZE ABIOTIC ENVIRONMENTAL STRESS

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

A novel method to quantify oxidase enzyme production was devised to examine aquatic plant stress due to toxic chemical exposure. Bioaccumulation of anthropogenic chemicals causes an increase in hydrogen peroxide concentrations in plant tissues triggering a cell signaling response whereby catalases are activated. Catalase production due to environmental stress precedes macroscopic evidence of plant stress such as necrosis or inhibited plant growth. In this bioassay, whole watercress (*Nasturtium officinale*) plants were exposed to three different concentrations of heavy metals (lead, nickel, manganese, and copper) and E85 (ethanol and gasoline mixture) over a 72 hour period. Following exposure, plants were macerated using a mortar and pestle to liberate catalases, and a one gram sample of the crude slurry was analyzed with a luminometer. The luminometer makes use of the luminescent reaction produced when hydrogen peroxide is broken down into water and an oxyradical thus indicating the presence and indirectly the quantity of catalase enzymes. Significant differences in luminometer-measured catalase production were found between treatments involving copper, nickel, and E85 and the control plants.

[1] Dept. of Biological Science, Tennessee State University, Nashville, TN
*christopherbeals@yahoo.com
[2] College of Engineering, Tennessee State University, Nashville, TN
[3] U.S. Geological Survey, Nashville, TN

INDICATIONS OF OIL BIODEGRADATION AT A CRUDE OIL SPILL ON CLEAR CREEK, OBED WILD AND SCENIC RIVER NATIONAL PARK

Jaala Brooks[1], Carlton Cobb[1], Brandon Cobb[1], Marquan Martin[1], Patrice Armstrong[2, 3], Mike Bradley[3], and Tom Byl[1,3]

The Obed Wild and Scenic River (WSR) National Park, in north central Tennessee is characterized by exceptional biological, scenic, and recreational resources, all dependent on the quality of water in the river. Oil and gas production is common in areas bordering the Obed WSR and exploratory drilling is expected to increase significantly in the future. In July of 2002 an exploratory drilling operation near the boundary of the WSR encountered a highly pressurized petroleum zone which produced an uncontrolled released of about 12,000 barrels of oil over 24-hours. The crude oil spilled from this operation was not contained before it flowed down a nearby embankment and infiltrated into the subsurface. After 7 years, oil from this spill continues to seep into a nearby stream. The objective of this project was to identify contaminated seeps, characterize the microbial community in soils and groundwater around the seeps, and measure the rate of naturally occurring biodegradation. Several new seeps were identified and located with GPS. Subsurface bacteria found in clean and contaminated sites along the stream included Pseudomonad bacteria, which are effective at biodegradation. Higher Pseudomonad concentrations were observed in soils with moderate concentrations of oils. Some of the more contaminated soils were dominated by sulfur-reducing bacteria, which are slow at biodegrading petroleum compounds. More efficient heterotrophic aerobic and iron-reducing bacteria were present, but in smaller proportions. These findings suggest that conditions are favorable for stimulating these bacteria with oxygen releasing compounds. The rates of biodegradation at the study site are currently under investigation using laboratory microcosms.

1 Civil and Environmental Engineering, Tennessee State University, Nashville, TN, jaalabrooks@yahoo.com;
2 Biology Dept, TSU, Nashville, TN
3 USGS, Nashville, TN

INTERPRETING A SPRING'S CHEMOGRAPHS TO ESTIMATE GROUNDWATER RECHARGE IN AN URBAN, KARST TERRAIN

Carlton Cobb[1], Lonnie Sharpe[1], Patrice Armstrong[2,3], Dafeng Hui[3], and Tom Byl[1,2]

Karst aquifers in urban settings are particularly vulnerable to contamination for at least three reasons. First, karst solution features and hydraulic processes tend to promote rapid entry of surface water into the groundwater system with little or no filtration. Second, urban settings tend to concentrate contaminant sources. Third, the urban landscape includes many large impervious surfaces which are commonly designed to direct surface runoff to sinkholes or losing stream reaches. The extent to which an aquifer is influenced by surface-water may be reflected in the apparent residence time of shallow water in the aquifer--the shorter the residence time; the greater the throughput. The objective of this project was to better understand the vulnerability of Nashville's shallow aquifer to contamination using a combination of outflow quality monitoring and conservative tracers to estimate residence time in the shallow karst aquifer. Temperature and conductivity were monitored nearly continuously for 2 years at Tumbling Rock Spring, located on Tennessee State University's campus in Nashville. Synoptic samples were collected to augment continuous monitoring and were analyzed for dissolved oxygen, pH, nitrate, sulfate, iron, and turbidity. Discharge was measured with each sample. Variations in constituent concentrations and patterns in spring-water chemographs were associated with rain events. The data show that groundwater discharging from the spring maintained a temperature of 17.5^{o} C +/- 1 degree year round. Specific conductance generally dropped during the drier summer months and then rose during the wet winter season. This pattern was punctuated by sharp peaks and valleys associated with rain events. Based on tracer studies using sodium chloride, up to 10 percent of the spring's flow has an estimated aquifer residence time of less than 1 month.

1 Civil & Environmental Engr., Tenn. State University, Nashville, TN
2 USGS, Nashville, TN
3 Biology Dept., Tenn. State University, Nashville, TN

THE IMPLICATIONS OF CONCENTRATIONS OF ELEMENTS IN THE NASHVILLE BASIN AREA WITH REGARDS TO MAGNESIUM (MG), IRON (FE), MANGANESE (MN), AND PHOSPHORUS (P)

S. Hovis, Mr. M. Graves, Ms. C. Shannon, Dr. W. Cribb[1], and Dr. W. Anderson[2]

The objective o f this research is to investigate variations in elemental concentrations in agricultural soils of the Nashville Basin particularly concerning iron Magnesium (Mg), Iron (Fe) and Manganese. Soil samples were collected from 16.4 acres of land off of Guy James Road in Rutherford County, TN that had not been fertilized for 20 years. Samples were taken at multiple sites with 3 samples per site taken by hand auger. The sites were marked by their GPS coordinates which were recorded, mapped, and organized from the most Northern latitude to the most Southern latitude. A collective sample of the 3 taken per site was air dried in the soils laboratory and the pH recorded. Each sample was then run through the XRF machine which analyzed them chemically through x-ray fluorescence. The concentrations of elements Mg, Fe, and Mn all peak around site 10. The area of study consists of a sloped face running down to a flood plain. This would result in water percolating into the soil and flowing from the most Northern latitude to the most Southern latitude and eventually to the East Fork of the Stones River. This process dissolves Fe and Mn minerals and precipitates Fe and Mn oxides around sample site 10 as a result of a fluctuation of the water table. The Mg concentration was found to be greatest between the Fe and Mn peaks. This could be due to potential Mg reactions. The P found in the soil samples remains relatively constant throughout all samples. This is indicative of little to no P leaching from the soil into the Stones River which could be a result of a well established vegetative habitat on the sampled area.

[1] Department of Geosciences
[2] School of Agribusiness and Agriscience

COMPARING THE TANKS-IN-SERIES AND CONTINUOUS-STIRRED FLOW REACTOR MODELS TO PREDICT CONTAMINANT REMOVAL IN A WETLAND

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

An 8 acre wetland on the campus of Tennessee State University in Nashville, Tennessee is fed by relatively uncontaminated spring flow throughout most of the year. The wetland also receives episodic surface-water runoff from a 2.2-square-mile urban basin and in the recent past this runoff included effluent from a sewer leak. The objective of this project was to determine how well the wetland attenuates non-point source (NPS) contamination in surface-water runoff. This study was conducted in two phases. First, tracer studies (sampling sodium chloride above and below the wetland) were used to measure residence-time and dispersion characteristics in the wetland. Second, the system was numerically modeled assuming a continuous stirred flow reactor (CSTR) and model estimates for chemical oxygen demand (COD) attenuation were compared to observed data. The wetland can be represented as two cells in series, each about 4 acres in area. The tracer studies found that mean residence time increased approximately 50 percent in the upper cell and 30 percent in the lower cell during storms. Dispersion increased 20 percent in the upper cell and 400 percent in the lower cell during storm-flow. Water was held longer during storms in the wetlands due to greater distribution into cattails and open areas, which helped to remove NPS contaminants. For the model comparison, the rate of COD removal was derived from field observations during the sewer leak episode. The CSTR model predicted the COD levels would drop to 2.58 milligrams per liter (mg/l). We observed COD exiting the wetland at 3 mg/L. These results demonstrate that the two-cell CSTR model produced a reasonable estimate of contaminant residence time and removal in the wetland.

1 Civil and Environmental Engineering, Tenn. State University, Nashville, TN
2 USGS, Nashville, TN

INCREASED RISK OF GROUNDWATER CONTAMINATION WITH Et-85 FUELS

Baibai Kamara[1], Loreal Spear[1], Christin Staples[1], Lonnie Sharpe[1], and Tom Byl[1,2]

The United States government is promoting alternative fuels to reduce our dependency on imported oil. Tennessee is promoting Et-85, a fuel that consists of 85 percent ethanol and 15 percent gasoline. The environmental fate of gas-alcohol mixtures has not been fully investigated, making the consequences of an uncontrolled spill of Et-85 difficult to predict. A better understanding of Et-85 mobility in the subsurface is of practical importance if Et-85 is to become widely used and stored. The purpose of this project was to determine if a commercial grade Et-85 mixture would dissolve more readily in water and move faster through water-saturated soil than regular gasoline. Solubility-in-water tests comparing gasoline with Et-85 found that the ethanol component in Et-85 acted as a co-solvent and enabled aromatic compounds to dissolve five times faster in water than in regular gasoline. Additional experiments were conducted to determine the migration rate of Et-85 fuel compounds. Sterile soil-column studies found that aromatic compounds from the Et-85 (such as benzene, toluene, and xylene (BTX)) moved three to four times faster than similar compounds in regular gasoline when transported by water through the soil. However, an additional test also found that aerobic biodegradation of Et-85 compounds is almost five times greater than for regular gasoline. Though Et-85 compounds may spread quickly in the event of a leak, it would appear that biodegradation may also remove these compounds more quickly from aerobic aquifers.

1 College of Engineering, Tenn. State University, Nashville, TN
2 USGS, Nashville, TN

IMPROVING THE RESIDENCE-TIME DISTRIBUTION MODEL TO ACCURATELY DESCRIBE CONTAMINANT FLOW IN NON-IDEAL FLOW SYSTEMS

Marquan Martin[1], Roger Painter[1], and Tom Byl[1,2]

The advection dispersion equation (ADE) is widely used as a predictor of residence time distributions (RTDs) for tracer breakthrough curves for non-ideal flow systems. Solutions of the ADE for tracer breakthrough curves for near plug-flow behavior are characteristically Gaussian in appearance. The symmetry of this solution often predicts finite tracer concentrations at zero time and is often not reflected in measured breakthrough curves, which generally have relatively long upper tails. Few quantitative tracer studies have found tracer concentrations normally distributed about the mean residence time. This suggests that a different conceptual approach may be appropriate in describing these systems in easily visualized terms. The objective of this project was to develop a more predictive model of tracer-breakthrough curves based on the gamma probability density function (pdf). The gamma distribution is a pdf of random variables that are exponentially distributed and is frequently used as a probability model for waiting times. In this poster the tracer residence time, the tracer travel distance and tracer linear velocity are assumed to be randomly distributed variables with gamma distributions. The RTD for tracer breakthrough curves was derived from the joint probability distribution for residence times derived from the individual distributions of tracer travel distance and linear velocity. This approach is compared and contrasted with the traditional approach based on the ADE for modeling tracer breakthrough data in non-ideal flow system sites.

1 Civil and Environmental Engr., Tenn. State University, Nashville, TN
2 USGS, Nashville, TN

CONCENTRATION-DISCHARGE RELATIONSHIPS IN A MINE IMPACTED CATCHMENT, NEW RIVER, TENNESSEE

Jenny Murphy[1]

Observing and interpreting changes to water quality is difficult due to the spatial and temporal variability of water chemistry. Long, decadal records of stream water chemistry are an invaluable tool for assessing changes to water quality yet such data sets are available for only a limited number of catchments. While empirical and complicated models exist for interpreting the impacts of land use changes and resource extraction these methods require substantial amounts of data and thus limit use to well-studied catchments. More often than not, temporally short and fragmented records of water quality are available, although water discharge records may be available for extended periods. Partial water chemistry data sets give a static perception of water quality, but by coupling water chemistry and discharge data, long-term discharge measurements can be used to indentify long and short term hydrochemical trends which can then be compared between time and space, as the available data allow. This study uses limited water chemistry and discharge data to assess changes to water quality in a catchment that has experienced periods of mining activity.

The New River (400 sq mi) and its nested, upland catchment, Indian Fork (4 sq mi), are located on the northern portion of the Cumberland Plateau in Tennessee and present an interesting case study for evaluating the impact of mining and land-use changes on hydrochemical processes across spatial and temporal scales. Historically, a significant quantity of coal was mined in the New River watershed; in 1974 approximately 56% of all coal mined in Tennessee was from the New River watershed (Hollyday and Sauer 1976). Mining peaked in the 1970s and declined until around 2003. During the 1970s, approximately 5% of the New River watershed was disturbed due to mining activities, logging accounts for an additional yet not quantified area (Minear and Tschantz 1976).

My objective is to identify changes in water quality, by using time-series analysis and concentration-discharge relationships, in the New River and Indian Fork watersheds and subsequently to interpret such changes, if they exist, in light of coal mining activity and land use disturbances in the watershed. Qualitative assessments of aerial photographs, written history, and legislation are used to interpret land-use changes, i.e., no formal land-use survey was completed during this study. The null hypothesis of my work is that there have been no observable changes to water quality in the Indian Fork or New River in three to four decades and chemical responses are expressed similarly between catchments. The objective is addressed by (1) characterizing short term c-Q (concentration-discharge) relationships using episodic hysteresis loops, (2) modeling long term water chemistry of the catchments using recursive time-series analysis and, (3) comparing results between catchments and across time. This study is confounded by the lack of available water data yet the use of above methods to assess changes to water quality may provide a useful tool for working in catchments where data are sparse.

[1] Vanderbilt University

AQUATOX MODELING IN STRESSOR IDENTIFICATION OF WATER QUALITY IMPACTS ON TENNESSEE STREAMS

Cynthia Torres, Jessica Murillo, and Adam Stroud

AQUATOX is an ecosystem simulation model which can predict the effects of pollutants or environmental conditions on aquatic ecosystems. The model is designed to model water quality resulting from inputs of nutrients, detritus, and organic chemicals. The response to inputs of specific organisms, including fish, invertebrates, and aquatic plants, is simulated. AQUATOX is supported by USEPA. We are using AQUATOX to provide "Stressor-Response Relationships from Ecological Simulation Models" in our CADDIS analysis of potential stressors in Coal Creek in Anderson County, Tennessee. In our analysis, we are using the water quality of a similarly situated TDEC reference stream, Big War Creek as our control; we input the dimensions and profile of the stretch of Coal we are modeling. Annual average temperature and insolation are input for the site from the AQUATOX database. We input seeds of periphyton and macroinvertebrates. Chemical loadings from upstream, the TDEC survey site upstream of the one we are modeling, and from the point source Lake City WWTP can be selectively input. We are modeling the impacts of nutrients (surrogate for stressor algae), and organic matter (surrogate for stressor DO).

CALIBRATION OF HSPF MODEL SIMULATED FLOW

Nicholas B. Vergatos*

It is common to use the Hydrologic Simulation Program-Fortran (HSPF) model to estimate the flow of waterways and rivers. The first step in using an HSPF model to estimate flows is to calibrate. Calibration is accomplished by comparing observed flow data from a continuous gauge to simulated flow data for the waterbody. Model parameters are adjusted until the modeled flow closely approximates observed flow. Typically, a set of criteria relating percent error between observed and simulated flows for various flow regimes and seasonal conditions are utilized to determine the validity of the calibration. One method to visually evaluate this calibration is comparison of simulated and observed hydrographs. Flow duration curves (FDCs) can also be used to compare simulated and observed flows. A series of FDCs was developed to illustrate how varying each individual calibration parameter affects the simulated flow. A FDC was prepared using the original value of a specific parameter from HSPF. FDCs were also prepared using the respective maximum and minimum possible and typical maximum and minimum values of the same parameter as specified in the EPA BASINS Technical Note 6: *Estimating Hydrology and Hydraulic Parameters for HSPF*. Each of the five FDCs for a specific parameter were combined on a single graph and can easily be compared, allowing for a clear, concise explanation of how changing the specified parameter influences the flow duration curve and how it relates to the calibration of the HSPF model.

*Senior, Case Western Reserve University, Cleveland, Ohio, vergatos@case.edu

PROTECTING THE UNIQUE ECOSYSTEM FROM CONTAMINATED STORM RUNOFF AT MAMMOTH CAVE, KY

Ashley West[1], Carlton Cobb[1], Brandon Cobb[1], Marquan Martin[1], Jaala Brooks[1],
Rickard Toomey[2] and Tom Byl[1,3]

Mammoth Cave is home to a unique cave ecosystem that could be harmed by contaminants carried into the cave system during storm events. This project was conducted to determine how well leaf-pack filter-systems act to attenuate storm runoff quality coming from seven parking lots in Mammoth Cave National Park. Grab samples were collected at the inlet and outlet of the seven filter systems, and analyzed for oil and grease, sediments, turbidity, gasoline compounds, nitrate, ammonia, fecal bacteria, dissolved iron, and chemical oxygen demand (COD). Before the first round of sampling, the filters in place had not been serviced for 8 years. Initial results showed that these did very little to attenuate most contaminants—in general, concentrations at the outlet were similar to those at the inlet. The exceptions were oil and grease which were attenuated by 20-70 percent. After replacing leaf packs and cleaning out debris, the re-conditioned filters did remove up-to 99% of benzene, toluene, ethyl-benzene, and xylene, and up to 90% of turbidity (suspended sediment), *E. coli*, chemical oxygen demand, and iron. However, the re-conditioned filters were no longer effective in removing oils and greases and did little to attenuate copper and ammonia in runoff. These results indicate that well-maintained filtration systems can be effective in removing many dissolved organic and particulate constituents but may not function as effectively as a clogged system for capturing floating constituents (skimming).

1 Tennessee State University, Nashville, TN, acdub12@yahoo.com;
2 Mammoth Cave National Park, Mammoth Cave, KY 42259;
3 USGS, Nashville, TN

EXHIBITORS and SPONSORS

A special thank you is extended to these companies that have supported the TN Section AWRA by participating this year as both sponsors and exhibitors.

City of Memphis
2714 Union Avenue Ext., Suite 625
Memphis, TN 38112
901-576-4332 phone
Contact: Sharon Gordon
E-mail: Sharon.gordon@memphistn.gov

The City of Memphis Storm Water Program is a comprehensive program that tracks and eliminates industrial, construction, and municipal sources of storm water discharges that adversely affect the quality of the surface waters as well as educates its citizens on the consequences of storm water pollution.

Hach Hydromet
5600 Lindbergh Drive
Loveland, CO 80539
512-528-9775
970-232-8594 cell
Contact: Bill Harrington
E-mail: bharring@hach.com
www.hachenvironmental.com

Hach Environmental designs, manufactures, and services Hydrolab and OTT instruments. Hydrolab multi-perameter water quality instruments incorporate multiple sensors into a single housing and are used for either unattended monitoring or sampling and profiling. OTT instruments include water level monitors, discharge monitoring instruments, and all weather precipitation gauges.

Sutron Corporation
23615 Valderama Ln.
Sorrento, FL 32776
Wade Loseman
South East Regional Sale Manager
(352) 357-9430 Office
(706) 888-7272 Cell Phone
Email: wloseman@sutron.com
http://www.sutron.com

As a global leader in providing innovative, dependable Hydrologic, Meteorologic and Oceanic Monitoring Systems, Sutron's equipment, stations and systems are known for extended longevity, the highest return on investment and the lowest down time. With proper maintenance, Sutron stations and systems will operate over a decade.

Tennessee Stream Mitigation Program
5000 Linbar Drive; Suite 265
Nashville, TN 37211
Phone: (615) 831-9311 x1
FAX: (615) 831-9081
Contact: Joey Woodard
Email: joey.woodard@tsmp.us
http:// www.tsmp.us

The Tennessee Stream Mitigation Program (TSMP) is an in-lieu-fee program that provides off-site compensatory mitigation for stream impacts associated with Section 404/401 water quality permits. With regulatory approval applicants may transfer mitigation responsibility to the TSMP at a rate of $200 per foot. The TSMP uses these funds to identify, develop and implement mitigation projects to enhance or restore habitat in and along degraded streams. The TSMP typically funds 100% of all costs associated with projects. Mitigation projects may be implemented on both private and public lands, and all TSMP projects are protected by a perpetual conservation easement.

Tennessee Water Resources Research Center

The University of Tennessee, Knoxville
U.T. Conference Center, B060
Knoxville, TN 37996-4134
Phone: (865) 974-2151
Fax: (865) 974-1838

TNWRRC Contact: Tim Gangaware
E-mail: gangwrrc@utk.edu

The Tennessee Water Resources Research Center (TNWRRC) and the Southeastern Water Resources Institute (SWRI) are the formal water resources research entities under the Institute for a Secure and Sustainable Environment (ISSE) at The University of Tennessee. The two organizations work synergistically together to address water resources research needs to the broad regional community.

The TNWRRC is a federally designated research institute headquartered at the University of Tennessee, Knoxville. The Center was established in 1964 by Governor Clement following the enactment of the Water Resources Research Act of 1964 (PL 88-379) by Congress. TNWRRC's missions include: (1) to assist and support all academic institutions of the state, public and private, in pursuing water resources research programs that address problem areas of concern to the state; (2) to promote education in fields related to water resources and to provide training opportunities for students and professionals in water resources related fields; and (3) to provide information dissemination and technology transfer services to state and local governments, academic institutions, professional groups, businesses and industries, environmental organizations, and others that have an interest in solving water resources problems.

ISSE
INSTITUTE FOR A SECURE AND SUSTAINABLE ENVIRONMENT

ISSE Contact: Dr. Randy Gentry
E-mail: rgentry@utk.edu
Website: isse.utk.edu

The University of Tennessee created the Institute for a Secure and Sustainable Environment (ISSE), pronounced ICE, to promote development of policies, technologies, and educational programs that cut across multiple disciplines, engage the university's research faculty and staff, and grow in response to pressing environmental issues facing the state, the nation, and the globe. ISSE became operational on July 1, 2006.

The institute represents a restructuring and expansion of the Waste Management Research and Education Institute—a state Center of Excellence established in 1985—to focus more broadly on environmental challenges. The institute will include programs previously found in two other long-standing organizations housed at the university and devoted to environmental research: the Joint Institute for Energy and Environment and the Energy, Environment and Resources Center. The consolidation of environmental research activities will enhance collaboration, facilitate more efficient administration, and build on existing strengths and on-going research efforts.

Sponsors

AquaShield™, Inc.
2705 Kanasita Drive
Chattanooga, TN 37343
Phone: (888) 344-9044 x1758
Direct: (423) 468-1758
Contact: Jason Moon
Email: jmoon@aquashieldinc.com
www.aquashieldinc.com

AquaShield™ is a stormwater treatment company helping customers provide quality, usable water with highly effective water treatment systems. The Aqua-Swirl™ is a hydrodynamic, vortex separator that has been independently verified to reduce floating debris and remove sediment by 91% on a net annual basis. The Aqua-Filter™ stormwater filtration system targets TSS, TPH, nutrients and metals with an 80% 22µm TSS removal at 16.5 gpm/ft2. Both systems have been independently verified, are simple to maintain, made from light-weight HDPE and can be custom sized for site specific needs.

Barge, Waggoner, Sumner & Cannon, Inc.
211 Commerce Street, Suite 600
Nashville, TN 37201
Phone: (615) 252-4255
Fax: (615) 255-6572
Contact: George Garden, P.E.
Vice President, Water Resources Department
E-mail: GCGarden@bwsc.net
http://www.bargewaggoner.com

Barge, Waggoner, Sumner & Cannon, Inc. is a professional services firm in Nashville, Tennessee, with offices in Ohio, Tennessee and Alabama. The staff of BWSC offers a wide range of water resource services, focused on water supply and treatment, groundwater, storm water, municipal and industrial wastewater, utility management, feasibility studies, watershed management and rehabilitation, and river and impoundment hydrology and hydraulics.

CDM
210 25th Avenue, North
Suite 1102
Nashville, TN 37201
Phone: (615) 340-6528
Contact: Kati Bell
Email: bellky@cdm.com
http://www.cdm.com/

CDM is a consulting, engineering, construction, and operations firm delivering exceptional service to public and private clients worldwide. An employee-owned corporation with over $1.3 billion in annual revenues and a multi-disciplinary staff of about 4,300 in more than 110 offices worldwide, CDM maintains the size, stability, and resources required to successfully undertake a diverse range of projects. Our full range of comprehensive services includes architectural and engineering design, environmental management and planning, transportation, management consulting, information management, and construction.

Center for the Management, Utilization and Protection of Water Resources
Tennessee Technological University
P.O. Box 5033
Cookeville, TN 38505
Phone: (931) 372-3507
Fax: (931) 372-6346
Contact: Dennis George, Director
E-mail: dgeorge@tntech.edu
http://www.tntech.edu/wrc

The Center for the Management, Utilization and Protection of Water Resources is an established Center of Excellence and is recognized for research on *Legionella* and *Legionella*-like bacteria; pesticide fate and transport in the environment; native and stocked fish habitat and survival; endangered mussels; and water and wastewater treatment using constructed wetlands. Its vision is enhancing education through research, and the Center accomplishes this through its world-renowned teams of interdisciplinary professionals.

Civil & Environmental Consultants, Inc.
405 Duke Drive, Suite 270
Franklin, TN 37067
(800) 763-2326
Contact: Beth Chesson
Phone: (615) 333-7797
Email: bchesson@cecinc.com
http://www.cecinc.com

Civil & Environmental Consultants, Inc. located in Franklin, TN, is a full services engineering and consulting firm specializing in stream restoration and assessments, EPSC and stormwater quality BMP design, and stormwater compliance strategy development. Our staff is made up of engineers, biologists, and environmental scientists.

EnSafe Inc.
5724 Summer Trees Drive
Memphis, TN 38134
(901) 372-7962 or (800) 588-7962
Contact: Katherine Terry
Email: kterry@ensafe.com
Contact: Paul Stoddard
Email: pstoddard@ensafe.com
http://www.ensafe.com/

EnSafe Inc., a global professional services firm, uses creative thinking to develop custom solutions for our clients' issues involving engineering, environment, health & safety, and technology. Founded in Memphis, Tennessee, in 1980, EnSafe provides environmental permitting, municipal (water/wastewater plant design, O&M, studies), compliance, and water quality management services, among others.

Fulghum, MacIndoe & Associates, Inc.
10330 Hardin Valley Road, Suite 201
Knoxville, TN 37932(865) 690-6419
Contact: Michael S. MacIndoe
Phone: (865) 251-5076
Cell: (865) 548-6165
Email: macindoe@fulghummacindoe.com
http://www.fulghummacindoe.com/

Fulghum, MacIndoe, & Associates, Inc. (FMA) is a Civil, Environmental, and Electrical Power Distribution firm who helps municipalities improve their infrastructure and developers, businesses, and individuals develop property for public and private projects. We focus on delivering our services on time with no surprises. Our team understands and stresses the importance of being passionate about our clients, their projects, and how their projects affect their future.

Ground Water Institute
The University of Memphis
300 Engineering Admin. Bldg.
Memphis, TN 38152-3170
Phone: (901) 678-3062
(901) 678-3078
Contact: Jerry Lee Anderson, Director
E-mail: jlandrsn@memphis.edu
http://www.gwi.memphis.edu

The Ground Water Institute is a research unit within the Herff College of Engineering at The University of Memphis. Established in 1992, the mission of the Institute is to understand, improve and protect current and future ground water quality and quantity through research, education and application.

John McFadden Aquatic Restoration Service and Supplies
923 Sullivan Bend Road
Mount Juliet, TN 37122
Contact: John McFadden
Phone: (615) 330-5364
E-mail: john_mcfadden@att.net

Our stream restoration work generally focuses on smaller 1st and 2nd order streams and may in some cases be utilized as mitigation required for permitting. Services provided include:

Watershed Restoration design and implementation
Watershed and water quality assessment
Stream bank stabilization
Riparian restoration
Wetland restoration
Low impact design services
Rain garden design and implementation
Aquatic resource alteration permitting
Locally grown and manufactured restoration products

John McFadden - Locally Manufactured Stream Restoration Products

---

Neel-Schaffer, Inc.
201 25th Avenue, North, Suite 800
Nashville, TN 37203
Phone: (615) 383-8420
Fax: (615) 383-9984
Contact: Tom Allen
E-mail: tallen@neel-schaffer.com
http://www.neel-schaffer.com/

NEEL-SCHAFFER
Solutions you can build upon

Providing solutions that its clients can build upon is the essence of Neel-Schaffer, Inc. Made up of engineers, planners, environmental scientists, landscape architects and surveyors, Neel-Schaffer is an employee-owned firm. Since 1983, it has grown from a company of 20 individuals to a 320-member-strong multi-disciplined firm. With offices located across the South, it services public and private clients, including federal, state, and local governmental agencies.

More than 70 percent of Neel-Schaffer's business comes from existing clients, which attests to the firm's ability to perform quality work. The expertise is recognized nationally as well. Neel-Schaffer consistently ranks among much larger national and international firms. It is currently listed in the Engineering News Record Top 500 Design Firms in the country and has been since 1994. It earns recognition annually from organizations such as the American Council of Engineering Companies (ACEC), the Solid Waste Association of North America and Associated General Contractors.

American Society of Civil Engineers, Tennessee Section/Environmental and Water Resources Committee
Contact: James C. Triplett, P.E., M.ASCE
TN ASCE President
Phone: (901) 755-7166
Contact: Ken Barry, P.E., D.WRE, M.ASCE
Environmental and Water Resources Committee Chair
Phone: (865) 970-0003
Email: kbarry@smeinc.com; http://sections.asce.org/tennessee/

How we deal with construction and post-construction storm water will be defining issues for civil engineering over the next generation. On Tuesday, April 13, 2010, TN AWRA and the Tennessee Section of ASCE will present a special one day Storm Water Conference. This Conference, conducted as part of the TN AWRA 20th Annual Water Resources Symposium, is a place where you can get a head-start on emerging storm water issues. Earn up to seven Professional Development Hours by participating in these activities:

- Soil and Water Assessment Tool (SWAT) Workshop
- Keynote luncheon address by Andy Reece, P.E., LEED AP, D. WRE
- Break-out sessions with presentations on low impact development, turbidity monitoring, water quality issues, hydraulics, and storm water products.
- Demonstrations of water monitoring equipment

All of this for $75 in one day at beautiful Montgomery Bell State Park, just 30 minutes west of Nashville (or for $100 you can attend the entire three day TN AWRA Water Resources Symposium). We hope you can attend.

Exhibitors

AMEC Earth & Environmental
3000 Ezell Road, Suite 100
Nashville, TN 37221
Phone: (615) 333-0630
Contact: Dustin Bambic
E-mail: dustin.bambic@amec.com
http://www.amec.com/

AMEC is a world leader in water resources services, employing more than 7,000 people in over 140 offices throughout North America. Our personnel in the Southeastern U.S. have extensive expertise in watershed studies, TMDL implementation, stormwater management and financing, NPDES compliance, hydrologic and hydraulic modeling, and floodplain management.

Architectural Wall Solutions
432 Woodycrest Avenue
Nashville, TN 37210
Contact: Jim Hammann
Phone: (217) 855-6656
Email: jhammann@bickesinc.com
Contact: Mike Smalley
Phone: (731) 803-2667
Email: mikesmalley@bellsouth.net
http://www.redirocktn.com

Redi-Rock retaining walls by Architectural Wall Solutions have been used for a myriad of water applications. Our diverse product line gives you the ability to design with freedom. The Redi-Rock system is widely accepted by engineers, architects, contractors, local, and state governments.

Crawford Hydrology Laboratory
Center for Cave and Karst Studies
1906 College Heights Blvd, #319
Bowling Green, KY 42101
Contact: Priscilla Baker
Email: crawford.hydrology@wku.edu
Phone: (270) 745-9224
http://caveandkarst.wku.edu/index.htm

Crawford Hydrology Laboratory provides professional consulting, field and laboratory services regarding groundwater questions in karst and non-karst areas. We specialize in groundwater tracing using fluorescent dyes, utilizing techniques developed and enhanced over 30 years. We provide supplies and analyses for quality groundwater tracing, and conduct full field investigations.

Jen-Hill Construction Materials
145 Old Shackle Island Road
Hendersonville, TN 37077
Phone: (800) 452-4435
FAX: (615) 822-9460
Contact: Trey Hightower
Email: info@jenhill.com
http://www.jenhill.com

Jen-Hill is focused on providing solutions through the use of the latest technologies to minimize the impact of development on the environment. Jen-Hill distributes products from the nation's leading manufacturers of Stormwater Treatment, Erosion & Sediment Control, Soil Stabilization, Riparian Stabilization, and Bioengineering.

Microbac Laboratories, Inc.
Knoxville Division
505 East Broadway Ave.
Maryville, TN 37804
Email: Knoxville@microbac.com
http://www.microbac.com

Microbac is a full service nationwide laboratory that specializes in the environmental analysis of drinking water, waste water, soil and microbial communities. Microbac also has extensive food testing capabilities for processed foods, food export, pathogens and contamination analysis. Microbac's biotech laboratory offers a multitude of molecular diagnostic services and augments both the environmental and food testing services of the company by providing rapid analysis of unknown organisms that are unable to be identified through traditional methods. The biotech lab specializes in identifying unknown bacteria and fungi as well as the analysis of specific gene targets and organisms including GMOs, viruses and parasites.

P.E. LaMoreaux & Associates, Inc. (PELA)
106 Administration Road, Suite 4
Oak Ridge, TN 37830
Phone: (865) 483-7483, ext. 101
Fax: (865) 483-7639
Contact: Art Pettit
E-mail: apettit@pela-tenn.com
http://www.pela-tenn.com

P.E. LaMoreaux & Associates, Inc. (PELA) is a full-service geological consulting firm that is internationally recognized for its karst expertise. PELA's Executive Vice President, Dr. Bashir A. Memon, leads PELA's technical programs while Art Pettit manages the Oak Ridge, Tennessee, office. PELA also offers a full suite of geological consulting services, with emphasis on hydrogeology, (including dye tracing), engineering geology, archaeological, geophysics and karst. PELA has developed a spectrum of geophysical techniques that it can apply to help solve many engineering or environmental problems. PELA's services are local in the Nashville, Chattanooga, Knoxville and the Tri-Cities area, and vicinity; for any significant project, PELA will not charge for travel time in these areas! PELA's exhibit will highlight various karst and geophysical services and will offer reprints of our many professional publications. Please stop by and visit us.

Roper Laser Co.
10913 Murdock Drive
Knoxville, TN 37932
Phone: (865) 675-5712
Contact: Adam Posan
Email: aposan@roperlaser.com
http://www.roperlaser.com/

Roper Laser is Georgia & East Tennessee's leading source for construction lasers, surveying instruments and automatic machine control systems. We are proud to represent brand names like Topcon, Cherne and PLS just to name a few. As one of the nation's largest GPS Machine Control suppliers, no company can match our experience and expertise when it comes to 3D surveying and control systems.

S&ME, Inc.
1413 Topside Road
Louisville, Tennessee 37777
Phone: (865) 970-0003
Contacts:
Ken Barry, P.E. kbarry@smeinc.com
Michael Pannell mpannell@smeinc.com
http://www.smeinc.com/

S&ME's environmental services include stream assessments, stream restoration design, wetlands assessments and mitigation, urban and construction stormwater management, flood modeling, stormwater modeling, GIS solutions, NPDES permitting, soil and groundwater assessment and remediation, natural resource permitting, toxicology, mining permitting, brownfields redevelopment, and solid waste design. Tennessee offices: Knoxville, Chattanooga, Nashville, Tri-Cities.

Sherman Dixie
200 42nd Ave North
Nashville, TN 37209
Contact: Mike Kusch
Phone: (615) 351-9164
Email: mkusch@shermandixie.com
http://www.shermandixie.com/

Terre Hill
485 Weaverland Valley Road
Terre Hill, PA 17581
Contact: Gene LaManna
Phone: (610) 914-2575
Email: glamanna@terrehill.com
http://www.terrehill.com/

Terre Hill Stormwater Systems manufactures stormwater treatment and management structures for NPDES stormwater requirements. Terre Kleen is an inclined plate hydrodynamic separator that provides the most cost effective sedimentation surface area pricing in the industry; Terre Arch is an HS 20 multi arch precast concrete underground stormwater storage structure. Coupled with the precast products and technical promotion skills of Sherman Dixie Concrete Industries as your local source of the Terre Hill and SDCI Stormwater Solutions.

Stevens Water Monitoring Systems, Inc.
12067 NE Glenn Widing Drive
Portland, OR 97220
Phone: (503) 445-8000
FAX: (503) 445-8001
Contact: Fred Holloway
Email: fholloway@stevenswater.com
http://www.stevenswater.com/

Since 1911 Stevens Water Monitoring Systems, Inc. has been a leader in the water monitoring industry. Our latest new product is the Stevens DataLog 3000 data logger. It is a powerful, flexible, versatile and scalable data logger that is designed using the latest digital signal processing technology.

Suntree Technologies, Inc.
798 Clearlake Road, Suite 2
Cocoa, FL 32922
Phone: (321) 637-7552
Contact: Tom Happel
Email: happel@suntreetech.com
http://www.suntreetech.com

Suntree Technologies Inc. has been designing and manufacturing stormwater BMP's since 1993. We can provide you with innovative stormwater treatment solutions that are cost effective and reliable. www.suntreetech.com

---

Tennessee Environmental Council
1 Vantage Way, Suite E-250
Nashville, TN 37228
Contact: John McFadden
Phone: (615) 330-5364
Email: john_mcfadden@att.net
http://www.tectn.org/

The Tennessee Environmental Council educates and advocates for the conservation and improvement of Tennessee's environment, communities and public health, with projects such as the Duck River Opportunities Project, the Tennessee Tree Project, and Sustainable Tennessee.

U.S. Geological Survey
Tennessee Water Science Center
640 Grassmere Park, Suite 100
Nashville, TN 37211
Phone: (615) 837-4701
Fax: (615) 837-4799
Contact: Scott Gain, Director
E-mail: wsgain@usgs.gov
http://tn.water.usgs.gov/

As the nation's largest water, earth and biological science and civilian mapping agency, the USGS works in cooperation with more than 2000 organizations across the country to provide reliable, impartial, scientific information to resource managers, planners, and other customers. This information is gathered in every state by USGS scientists to minimize the loss of life and property from natural disasters, contribute to sound economic and physical development of the nation's resources, and enhance the quality of life by monitoring water, biological, energy, and mineral resources. Information on water programs in Tennessee is available at http://tn.water.usgs.gov/.

Water Quality Matters!
Thomas B. Lawrence, PE
231 N. Avalon St.
Memphis, TN 38112
Contact: Tom Lawrence
Phone: (901) 274-2829
Email: bus@thecave.com

Water Quality Matters!

Water Quality Matters! is an water quality consulting firm that has provides expertise with environmental compliance to assist with developing excellent and cost-effective ways to comply with NPDES storm water permit requirements. The principal engineer, Thomas B. Lawrence, has nearly 20 years of water quality experience and has developed technical compliance and educational programs that have been well received by regulators, including the EPA.

YSI

38 Earles Court
Rochester, MA 02770
Contact: Kevin McClurg
Phone: (508) 243-4083
E-mail: kmcclurg@ysi.com
http://www.ysi.com/

YSI is a developer and manufacturer of sensors, instruments, software, and data collection platforms for environmental water quality monitoring and testing. Reaching beyond our products, we build relationships with our customers through our dedicated customer service, including technical applications and service support.

Tennessee Section
American Water Resources Association

Proceedings compiled by the Center for the Management, Utilization and Protection of Water Resources —
Tennessee Technological University — and the U.S. Geological Survey