Proceedings of
the Twenty-First Tennessee Water Resources Symposium

April 13-15, 2011

Proceedings from the

21st Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 13-15, 2011

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Tennessee Section of the American Water Resources Association

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PREFACE

Please accept our warm welcome to the Twenty-First Tennessee Water Resource Symposium at Montgomery Bell State Park (MBSP) sponsored by the Tennessee Section of the American Water Resource Association (AWRA) and, for a second straight year, by the Tennessee Section of the American Society of Civil Engineers. We hope that you will find the offerings of this year's Symposium beneficial to your professional and general water management endeavors/interests. This 2011 Symposium Proceedings will hopefully serve as a future reminder of time well spent as well as a reference for the various topics and considerations covered in this year's Symposium.

Although our attendees/participants historically span a wide range of professional water management genres, the organizing committee felt recent events served to identify a common need among all water professionals to address the topic of "Responding to the Unexpected". As everyone remembers and most likely continues to deal with issues related to the historic May 2010 flood event, still fresh on our minds are other unexpected events such as the Kingston Ash Pond spill and the drinking water shortages created by drought conditions in the not-so-distant past. Such events serve to evidence the range of extremes and various considerations associated with water management. In addition, the recent issues associated with the recent Japanese earthquake have served to once again make us contemplate what water management issues might be created if a major earthquake occurred along the New Madrid fault or if other types of natural disasters occurred anywhere within our State. Then there is also the possibility of both routine and unexpected water management structure/system failures that we potentially face each and every day. And while one could think such considerations as somewhat morose, it is only in proactively envisioning such problematic events in light of our own responsibilities that are we best able to be better prepared for those – albeit unlikely – situations.

Toward that end, both our keynote and luncheon speakers this year will provide historical perspectives as well as recovery achievements relating to just such unforeseen water-related disasters – the TVA ash spill and the Nashville Flood of 2010, respectively. It is our sincere hope that these sessions will provide both general and specific insights that will assist you if ever faced with responding to an emergency scenario in your particular area of responsibility or expertise.

We, as is our annual practice, have various presentations scheduled covering virtually all aspects of water management including such topics as groundwater, stormwater, stream health and restoration, monitoring, technology, modeling, water supply, and watershed planning. We also look forward to a strong group of exhibitors and sponsors for which we are very appreciative. Please take the opportunity to pass along your thanks to them as you visit their booths and exhibits during the Symposium. Furthermore, take time to stop by and speak to those presenting posters as well.

Our "first morning" workshop presentation this year will cover the OASIS Model, which is a unique software program that realistically simulates the routing of water through a water resources system. This training should be interesting given its various potential applications. Also this year, we have added an "Engineering Track" of presentation sessions (see the Symposium Agenda for more details). Also, please take advantage of the various networking opportunities available to you both during the official sessions and during those other times when you can interact with various other cohorts and professionals from across the state in a more relaxed atmosphere such as around the MBSP hotel/conference facility, at the golf tournament, while participating in the fun run, or during one of the scheduled musical entertainment activities.

I would be remiss if I didn't communicate my thanks to the organizing committee that made this event possible. There is much work needed to bring this event to fruition each year and the behind-the-scenes efforts to make this 2011 AWRA Symposium happen have been no exception. I would offer special appreciation and recognition to Lori Weir, who has yet again done a magnificent job in keeping all things Symposium-related moving in the right direction and on time!

And to you, our 2011 AWRA Symposium attendees, thank you for taking time out of your busy schedule to participate in this year's event, especially in light of these economic times. It is our sincere wish that this year's Symposium will provide you tangible benefits for many years to come!

Michael Hunt, President, Tennessee Section AWRA, 2011 Conference Chair

2010-2011 TN AWRA OFFICERS

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21st TENNESSEE WATER RESOURCES SYMPOSIUM

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- Larry Lewis, Tennessee Association of Utility Districts
- Forbes Walker, University of Tennessee
- Sherry Wang, Tennessee Department of Environment and Conservation

12:00 – 1:30 p.m.
Wednesday, April 13
Keynote Address *by* Dennis Yankee, Senior Manager, Environmental Monitoring and Analysis, Tennessee Valley Authority

TVA KINGSTON ASH RECOVERY STATUS

Dennis Yankee[1], Steve McCracken[1], Craig Zeller[2]

The December, 2008, Kingston fly ash spill deposited 5.4 million cubic yards of ash into portions of Watts Bar reservoir. Most of the ash has been removed from the Emory River under an Administrative Order on Consent between the Tennessee Valley Authority and the US Environmental Protection Agency under the regulatory authority of the Comprehensive Environmental Response, Compensation, and Liability Act. The Superfund program was selected as the preferred regulatory framework due to its comprehensive human health and ecological risk assessment process and its proven ability to engage multiple stakeholders in large, complex environmental cleanup projects.

The ash recovery project was divided into three distinct phases. The Time-Critical removal involved wet excavation, mechanical/hydraulic dredging, rapid materials handling and off-site disposal via rail of ~3.3 million cubic yards of ash from the Emory River. River dredging was completed in May, 2010, and off-site disposal at an approved landfill in Perry County, AL was completed in December, 2010. Non-Time-Critical Removal Actions will address excavating and placing ~2.5 million CY of ash from embayments into a re-constructed cell (Phase 2), and to assess the environmental risks posed to ecological receptors by residual ash in the river system (Phase 3).

This presentation provides a summary of progress to date and plans for Phases 2 and 3.

[1] Tennessee Valley Authority Kingston Ash Recovery Project, 1134 Swan Pond Road, Harriman, TN 37748
[2] U.S. Environmental Protection Agency, Region 4, 61 Forsyth Street, SW, Atlanta, GA 30303

12:00 – 1:30 p.m.
Thursday, April 14
Luncheon Presentation *by* Scott Potter, Metro Water Services Director

SESSION 1A

FLY ASH I

FLY ASH II

SESSION 1B

STORMWATER I

STORMWATER II

SESSION 1C

GROUNDWATER

PLANNING

SESSION 2A

ECOLOGY/BIOLOGY I

ECOLOGY/BIOLOGY II

HEALTH I

HEALTH II

SESSION 2B

STORMWATER III

WATER SUPPLY

SEDIMENT AND GEOMORPHOLOGY I

MONITORING

SESSION 2C

SWAT

MODELING

METHODS & TECHNOLOGY

RESTORATION

SESSION 3A

MAY 2010 FLOOD-FEDERAL RESPONSE

SESSION 3B

SEDIMENT AND GEOMORPHOLOGY II

SESSION 3C

KARST

PROFESSIONAL POSTERS

STUDENT POSTERS

RESPONDING TO THE UNEXPECTED: LESSONS FROM THE MAY FLOOD (Panel 1)
Moderator: Scott Gain, USGS
Panelists: Bob Sneed, USACE; TEMA; Chief Stephen Halford, Nashville Fire Department; Paul Davis, TDEC-WPC; Tom Womack, TN Dept. of Agriculture; NWS (No abstracts available)

SESSION 1A

FLY ASH I
1:30 p.m. – 3:00 p.m.

Integrated Ecological Research TVA Kingston Ash Recovery Project
Neil Carriker, Dennis Yankee, Rick Sherrard, William Rogers, Dan Jones, Suzy Young, and Paul Clay

Simulation of Erosion, Transport, and Long-Term Fate of Coal Fly Ash from the TVA Kingston Site
Stephen H. Scott

Assessing Risks in a Dynamic Environment—The TVA Kingston Ash Recovery Project
Daniel Jones, Mark Stack, Suzy Young, and Neil Carriker

FLY ASH II
3:30 p.m. – 5:00 p.m.

Assessment of Metal Bioaccumulation and Health of Fish Populations in the Vicinity of the Kingston Fly Ash Release
S. Marshall Adams and Allison M. Fortner

The Effects of Fly Ash Release from the TVA Kingston Steam Plant on Fish and Benthic Macroinvertebrate Assemblages
Tyler Baker, Kurt Lakin, Donny Lowery, and John Smith

Bioaccumulation, Maternal Transfer, and Effects of the TVA Kingston Ash Spill
Suzy Young, William Hopkins, and T. Hill Henry

INTEGRATED ECOLOGICAL RESEARCH TVA KINGSTON ASH RECOVERY PROJECT

Neil Carriker[1], Dennis Yankee[1], Rick Sherrard[1], William Rogers[1], Dan Jones[2], Suzy Young[2], and Paul Clay[3]

INTRODUCTION

The Kingston fly ash spill deposited several million cubic yards of ash into portions of Watts Bar reservoir. Most of the ash has been removed from the Emory River, but about 300,000 cubic yards remains that may be impossible to remove without causing more environmental damages than benefits. TVA has developed an integrated research program to evaluate the potential for long-term adverse environmental effects.

APPROACH

TVA's approach draws on its own technical expertise, nationally-recognized third-party researchers, and academic institutions to assess effects of ash-related contaminants on ecological receptors at multiple trophic levels. Primary objectives are to 1) accurately assess immediate and intermediate-term effects of the spill on the aquatic ecology of the system, 2) develop information necessary to predict long-term system responses to ash that may remain in the river, and 3) identify potential problems for which innovative solutions must be developed.

This research spans multiple disciplines (e.g., environmental geochemistry, toxicology, and ecology), and examines ecological effects at cellular, organ, organism, and population levels. For key contaminants such as arsenic and selenium, it includes characterizing chemical speciation, bioaccumulation, and biogeochemical transformation rates, and the effects of environmental conditions on those rates.
This presentation describes the different components of this research program, the methods being used to facilitate coordination and communication among researchers, and preliminary results of the various investigations.

[1] Tennessee Valley Authority Kingston Ash Recovery Project, 1134 Swan Pond Road, Harriman, TN 37748
[2] Arcadis U.S., Inc. | 114 Lovell Road, Suite 202 | Knoxville, TN, 37934
[3] Restoration Services, Inc. Hwy 58 Flannigan's Loop Rd. P.O. box 5177 Oak Ridge, TN 37831

SIMULATION OF EROSION, TRANSPORT, AND LONG-TERM FATE OF COAL FLY ASH FROM THE TVA KINGSTON SITE

Stephen H. Scott, Ph.D., P.E.[1]

INTRODUCTION

In December of 2008 an 84-acre containment berm failed on a fly ash storage facility at the TVA Kingston Fossil Plant, releasing approximately 6 million cubic yards of ash which impacted approximately 300 acres of the surrounding area, including 3 million cubic yards of ash which deposited in the Emory River. The ash completely filled the Emory River channel adjacent to the Swan Pond Embayment, with ash transporting more than 2 miles upstream in the Emory River due to the momentum of the slurry release.

After the spill, the channel thalweg was filled with ash (ash depths up to 30 feet), thus the channel capacity was significantly reduced. This in turn resulted in an immediate flood risk for the numerous properties that were located on both sides of the channel. Studies conducted by the TVA indicated that the ash deposits in the river increased the predicted flood elevation for the 100 year flood by 8 feet.

APPROACH

To counter the increased flood and sediment transport risk, the TVA and EPA initiated an aggressive dredging operation to restore the Emory River channel capacity within one year of the spill. This effort involved bringing in a number of high capacity dredges that worked 24 hours a day until the channel was restored. However, a number of relatively large flow events occurred in the Emory River before the channel was completely cleared, including a three year return storm event (~70,000 cfs) that occurred in May of 2009. To better understand the impact of fly ash deposits on Emory River hydraulics and sediment transport, the EPA contracted with the Engineering Research and Development Center at Waterways Experiment Station (ERDCWES) to model the Watts Bar reservoir system. A two-dimensional sediment transport model was developed for the Emory, Clinch, and Tennessee Rivers, from Emory River Mile 4.0 to Watts Bar dam at Tennessee River Mile 530 (45 miles).

This paper presents the modeling background, procedures, and results. In addition, the concept of long-term natural recovery of Watts Bar reservoir is discussed. The model used to conduct the fly ash transport study will be utilized to evaluate the impact of natural incoming sediment load on fly ash deposits in the reservoir. Natural sediment loads will be routed into Watts Bar reservoir to evaluate the long term deposition and mixing with residual fly ash deposits. Timelines will be estimated for the dilution and burial of fly ash by the natural sediment load from the Emory, Clinch, and Tennessee Rivers.

[1] Research Hydraulic Engineer, Engineering Research and Development Center, Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180

ASSESSING RISKS IN A DYNAMIC ENVIRONMENT – THE TVA KINGSTON ASH RECOVERY PROJECT

Daniel Jones[1]*, Mark Stack[2], Suzy Young[1], and Neil Carriker[3]

Assessing and managing potential risks to human health and the environment have been core components of the Kingston Ash Recovery Project since day one. The release of several million cubic yards of ash into the environment resulted in unstable conditions onsite and in the adjacent river system. The initial response included efforts to stabilize the ash in order to reduce risks of further release. As the recovery effort evolved over time, so did the risk assessment and management process.

The decision to dredge ash from the Emory River channel during the Phase 1 Time Critical Removal Action was supported by assessments of upstream flooding risks, downstream migration risks, and potential constituent dissolution risks. The Phase 2 Non-Time Critical Removal Action decision was supported by screening assessments of chemical risks to human and ecological receptors for direct contact to ash as soil. These assessments were commensurate in detail and complexity to their somewhat limited role in the overall decision-making process. The Phase 3 Non-Time Critical Removal Action will address approximately 20 miles of river/reservoir where residual ash may be present to varying degrees. This is a complex and dynamic system with numerous potential receptors of concern. The human health and ecological risk assessments are being tailored to support cleanup and long term stewardship goals for this multiuse river system. This presentation describes the risk assessment strategies for the various phases of the ash recovery project.

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1 ARCADIS U.S., Inc., 114 Lovell Road, Suite 202, Knoxville, TN, 37934
2 Jacobs 125 Broadway Ave, Oak Ridge, TN 37830
3 Tennessee Valley Authority Kingston Ash Recovery Project, 1134 Swan Pond Road, Harriman, TN 37748

ASSESSMENT OF METAL BIOACCUMULATION AND HEALTH OF FISH POPULATIONS IN THE VICINITY OF THE KINGSTON FLY ASH RELEASE

S. Marshall Adams[1] and Allison M. Fortner[1]

As a major component of the comprehensive biological monitoring and assessment project related to the TVA Kingston fly ash release, fish health and bioaccumulation studies have been conducted for the purpose of determining if fly ash-associated metals are affecting the health of sentinel fish populations in the vicinity of the spill. Three species of fish, representing different trophic levels and home ranges, were sampled at sites in the immediate vicinity of the fly ash release and at multiple reference sites upstream and downstream of the release. Muscle, liver, and ovarian tissue from individual fish were analyzed for 25 metals typically associated with fly ash, and a suite of fish health responses including various biochemical, physiological, histopathological, and overall condition indicators were also measured. Results of these studies indicate that selenium and arsenic are the only metals that appear to be consistently bioaccumulated above background levels in fish tissue and these levels are highest in fish downstream of the spill displaying a spatial downstream gradient. The various indicators of fish health also show that the condition of fish is somewhat degraded downstream with effects appearing to be localized primarily to resident fish species in a small area about 2 miles below the spill. In this study, food chain studies in combination with measurement of multiple bioindicators provides a weight-of-evidence approach for the Ecological Risk Assessment process and also for evaluating possible causal relationships between exposure to fly ash-associated metals and biological responses of sentinel fish species.

1 Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

THE EFFECTS OF FLY ASH RELEASE FROM THE TVA KINGSTON STEAM PLANT ON FISH AND BENTHIC MACROINVERTEBRATE ASSEMBLAGES

Tyler Baker[1]*, Kurt Lakin[1], Donny Lowery[1], and John Smith[2]

ABSTRACT

On December 22, 2008, a dike failure at the Tennessee Valley Authority's (TVA) Kingston Fossil Plant (KIF) released an estimated 5.4 million cubic yards of fly ash into the environment. The comprehensive assessment of the ecological consequences of the TVA Kingston fly ash release includes studies of fish and benthic macroinvertebrate assemblages.

TVA's Reservoir Fish Assemblage Index (RFAI) and Spring Sport Fish Survey (SSS) methodologies are being used to evaluate changes in fish community structure and populations and evaluate the sport fishery (i.e., largemouth bass) in the vicinity of the spill. The RFAI methodology uses boat electrofishing and gill netting to collect fish from a variety of habitat types based on their proportions in the study area. Fish are collected with the SSS methodology using boat electrofishing; this method specifically focuses on monitoring long-term trends in black bass populations. The results of fish surveys conducted in 2009 and 2010 are compared to those of surveys conducted in the area prior to the spill. Initial assessments of the benthic macroinvertebrate assemblage were conducted in January and December, 2009, with quantitative collections at sites upstream and downstream of the spill; no historical data were available for the affected environment. Benthic invertebrate samples are collected with a Ponar grab sampler and analyzed in the laboratory for taxonomic identification and enumeration. This presentation provides an overview of the sampling methodologies and the most recent findings.

[1] Tennessee Valley Authority Kingston Ash Recovery Project, 1134 Swan Pond Road, Harriman, TN 37748
[2] Oak Ridge National Laboratory, Oak Ridge, TN 37830

BIOACCUMULATION, MATERNAL TRANSFER, AND EFFECTS OF THE TVA KINGSTON ASH SPILL

Suzy Young[1]*, William Hopkins[2], and T. Hill Henry[3]

ABSTRACT

The release of fly ash at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) on December 22, 2008 discharged approximately 5.4 million cubic yards of ash slurry, which contains metals and metalloids that might pose a risk to ecological receptors within the adjacent aquatic and terrestrial systems. TVA and collaborating organizations have continued and expanded the studies initiated in the aftermath of the release in order to document whether the ash spill has exposed wildlife to trace elements and assess impacts of the spill on wildlife resources.

Target species were selected that encompassed a range of feeding ecologies and life histories. To date, sampling has primarily included piscivorous birds (osprey and great blue herons), herbivorous birds (Canada geese), insectivorous birds (tree swallows), predatory and benthic feeding turtles (musk, softshell turtles, and snapping turtles), spring breeding amphibians (spring peepers, chorus frogs, and toads), and omnivorous mammals (raccoons). Tissue or blood concentrations of trace metals were measured in each receptor from multiple locations in the vicinity of the release. Measures of reproductive success for birds (e.g., clutch size and hatching success) also were measured when feasible. Beginning next year, effects-based work will be initiated to determine whether the spill is adversely affecting physiological and reproductive attributes of turtles and tree swallows in the area. An overview of monitoring efforts thus far and future effects-based research plans will be presented.

[1] ARCADIS U.S., Inc., 114 Lovell Road, Suite 202, Knoxville, TN, 37934
[2] Virginia Polytechnic Institute & State University, Wildlife Ecotoxicology, Blacksburg, VA, 24061
[3] Tennessee Valley Authority, 400 West Summit Hill Drive, Knoxville, TN, 37902

SESSION 1B

STORMWATER I
1:30 p.m. – 3:00 p.m.

Development of a Geographic Information System for Analysis and Prioritization of Findings from Visual Assessment Surveys of Stream Corridors in Crossville, Tennessee
Karina V. Bynum

Water Sensitive Urban Design
Alan J. Wyatt

Metro Nashville's MS4 Program: Before and After the Flood
J. Hayes

STORMWATER II
3:30 p.m. – 5:00 p.m.

Water Quality of Fletcher Creek, Shelby County, TN During Storm and Non-storm Discharge: Relationships to Surface- and Ground-Water Hydrology
Daniel Larsen and Jack Grubaugh

Construction Stormwater Management and Monitoring for the New Cleveland Municipal Airport
Brent C. Wood, Troy Buttrey, and William K. Barry

The Stream Corridor Assessment: A Rapid Method of Prioritizing Watershed Health in Stock Creek, Beaver Creek, and Bullrun Creek, Knox County, TN
Michael S. Hamrick

DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM FOR ANALYSIS AND PRIORITIZATION OF FINDINGS FROM VISUAL ASSESSMENT SURVEYS OF STREAM CORRIDORS IN CROSSVILLE, TENNESSEE

Karina V. Bynum, M.S., P. E. [1]*

Monitoring under the stormwater permit of MS4 communities requires visual surveys of streams within their jurisdiction. The City of Crossville, as many other communities, used the Stream Corridor Assessment Survey developed by Maryland Department of Natural Resources recommended by TDEC. Extensive data from this survey is captured in a bank of worksheets describing various conditions encountered in the stream. The quantity and complexity of the information gathered from the field presents an opportunity to inform strategic decisions in stormwater management, urban growth planning and local watershed development. The City of Crossville serves as a pilot project to develop a system for data management and utilization under the City's stormwater program to extract information for watershed planning and project prioritization. A GIS geodatabase was developed for storage, analysis and ranking of findings from visual stream assessment surveys and other stormwater monitoring and watershed restoration efforts. The retrieval of the monitoring data is open to the public and is serviced through a map interface published on the web. This presentation introduces the input worksheet templates, the geodatabase structure, and the map interface. The analysis and prioritization of survey findings is also discussed along with map products developed for decision makers and watershed outreach. The City of Crossville developed this system as an adjustable template for other interested communities and watershed associations.

[1] TDEC – Division of Water Pollution Control, 1221 South Willow Avenue, Cookeville, TN 38506, Karina.Bynum@tn.gov

WATER SENSITIVE URBAN DESIGN

Alan J. Wyatt, RLA/ASLA/LEED AP

Droughts and torrential floods, shortage of drinking water, 10 major U.S. cities face water shortage, collapsing and outdated infrastructure, and carcinogens found in the water supplies of 31 American cities – these are some of the headlines and issues facing our communities with potable and storm water management. Are we in a water crisis? Is it time we think of rainfall as a 'resource' rather than a nuisance? Is there an environmental, social, and economic solution?

> *To waste and destroy our natural resources, to skin and exhaust the land (water) instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right had down to them."*
> *Theodore Roosevelt*

TURNING GREEN TO BLUE

Meeting these issues facing our communities requires a comprehensive sustainable approach through economic, social, and environmental solutions. The public's interest in "Green" or "Earthkind" solutions presents a new philosophical approach to urban planning and design that aims to minimize hydrological and water quality impact of urban development and redevelopment. Sustainable solutions for managing our water resources provides for technical and non-technical solutions. Integrating a total water cycle management into the urban design and built form – including site engineering, landscape architecture, and building architecture. Our aim should be to provide a more economical and less environmental damaging way of providing urban water, waste water and storm water solutions.

WATER SENSITIVE APPROACH

The term "Water Sensitive Urban Design" was first used in Australia in 1994 and expanded worldwide the concept of integrated land and water planning and management in the late 1990's. The objectives of the philosophical approach to water resource management is to protect natural systems, integrate storm water into the landscape; protect water quality; and reduce runoff and peak flows. Water Sensitive Urban Design aims to see that the hydrologic cycle is managed as a resource, having quantitative and qualitative impacts on land, water and biodiversity, and the community's aesthetic and recreational enjoyment as well as the economic vitality. The premise of Water Sensitive Urban Design is that the process of urban development, and most importantly redevelopment, no matter what scale or density, needs to address the sustainability of the hydrologic cycle and environment. The approach for water sensitive urban design:

- Detention, rather than rapid conveyance of storm water;
- Capture and reuse of storm water as an alternative source of water to potable water;
- Use of vegetation for filtering purposes;
- Water-efficient landscaping;
- Protection of water-related environmental, recreational and cultural values;
- Localized water harvesting for various uses; and
- Localized wastewater/storm water treatment systems.

LEGISLATION & REGULATONS

While many communities have started incorporating Water Sensitive Urban Design practices into their water and storm water management plans and regulations, many cities and towns have resisted accepting the practices due to 'time and trusted' engineering practices, lack of knowledge, building codes, anticipated costs, and other factors. Federal regulations such as the Clean Water Act and other regulatory requirements from federal, state, and local authorities have started to address the critical issues of potable water and storm water management, pollution prevention, clean potable water availability, and water restrictions. In recent years, many communities have begun storm water impact fees to offset raising infrastructure costs due to expanding development, issuing water use restrictions (particularly on landscape irrigation), and other regulations managing storm water and potable water use. Water Sensitive Urban Design practices have been incorporated into many communities and projects to off-set these storm water impact fees and restricted water use, such as rain gardens, porous paving, green-roofs, grey water and rain water re-use systems.

Relevant federal, state, and local regulations, standards, and guidelines, where they exist, should be consulted to ensure that any local requirements are met. The adoption of Water Sensitive Urban Design practices and guidelines should be adopted as a shared national objective, while allowing flexibility of response to differing circumstances at state and local levels.

WATER SENSITIVE URBAN DESIGN & 'GREEN' BUILDING STANDARDS

Many clients today are asking how Water Sensitive Urban Design works in conjunction with local or national 'green' building rating systems and standards. With many of the local and regional energy and environmental 'green' building standards, water conservation measures are primarily focused on interior potable water use reduction such as 'water saving fixtures.' In the exterior environment, water use and conservation practices mention the use of 'drought-tolerant' or native plantings, reduced lawn areas, and no or limited irrigation systems.

The United States Green Building Council (U.S.G.B.C.) in their "green" building rating system standards and programs, Leadership in Energy and Environmental Design (LEED), identify a wide array of water conservation practices. In the New Construction rating system, credit for water quality and conservation practices includes construction activity pollution prevention, protection of natural habitat, and storm water management. In addition, credits can be received for water use reduction, water-efficient landscaping, the use of innovative wastewater technologies, and reduction of water usage. In U.S.G.B.C. LEED's Neighborhood Development rating system program, water usage and conservation are addressed in proximity to water and wastewater infrastructure, wetland and water body conservation, floodplain avoidance, wetland conservation, and restoration and/or conservation of wetland habitat.

The Sustainable Site Initiative is a joint venture between the American Society of Landscape Architects, U.S. Botanic Garden, and the Lady Bird Johnson Wildflower Center to develop standards of practice for sustainable sites. Currently under final review and pilot program development, the new program is intended to set national standards for sustainable site and landscape practices. The water related sections in the Sustainable Sites Initiative include the protection of floodplains and preservation of wetlands, reduction of potable water use for landscape irrigation by 50% to 75%, and the protection and restoration of riparian, wetland, and shoreline buffers. Other practices included in the Initiative offer credits for rehabilitation of streams, wetlands and shorelines; managing the storm water on-site; protecting and enhancing on-site water resources and water quality; the design of rainwater/storm water features to provide a landscape amenity; and the maintenance of water feature to conserve water and other natural resources.

BEST PLANNING PRACTICES

The integration of Water Sensitive Urban Design in the planning process of urban development as well as most importantly, redevelopment, needs to address adequately the sustainability of the natural and water environment. This planning process must include a comprehensive approach and involve 1) open communication and a collaborative team of the client, users, community based groups, consultants/design team, vendors, regulatory agencies, and contractors; 2) a Planning, Execution, Monitoring and Evaluation Process; 3) incorporation of the sustainable practices of environmental sensitivity, economic feasibility, and social responsible solutions and results; 4) a thorough site and hydrological analysis; 5) the use of natural systems and technology; 6) respect of cultural, community and historical values; 7) a clear understanding of the client's (public's) mandate and program; 8) considerate of the human health, safety, and welfare issues; and 9) responsive to the long-term economic vitality of the community.

Examples of Best Planning Practices adapted to a wide scale of projects, include:

- The identification and protection of land to allow for an integrated storm water system, incorporating storage locations, drainage and overflow lines and discharge points;
- The identification of developable and non-developable areas;
- The identification and protection of public open space networks including remnant vegetation, natural drainage lines, recreational, cultural, and environmental features; and
- The identification of options for the use of water-conserving measures at the design level for:

    - Road layout,
    - Building design;
    - Parks, open space, and recreation;
    - Internal infrastructure services;
    - Residential, commercial, institutional, and
    - Streetscapes

BEST MANAGEMENT PRACTICES

Best Management Practices (BMP's) refers to the structural and non-structural elements of a design that performs the prevention, collection, treatment, conveyance, and storage and reuse functions of Water Sensitive Urban Design. Each of these BMP's offers its own unique use and performance, benefit and risk. In many cases, there are overlaps or synergies between the BMP's that should be considered in the evaluation and design process. Also, it is most importantly noted, risks and ongoing maintenance obligations with the implementation of Water Sensitive Urban Design practices should be considered as part of the overall evaluation process. When considering the use of Water Sensitive Urban Design practices, one should use of philosophical approach of a comprehensive and integrated system, using both natural and traditional/man-made components. These practices and guidelines do not promote an "all or nothing" approach to Water Sensitive Urban Design, rather that these are ideas and objectives progressively or incrementally applied, allowing knowledge and measures of effectiveness, while at the same time minimizing the risks of implementation.

<u>Water Reduction Techniques</u>:

- Water Efficient Fixtures and Fittings – the major component in potable water reduction is the use of water efficient fixtures and fittings in our homes and places of business. Water efficient showerheads and dual flush toilets can reduce potable water usage up to 20%. These systems can easily be incorporated into existing and new buildings and in some communities, tax incentives are available.

- Rainwater Tanks – collection of rainwater into storage tanks that are to conserve water usage through substituting the potable water supply. This water should be used for non-potable purposes, such as landscape watering, toilet flushing, and clothes washing, due to health risks from pollutants in urban areas.
- Reticulated Recycled Water – using a 'third' pipe system for recycled water can be incorporated into building and site systems for non-potable uses.
- Storm Water Harvesting and Reuse – collection and reuse of storm water for potable water substitution, non-drinking uses.
- Greywater Treatment and Reuse – the collection and reuse of greywater for potable water substitution can result in costs savings, reduced sewage fees and provide substantial water savings.
- Water Use Educational Programs – Community educational programs on potable water usage reduction and the incorporation of BMP's into the local community can provide a community "buy-in" of water conservation.

Storm Water Management Techniques:

- Sediment Basins – provide flow control and water treatment, usually consisting of an inlet pond to a bio-retention basin or wetland.
- Bio-retention Swales – provides both functions as a flow conveyance and water quality treatment facility.
- Bio-retention Basins – a flow conveyance and water treatment system.
- Sand Filters – provides similar function to bio-retention system, usually without the vegetation filtration.
- Swales and Buffer Strips – provides both a flow conveyance function, along the swale, and water treatment role through sedimentation and vegetation contact.
- Constructed Wetlands – shallow water bodies that use extended detention, fine filtration and biological pollutant uptake for storm water.
- Ponds and Lakes – created bodies of open water to provide water storage for storm water reuse and help in flood detention.
- Infiltration Systems – helping storm water infiltrate surrounding soils, these systems are dependent on suitability of soil for drainage.
- Aquifer Storage and Recovery – systems designed to recharge underground aquifers through natural means, pumping systems or gravity feed.
- Porous Paving – permeable pavement systems that allow rainfall to penetrate the pavement to a coarse sub-base and then to infiltrate to surrounding soils.
- Green Roofs – typically a vegetative roof with water proofing, root repellant system, light-weight growing media, and drainage system that provides rain collection and filtration to a storage facility for rain water reuse for landscaping and grey water usage. Also, these roof systems help in reduced runoff, pollutant reduction, and lessen the 'heat-island' impact.
- Xeriscaping – landscape plantings that require no artificial water supplement to natural rainfall. Usually plants are extremely drought tolerant and native to the location.

RISKS, ISSUES & BENEFITS

Water Sensitive Urban Design can provide significant benefits; however, there are risks and issues linked with its implementation if not adequately addressed which can impact its effectiveness.

- Infrastructure/Services – incorporating the BMP's with the local infrastructure without causing major disruption and relocation of services.
- Construction and Establishment – two major risks with the BMP's are construction and establishment of storm water techniques. Minimizing sediment erosion is critical to the overall implementation. Secondly, the highest failure of BMP's is the poor construction and/or establishment of the system.
- Erosion Scour – during large rainfall events, large and intense volumes of storm water can erode and scour within many of the storm water BMP's. This fast and large volume of water can cause erosion, scour, pollutant and sediment remobilization, and loss of 'biofilms'.
- Public Safety – the integration of storm water BMP's into the public landscape offers the potential risks to the public safety due to standing water and flow conveyance. Mitigating these risks, gradual slopes, dense plantings and protective fencing can be incorporated into the BMP.
- Maintenance – many of the BMP's are natural treatment mechanisms and require regular maintenance to ensure they are performing to their designed objectives. During the first years of establishment, maintenance costs can be higher than conventional storm water systems; however, over the life cycle costs of the system, these costs are reduced.
- Local Codes and Regulations – most municipal storm water management plans and policies prohibit the type of 'green' infrastructure storm water management techniques discussed here. A thorough understanding and commitment to the overall principles of Water Sensitive Urban Design requires policy makers to make an effort to provide the leadership to integrate these systems into existing regulatory storm water management policy.

The benefits of incorporating a Water Sensitive Design approach in our urban development and redevelopment philosophy is

- Reduction of the use of limited potable water supply;
- Reduce the need for expensive infrastructure;
- Reduce the impact of floods;
- Reduction of pollutants;
- Creation of environmental diversity; and
- Create amenities for leisure and recreation.

CONCLUSION

Is Water Sensitive Urban Design the answer to our community's water issues? The philosophy and techniques of Water Sensitive Urban Design does not offer the magic 'panacea' to our community's future in facing our water issues but as a viable alternative solution and approach to meet our future challenges. With our towns and cities facing major economic challenges, aging infrastructure, raising fees and costs for water, drinkable water shortages, and the fore coming development and redevelopment, our public policy leaders and professionals need to look at a new philosophy of addressing the sustainability of the water environment, more importantly, the sustainability of our communities and the natural environment for future generations.

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METRO NASHVILLE'S MS4 PROGRAM: BEFORE AND AFTER THE FLOOD

J. Hayes

The Metropolitan Government of Nashville has recently completed two "cycles" of its Municipal Separate Storm Sewer System (MS4) permit. While achieving permit compliance requires multi-departmental cooperation, the Metro Water Services (MWS) Stormwater Division is the primary department within Nashville Government dedicated to ensuring MS4 permit compliance measures are continued. The Stormwater Division has developed several permit compliance programs over the previous two permit cycles, such as the grading permit program, an intensive sampling/stream monitoring program, an IDDE and industrial inspection program, etc. The Stormwater Division has always received unwavering support from the MWS Director and Mayor's Office and has always been given the necessary resources to perform all MS4 permit compliance activities. The strength of the program's resources was best demonstrated in the aftermath of the May 2010 floods. While some staff duties were temporarily refocused following the flood, MS4 permit compliance and the water quality of Nashville's streams always remained a top priority.

Immediately following the flood, the primary focus for all of Metro Nashville government became public safety. In the Stormwater Division, environmental and engineering staff conducted a county-wide field survey of all stormwater infrastructure to identify washed out culverts/bridges. Numerous damaged culverts and bridges were found, barricaded, and logged into GIS for future repairs. While performing the damage assessment, staff also responded to environmental concerns such as hazardous spills. After the initial damage assessments, MWS environmental staff performed a field reconnaissance of the major creeks and rivers within Metro and logged locations of large debris fields and any potential hazardous materials, which were forwarded to the EPA On-Scene Coordinator (OSC) for removal by that task force. Metro environmental staff also worked cooperatively with the TDEC Water Pollution Control to monitor pathogen levels within Metro streams until they returned to normal levels.

After the initial assessments the Stormwater Division began to shift its duties to recovery items. Thousands of property owners began seeking building permits for flood-damaged properties. Each individual permit application had to be reviewed by the Stormwater Engineering Section for compliance with floodplain and other stormwater regulations. The Stormwater Maintenance Sections were inundated with hundreds of calls on drainage complaints that had to be investigated, repaired, and/or designed for future repair. In addition, the Stormwater Maintenance Sections had to document specific flood-caused infrastructure damage and coordinate with FEMA to determine which repairs would qualify for FEMA reimbursement and which floodplain properties would be part of Nashville's buyout program. Despite all of these additional tasks, MS4 compliance activities such as in the issuance of grading permits, inspection of construction sites, IDDE investigations, etc. also continued

In the wake of the flood, MWS is revisiting potential policy changes that now seem appropriate. Such items under review include industrial materials stored within the floodplain and responsible parties on dealing with landslides from private properties that were seen to significantly impact creeks or other drainage ways. Metro is conducting a comprehensive review of its floodplain regulations that will most likely result in changes later this year on how activities within designated floodplain areas are regulated so as to reduce future losses from flooding events.

WATER QUALITY OF FLETCHER CREEK, SHELBY COUNTY, TN DURING STORM AND NON-STORM DISCHARGE: RELATIONSHIPS TO SURFACE- AND GROUND-WATER HYDROLOGY

Daniel Larsen[1*] and Jack Grubaugh[2]

Aspects of the hydrology, water quality, and benthic community of Fletcher Creek were investigated during fall 2009 to determine the hydrologic characteristics of the stream and associated water quality during storm and non-storm discharge events in the creek. The Fletcher Creek watershed lies within the Memphis urban and suburban area. Runoff from storm events is delivered quickly to the channel and stream discharge responds rapidly to storm events. Ground-water levels in the watershed indicate that Fletcher Creek is, in part, a losing stream. As such, stream discharge persists only for a short time after storms with little to no non-storm conveyance.

The hydrochemical composition of Fletcher Creek water is generally similar to that of shallow ground water in the Memphis area, although the water quality of individual tributaries of Fletcher Creek varies. Low fluoride concentrations suggest that most of the water in the creek is from precipitation-related runoff, rather than runoff of municipal treated water. Dissolved nutrient concentrations, and *E. coli* and total coliform plate counts generally show increased values during storm flows in comparison to base flow.

The hydrologic behavior and sediment- and nutrient-dominated water quality are reflected in the macroinvertebrate community composition of Fletcher Creek. Comparison of biotic integrity on Fletcher Creek to the Wolf River indicates that Fletcher Creek is a highly-impacted stream system unable to support a significant macroinvertebrate community. Flashy storm discharge and associated water quality impacts are likely to be the major causes for poor aquatic community development in the Fletcher Creek watershed.

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CONSTRUCTION STORMWATER MANAGEMENT AND MONITORING FOR THE NEW CLEVELAND MUNICIPAL AIRPORT

Brent C. Wood, PE, CPESC[1]*, Troy Buttrey, PE[2], and
William K. Barry, PE, D. WRE[3]

ABSTRACT

Requirements for managing and monitoring of construction stormwater in National Pollutant Discharge Elimination System (NPDES) permits are changing. For the construction of the new Cleveland Municipal Airport in Cleveland, Tennessee, the Tennessee Department of Envionment and Conservation (TDEC) issued a site-specific NPDES permit. Erosion and sediment control plans included large sedimentation basins, rapid implementation of temporary stabilization, and a contingency for the use of polymers, if required. The permit also requires continous monitoring of outfalls with contributing watershed area greater than 50 acres and at upstream and downstream locations in Little Chatata Creek for turbidity and flow, as well as instituting grab sampling requirements for flow, turbidity, and total suspended solids for all outfalls. Cost effective implementation of these monitoring requirements involved use of a mix of automotated samplers and manual sampling. Erosion and sediment control measures have, to date, proven very effective in maintaing compliance with the NPDES permit. This presentation documents erosion and sediment control design and monitoring approaches and implementation to date, and identifies lessons learned and challenges ahead.

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THE STREAM CORRIDOR ASSESSMENT: A RAPID METHOD OF PRIORITIZING WATERSHED HEALTH IN STOCK CREEK, BEAVER CREEK, AND BULLRUN CREEK, KNOX COUNTY, TN

Michael S. Hamrick[1]

INTRODUCTION

Over the years, the focus of environmental managers has expanded from trying to control discharges from sewage treatment plants and factories, to present efforts of managing non-point source pollution and restoring degraded stream systems. As the focus of environmental managers has expanded, there has been a growing need to improve survey methods and provide new tools to identify and assess a variety of environmental problems over fairly large geographic areas. In response to this need, the Watershed Restoration Division of the Maryland Department of Natural Resources developed the Stream Corridor Assessment (SCA) survey as a tool that environmental managers can use to quickly identify a variety of environmental problems within a watershed's stream network. The survey is not intended to be a detailed scientific survey nor will it replace the more standard chemical and biological surveys. Instead, the SCA is intended to provide a rapid method of examining an entire drainage network so future monitoring, management and conservation efforts can be better targeted (Yetman, 2001). Knox County Stormwater Management has modified these protocols to streamline workflows while maintaining the survey's objectives.

APPROACH

Knox County Stormwater Management (KCSM) implemented a modified protocol of the SCA following the completion of an initial outfall inventory. Digital field information is collected using Trimble GPS receivers and Kodak cameras. This method eliminated hard copy records, reduced survey equipment, and integrated data collection into our geographic information system (GIS). The modifications KCSM made to the SCA protocols focused on how the survey data is captured, not on the information collected. The modified SCA is conducted by KCSM staff and AmeriCorps volunteers. Survey crews are trained in the logistics of conducting the survey, identifying environmental problems, and basic global positioning system (GPS) use. While the SCA is conducted, survey crews evaluate the severity of existing conditions on a scale of one to five, with one representing the worst conditions encountered. These evaluations are subjective and based on the survey crew's evaluation at the time of the survey. Data integrity is maintained by using the same personnel to conduct the survey, with the exception of the AmeriCorps volunteers who change annually. Field data is regularly incorporated into a master repository. Using Trimble Pathfinder Office v 4.10, the data is differentially corrected and exported as a shapefile. Those shapefiles are then appended to their respective feature classes in the geodatabase. New line features are created from the point field data using the trace tool. A join attribute is created and populated when the new line feature is created. Point attributes are then joined to the newly created lines. Line density is calculated for segments with a severity rating of one or two, and zonal statistics are calculated for subwatersheds using the density raster. These statistics are used to prioritize subwatershed action.

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RESULTS AND DISCUSSION

Two hundred twenty miles of stream, in three watersheds, have been surveyed by KCSM. Severity ratings in Stock Creek were normally distributed for both bank erosion and inadequate buffer features. Bank erosion severity ratings for Stock Creek were as follows: 1 – 6.9%, 2 – 26.2%, 3 – 36.8%, 4 – 24.1%, 5 – 6.9%. Inadequate Buffer severity ratings in Stock Creek were as follows: 1 – 8.1%, 2 – 26.7%, 3 – 31.9%, 4 – 26.8%, 5 – 5.6%. Beaver Creek and Bullrun Creek watersheds have a gap in the data representing the main trunk of the stream networks. These stream reaches have not been completed to date, and are reported as a severity rating of '0'. Bank erosion severity ratings for Beaver Creek are as follows: 0 – 31.1%, 1 – 2.2%, 2 – 13.6%, 3 – 37.7%, 4 – 14.3%, 5 – 2.3%. Inadequate buffer severity ratings for Beaver Creek are as follows: 0 – 27.3%, 1 – 2.5%, 2 – 22.3%, 3 – 34.4%, 4 – 11.4%, 5 – 0.9%. Bank erosion severity ratings for Bullrun Creek were as follows: 0 – 32.8%, 1 – 0%, 2 – 6.7%, 3 – 30.5%, 4 – 29.3%, 5 – 1.6%. Inadequate buffer severity ratings for Bullrun Creek were as follows: 0 – 29.8%, 1 – 1.9%, 2 – 27%, 3 – 22.1%, 4 – 10.8%, 5 – 7.5%. It is expected that Bullrun and Beaver Creeks will have normally distributed severity ratings. Upon survey completion, the subwatersheds in Bullrun and Beaver Creeks will be prioritized. Subwatershed prioritization has been completed for Stock Creek.

Stock Creek prioritization identified subwatersheds along the main trunk and mouth of Stock Creek in need of attention to address bank erosion. This may be due to the Ft. Loudon Lake impoundment. The mouth of Stock Creek is inundated by impoundment backwater, and bank erosion could be influenced by boat traffic (Dorava, 1997). Severe bank erosion in these areas could be given less priority than those areas where wave action is not contributing to stream bank erosion. Subwatersheds lacking adequate buffers were concentrated in the tributaries and upstream reaches of Stock Creek where landuse is largely agricultural. The inadequate buffer survey could be enhanced by distinguishing between native and exotic vegetation. The majority of riparian vegetation in Stock Creek is dominated by overland exotic, invasive plant species such as privet (*Ligustrum sp.*) and honeysuckle (*Lonicera sp.*). Restoration of these riparian areas could reduce nutrient loading and help stabilize stream banks (Osborne, 1993).

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SESSION 1C

GROUNDWATER
1:30 p.m. – 3:00 p.m.

Contaminant Load and Sources to Tributaries Near the Velsicol Dump, Hardeman County, Tennessee
Michael Bradley and Tom Byl

Did Memphis Take Mississippi's Groundwater? The $1.3 Billion Question
Brian Waldron and Dan Larsen

The Times They are A-Changin': The Evolution of Clean Water Act Requirements
Dustin Bambic

PLANNING
3:30 p.m. – 5:00 p.m.

Critical Area Identification for Watershed Planning
Jonathan Hagen, Joshua Rogers, Rebecca Robinson, and Mounir Minkara

Consensus Building and Its Role in Successful Stormwater Utility Implementation
David Mason

Urban Recreational Greenways: Opportunities for Better Stormwater Management?
John F. McFadden, Mark Ivy, Paul Whitworth, Tara Perry, and Frank Bailey

CONTAMINANT LOAD AND SOURCES TO TRIBUTARIES NEAR THE VELSICOL DUMP, HARDEMAN COUNTY, TENNESSEE

Michael Bradley[1] and Tom Byl[1]

During June through November 2011, the U.S. Geological Survey, in cooperation with the Tennessee Division of Remediation and Environ Corporation, conducted an investigation of groundwater contamination at the Velsicol/Hardeman County landfill to identify contaminant loads in the tributaries, contaminant sources, and the mode of contaminant transport. Seepage was measured and water quality sampled along the tributaries.

Results from an earlier phase of the study demonstrated that redox conditions, microbial communities, and general geochemistry are favorable for natural or enhanced attenuation of contaminants at this site. In general, contamination from the landfill continues to migrate from the landfill to Pugh Creek to the east, to the Clover Creek wetlands to the north, and to Clover Creek tributaries west of the site. A large contaminant mass remains in the subsurface, and dissolved phase VOCs are being released along the tributaries to Clover Creek and at seeps along the southern edge of the Clover Creek wetland.

Our seepage investigation and water-quality results identify a two-phase mode of contaminant transport to the tributaries. A diffuse ground-water plume transports contaminants to the streams, resulting in relatively low but consistent concentrations and loads in the tributaries. High permeability zones related to gravel in the terrace deposits and concentrated flow near sand/clay contacts produce seeps and springs along the banks of the tributaries and the edge of the Clover Creek wetland. The seeps and springs show concentrations of carbon tetrachloride ranging from 2,000 to more than 15,000 micrograms per liter, notably higher than contaminant concentrations in the tributaries.

[1] U.S. Geological Survey

DID MEMPHIS TAKE MISSISSIPPI'S GROUND WATER?
THE $1.3 BILLION QUESTION.

Brian Waldron and Dan Larsen

Transboundary water disputes are becoming a more common occurrence as fresh water resources become strained. Conflicts, arising when water usage by one party becomes restricted due the actions of a second party, occur at varying scales, from large international scale to smaller, intra-state jurisdictional scales. In 2005, the State of Mississippi filed a lawsuit against the City of Memphis and Memphis Light, Gas and Water (MLGW) in Tennessee, seeking apportionment and compensation ($1.3 billion US dollars) for ground water that has been artificially pulled across the state line between DeSoto and Shelby counties due to extensive withdrawals by the defendants. Their claim is based on the predevelopment ground-water level conditions of the Memphis aquifer that show an east-to-west gradient, paralleling the state line. They argue that since the predevelopment period, which is considered to have ended in 1886 with construction of the first commercial well in Memphis, ground-water withdrawals in Tennessee, primarily within Shelby County, have caused the gradient across the DeSoto – Shelby county line to reorient southeast to northwest. We provide a new pre-development potentiometric surface of the Memphis aquifer based on historical records between 1886 and 1904 that shows the natural hydraulic gradient of ground-water was southeast to northwest prior to commercial ground-water extraction in Shelby County and, thus, predevelopment flow was northwestward from Mississippi to Tennessee. We argue based on the new potentiometric surface map that a calculation based on previous estimates of predevelopment conditions greatly over exaggerate the total quantity of interstate water transfer.

THE TIMES THEY ARE A-CHANGIN': THE EVOLUTION OF CLEAN WATER ACT REQUIREMENTS

Dustin Bambic[1]

Since the 1970s, the regulations and requirements associated with the Clean Water Act have evolved tremendously. In early years, the program emphasized point sources such as municipal wastewater treatment plants, but in the 1990s the program shifted to include non-point sources such as stormwater. This presentation will describe trends in requirements over the last five years, with an emphasis on stormwater requirements. Overall, requirements for stormwater agencies has become increasingly "numeric", with early permits emphasizing a practical requirement called "Maximum Extent Practicable" and recent permits emphasizing water quality-based effluent limits (e.g., the concentration of a pollutant-of-concern must be below a certain level at all times). Similarly, in early years of the total maximum daily load (TMDL) program, stormwater agencies were expected to simply meet their six minimum control measures (public outreach, etc.) and that would in turn result in TMDL compliance. Recently, however, TMDLs have been integrated into permits with specific provisions regarding the location and timing of best management practices (BMPs) and, in some cases, a detailed schedule of BMP implementation. Furthermore, the "scope" of the TMDL program is increasingly stretched, with recent examples incorporating restrictions on the level of construction in the watershed and even language regarding the pre- versus post-development volumes of runoff from developed areas. In fact, some TMDLs have begun to encroach upon the issue of "pollutant versus pollution", which is clearly defined in the Clean Water Act, yet TMDLs based on flow rates are being adopted in the Northeast (e.g., compliance is based on reduction in the 1-year, 24-hour in-stream flow rate). The implications of these policy changes are far-reaching yet highly specific with regards to the agencies, watersheds, and pollutants. Some case studies will be presented and potential future issues will be discussed, which should be of interest to a wide array of stakeholders including municipal, state, federal, and non-governmental agencies.

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CRITICAL AREA IDENTIFICATION FOR WATERSHED PLANNING

Jonathan Hagen*, Joshua Rogers, Rebecca Robinson, and Mounir Minkara, Ph.D., PE[1]

Perhaps the most important step in the watershed planning process is the identification and characterization of natural patterns and processes of a watershed, its problems, and the subsequent management measures that will control nonpoint source pollution. To specifically address this goal the EPA recommends prioritizing critical areas within the watershed, estimating pollutant loads, and implementing appropriate BMPs at these critical areas and pollutant sources. Locating such hot spots, however, is complicated in that it involves a variety of data needs (hydrologic, biologic, geologic, social, etc.) and a variety of disciplines (stormwater engineering, stream ecology, landscape architecture, etc.) in order to account for site specific characteristics, limitations, and efficiencies. As the challenge lies in understanding and building on existing data, locating and organizing data at the local level is critical. The needs and sources of local information will depend on the kinds of land uses, pollution parameters, types of impairment, and history in the community.

To identify critical areas for the planning areas, the local program office adapted a watershed characterization and prioritization analysis. This analysis is a desktop exercise that utilizes the best available data on land uses, drainage areas, and a variety of screening factors suggested by the Center for Watershed Protection (CWP 2004) to determine the level of (potentially) degraded water quality among subwatersheds. This process will be used to assist water quality managers in determining the most appropriate (i.e. most degraded and suitable for restoration) basins to focus attention and allocate resources for the goal of improving overall watershed health.

City of Chattanooga Water Quality Program staff conducted a characterization and prioritization analysis for subwatersheds draining to major outfalls as defined by 40 CFR 122.26(b)(5). The parameters and corresponding scores that were chosen for study are listed below and will be discussed further at the Symposium. Each parameter was analyzed using GIS and current City data. Despite the fact that many of these metrics capture just a part of more complicated ecological or social properties, collectively they represent lines of evidence that will support restoration strategies.

Watershed Characterization and Prioritization Parameters, Ranges and Scores.

Parameter	1	2	3
Percent Impervious	0-10%	11-25%	+25%
BMP Density	>0.1	0.01≤X≤0.1	<0.01
IDDE Density	0	0<X<0.01	≥0.01
SSO Events	0	1-4	5+
Age of Infrastructure	<25 yrs	25-50 yrs	>50 yrs
TSS (lbs/ac)	<200	200-400	>400
Pathogens (cfu/100mL)	<126	126-750	>750
Stream Density (ft/ac)	<50	50-100	>100

Summing the parameter metrics identified above provided the results further identifying critical areas in our study area. From the figure below it can be seen that basins surrounding Interstate 24 score low in the prioritization ranking. This could be the result of additional BMPs placed in and around commercial and

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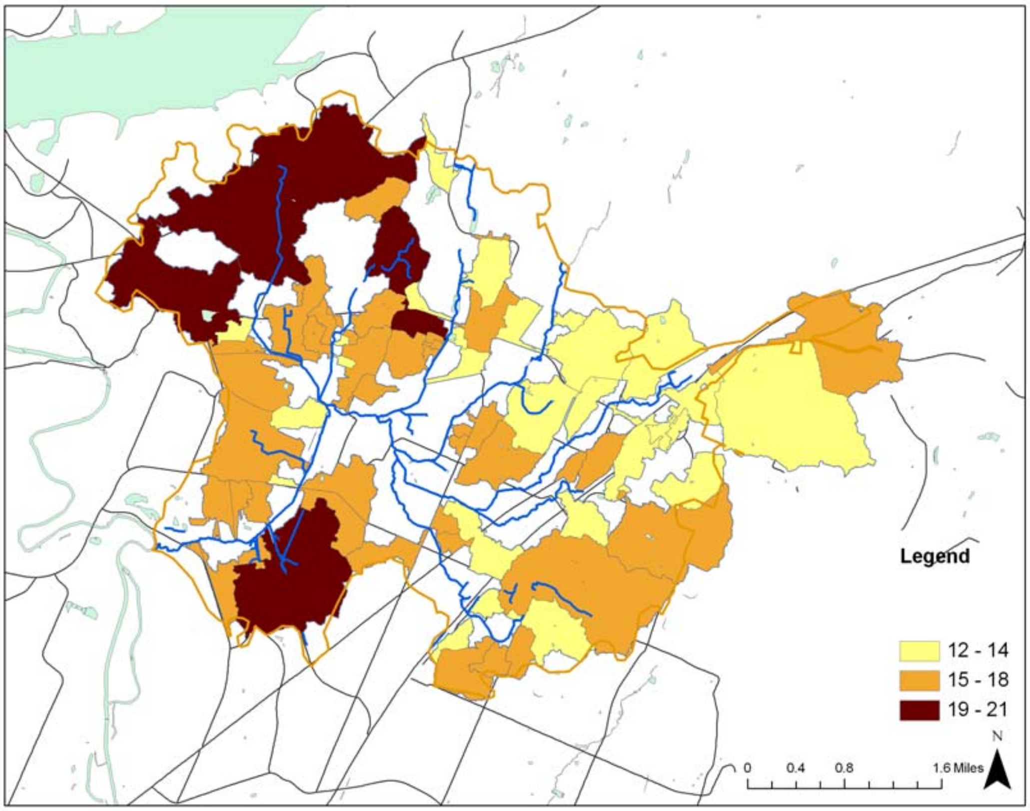
industrial facilities; which tend to congregate in this area. Similarly, age of sanitary infrastructure is likely newer in these basins as a result of more recent development. Conversely, basins located in the northwest of study area display higher scores; likely as a result of elevated age of infrastructure, lower BMP counts, and higher illicit discharge occurrences. The two basins with the highest score had the highest SSO occurrences, supporting the utility of this parameter.



Identification of critical areas within Friar Branch Watershed, with larger values (darker colors) representing areas of greater priority.

Although this exercise is admittedly simple relative to the complex ecological patterns and processes found in natural systems, it does highlight critical areas in which initial efforts may be placed. We are confident that this approach and the parameters included are useful to include in watershed management process. This analysis will specifically be used for 1) developing an inventory of problematic stream segments, 2) identifying and prioritizing stream restoration programs, 3) establishing proper management of activities impacting certain stream reaches, and 4) establishing pre- and post-restoration water quality studies within City waters.

CONSENSUS BUILDING AND ITS ROLE IN SUCCESSFUL STORMWATER UTILITY IMPLEMENTATION

David Mason, P.E., D.WRE[1]

INTRODUCTION

In today's tough economic times, the thought of implementing a new funding program is daunting. However, increased regulatory requirements related to the NPDES program and TMDLs will force many programs down the stormwater utility path. One key for the successful implementation of a stormwater utility is an effective public involvement program.

The use of a stormwater management advisory committee is crucial to building a consensus on both the level of stormwater service to be provided by a community as well as the most effective and equitable method for funding the program. This presentation will explore the role of the stormwater advisory group in the process of building and sustaining a comprehensive stormwater management program that is adequately funded to meet today's many stormwater challenges. The presentation will describe the proper make-up of such a committee, necessary information to convey the challenges facing stormwater programs, the process for consensus building, and the committee's role in bringing the message back to their constituents to garner support and understanding of the need for the program.

APPROACH

When attempting to implement a stormwater funding program, a key pitfall to avoid early in the process is to focus on the amount of money you want to generate. You may wish to develop the "cadillac" of stormwater programs to meet your NPDES permit requirements and other water quality/quanity goals. However, the key to the successful implementation of a stormwater funding program must first focus on the services to be provided. The public must want the stormwater service provided by the new revenues before they will agree to pay for them. For this reason, it is important to engage the public early in the process of stormwater utility development and the most effective method for achieving this engagement is through the formation of a Stormwater Advisory Committee (SWAC).

The first step in the process is to define the public involvement team within the community organization. This team may consist of engineering staff, public works staff, public information staff, staff in the city/county manager's office, outside consultants, etc. This team must then collaborate to assess the community's needs. Is the driver for the progam only a regulatory requirement? Does the City/County get frequent calls regarding other stormwater issues? Have large capital projects been identified that lack funding to imlpement?

Next, the public involvement team will want to identify members of the community that may regularly deal with stormwater issues and/or organizations/businesses that may be most affected by a new user fee. This committee should be a broadly based with diverse opinions. In short, do not only invite your friends, but also invite your "enemies." The best place to address questions and educate community members that may be opposed to a new fee is in a forum such as this, which is a controlled and facilitated process. Groups to consider as representatives include homeowners, citizen action committees, large commercial

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properties, hospitals, schools, large industries, small businesses, environmental groups, and tax-exempt property owners (such as, churches).

Once the group is established, the next step is to identify a planned but flexible roadmap for achieving consensus. Most SWAC processes include 6-8 meetings covering a variety of topics such as basic stormwaters services, regulatory requirements, the current level of service being provided, the cost of that service. As noted previously, the stakeholders must first understand the existing program and needs before discussing options for funding. Once the committee is able to buy-in to the fact that an increased level of service is required, only then should you move on to discussing the proper way to fund an expanded program.

Now that the committee has agreed on a level of service, the next step is to identify all available funding options. This should not be a foregone conclusion. The SWAC should be led through a discussion of all funding options. No option should be left off the table. The pros and cons of each option should be presented with an emphasis on fairness and equity. It is through that discussion that the committee will begin to understand the benefits of a user fee based system of charges for stormwater. If a property produces more runoff (regardless of tax status), then that property should fund a larger burden of the stormwater service than a property that produces less runoff.

Following the discussion on level of service and funding options, the committee should then be prepared to begin developing a group consensus regarding the stormwater program. Depending on the make-up of the group, this consensus building process may be done openly in the room with everyone participating or it may be more advantageous to split the group into break-out sessions where each person may feel more comfortable to voice their opinion. It should be noted that unanimous support is not the target outcome. A general consensus on the issues/topics is a positive outcome. It then becomes the City/County Commissioner's responsibility to act on this recommendation. However, broad support from a public committee makes this political choice a must easier process.

RESULTS AND DISCUSSION

The development of a SWAC certainly has its advantages and disadvantages. The advantage is that your message can be tested in a small group before wider distribution, the feed-back is immediate, and committee members can become champions/advocates for your program once consensus is reached. However, the disadvantages are that it takes time (and money, likely) to do it correctly, the stakeholders must agree with the process and have responsibility in order to support it, and an experienced facilitator (not always available) is often the difference between success and failure.

Universally, our experience across the country has been that a well run, well organized SWAC process provides the best foundation for successful implementation of a new user fee program. The citizens in key sectors of your City/County become well-informed of your program and often can become an extension of your public information staff when they go back into the community. Also, support by a citizen's group can provide a "buffer" for City/County commissioners when making the tough choice of implementing a new fee.

One thing to remember is that the public information/involvment process does not end once a new fee is approved. In fact, this is only the beginning. The messages conveyed to your SWAC should then be disseminated to the general public. This may be accomplished through utility mailers, news/radio ads, and/or speaker's bureaus. Also, the use of any new revenues should be well-documented for public consumption. And lastly….report on your successes! The best way to develop continued report for your program is to show your customers that benefits that their fee is providing.

URBAN RECREATIONAL GREENWAYS: OPPORTUNITIES FOR BETTER STORMWATER MANAGEMENT?

John F. McFadden[1], Mark Ivy [2], Paul Whitworth[3], Tara Perry[4], and Frank Bailey[5]

Greenways are linear open spaces which typically follow natural corridors and are generally designed and managed to support conservation and recreation. These facilities are often times located along river corridors and in floodplains and flood ways. Within these corridors Ahern's (2004) greenway theory suggested that there are three hypotheses related to greenway value: co-occurrence of resources, inherent benefits of connectivity, and the compatibility of uses. The compatibility of recreation and conservation uses was the foundation for the current study.

The study explored opportunities for better integration of stormwater management and recreational facilities and uses in urban greenways. Several Middle Tennessee greenways were visually surveyed to achieve the study purpose. Study findings revealed opportunities to promote better stormwater management while potentially enhancing the recreational experience through increased opportunity. Sub-surface drainage can be enhanced along linear paved trails within greenways through the implementation of small rain gardens or infiltration basins, potentially enhancing recreational experiences by increasing aesthetics and creating additional opportunities for nature observation and watershed education.

Study results may help planners and designers better integrate conservation of natural resources and recreation infrastructure in riparian greenways. Furthermore, study results may be helpful to greenway and stormwater managers interested in understanding how vegetation management may enhance the recreational environment and have a positive impact on stormwater. Finally, the exploratory study results may indicate future research directions such as the need to quantify the potential for storm and flood water infiltration and storage associated with forested greenways.

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SESSION 2A

ECOLOGY/BIOLOGY I
8:30 a.m. – 10:00 a.m.

Review of USEPA Draft Ammonia Water Quality Criteria—Role of Freshwater Mussels and Unique Implementation Issues
Scott Hall

The Interaction of Chemical, Hydrological, and Basin Factors Influencing Brook Trout in Great Smoky Mountain Streams
Keil J. Neff and John Schwartz

Exposure of Fish to Pharmaceutical Products in Surface Waters
June-Woo Park and Theodore B. Henry

ECOLOGY/BIOLOGY II
10:30 a.m. – 12:00 p.m.

Detection of Environmental Estrogens in Tennessee Waters by Assessment of Vitellogenin Gene Expression in Fishes
Michelle H. Connolly, Jill K. Wilson, Tze Ping Heah, and Theodore B. Henry

Regression Models of Ecological Streamflow Characteristics in the Cumberland and Tennessee River Valleys
Rodney R. Knight, W. Scott Gain, and William J. Wolfe

Potential Use of Substrate Metrics in Tracking TMDL Targets: Relationships Between Fine Particles on the Channel Bed and Benthic Habitat Status in Streams of the Ridge and Valley Ecoregion
Hunter Terrell and Carol Harden

HEALTH I
1:30 p.m. – 3:00 p.m.

Pilot Study to Assess Flood Related Well Water Contamination via Ultrafiltration
Judy Manners, Ellen Yard, Matthew Murphy, Vince Hill, and L. Rand Carpenter

Recovery of Streams in the Mill Creek Watershed from the May 2010 Flood Using E. coli as Indicator Bacteria
Mary Garmon

Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox: An Overview with Examples of Application in Tennessee
Benjamin J. Sherman

HEALTH II
3:30 p.m. – 5:00 p.m.

Molecular Study of Microbiological Integrity of Water Supply: Focusing on the Water Distribution System
Qiang He and Yan Zhang

Environmental Factors Affecting Relationships Between Bacteroides and E. coli in Mixed Land-Use Watersheds
Alice Layton, Dan Williams, Shawn Hawkins, James Farmer, Forbes Walker and Anne Choquette

In-Field Decay Rates of E. coli and Bovine Bacteroides in Beef Cattle Manure
Jiangwei Liu, Shawn Hawkins, Dan Williams, Alice Layton, and Forbes Walker

REVIEW OF USEPA'S DRAFT AMMONIA WATER QUALITY CRITERIA– ROLE OF FRESHWATER MUSSELS AND UNIQUE IMPLEMENTATION ISSUES

Scott Hall, ENVIRON

USEPA's proposed ammonia water quality criteria (WQC) have not been finalized pending public comment. Some form of the criteria will be adopted by USEPA, and state regulatory agencies who will implement these criteria into NPDES discharge permits. Like past (1999) ammonia WQC, the proposed criteria are pH- and temperature-dependant. The re-derived criteria make use of a much larger database than the 1999 criteria derivation, and include data on freshwater mussels. Addition of the mussel toxicity test data results in much lower ammonia criteria for the "mussels present" condition. The southeastern U.S. contains some of the highest diversity and dominance of mussels in surface waters anywhere in the nation, and the more stringent criteria will clearly impact ammonia discharge limits in this region, particularly for effluent-dominated streams. While the data on ammonia toxicity to mussels consistently indicate such species are highly sensitive to ammonia, there are some concerns related to the data used in criteria re-derivation. Additionally, there are issues related to the environmental relevance of the mussel toxicity test data with respect to the way WQC are applied in discharge permits, and there are key concerns related to the way WQC are applied in the NPDES discharge program. This presentation updates the status of the proposed ammonia WQC, presents the strengths and concerns of the proposed criteria, and highlights potential issues related to criteria implementation in the NPDES discharge program. At the time of this abstract submittal, EPA was considering addition of data on non-pulmonate snails to the ammonia criteria database and re-derivation of the criteria. The status of those studies and data will also be reviewed. The proposed "mussels present" chronic criteria are almost 80 percent lower than the existing ammonia criteria.

THE INTERACTION OF CHEMICAL, HYDROLOGICAL, AND BASIN FACTORS INFLUENCING BROOK TROUT IN GREAT SMOKY MOUNTAIN STREAMS

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

In the Great Smoky Mountains National Park, basin factors governing local chemical processes control stream acidification response, and the interaction of chemical, hydrological, and basin factors influence native brook trout populations. This research examined the effects of elevation, basin area, Anakeesta geology, soil, and vegetation on stream chemistry; and evaluated trout densities with respect to baseflow chemical constituents, basin characteristics, and hydrology. Elevation, basin slope, and chemical and physical soil characteristics were found to be the primary basin factors influencing episodic stream acidification. Sites above 975m had significantly lower pH, ANC, sodium, and silicon and higher nitrate concentrations than lower elevation sites in baseflow and stormflow ($p<0.05$). Nitrate, sodium, magnesium, silicon, and base cation concentrations were significantly lower in streams with $<10km^2$ basins ($p<0.05$). Area-weighted average soil slope and saturated hydraulic conductivity were negatively correlated with pH, ANC, sodium, potassium, and silicon concentrations, and were positively correlated with nitrate, sulfate, aluminum, and magnesium concentrations ($p<0.01$). Basin factors accounted for the greatest proportion of variability in young-of-year (YOY) and adult brook trout densities. Adult brook trout densities were positively correlated ($p<0.05$) with elevation and average soil cation exchange concentration. Spatial variability was greater than temporal variability in trout populations, and temporal variability in YOY populations was more than double the variability in adult populations. Fall flows were positively correlated ($p<0.05$) with total brook trout densities and YOY trout densities were significantly lower when there was a flood within one year of the fish sampling date.

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EXPOSURE OF FISH TO PHARMACEUTICAL PRODUCTS IN SURFACE WATERS

June-Woo Park[1*] and Theodore B. Henry[2]

Pharmaceuticals can contaminate surface waters after their prescribed medical use and have the potential to negatively affect aquatic organisms. Selective serotonin reuptake inhibitors (SSRIs; e.g., Prozac®) are of particular environmental concern because they are biologically active at low concentrations, and have been detected in surface waters downstream of wastewater treatment plants. SSRIs are among the most frequently prescribed drugs in human medicine and patients typically continue treatment over long periods of time. In non-target organisms like fish, SSRIs can act on neuroendocrine signaling system and potentially influence higher levels of biological organization including reproduction and behavior. We previously found a delayed development of adult sexual morphology in western mosquitofish (*Gambusia affinis*) by the chronic (100d) exposure of SSRI (fluoxetine, 60 ppb), suggesting potential impacts on fish reproduction. For a better understanding of biochemical pathways underlined by SSRIs exposure, we evaluated global gene expression profiles for two SSRIs (fluoxetine and sertraline) exposures to zebrafish (*Danio rerio*) and investigated if expression patterns of specific genes could be used as indicators of SSRI exposure in fish. They were exposed to two concentrations (25 and 250 ppb) each of SSRIs for 5d for microarray analysis (Affymetrix GeneChip® Zebrafish Genome Array). No mortality or behavioral abnormalities were observed, however alterations in global gene expression indicated treatment effects on gene regulation. Many genes with significantly altered (> 1.5 fold) relative to control groups were identified. The observed changes in gene regulation will be exploited to develop biomarkers and thus to monitor the exposure of wild fish to SSRIs.

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DETECTION OF ENVIRONMENTAL ESTROGENS IN TENNESSEE WATERS BY ASSESSMENT OF VITELLOGENIN GENE EXPRESSION IN FISHES

Michelle H. Connolly*[1], Jill K. Wilson[1], Tze Ping Heah[1], and Theodore B. Henry[1]

Environmental estrogens are substances (both natural and anthropogenic) that mimic the activity of estrogen and can negatively affect the physiology of aquatic organisms. Numerous aquatic environments in the U.S. are contaminated by environmental estrogens and negative effects on fish are possible at all levels of biological organization. Male fish exposed to environmental estrogens can be feminized with consequent changes in behavior, development and reproductive physiology. Vitellogenin genes (*vtg*) are induced by endogenous estrogen and code for egg yolk precursor proteins in adult female fish, but are also induced in young or male fish exposed to environmental estrogens. Consequently, expression of *vtg* in young or male fish has become a biomarker of exposure to environmental estrogens. We have developed a bioassay to measure expression of *vtg* based on real-time reverse transcriptase PCR (qRT-PCR) to quantify exposure to environmental estrogens and enhance understanding of fish reproductive physiology. Our group has used this assay to evaluate the estrogenicity of various natural and anthropogenic substances and to evaluate the normal fluctuation in *vtg* expression that occurs during oogenesis in female zebrafish (*Danio rerio*). These results will be presented along with results of our current efforts to investigate expression of *vtg* in male largemouth bass *Micropterus salmoides* that were collected from East Tennessee reservoirs to evaluate the presence of environmental estrogens in these systems.

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REGRESSION MODELS OF ECOLOGICAL STREAMFLOW CHARACTERISTICS IN THE CUMBERLAND AND TENNESSEE RIVER VALLEYS

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

Predictive equations were developed using stepbackward regression for 19 ecologically relevant streamflow characteristics grouped in five major classes (magnitude, ratio, frequency, variability, and date) for use in the Tennessee and Cumberland River watersheds. Basin characteristics explain 50 percent or more of the variation for 10 of the 19 equations. Independent variables identified through stepbackward regression were statistically significant in 81 of 304 coefficients tested across 19 models ($\alpha < 0.0001$) and represent four major groups: climate, physical landscape features, regional indicators, and land use. The most influential variables for determining hydrologic response were in the land-use and climate groups: daily temperature range, percent agricultural land use, and monthly mean precipitation. These three variables were major explanatory factors in 17, 15, and 13 models, respectively. The equations and independent datasets were used to explore the broad relation between basin properties and streamflow and its implications for the study of ecological flow requirements. Key results include a high degree of hydrologic variability among least disturbed Blue Ridge streams, similar hydrologic behavior for watersheds with widely varying degrees of forest cover, and distinct hydrologic profiles for streams in different geographic regions.

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POTENTIAL USE OF SUBSTRATE METRICS IN TRACKING TMDL TARGETS: RELATIONSHIPS BETWEEN FINE PARTICLES ON THE CHANNEL BED AND BENTHIC HABITAT STATUS IN STREAMS OF THE RIDGE AND VALLEY ECOREGION

Hunter Terrell[1] and Carol Harden

Progress towards meeting TMDL standards for sediment and habitat degradation is currently monitored using macroinvertebrate indices of biological integrity. Although effective, macroinvertebrate surveys can be expensive and time consuming. As of yet, no substrate metrics have been established to support efforts to measure progress towards TMDL standards. To address this, we examined relationships between substrate metrics and biotic integrity indices for 38 riffle reaches in the Ridge and Valley in east Tennessee. Reaches were chosen from sites in the Ridge and Valley ecoregion for which TDEC has assessed macroinvertebrates. We obtained macroinvertebrate biotic integrity metrics from the state of Tennessee and used a modified method of EPA's Environmental Monitoring and Assessment Program to visually estimate embeddedness of streambed particles and characterize the substrate of sample riffles. Analysis indicates that embeddedness of the channel bed and D_{50} of sample riffles are negatively and positively correlated, respectively, with biotic integrity scores. Visual estimation of embeddedness could potentially be an effective metric for monitoring progress towards TMDL targets; however, visual estimation of embeddedness on the stream channel is highly subjective and may vary between surveyors.

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PILOT STUDY TO ASSESS FLOOD RELATED WELL WATER CONTAMINATION VIA ULTRAFILTRATION

Judy Manners, M.S.[1*], Ellen Yard, Ph.D[2], Matthew Murphy, Ph.D.[2], Vince Hill, Ph.D[2] and L. Rand Carpenter, DVM[1]

INTRODUCTION

About 15% of the U.S. population, or nearly 50 million people, obtain their drinking water from domestic wells, which are not protected by the Safe Drinking Water Act. Even when properly constructed and maintained, wells are at risk for contamination from flooding, particularly if flood water seeps into a submerged well through the well head or casing. Although well owners are instructed to clean their wells prior to use following a flood, there is a possibility of residual contamination if cleaning does not remove all pathogens or if there is aquifer contamination. Additionally, some pathogens are resistant to chlorination. There is minimal information concerning the type and quantity of contaminants present in well water after flood events. One reason for the scarcity of previous research stems from difficulties in testing water sources for pathogens. However, the recent development of ultrafilter field sampling techniques increases the feasibility of testing water sources for multiple viruses and parasites.

The goal of this pilot study was to assess flood-related well water contamination. Specifically, our objectives were to assess the feasibility of conducting ultrafilter field sampling in flood and domestic well water; and, to characterize and compare microbial, pathogenic, and chemical contaminants in flood water, flooded wells, and non-flooded wells. For this study, *flood*, was defined as an area reaching the National Weather Service (NWS) category of “Major Flooding” including extensive inundation of structures and roads, significant evacuations of people or transfer of property to higher elevations, and an NWS issued statement describing roadway “ponding” or “flooding”. *Domestic well* was defined as a private well serving 1 household and serving as the residence’s primary source of drinking water.

Tennessee flooding during May 2010 reached a 1,000 year flood event in some counties as defined by the U.S. Geological Survey. Over these two days, rainfall totaled 17 inches in some areas. Flash flooding occurred along the Cumberland and Lower Tennessee Rivers and their tributaries in response to a 36 hour rainfall event during May 1 and 2, 2010.

For this study, flood water samples were collected from Cheatham Reservoir, an impoundment of the Cumberland River. The Cumberland River flows approximatley 697 miles from eastern Kentucky through northern middle Tennessee to the Ohio River at Smithland, Kentucky. Cheatham Dam is located at river mile 148.7, in middle Tennessee. Cheatham Reservoir covers approximately 7,450 acres at normal pool and extends 67.5 miles upstream from Cheatham Dam near Ashland City, through Nashville, to Old Hickory Dam in Hendersonville, river mile 216.2. Major tributaries draining to Cheatham Reservior include 2 rivers, the Stone’s and Harpeth; and 7 large creeks: Mill, Richland, Whites, Marrowbone, Pond, Sams, and Sycamore. Major flooding occurred on all tributaries to Cheatham Reservoir.

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Domestic wells were selected from flooded and non-flooded regions near Cheatham Reservoir. Well owners were identified from multiple sources including; a hot line established by the Tennessee Department of Environment and Conservation's (TDEC) Division of Groundwater Protection, property parcel records, maps of water sytem distribution areas, and by personal communication with local residents.

APPROACH

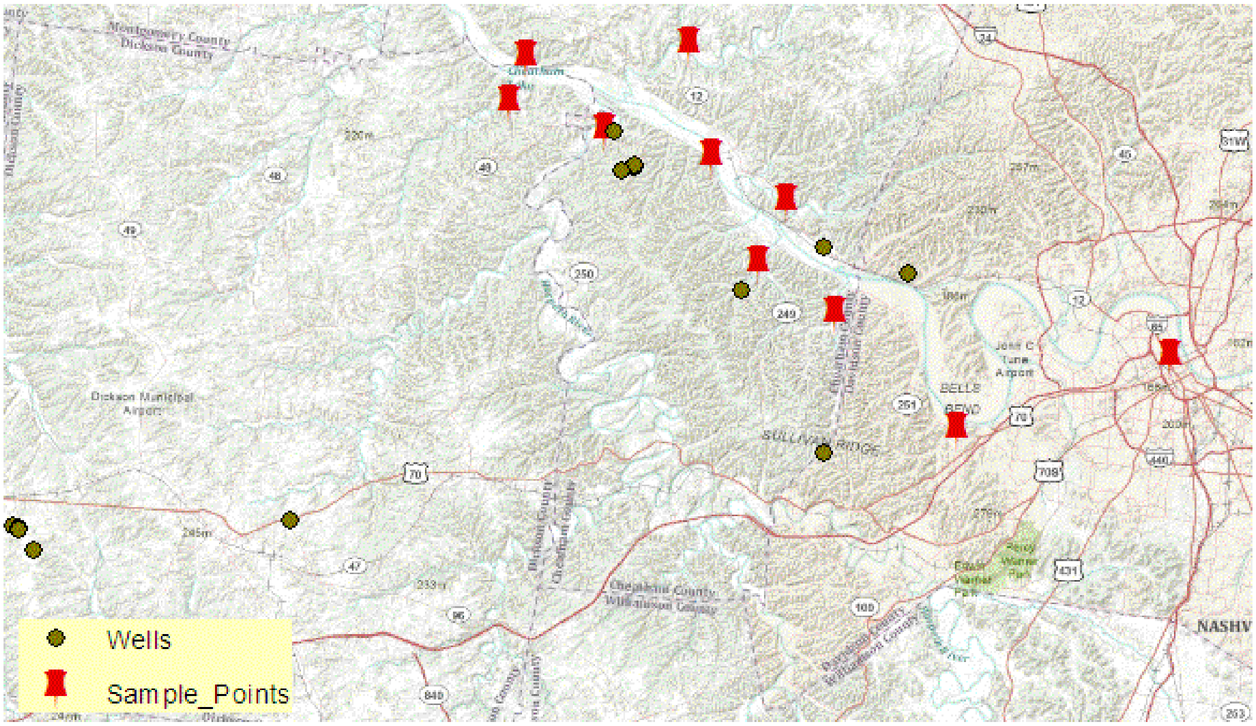
Ten flood water samples were collected during May 5 and 6, 2010 from Cheatham Reservoir as flood waters were receding. Flood water sampling locations were confined to a 40 mile stretch of Cheatham Reservoir from Nashville to Ashland City. Specifc locations were chosen in an attempt to collect representative samples of the flood water. However, accessibility was limited during flood conditions. Sample locations were georeferenced with GPS units.

Flood water samples were collected from the edge of the water according to the Centers for Disease Control and Prevention's (CDC) Pilot Field Ultrafiltration Protocol. A peristaltic pump with tubing was used to filter 100 liters of water through a 30 kiloDalton (kDa) micron dialysis filter. The tubing was discarded after each sample was collected to prevent contamination among samples. Twenty liter carboys were used to measure the water being discharged from the filter apparatus. Grab samples were collected in glass vials. Samples were shipped to the Colorado State Laboratory for analysis under EPA Method 300, Determination of Inorganic Anions by Ion Chromatography for nitrates. Filters were shipped to the CDC laboratory in Atlanta and analyzed for pathogen concentrations of *E. coli*, *Enterococcus*, *Cryptosporidium, Giarida*, norovirus, enterovirus, *Campylobacter, Salmonella*, hepatitis A virus, and adenovirus. Water quality parameters of temperature, pH, conductivity, dissolved oxygen (DO), turbidity were measured with a HORIBA handheld water quality instrument.

Post flood surface and well water sampling began in June 2010. For general comparison of flood to post flood suface water conditions, 3 surface water samples were collected on June 10, 2010. The post flood locations were in the vicinity of previous sampling locations; however, specific edge of water locations varied with the diffence between flood stage and normal pool. Seventeen water wells were selected, 6 had been flooded and 11 were non-flooded (Figure 1).

Water well sampling methodology was the same as the surface water; except, the peristaltic pump was unnecessary as the sampling aparatus was modified to include a fitting for the outdoor faucet. Water was drawn from the well by the existing pump and allowed to run for several minutes before collecting water samples. Water was captured in a plastic container so that water quality parameters could be measured. Samples were collected from the faucet for nitrates and Atrazine. Water wells with high contaminant concentrations were resampled at quarterly intervals.

Figure 1. Sampling Locations



RESULTS AND DISCUSSION

Ten flood and 3 post flood surface water and 17 post-flood well water samples were assessed for the following contaminants via ultrafiltration of 100 liters of water: total coliform, *E. coli*, *Enterococcus*, *Cryptosporidium, Giarida*, norovirus, enterovirus, *Campylobacter, Salmonella*, hepatitis A virus, and adenovirus. Grab samples were analyzed for nitrates and Atrazine™. Temperature, pH, conductivity, and turbidity were measured in the field with handheld water quailty instruments.

The flood water fecal indicator concentration ranges in MPN/100ml were: total coliforms: 845 – 120,980; *E. coli*: 14 – 12,098; and *Enterococcus*: 14 – 2,897. All flood water samples were positive for *Salmonella* but negative for *Campylobacter* bacteria*.* All were negative for *Cryptosporidium ,Giardia,* norovirus, enterovirus, and hepatitis A virus. However, Adenovirus CT values ranged from negative to 41. Nitrate and Artrazine levels were negligible (Tables 1-2).

Three post flood water samples were collected in June 2010 to compare flood and nonflood surface water conditions. Nitrates ranged from 0.15-0.32 mg/L. Atrazine was not detected. Samples were negative for viruses, except Adenovirus CT values ranged from 39-41. Two of the three samples showed a decrease of fecal indicators. However, one sample, DW009, had total coliform, *E. coli*, and *Enterococcus* concentrations higher post flood than during the flood. One post flood sample, DW011, cultured positive for *Salmonella*. (Tables 3-4).

The elevated bacteria level from Highway 49 Riverview Restaurant sample location may be due to discharge of untreated wastewater from a nearby flood damaged restruarant and campground or from a nearby sewage treatment plant damaged in the flood event. Untreated wastewater continued to discharge from this wastewater treatment plant until September 2010.

All wells sampled June 2010 tested negative for *E.coli 0157:H7*. For well water, fecal indicator concentrations ranges in MPN/100ml were: total coliforms: <0.05 – 711; *E. coli:* <0.05 – 480; *Enterococcus*: < 0.05 – 99. All well samples were negative for viruses, *Cryptosporidium* and *Giardia*. Nitrate values ranged from non-detect to 2.1 mg/L. Atrazine was not detected in any well water samples.One well had the highest concentrations. Water from this same well also cultured positive for *Salmonella* and *Campylobacter* (Tables 5-8).

Two wells having high concentrations of *E. coli*, DW012 and DW013, were repeat sampled in August 2010. During this sampling event, both wells were culture negative for *Salmonella* and *Campylobacter*. However, well DW013 still contained high levels of fecal indicator bacteria, though decreased in concentration.

Results were inconclusive on whether the flood water contaminated the well water. Ultrafiltration techniques were successful and easily adaptible to field situations. Increased turbidity appeared to slow filtering.

Table 1. Flood Water, Water Quality Parameters

Sample ID	Location Name	pH	Temperature (ºC)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Nitrate (mg/L)	Atrazine (ppb)
F001	Harpeth Valley Utilities	7.34	24.8	28.8	71.9	423	0.42	<0.2
F002	Pond Creek	7.31	23.91	34.1	5.74	163	0.3	<0.2
F003	Hwy 49 at Harpeth River	7.3	22.38	23.6	5.27	192	0.48	<0.2
F004	Dry Creek Rd at Hwy 249	5.4	16.19	23.2	0.41	121	0.2	<0.2
F005	Hwy 49 at Riverview Restaurant	6.74	18.08	37.8	1.68	424	0.48	<0.2
F006	Lock A Road	7.28	21.62	50.2	6.8	98	0.25	<0.2
F013	Corner of Harrison and Rosa Parks	5.53	21	149	10.4	267	2.2	<0.2
F014	Marrow Bone Creek (next to road)	7.79	23.2	163	13.26	34	0.14	<0.2
F015	Harris Town and Lockertsville Rd	7.12	20.6	11.3	9.87	223	0.57	<0.2
F016	Cheatham Dam	7.59	24.57	75.1	12.4	140	0.38	<0.2

Table 2. Flood Water, Bacteria and Adenovirus Results

ID	Location Name	Total Coliforms (MPN/100mL)	E. coli (MPN/100mL)	Enterococci (MPN/100mL)	Salmonella Culture	Campylobacter Culture	Adenovirus CT Values
F001	Harpeth Valley Utilities	12,098	12,098	2,897	positive	negative	34
F002	Pond Creek	12,098	178	2,053	positive	negative	40
F003	Hwy 49 at Harpeth River	5,725	124	27	positive	negative	41
F004	Dry Creek Rd at Hwy 249	120,980	149	993	positive	negative	negative
F005	Hwy 49 Riverview Restaurant	14,545	143	44	positive	negative	39
F006	Lock A Road	4,400	24	75	positive	positive	40
F013	Corner of Harrison and Rosa Parks	120,980	1,995	274	positive	negative	35
F014	Marrow Bone Creek (next to road)	70,680	107	777	positive	negative	40
F015	Harris Town and Lockertsville Rd	21,760	78	460	positive	negative	negative
F016	Cheatham Dam	845	14	14	positive	negative	41

Table 3. Surface Water Comparison Flood, Post Flood Water Quality

Sample ID	Location	pH	Temperature (ºC)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Nitrate (mg/L)	Atrazine (ppb)
F002	Pond Creek	7.31	23.91	34.1	5.74	163	0.3	<0.2
DW011	Beside 3639 River Road	7.76	26.76	92	8.05	0.246	--	--
F005	Hwy 49 Riverview Restaurant	6.74	18.08	37.8	1.68	424	0.48	<0.2
DW009	Hwy 49 Riverview Restaurant	8.14	25.6	24.7	8.17	0.227	--	--
F014	Marrowbone Creek at Hwy 12	7.79	23.2	163	13.26	34	0.14	<0.2
DW021	Marrowbone Creek	7.96	26.2	22.2	10.75	0.229	0.32	<0.3

Table 4. Surface Water Comparison Flood, Post Flood Bacteria and Adenovirus

Sample ID	Collection Date	Total Coliforms (MPN/100mL)	E. coli (MPN/100mL)	Enterococci (MPN/100mL)	Salmonella Culture	E. coli 0157:H7 Culture	Campylobacter Culture	Adenovirus CT Values
F002	05-May-10	12,098.00	177.50	2,053.00	positive	negative	negative	40
DW011	09-Jun-10	3635	121	335	positive	negative	negative	41
F005	06-May-10	14,545.00	142.55	43.90	positive	negative	negative	39
DW009	**09-Jun-10**	**217,600.00**	**35,600.00**	**7,765.50**	negative	negative	negative	39
F014	06-May-10	70,680.00	107.10	776.55	positive	negative	negative	40
DW021	10-Jun-10	>120.98	32	56	negative	negative	negative	negative

Table 5. June 2010 Well Water, Water Quality Parameters

Sample ID	Collection Date	pH	Temperature (ºC)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Nitrate (mg/L)	Atrazine (ppb)
DW001	08-Jun-10	5.94	21.08	0	11.53	0.035	0.17	<0.25
DW002	08-Jun-10	6.25	20.87	14.5	10.79	0.028	<0.1	<0.25
DW003	08-Jun-10	5.66	22.54	0	9.07	0.033	0.65	<0.25
DW004	08-Jun-10	6.72	28.33	2	15.43	0.3	0.15	<0.25
DW005	08-Jun-10	7.13	22.28	2.1	11.72	0.251	0.52	<0.25
DW006	08-Jun-10	6.84	23.54	0	7.71	0.131	0.94	<0.25
DW007	09-Jun-10	7.39	22.35	2.4	30.28	0.527	-	-
DW008	09-Jun-10	7.52	18.62	0	19.48	0.436	-	-
DW010	09-Jun-10	7.79	23.94	0.3	7.28	1.21	-	-
DW012	**10-Jun-10**	**7.43**	**18.45**	**80.5**	**20.97**	**2.47**	**<0.1**	**<0.3**
DW013	**10-Jun-10**	**7.56**	**19.96**	**1.1**	**6.47**	**138**	**<0.1**	**<0.3**
DW014	10-Jun-10	7.74	21.77	0.3	10.03	0.483	0.28	<0.3
DW016	10-Jun-10	7.91	12.24	0	7.82	0.366	0.48	<0.3
DW017	10-Jun-10	7.75	21.8	0	8.17	0.457	0.46	<0.3
DW018	10-Jun-10	7.67	21.12	0	8.8	0.43	0.55	<0.3
DW019	10-Jun-10	7.41	21.94	0	6.54	0.451	1.4	<0.3
DW020	10-Jun-10	7.75	23.7	0	7.16	0.445	0.72	<0.3

Table 6. June 2010 Water Wells, Bacteria and Adenovirus Results

Sample ID	Collection Date	Total Coliforms (MPN/100mL)	E. coli (MPN/100mL)	Enterococci (MPN/100mL)	Salmonella Culture	E. coli 0157:H7 Culture	Campylobacter Culture	Adenovirus CT Values
DW001	08-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW002	08-Jun-10	1.8	<0.05	0.05	negative	negative	negative	negative
DW003	08-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW004	08-Jun-10	1.40	0.10	<0.05	negative	negative	negative	negative
DW005	08-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW006	08-Jun-10	0.21	<0.05	<0.05	negative	negative	negative	negative
DW007	09-Jun-10	2.24	0.43	0.05	negative	negative	negative	negative
DW008	09-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW010	09-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW012	**10-Jun-10**	**187**	**65**	**7.6**	**negative**	**negative**	**negative**	negative
DW013	**10-Jun-10**	**711**	**480**	**99**	**positive**	**negative**	**positive**	negative
DW014	10-Jun-10	13	<0.05	<0.05	negative	negative	negative	negative
DW016	10-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW017	10-Jun-10	<0.05	<0.05	<0.05	negative	negative	negative	negative
DW018	10-Jun-10	0.375	0.26	<0.05	negative	negative	negative	negative
DW019	10-Jun-10	1.9	1.1	0.16	negative	negative	negative	negative
DW020	10-Jun-10	2.6	2.0	0.16	negative	negative	negative	negative

Table 7. Well Water Quality Parameters Comparison between Wells with High Bacteria Concentration

ID	Date	Time	pH	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Nitrate (mg/L)	Atrazine (ppb)
DW012	10-Jun-10	9:40 AM	7.43	18.45	80.5	20.97	2.47	<0.1	<0.3
	25-Aug-10	9:55 a.m.	6.39	23.2	51.4	11.5	0.88	<0.2	—
DW013	10-Jun-10	9:44 AM	7.56	19.96	1.1	6.47	138	<0.1	<0.3
	25-Aug-10	8:55 a.m.	5.69	19.6	0	10.9	1.21	<0.1	—

Table 8. Well Water Bacteria and Adenovirus Results, Comparison between wells with high bacteria levels

ID	Date	Total Coliforms (MPN/100mL)	E. coli (MPN/100mL)	Enterococci (MPN/100mL)	Salmonella Culture	E. coli 0157:H7 Culture	Campylobacter Culture	Adenovirus CT Values
DW012	10-Jun-10	187	65	7.6	negative	negative	negative	negative
	25-Aug-10	16	6.5	1.0	negative	negative	negative	negative
DW013	10-Jun-10	711	480	99	positive	negative	positive	negative
	25-Aug-10	1.9	0.10	0.26	negative	negative	negative	negative

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RECOVERY OF STREAMS IN THE MILL CREEK WATERSHED FROM THE MAY 2010 FLOOD USING *E. COLI* AS INDICATOR BACTERIA

Mary Garmon[1]

Between May 1st and 2nd, 2010, Nashville, TN received an unprecedented 13.53 inches of precipitation. During the subsequent flood, pollutants inundated receiving waters and public health and safety became a major concern. Bacteria levels increased due to runoff pollutants and exceeded water quality standards.

This study focuses on the Lower Mill Creek Watershed, which is located in the Greater Nashville Area. *Escherichia coli* levels were studied before and after the catastrophic storm to determine if and when bacteria levels returned to pre-flood conditions. There were 11 sample sites selected in nine streams within Lower Mill Creek Watershed. F-tests and t-tests were used to compare variance and means of *E. coli* samples taken before and after the flood. A paired t-test determined the significance of overall means before and after the flood. Dissolved oxygen, conductivity, temperature, and pH were also measured for each water sample.

On average, *E. coli* concentrations increased ($P=0.0005$) from 215 MPN before the flood to 560 MPN after the flood. Six of the 12 sample sites had significantly ($P \leq 0.05$) higher *E. coli* concentrations after the flood. Sanitary sewer overflows were prevalent on many of the streams that exhibited high *E. coli* values. The *E. coli* values remained elevated in many streams until the end of June 2010. Trends in the chemical properties of the streams reflected normal changes in temperature and season during the study period, which complicated the statistical analyses. Forecasting the level of impact of a large-scale flood on a stream is a difficult task. However, the results showed that flooding can have long-term effects, including biological hazards, on receiving waters. *E. coli* levels in many of the streams were significantly higher after the flood for extended periods of time. It is advisable to avoid human contact with receiving waters after a storm or flood event to reduce the potential for transmission of harmful bacteria.

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SANITARY SEWER OVERFLOW ANALYSIS AND PLANNING (SSOAP) TOOLBOX: AN OVERVIEW WITH EXAMPLES OF APPLICATION IN TENNESSEE

Benjamin J. Sherman, P.E., D.WRE[1]

A properly designed, operated and maintained sanitary sewer system is meant to collect and convey all of the sewage that flows into to a wastewater treatment plant. However, occasional unintentional discharges of raw sewage from municipal sanitary sewers – called sanitary sewer overflows (SSOs) – occur in many systems.

Rainfall-derived infiltration and inflow (RDII) into sanitary sewer systems has long been recognized as a major source of operating problems, causing poor performance of many sewer systems. RDII is the main cause of SSOs to customer basements, streets, or nearby streams and can also cause serious operating problems at wastewater treatment facilities. There is a need to develop proven methodologies and computer tools to assist communities in developing SSO control plans that are in line with their projected annual capital budgets and provide flexibility in future improvements.

An overview of the software tools, named the Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox, is the focus of this presentation with examples of condition assessment in Tennessee.

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MOLECULAR STUDY OF MICROBIOLOGICAL INTEGRITY OF WATER SUPPLY: FOCUSING ON THE WATER DISTRIBUTION SYSTEM

Qiang He[1] and Yan Zhang[1]

Data on waterborne disease outbreaks suggest that water supply, particularly the water distribution systems, remains an important source of contamination that has yet to be fully addressed. Biofilms are a common presence in most water supply systems despite the various controlling efforts. Therefore, with the goal to develop effective measures to minimize the degradation of microbiological quality of drinking water in water supply systems, the overall objective of this study is to identify the processes controlling the development of biofilms. Molecular microbial ecology tools, such as pyrosequencing and clone library analysis, were used to characterize biofilms in water distribution systems. Piping material significantly affected the biofilm bacterial community structure. Among the three piping materials studied, galvanized iron, copper, and PVC, biofilm development was the least in copper pipes. Accordingly, pipes of galvanized iron and PVC supported more biofilm development as well as higher biodiversity in the biofilm communities. The predominant populations varied in biofilms in different piping materials, but all belonging to the family of *Sphingomonadaceae*, suggesting a link to the presence of these bacteria in the planktonic populations of source water. More importantly, the biofilms were found to be reservoirs of diverse opportunistic pathogens at low abundance.

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ENVIRONMENTAL FACTORS AFFECTING RELATIONSHIPS BETWEEN *BACTEROIDES* AND *E. COLI* IN MIXED LAND-USE WATERSHEDS

Alice Layton[1]*, Dan Williams[2], Shawn Hawkins[3], James Farmer[4], Forbes Walker[5] and Anne Choquette[6]

WATER QUALITY MONITORING AND ASSESSMENTS

Many watersheds in Tennessee include a mixture of land uses consisting of agricultural lands, rural residences, and small to medium cities. Often, the surface waters in these watersheds are used for drinking-water, agricultural needs, and also receive effluent from municipal wastewater treatment plants. Currently, measurement of *E. coli* concentrations forms the basis for determining whether surface waters meet the acceptable "pathogen" water quality limit for delineating impaired waters. *E. coli* and/or fecal coliforms were chosen over two decades ago as indicator organisms of potential disease risk based on a limited number of epidemiological studies. With the growing recognition that *E. coli* alone cannot be used to determine types of fecal pollution, the U.S. Environmental Protection Agency (EPA) is considering the use of other indicators such as *Bacteroide*s sp. for use as fecal source identifiers in coastal waters and beach areas. Recent research suggests that although *Bacteroides* and *E. coli* are both fecal indicator bacteria they may have different sensitivities to variations in environmental conditions. Over the past five years we have collected *Bacteroides* and *E. coli* concentration data for hundreds of samples from seven watersheds in east and middle Tennessee, providing information on the relationships between these two fecal indicators in the context of environmental conditions such as seasonality, water temperature and dissolved oxygen concentration. Understanding the relationships between *E. coli* and *Bacteroides* concentrations and whether the relationships between these bacterial species change in different environmental conditions, will aid in the use of *Bacteroides* species as fecal source indicators in EPA Total Maximum Daily Load models and in the U.S. Department of Agriculture's Soil Water Assessment Tool (SWAT).

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IN-FIELD DECAY RATES OF *E. COLI* AND BOVINE *BACTEROIDES* IN BEEF CATTLE MANURE

Jiangwei Liu[1]*, Shawn Hawkins[2]*, Dan Williams[3], Alice Layton[4], and Forbes Walker[5]

According to the 2010 305(b) Report-Status of Water Quality in Tennessee, approximately one fourth (24%) of all impaired stream miles are due at least in part to high pathogen concentrations (regulated in Tennessee using *Escherichia coli* as a fecal pollution indicator). The 2010 303(b) Report further indicates that agriculture is the largest source of overall stream impairment (42%). Fecal waste from pastured beef cattle is certainly a potential source of *E. coli* and genetic source tracking markers for bovine *Bacteriodes* spp. are available to bolster the assertion that cattle are an important source of high *E. coli* concentrations in impaired streams. Watershed scale simulations of the fate and transport of these bacteria from livestock pastures could be useful in the effort to improve water quality and can be made using the Soil and Water Assessment Tool (SWAT), a water quality model developed for rural, largely agricultural watersheds where beef cattle are predominantly found. However, SWAT requires accurate estimates of model parameters, such as the initial concentration of *E. coli* and bovine *Bacteroides* in manure as well as in-field decay coefficients. Surprisingly, there are no published data simultaneously documenting beef cattle manure *E. coli* and bovine *Bacterioides* in-field decay coefficients, which limits the usefulness of models like SWAT in the effort to reduce impairment. Herein we present preliminary data documenting the concentration of *E. coli* and bovine *Bacteriodes* in beef cattle manure as well as in-field decay rates. Data address variability between individual animals and the effects of seasonal feeding patterns.

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SESSION 2B

STORMWATER III
8:30 a.m. – 10:00 a.m.

Keeping Score—Using the USEPA Scorecard to Facilitate Holistic MS4 Compliance
Candice Owen, Rebecca Dohn, Byron Hinchey, Heather Williams, Andrew Reese, and Kim Hawkins

Constructed Floodplain Wetland for Stormwater Pollutant Management
Andrea Ludwig and W. Cully Hession

An Evaluation of Market-Based Strategies for Watershed Restoration in West Tennessee
Christopher A. Bridges, Jacob M. Blue, Gary D. Paradoski, J. Douglas Eppich, James A. Klang, Steven I. Apfelbaum, and Mark. S. Kieser

WATER SUPPLY
10:30 a.m. – 12:00 p.m.

Assimilative Capacity Modeling in Support of the Georgia Comprehensive State-Wide Water Management Plan
Brian Watson, Jeremy Wyss, Steven Davie, and Elizabeth Booth

System Modeling for Integrated Water Resource Planning
Leeann Williams, Jamie Lefkowitz, and Mark Hilty

Evaluating Groundwater Availability in Support of Georgia's Comprehensive State-Wide Water Management Plan
John D. Boyer

SEDIMENT & GEOMORPHOLOGY I
1:30 p.m. – 3:00 p.m.

Calculating Suspended-Sediment Concentration and Sediment Loads for Tennessee Streams
Melissa A. Harris

Bankfull Geomorphic Relationships and Reference Reach Assessment of the Ridge and Valley Physiographic Province
James Brady McPherson

Design and Construction of the Little Chatata Creek Realignment for the New Cleveland Municipal Airport
Michael Pannell, Brent C. Wood, Elizabeth M. Porter, and William K. Barry

MONITORING
3:30 p.m. – 5:00 p.m.

Up the Creek with a Paddle: Performance of a Visual Stream Assessment on a Non-Wadeable Stream
Michelle Hatcher and Bobby Allen

Dajugezhuang Village Comprehensive Village Waste Management Demonstration Project: Implications for Nutrient Management and Water Quality in China
Forbes Walker, Hailin Zhang, Terry Oda, and John Ungvarsky

TDOT Turbidity Sampling: Lessons Learned
Greg Russell and Beth Chesson

KEEPING SCORE – USING THE USEPA SCORECARD TO FACILITATE HOLISTIC MS4 COMPLIANCE

Candice Owen[1,*], Rebecca Dohn[2], Byron Hinchey[1], Heather Williams[3], Andrew Reese[1], Kim Hawkins[4]

In 2010, the State of Tennessee released new NPDES requirements for stormwater agencies, including a new Phase II MS4 Stormwater permit and one Phase I MS4 permit. Other Phase I MS4s are anticipating new permits in 2011. The permits come with additional requirements including a volume-based post-construction management approach and more stringent water quality monitoring requirements. A shift towards greener post-construction BMPs is also emphasized. How to integrate these new regulations with existing municipal codes and ordinances while minimizing conflicts is a challenge.

To help meet this challenge, all new Tennessee MS4 permits to date have required the use of the USEPA Scorecard, a document published by the USEPA in 2009. The Scorecard is essentially designed to aid municipalities in the examination of local codes and ordinances across multiple departments to ensure that these codes work together to protect water quality and aid green infrastructure implementation.
Using the EPA Scorecard to find all conflicts in local codes can be a daunting task for any municipality, especially large cities where each department can have hundreds of codes and procedures. Metro Nashville is in the process of creating Stormwater Management Manual Volume V – LID Manual, updating the prior four manuals in order to incorporate anticipated permit requirements. Development of the manual includes: completion of the scorecard, stakeholder meetings, development of technical criteria and selection of incentives. To facilitate completion of the Scorecard, Metro set up meetings with staff from multiple departments to explain the purpose of the Scorecard, how to fill in sections and how results would be used. Small modifications were added to the scorecard to help better understand the ease or difficulty in addressing existing conflicts. Additionally, individual meetings were conducted to highlight specific ordinances and codes that needed to be changed or re-examined. The resulting final report contains a list of regulatory barriers that will need to be addressed as the new manual is implemented.
By walking through the Scorecard and the steps Metro Nashville has taken to complete the Scorecard, other municipalities can gain a better understanding of what the scorecard entails including an example of how to use the document, as well to ways to make the Scorecard work more effectively for Tennessee's MS4s.

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CONSTRUCTED FLOODPLAIN WETLAND FOR STORMWATER POLLUTANT MANAGEMENT

Andrea Ludwig[1]* and W. Cully Hession[2]

A 0.2-hectare emergent wetland was constructed in the floodplain of Opequon Creek in the Ridge and Valley of Virginia as a best management practice for stormwater management. Research goals were to 1) determine if wetland hydrology existed on site, 2) estimate wetland hydraulic characteristics during overbank flows, and 3) evaluate the event-scale nutrient assimilative capacity of the constructed wetland. Wetland hydroperiod and groundwater gradients were measured in nested piezometers, and water table elevations demonstrated that wetland hydrology existed on the site. Residence time distributions of the high and low marsh features identified a considerable degree of flow dispersion and variable roughness. Total suspended solid concentrations decreased with increasing residence times in both experiments. Mass reduction of pollutants were 73% total suspended solids (TSS), 54% ammonia (NH_3), 16% nitrage (NO_3), 16% total nitrogen (TN), 23% orthophosphorus (PO_4), and 37% total phosphorus (TP) in the fall, and 69% TSS, 58% NH_3, 7% NO_3, 22% TN, 8% PO_4, and 25% TP in the spring. Dissolved nitrogen species were more rapidly removed than dissolved phosphorus. TSS, TP, and TN removal were greater and faster than dissolved nutrient species, suggesting that physical settling was the dominant removal mechanisms of stormwater pollutants.

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AN EVALUATION OF MARKET-BASED STRATEGIES FOR WATERSHED RESTORATION IN WEST TENNESSEE

Christopher A. Bridges[1]*, Jacob M. Blue[2], Gary D. Paradoski[2], J. Douglas Eppich[3], James A. Klang[4], Steven I. Apfelbaum[2] and Mark S. Kieser[4]

The river systems of West Tennessee pose unique geomorphologic challenges for water resource managers, particularly along reaches impacted by historic channel alteration and associated changes in stormwater runoff. While multiple projects have been successfully completed by regional agencies and organizations to restore ecological functions of small tributaries, significant limitations must be overcome to implement river ecosystem restoration at the watershed-scale. Given the high costs associated with sediment control and channel rehabilitation efforts in the region, the development of market-based solutions may be one of the most viable options for large-scale ecosystem restoration. Therefore, the Tennessee Chapter of The Nature Conservancy has initiated a feasibility study to explore the potential for water quality trading and wetland restoration to provide cost-effective improvements in water quality and wildlife habitat in the Hatchie, Loosahatchie and Wolf River watersheds.

Preliminary hydrologic modeling and economic analyses suggest that water quality trading may be possible in the project area, which could contribute to both local stream quality restoration and, if applied at a larger scale, to the reduction of Gulf Coast hypoxia. However, implementation of new EPA municipal stormwater permit recommendations and associated wasteload allocations in Total Maximum Daily Loads will likely play significant roles in the development of any trading system to market hydrologic ecosystem services in the region. Still, this project is building upon existing strategies for river conservation by exploring both the economic and ecological dimensions of water quality trading as a cost-effective option for stormwater impact mitigation, wildlife habitat improvement and watershed restoration.

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ASSIMILATIVE CAPACITY MODELING IN SUPPORT OF THE GEORGIA COMPREHENSIVE STATE-WIDE WATER MANAGEMENT PLAN

Brian Watson*[1], PE, PH; Jeremy Wyss; Steven Davie, PE; Elizabeth A. Booth, PE, PhD

In January 2008, the Georgia Water Council approved the Georgia Comprehensive State-Wide Water Management Plan (GA Water Plan). The purpose of GA Water Plan is to guide the state of Georgia with managing its water resources in a sustainable manner. This means not only allowing growth in Georgia, but also maintaining the ecological and biological health of the State's rivers, lakes and estuaries, as well as protecting state water quality standards. In order to evaluate the State's resources, the Georgia Environmental Protection Division with the assistance of other state agencies, the University System of Georgia and other research institutions, the U.S. Geological Survey and contractors are conducting water resource assessments to determine Surface Water Availability, Groundwater Availability, and Assimilative Capacity of the surface water resources. The assessments will include the compilation and management of data, computer modeling of both current and future needs, and additional monitoring if needed. Results of the assessments will be provided Regional Planning Councils as a starting point for the development of a recommended Water Development and Conservation Plan. The Assimilative Capacity resource assessment included the development and calibration of a series of linked models including GADosag, EPDRIV-1D, LSPC, and EFDC. Once calibrated these models were used to evaluate a number of scenarios such as impacts due to the projected land use and point source discharges in 2050. These models were also used in the development and/or evaluation of nutrient criteria.

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SYSTEM MODELING FOR INTEGRATED WATER RESOURCE PLANNING

Leeann Williams[1], Jamie Lefkowitz[2], and Mark Hilty[3]

Integrated Water Resource Planning is increasingly being recognized as an efficient, reliable method for developing long term plans encompassing all the water resource systems within a community, region, or larger watershed area. The City of Franklin, Tennessee, is using an Integrated Water Resource Plan (IWRP) method to evaluate and select a set of plans that consider not only the Harpeth River, tributary streams, water distribution, wastewater collection, water reuse, and stormwater, but also the critical concept of how all these systems interact and affect each other.

Phase I of the City of Franklin's IWRP used the STELLA software to simulate the water resource systems at a high conceptual level. STELLA is a dynamic and graphical tool used to simulate interactions between and within subsystems that are part of a larger interconnected system. Once the existing system baseline model was developed, identified options and alternatives for each system were added to the modeled environment in order to be evaluated. Each individual option may be turned on or off, or adjusted as desired; using this method, an option within one system could be seen to have an effect on one or more other water resource systems.

This presentation will show how water resource systems may be evaluated together using an example in the STELLA software and consideration of how a single project (or group of projects) affects the integrated system and provides valuable insight to future planning.

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EVALUATING GROUNDWATER AVAILABILITY IN SUPPORT OF GEORGIA'S COMPREHENSIVE STATE-WIDE WATER MANAGEMENT PLAN

John D. Boyer, PE, BCEE, D.WRE*

Georgia's landmark Comprehensive State-wide Water Management Plan employs advanced water supply planning concepts, including the use of water resource assessments to determine how much water can be consumed from the state's major rivers, lakes, and aquifers without causing unacceptable impacts. To evaluate the state's groundwater resources, aquifers were prioritized based on the functional characteristics of the aquifer, existing evidence of adverse affects due to withdrawals, and whether demand forecasts suggest significant increases in withdrawals placed on that aquifer in the years ahead. Three approaches, ranging from a simple water balances to the development and application of numerical models with transient simulation capabilities, were used to quantify groundwater availability during dry years. Depending upon the available information for each representative aquifer, the most appropriate approach was then used to provide an initial estimate of the sustainable yield of the aquifer. The results of each assessment are being provided to Georgia's ten Regional Water Planning Councils to assist in the determination of sustainable yields. The different approaches used to assess groundwater availability and determine sustainable yield in each of Georgia's physiographic provinces will be presented and their applicability for use in Tennessee to assist with local, regional, and/or statewide water supply planning and management will be discussed.

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CALCULATING SUSPENDED-SEDIMENT CONCENTRATION AND SEDIMENT LOADS FOR TENNESSEE STREAMS

Melissa A. Harris[1]

Turbidity can be an effective surrogate measure of suspended sediment concentration (SSC). However, instrument detection limits and periods of missing record complicate estimation of SSC from continuous turbidity records. In small headwater streams, flashy hydrologic response and rapid changes in turbidity across wide ranges introducer additional complications. As part of a multiyear study of sediment transport from highway construction areas, the U.S. Geological Survey, in cooperation with Tennessee Department of Transportation, developed an approach to estimating SSC from turbidity and streamflow records in small headwater streams.

Continuous suspended-sediment concentration (SSC) and sediment loads were calculated from measured turbidity, discharge, and discrete SSC data for four streams in Tennessee for water years 2005 through 2009. The calculations were based on measured turbidity, where it was available, and on the close relation between turbidity and SSC. However, turbidity records contain numerous gaps in time-series data during periods of high sediment transport, due to instrument detection limits and equipment malfunctions. A hierarchical method for calculating SSC was developed to address periods of missing turbidity data.

In the past, suspended-sediment has generally been calculated through ratings based on the logarithmic-linear regression of SSC on discharge, but this approach tends to under-predict SSC at high turbidity and underestimate annual loads for these streams. Within our modified approach, ratings of SSC to turbidity were used to estimate SSC from time-series data and discrete turbidity samples. For turbidity data gaps, ratings of SSC based on discharge were used to estimate SSC. The discharge-based time series were shifted fit them smoothly to both point values of SSC based on samples and calculated SSC values at both ends of the gaps. Daily and annual sediment loads were then calculated according to standard USGS procedures. The effect of this combined approach on the computed annual loads for four sites across 4 years was a median upward shift of 14 percent.

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BANKFULL GEOMORPHIC RELATIONSHIPS AND REFERENCE REACH ASSESSMENT OF THE RIDGE AND VALLEY PHYSIOGRAPHIC PROVINCE

James Brady McPherson[1]

Stream and river channels are disturbed by human development and naturally occurring events. In recent years the principles of natural channel design have been applied to the restoration of channels. Natural channel design involves rebuilding a channel with the appropriate cross section dimensions, slope, and plan-view pattern so that it can pass the water and sediment loads supplied to it while maintaining its appropriate form. Stream channels restored to natural and stable conditions are more likely to remain stable over time and reduce erosion and sedimentation, provide aquatic habitat, and offer increased aesthetic value to the public. Regionally based relationships between drainage area and the bankfull channel geometry parameters are important tools for designing and restoring degraded stream channels. Bankfull parameters used to develop these regional curves must be examined at stream gage locations with sufficient flow data and separated by physiographic province. A network of reference sites across the physiographic province will aid in the development of a stream channel reference condition design database for the Ridge and Valley. The reference reach assessments will provide baseline geomorphic information, such as dimension, pattern and profile, as well as stability and habitat conditions for use in restoration. The Regional curves and reference reach assessments funded by Tennessee Stream Mitigation Program for the Ridge and Valley physiographic province will greatly benefit natural channel design restoration.

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DESIGN AND CONSTRUCTION OF THE LITTLE CHATATA CREEK REALIGNMENT FOR THE NEW CLEVELAND MUNICIPAL AIRPORT

Michael Pannell, CPESC[1]*, Brent C. Wood, PE, CPESC[2]*, Elizabeth M. Porter, PG[3],
William K. Barry, PE, D. WRE[4]

After a long evaluation process, an approximately 200 acre site just northeast of Cleveland, Tennessee was choosen in 2006 as the location of the new Cleveland Municipal Airport. In order to construct the new airport at this site, _,___ feet of Little Chatata Creek, a 303(d) listed impaired stream, would require realignment. ___ acres of wetland would also require mitigation. The vertical and horizontal placement of the runway and taxiway on the relatively narrow site, National Flood Insurance Program compliance considerations, location of an archeological site, karst geology, and special requirements for minimizing wildlife attractants near flight opperations required several innovative features and careful design analysis for the stream realignment. Among these were design and installation of a large culvert to accommodate flood flows, realigned channel geomorphic design to obtain the required mitigation length while having a stable channel, construction contingencies if karst features such as sinkholes were encountered, selection of plantings with mature heights that would minimize attraction of roosting birds, and movement of wetland mitigation to an off-site location (a former golf couse) within the same HUC __. Construction of the realigned stream was completed in 2010. Wetland mitigation is being conducted using an observational approach and completion is expected in 2011. This presentation documents the desgin and construction challenges for this project.

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UP THE CREEK WITH A PADDLE: PERFORMANCE OF A VISUAL STREAM ASSESSMENT ON A NON-WADEABLE STREAM

Michelle Hatcher[1] and Bobby Allen, P.E.[2]

The City of Memphis, assisted by CDM, performed a visual stream assessment for the Wolf River in the urbanized sections of the river. The River has a pathogen TMDL developed for several sections of the River within the City limits; and as required by TDEC, is required to be assessed every 5 years. This assessment required the development of a non-wadeable stream assessment protocol that utilized a combination of various guidance documents. The assessment was performed through a combination of canoe access within the River to allow for investigation of the banks with follow-up reconnaissance via foot to verify areas of concern and collect required additional data. After the assessment was completed, the data was compiled into an evaluation report to assess the overall health of the River and provide a baseline for continuing assessments in the future. The objective of the assessment was the identification and prioritization of stream impairment sources and identification of potential BMPs and corrective measures to remedy the priority areas.

This presentation will describe the protocol development, coordination with regulatory agencies, methods and logistics for performing the assessment in a non-wadeable river, examples of potential data produced from the assessment, and methodology for compiling all of the data and summarizing the findings into a useable format. With the increasing development of TMDLs throughout the state and requirements for performance of visual stream assessments, this presentation will provide an overview and specific examples of a successful visual assessment along with some lessons learned from our experiences.

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DAJUGEZHUANG VILLAGE COMPREHENSIVE VILLAGE WASTE MANAGEMENT DEMONSTRATION PROJECT: IMPLICATIONS FOR NUTRIENT MANAGEMENT AND WATER QUALITY IN CHINA

Forbes Walker[1], Hailin Zhang[2], Terry Oda[3], and John Ungvarsky[4]

ABSTRACT

Since 2003, the U.S. EPA has been providing technical and financial support to the Tianjin municipality (approximately 100 miles east of Beijing) to ensure delivery of safe drinking water to the city through protection of the Yuqiao Reservoir. During the initial phase of this project (2003 to 2006) work focused on monitoring water quality in the Yuqiao reservoir and pollution sources in perimeter area to identify the most pressing issues threatening the delivery of safe drinking water to Tianjin. In 2006 a joint proposal was submitted by the US EPA and Tianjin Environmental Protection Bureau (TEPB) to complete a feasibility study on village waste management and treatment that would protect water quality of the Yuqiao Reservoir. Anaerobic digestion systems and nutrient management were recommended as ways to treat village waste and control pollution. Implementation of the first phase of this project began in 2009, with the construction of approximately 110 household biogas units in the village and initial implementation of a comprehensive village waste management plan (CVMP). In August 2010, the authors visited the Yuqiao source water protection demonstration project in Dajugezhuang village in Ji County, Tianjin to review progress of the village-scale demonstration project and to assist with capacity building and development and implementation of nutrient management strategies. This presentation will give an overview of the findings of the authors and its implications for nutrient management and water quality in this region of China.

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TDOT TURBIDITY SAMPLING: LESSONS LEARNED

Greg Russell[1] and Beth Chesson[2]

In anticipation of the EPA ELG requirements, TDOT initiated a pilot turbidity sampling program on several sites throughout the state. Civil & Environmental Consultants, Inc. (CEC) worked with TDOT to develop a sampling protocol for grab samples and automated sampling. This presentation will present the sampling findings and, more importantly, describe problems encountered with sampling for turbidity.

[1] TDOT
[2] CEC

SESSION 2C

SWAT
8:30 a.m. – 10:00 a.m.

Evaluation of an Intensive Data Collection System to Calibrate the Soil and Water Assessment Tool
Hannah Armstrong, Shawn Hawkins, Wesley Wright, and Forbes Walker

Application of Soil and Water Assessment Tool (SWAT) for Water Quality Simulations: Importance of Crop Yield Calibration
Surendran Nair Sujithkumar, Kevin W. King, and Jonathan D. Witter

Watershed Modeling Using an Intensive, Short Term Data Collection Technique: SWAT Application to Lick Creek Watershed in Greene County, TN
Sujithkumar Surendran Nair, Hannah Armstrong, Wesley Wright, and Shawn Hawkins

MODELING
10:30 a.m. – 12:00 p.m.

Using SWAT to Simulate the Effects of Land Use Change on Water Quality for the Oostanaula Creek Watershed
Xia “Vivian” Zhou, Christopher D. Clark, and Sujithkumar Surendran

Use of the River 2D Hydrodynamic Model for Stream Restoration Assessment and Design
John S. Schwartz and Keil Neff

CWMS Software Modeling for Cumberland River Reservoir Operation Decisions
Clint Neel and Shaun Carney

METHODS & TECHNOLOGY
1:30 p.m. – 3:00 p.m.

Selecting the Right Stormwater Treatment Technology
Mark B. Miller

Leaching and Adsorption of Storm Water Contaminats Associated with Fly Ash-Amended Pervious Concrete
Brian Bachner, Jessie Weatherly, and John P. DiVincenzo

Bench-Scale Treatability Using Chemical Agents in Clay-Rich Residuum Contaminated with Residues for Explosives Manufacturing
Larry D. McKay, Joe Zhang, Dan Williams, Beth Lavoie, Frank Bogle, Ronnie Britto, and Madhu Patel

RESTORATION
3:30 p.m. – 5:00 p.m.

Comparison of Two Watershed Projects (Initial Similarity was Mistaken)
Lena Beth Carmichael

The Practice of Stream Restoration in West Tennessee
Nathan S. Ober

Setting Realistic Goals and Expectations for the Longview Branch Urban Stream Restoration Project
Michael K. Sloop

EVALUATION OF AN INTENSIVE DATA COLLECTION SYSTEM TO CALIBRATE THE SOIL AND WATER ASSESSMENT TOOL

Hannah Armstrong[1]*, Shawn Hawkins[2], Wesley Wright[3], and Forbes Walker[4]

The Soil and Water Assessment Tool (SWAT) is a water quality model used to identify pollutant sources and evaluate best management practices in agricultural, ungauged watersheds. A challenge that model users face is the lack of adequate and current water quality and discharge data within the targeted watersheds. In this presentation, we showcase and evaluate an intensive water quality data collection system to calibrate the SWAT model. Components of this sampling system are powered with solar panels and were installed in the Fall of 2009 in two adjacent watersheds in Greene County, TN: Lick Creek, a largely agricultural and extensively impaired watershed, and Little Chucky, a high quality Ecoregion 67g region reference stream. The sampling system consists of refrigerated samplers (for water quality parameters that can be preserved), biweekly collection of grab samples (for water quality parameters that cannot be preserved), multi-parameter sondes for measuring in-stream parameters and stream discharge, and a rain gauge network. We will evaluate the overall system reliability and provide design guidelines for the power supply system. Preliminary water quality data collected with the system will be compared to the Tennessee General Water Quality Criteria for Ecoregion 67g.

* speaker presenting the paper

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APPLICATION OF SOILWATER ASSESSMENT TOOL (SWAT) FOR WATER QUALITY SIMULATIONS: IMPORTANCE OF CROP YIELD CALIBRATION

Surendran Nair Sujithkumar [1,*], Kevin W. King [2], and Jonathan D. Witter [3]

The Soil and Water Assessment Tool (SWAT) is a basin-scale computer model designed for assessing watershed-scale impacts of conservation management, particularly for agricultural dominated watersheds. In general, calibration and validation of SWAT typically has been performed by comparing the simulated surface runoff, and nutrient concentration in runoff, against measured values at a watershed outlet. However, the processes affecting the water balance in an agricultural watershed are highly influenced by crop production. A rigorous calibration procedure is outlined and demonstrated using data from Upper Big Walnut Creek (UBWC) watershed in central Ohio, USA. A four stage iterative calibration process was used. The four stages and the sequence of their application were: 1) parameter selection, 2) hydrology calibration, 3) crop yield calibration, and 4) nutrient loading calibration. Progressive calibration that integrated crop yield predictions with stream flow and nutrient loadings resulted in increased prediction accuracy for both calibration and validation time periods. Compared to traditional calibration approaches (no crop yield calibration), the four-stage approach (with crop yield calibration) produced improved prediction and regression statistics. Using the proposed four stage calibration will provide a greater level of confidence in the predicted results compared to a calibration approach that does not address crop yield calibration.

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WATERSHED MODELING USING AN INTENSIVE, SHORT TERM DATA COLLECTION TECHNIQUE: SWAT APPLICATION TO LICK CREEK WATERSHED IN GREENE COUNTY, TN

Sujithkumar Surendran Nair[1], Hannah Armstrong[2], Wesley Wright[2], Shawn Hawkins[2]

Watershed-scale water-quality simulation tools provide a convenient and economical means to evaluate the environmental impact of conservation practices. However, collecting long term stream flow and nutrient loading data is an impractical and economic constraint for using modeling tools to prioritize conservation practice installations, especially in ungauged, largely agricultural watersheds. This paper presents an approach for watershed modeling using intensive data collection over a short period of time for the impaired Lick Creek watershed in Greene County, TN using the Soil Water Analysis Tool. Elements of the model calibration and validation will be presented.

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USING SWAT TO SIMULATE THE EFFECTS OF LAND USE CHANGE ON WATER QUALITY FOR THE OOSTANAULA CREEK WATERSHED

Xia "Vivian" Zhou[1*], Christopher D. Clark[1], and Sujithkumar Surendran[1]

INTRODUCTION

The Soil and Water Assessment Tool (SWAT) model is used to simulate the effects of land use change on water quality in the Oostanaula Creek Watershed (Figure 1) in the East Tennessee Counties of McMinn and Monroe. The Oostanaula Creek watershed covers 70.3 square miles (TDEC, 2002) and hay and forest are the primary land uses (Figure 2). Tennessee's proposed 2010 303(d) list identifies segments of Oostanaula Creek that are impaired due to E. coli, phosphorus, and loss of biological integrity due to siltation (TDEC, 2010). The watershed is also located near the demonstration scale biorefinery in Vonore and thus would likely experience widespread switchgrass planting if the demonstration scale biorefinery is expanded into a commercial scale facility. Widespread land use conversion to switchgrass[2] production could substantially reduce sediment, bacteria, and nutrient loads into water resources. Thus, the objective of this research is to analyze the effects of the large-scale planting of switchgrass as a bioenergy feedstock in the watershed on water quality in Oostanaula Creek and on Oostanaula Creek's ability to meet applicable water quality standards.

METHODS AND RESULTS

Oostanaula Creek watershed boundaries were delineated through ArcSWAT (2009) with USGS digital elevation model (DEM) data obtained from US Geological Survey (USGS). Land Use data was uploaded from National Land Cover Database (2001); and Soil Survey Geographic Database (SSURGO) data was acquired from Natural Resource Conservation Service (NRCS). Multiple slope classification was defined as three categories: from lower limit to 0.5%, from0.5% to 1%, and from 1% to upper limit (Srinivasan, 2008). The watershed was divided into twenty six sub-watersheds and each sub-watershed was divided into multiple hydrologic response units (HRU).

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[2] Switchgrass is a tall, hardy, and perennial grass native to North America, with a strong and deep root system that can prevent soil erosion and filter nutrient loads (Rinehart, 2006).

Precipitation and temperature for Oostanaula Creek were represented by two weather stations in and around the watershed: Athens and Cleveland. Daily precipitation and temperature data from 1975 to 2010 were obtained from National Climatic Data Center (NCDC). Daily stream flow data were acquired from USGS gauge station (03565500) located near Sanford in the watershed (Figure 1). Calibration for flow was conducted from 1999 through 2010 and validation was from 1975 through 1989 with five years of warming up period included each. There is a time period gap between the calibration and validation due to missing flow data of the USGS gauge station from 1990 through 2003. Statistical criteria such as Nash-Suttcliffe Efficency (E) and R^2 were calculated to verify the model predictions. Predicted values match with the observed values for flow calibration and validation with E and R^2 greater than 0.7 (Figures 3 and 4). Sediment and nutrient data from June 17 to December 14, 2010 was obtained and we are in the process of obtaining sediment and nutrient data from October 2002 to December 2003. Sediments and nutrients will be calibrated and validated for the two periods. After calibration and validation, the model will be used to simulate the large scale conversion of agricultural lands in the watershed from their current use to the production of switchgrass for use as a biofuel feedstock.

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Srinivasan, R., “Beginner SWAT Training Manual.” *Texas A&M University, Spatial Sciences Laboratory Blackland Research Center* (2008).

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TDEC, 2002, Total Maximum Daily Load for Fecal Coliform In Oostanaula Creek Hiwassee River Watershed (HUC 06020002) McMinn & Monroe Counties, Tennessee. Division of Water Pollution Control, Tennessee Department of Environment and Conservation, Nashville, TN.

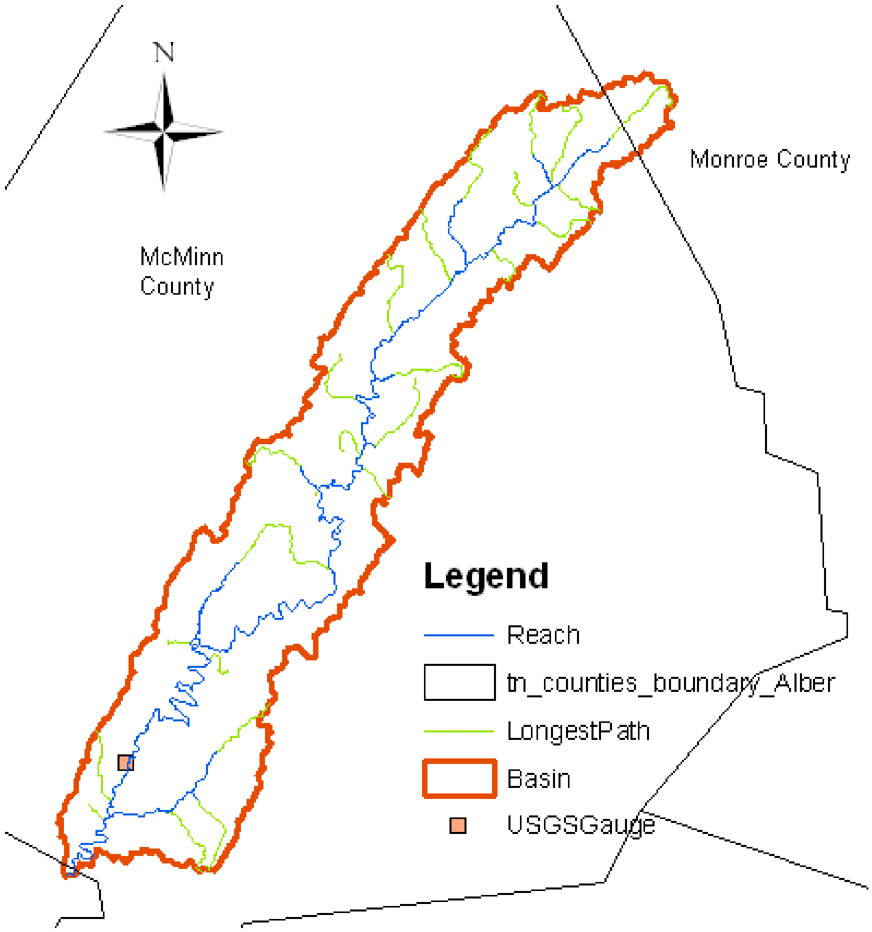

Figure 1. Oostanaula Creek Watershed

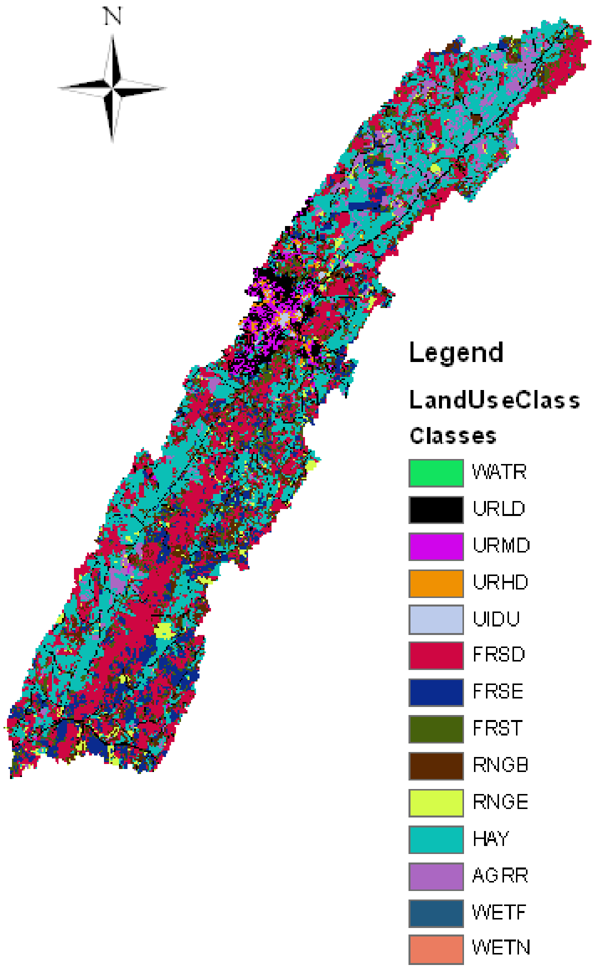

Figure 2. Land Uses for Oostanaula Creek Watershed

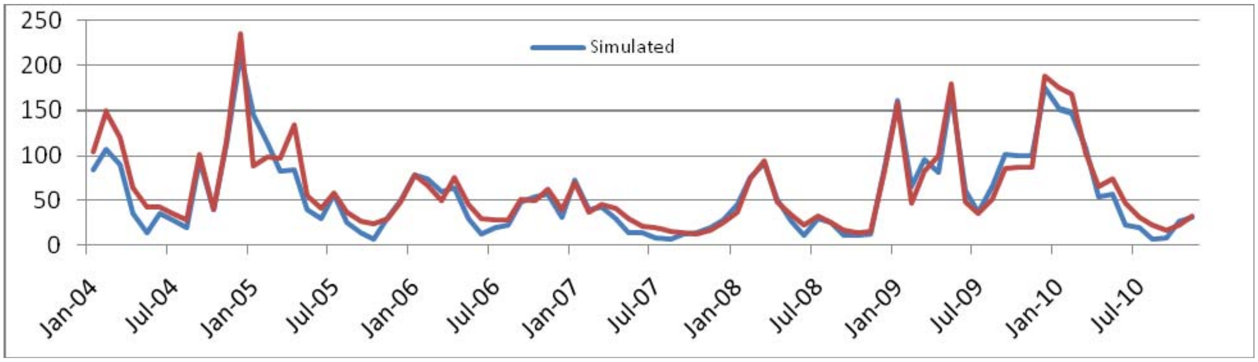

Figure 3. Observed and Simulated Monthly Flow for Calibration Period

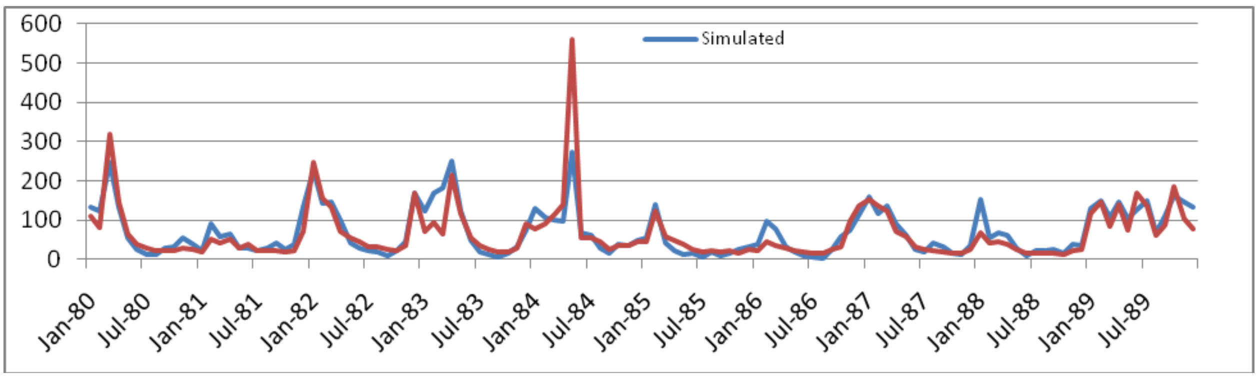

Figure 4. Observed and Simulated Monthly Flow for Validation Period

USE OF THE RIVER2D HYDRODYNAMIC MODEL FOR STREAM RESTORATION ASSESSMENT AND DESIGN

John S. Schwartz, Ph.D., PE[1], and Keil Neff[2]

In urbanizing streams, two-dimensional hydrodynamic modeling is essential for prediction of flow capacity channel stability, infrastructure protection, and habitat enhancement performance. River2D, a two-dimensional hydrodynamic model developed by the University of Alberta has the capability to meet these stream restoration assessment and design needs. As a restoration tool, depth-average velocities and shear velocities among a finite element grid can be assessed for maximums and minimum s spatially throughout a design reach for current conditions and multiple project geomorphologies. Habitat quality can be estimated per fish species using habitat suitability indices for velocity, depth, and channel substrate, in which River2D computed weighted usable areas (WUAs) per species. Examples of model performance and their output's use in the design process will be presented for the 1) Embarras River, Champaign County, Illinois; 2) Middle Prong of the Little Pigeon River, Sevier County, Tennessee; and 3) Beaver Creek, Knox County, Tennessee. River2D modeling on Beaver Creek represents the design effort in an urban-constrained stream, in which the project is under construction.

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CWMS SOFTWARE MODELING FOR CUMBERLAND RIVER RESERVOIR OPERATION DECISIONS

Clint Neel[1]* and Shaun Carney[2]

The Corps Water Management System (CWMS) software suite integrates several hydrologic and hydraulic models including HEC-HMS, HEC-ResSim, and HEC-RAS into one user interface for daily reservoir operation simulations. In 2010 Riverside Technology, inc. developed a CWMS version 2.0 model of the Cumberland River including a HEC-HMS hydrology model of the entire drainage basin and a HEC-ResSim reservoir simulation model of the Cumberland River reservoirs. The HEC-HMS hydrology model watersheds were delineated at stream gage locations for daily runoff calibrations, and rules were added to HEC-ResSim for coordinated reservoir releases during flood operations. Scripts were added for converting power generation schedules to reservoir releases and to set the timing of release decisions for guide curve operations. In addition, a HEC-RAS River Analysis System model of Kentucky and Barkley Lakes was developed for routing upstream releases and local inflows down these hydraulically complex reservoir systems which are connected by a canal. This integrated system of models is useful to the Nashville District U.S. Army Corps of Engineers for forecasting reservoir conditions and making daily water management decisions.

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SELECTING THE RIGHT STORMWATER TREATMENT TECHNOLOGY

Mark B. Miller, P.G.[1]

Properly selecting a post-construction flow-through stormwater treatment system can present a challenge to site designers, regulatory agencies and end users alike. This presentation describes site and system design factors to consider when determining whether manufactured hydrodynamic separation, filtration, or catch basin (insert) technologies can be implemented to meet pollutant removal goals. Stormwater programs often establish a water quality treatment goal of 80% sediment removal either for individual storms or on a net annual basis. It is important for any BMP to be properly implemented in conditions for which it is designed. The technology selection process often fails to adequately consider the nature of the pollutants in context with the performance capabilities of the treatment approach. For example, hydrodynamic separators exhibit decreasing performance with decreasing particle size. Hence, if silt is the dominant particulate in the runoff, then filtration would be more effective in those cases. Improper use of a treatment technology can lead to poor performance as well as inaccurate interpretations regarding performance capabilities of the device as a whole. Factors in need of understanding for the proper selection of flow-through treatment systems include anticipated suspended sediment concentrations, particle size distribution, sizing (footprint), water quality treatment flow rate (design storm), and maintenance frequency.

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LEACHING AND ADSORPTION OF STORM WATER CONTAMINANTS ASSOCIATED WITH FLY ASH-AMENDED PERVIOUS CONCRETE

Brain Bachner, Jessie Weatherly, and John P. DiVincenzo

The use of concrete and asphalt has increased over the last few decades due to the expansion of urban areas. As a result, the problem of storm water generated urban runoff has also increased. Pervious concrete is one alternative to impervious asphalt and impervious concrete as a way to reduce both the volume of urban runoff and the amount of contaminants in urban runoff. This research looked at several pervious concrete cores with varying fly ash mixtures to determine leaching of contaminants from the cores themselves, as well as any adsorption of contaminants from simulated storm-generated urban runoff. Contaminants of interest included hydrocarbons and nutrient anions (SO_4^{2-}, Cl^-, NO_3^- , and PO_4^{3-}). A rain storm water simulator consisting of PVC piping and a shower head was used to deliver simulated water solutions onto the blocks, the outflow of which was then collected and analyzed. The results of the leaching studies indicate no appreciable leaching of PAHs from the pervious concrete blocks. Of the four nutrient anions tested, a moderate amount of sulfate (29.3 ppm) and a small amount of chloride (0.7 ppm) was observed to have leached out of the pervious concrete blocks. Both phosphate and nitrate were undetectable in the leachate. The adsorption studies performed on the blocks showed substantial adsorption of motor oil hydrocarbons (≥80%) and moderate adsorption of phosphate (30% on average) with continued removal. These results are important for demonstrating the benefits of increased use of pervious surfaces in urban environments.

BENCH-SCALE TREATABILITY USING CHEMICAL AGENTS IN CLAY-RICH RESIDUUM CONTAMINATED WITH RESIDUES FROM EXPLOSIVES MANUFACTURING

Larry D. McKay[1*], Joe Zhang[2], Dan Williams[3], Beth Lavoie[1], Frank Bogle[4], Ronnie Britto[5] and Madhu Patel[5]

A bench-scale study was carried out to determine the effectiveness of different types of chemical treatments for breaking down of explosive residues (mainly DNT and TNT) in clay-rich residual soils. The research is related to clean up of an explosive manufacturing site, which is underlain by 7-40 m of fractured clay-rich residuum derived from weathering of carbonate bedrock. In some areas the zone of contamination extends to depths below the water table, so there was great interest in determining whether chemical treatments could be used for in-situ clean up in this relatively low hydraulic conductivity material.

Undisturbed core samples (3.5" diameter by 2.5' length) of residuum from the former manufacturing site were collected using a CME core barrel and hollow stem augers. A composite sample from several core samples was dried and crushed to sand-sized particles for use in batch microcosm tests with different chemical treatments or controls. Initial concentrations of total explosive compounds (DNT + TNT + …) was approximately 2500 mg/kg for the chemical treatment batch tests. Triplicate slurry samples were made using the composite soil, sterile de-ionized water and a chemical treatment, then placed in glass jar and shaken, with subsamples collected for explosive compound analysis (using EPA Method 8330) at times of zero, 24, 48 and 72 hours. In all cases, but one, the chemical treatment was added to the slurry at time zero. For the remaining case, the samples were treated by bubbling ozonated oxygen through the slurry for the duration of the batch test. The most effective treatment was the addition of NaOH, which at concentrations of 50 or 100 mM, raised the soil pH to above 11 and removed more than 98% of the explosives compounds. The mechanism responsible for explosive removal in the experiments is believed to be alkaline hydrolysis, which has been observed in previous experimental studies, but this is the first example in clay-rich soils. Ozone, or ozone combined with lower levels of NaOH, was also effective, with removal of 70 to 90% of the explosives. Sodium persulfate and Modified Fenton's Reagent (catalyzed H2O2), both of which have been used for cleaning up a range of organic contaminants in groundwater or soil, proved to be much less effective, with 17 to 42% removal of total explosive compounds.

Based on the batch tests, three chemical treatments (NaOH, NaOH plus ozone and ozone-only) were selected for further testing using undisturbed clay-rich soil columns to simulate in-situ conditions. The columns, each 7" long, initially contained approximately 3,100 to 10,500 mg of total explosives per kg of soil. The columns were flushed with at least 30 pore volumes (PV) of artificial groundwater containing one of the treatments (or a control, with no treatment) at flow rate of approximately 1 ml/minute.

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Concentrations of explosive compounds were monitored in the column effluent throughout the experiments. After approximately 15 and 30 PV of treatment, the flow was stopped for 5-10 days to determine whether there was a “rebound” in explosive concentrations in the effluent, which would be indicative of incomplete soil cleanup. At the end of each experiment, the columns were dissected and subsamples collected to compare concentrations of explosive compounds in the treated soil and in the untreated soil immediately above and below the columns. Effluent concentrations in the control column and the ozone-only column showed substantial reduction in explosive concentrations (>70%) during the flushing portion of the experiment, but the concentrations rebounded to values near the initial conditions after each flow interruption. This indicates that flushing with water or water plus ozone was successful in cleaning up the soil nearest the fractures or macropores, but not vast majority of the matrix soil. This was confirmed by comparing explosive concentrations in the post-treatment soil with the pre-treatment soil, which showed very little change (representing a decrease of zero to about 10 %).

Treatment of the columns with NaOH (50 mM) or NaoH (200 mM) plus ozone, showed dramatic decreases in explosive compound concentrations in both the effluent and the post-treatment soil. In both cases, explosive concentrations in the effluent were typically less than 10% of the pre-treatment concentration and showed only small rises after each flow interruption. Analysis of the post-treatment soils typically indicated > 99% removal of explosives compounds for both of these treatments. There were no remaining “hot spots” of contamination in the post-treatment soil cores, which indicates that the treatments were effective at spreading through both the fractures/macropores and the finer-grained matrix pores. The experiments show great promise for in-situ treatment of explosives contaminated groundwater and soil. However, additional experiments at the lab-scale are needed to determine optimum concentrations of chemical treatment agents. As well, pilot-scale field tests are needed to determine effectiveness of methods for delivering chemical treatments to the fine-grained residuum and for confirming treatment efficacy.

COMPARISON OF TWO WATERSHED PROJECTS (INITIAL SIMILARITY WAS MISTAKEN)

Lena Beth Carmichael, UT Extension

INTRODUCTION

University of Tennessee Extension has developed and conducted two watershed restoration projects in southeast Tennessee: Pond Creek Watershed in McMinn, Monroe, and Loudon Counties, flowing north to the Tennessee River, and Oostanaula Creek Watershed, from the edge of Monroe County, south to the Hiwassee River. Initial observations found these watersheds to be similar. It was expected that activities in Pond Creek would be followed in Oostanaula, with similar results. This has not been the case. Rural Pond Creek watershed is decidedly different from Oostanaula Creek watershed which includes parts of Niota, Athens, and Calhoun, TN. Demographics of farmers and management practices are also different. Various challenges have been presented by involvement of several agencies within Oostanaula's watershed group.

APPROACH

Oostanaula Watershed Project received funds directly from USDA in Washington, D.C. The grant proposal was prepared by Dr. Forbes Walker and others at UT-K involving several Departments including Biosystems Engineering and Agricultural Economics on the Ag Campus, as well as Microbiology and Civil Engineering on "the Hill". Multiple research projects are being conducted within this project. Oostanaula Watershed Project was organized with personnel from various involved and interested agencies: UT Extension, USDA (Natural Resource Conservation Service), TVA, TDA, EPA – Region 4 (Atlanta), TDEC, City of Athens – Public Works, and Athens Utilities Board.

RESULTS AND DISCUSSION

The resulting watershed restoration project has input from many directions, with funding from various sources. Multiple examples of progress will be given. However, challenges erupt while coordinating these agencies into one watershed project. Activities resemble a video-game character jumping from a moving pedestal to a slide, to a ladder, only to be hit by a flying tomato. Our perspective is that when life gives you tomatoes, make catsup – it lasts longer, and more people benefit in the long run.

THE PRACTICE OF STREAM RESTORATION IN WEST TENNESSEE

Nathan S. Ober[1]

Practitioners of stream restoration in the alluvial and loess plains of West Tennessee should be cognizant of the dynamic nature of sand bed streams. The anthropogenic disturbances of these streams over time have degraded much of the eco-region leaving an abundance of entrenched stream channels with abnormally high stream power. Soil properties and the stratigraphy of geologic deposits dictate our design approach and success. Sediment transport of sand bed streams is capacity driven and can be modeled with RIVERMorph© stream restoration software. The May flood of 2010 has altered many of the stream types and caused a shift in the evolutionary model of these streams. Stream restoration success and failure in West Tennessee are presented including; the design approach for incised rivers, soil properties and geotechnical investigation, adaptive management techniques, and restoration objectives.

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SETTING REALISTIC GOALS AND EXPECTATIONS FOR THE LONGVIEW BRANCH URBAN STREAM RESTORATION PROJECT

Michael K. Sloop, P.E., CDM

Longview Branch is located in Raleigh, North Carolina and drainage 324 acres of residential and institutional development. An evaluation of Longview Branch and its contributing drainage area identified common symptoms of urban development such as high, flashy storm flows; increased sediment loads from construction activity; toxic pollutants such as oils and greases, pesticides, and fertilizers; increased water temperatures; and horizontal constraints that do not allow lateral channel migration (i.e., meandering). In the case of Longview Branch, each of these constraints as well as other factors limit the ability to utilize natural channel design procedures such as restoring sinuosity, reconnecting the floodplain, and reducing peak flow shear stress and velocity, thus preventing the ability to restore habitat, ecological diversity, and water quality to pre-development conditions.

However, the inability to restore Longview Branch to its pre-development condition should not discount the improvements that can be made. Longview Branch is a common example of an urban stream incapable of being restored to pre-development conditions. Understanding that limitation and identifying other project constraints allowed achievable goals to be developed and expectations managed such that a design tailored specific to Longview Branch could be developed with the ability to provide a positive impact on the watershed and help to address downstream impacted waters by reducing stream bank erosion and improving habitat, ecological diversity, water quality; aesthetics, and public education and awareness.

SESSION 3A

MAY 2010 FLOOD-FEDERAL RESPONSE
8:30 a.m. – 10:00 a.m.

Cooperative Efforts of Metro-Nashville Government, the U.S. Army Corps of Engineers, the National Weather Service and the U.S. Geolocial Survey to Enhance Local Flood Preparedness Following the May 2010 Flood
Jamie G. James

Rapid Response: Working Collaboratively with State and Federal Agencies to Collect High Water Marks after the 2010 Nashville Flooding
Michael J. Taylor and Jaime Tyson

Real-Time Flood-Inundation Mapping Tools for the Cumberland River Near Nashville, Tennessee
Shannon Williams

RESPONDING TO THE UNEXPECTED: LESSONS FROM THE MAY FLOOD (Panel 1)
10:30 a.m. – 12:00 p.m.
Moderator: Scott Gain, USGS
Panelists: Bob Sneed, USACE; TEMA; Chief Stephen Halford, Nashville Fire Department; Paul Davis, TDEC-WPC; Tom Womack, TN Dept. of Agriculture; NWS (No abstracts available)

COOPERATIVE EFFORTS OF METRO-NASHVILLE GOVERNMENT, THE U.S. ARMY CORPS OF ENGINEERS, THE NATIONAL WEATHER SERVICE AND THE U.S. GEOLOGICAL SURVEY TO ENHANCE LOCAL FLOOD PREPAREDNESS FOLLOWING THE MAY 2010 FLOOD

Jamie G. James, P.E., Nashville District, USACE

The aftermath of the May 2010 flood in Davidson County and middle Tennessee showed the need for greater cooperative efforts between local and federal agencies in flood preparedness. There were issues highlighted in the U.S. Army Corps of Engineers (USACE) After-Action Report (AAR) that could be addressed immediately, but other items required further development of products and procedures to better enable emergency preparedness and response in the event of another flood. In August 2010 representatives of Metro-Nashville Government (Metro), the U.S. Army Corps of Engineers' Nashville District (Nashville District), the National Weather Service (NWS) and the U.S. Geological Survey (USGS) began an effort to identify, produce and implement new measures that will provide more timely warning, better management of resources and reduce human impacts from flooding. The Nashville District and Metro entered into an agreement that provided the framework for each agency to bring its expertise and resources to the group with the result that new tools are available for emergency managers to cope with flooding. Metro developed a separate agreement with the U.S. Geological Survey to add that agency's capabilities to the overall effort. The National Weather Service joined in the effort in cooperation, but without formal agreements.

Metro Nashville Government served as the hub of the wheel in the efforts to provide better flood warning and response within greater Nashville. As previously mentioned, Metro developed agreements with two of the three federal agencies involved, and served as the coordinator of all tasks. Beginning in August, 2010, the project team began bi-weekly meetings to track progress, foster communication between agencies, and ensure that the products were developed in ways that met the needs of emergency managers. Each concern was given place on the agenda, with topical discussion lead by the appropriate agency. Meetings were normally limited to 1 ½ hours or less, but were expanded as necessary to provide conclusions to any issues before the meeting adjourned.

Early on, the team discussed capabilities that each agency could bring to the table and the formats in which Metro could display and utilize the items produced. It was noted that the Nashville District had expertise and experience in hydraulic modeling of the affected streams in Davidson County; that NWS is the lead federal agency in issuing flood warnings; and that USGS could provide expertise in stream gauging networks and data collection. Metro has an extensive Geographic Information System (GIS), from which many of the parameters needed for stream models could be obtained, and which would be useful for the display of results and warning information. Additionally, issues such as how to provide access and widest dissemination possible, and even down to technical issues as data interoperability and horizontal and vertical datum, were coordinated by the project team. We realized early on that the products had to be useful to emergency managers and higher level decision makers, and sometimes those groups need different levels of detail.

There were two rounds of products produced for this project. The first round, known internally as intermediate products, produced preliminary inundation layers for the Cumberland River inside Davidson County based on the May 2010 flood and NWS flood warning levels for the Nashville Gage, and for Mill Creek and Richland Creek based on similar criteria for gages in those stream basins. The second round of products included inundation layers for the three previous streams, and also for the Harpeth River, Whites Creek and Browns Creek. Using flood profile information, the inundation layers and Metro GIS data, the team was able to identify critical infrastructure and the point at which flood damage occurs, the appropriate warning level for that infrastructure and the potential effect on flood response. This information was incorporated into Metro GIS mapping with a tool developed by Metro Staff so that emergency managers and higher level decision makers could view the approximate flooded area along these six streams based on the current gage reading, or probable flooded area based on the gage forecast.

Future plans are to add flood timing information to the existing information and hold table-top exercises to test the response system and make adjustments. In addition to developing these valuable flood response tools, the project served to enhance communication between the four agencies central to flood emergency response in Davidson County: Metro Government, USACE, NWS and USGS.

RAPID RESPONSE: WORKING COLLABORATIVELY WITH STATE AND FEDERAL AGENCIES TO COLLECT HIGH WATER MARKS AFTER THE 2010 NASHVILLE FLOODING

Michael J. Taylor, PE, CFM – AECOM
Jaime Tyson, CFM – AECOM

The news reports of the Nashville flood disaster the first week of May 2010 quickly turned focus to the impressive Nashville recovery. Residents of Middle Tennessee wasted little time cleaning up, helping neighbors and those less fortunate, and rebuilding their communities.

In order to learn the lessons from a flood event little time can be wasted on the data collection side as well. The May 2010 storm in Middle Tennessee was no exception. The key is collecting the data before it is washed away – literally.

AECOM was contracted by the Federal Emergency Management Agency (FEMA) to identify and survey high water marks in metropolitan Nashville after the May 2010 flood event. FEMA identified nine areas of importance for data collection. Rather than operate the project in a vacuum, FEMA and AECOM quickly met with officials from the State of Tennessee, the United States Army Corps of Engineers (USACE) and the United States Geological Survey (USGS) to and determined where each agency was in the field collecting high water marks. Working together, the number of high water marks could be maximized and no duplicate work performed.
In fact, FEMA was able to pay for the surveying of high water marks identified by the USACE.

AECOM used GIS tools to create a database of identification and survey information as well as to provide daily updates of points collected, which was shared across Federal and State agencies. There have been many uses for the data including determining the effectiveness of buyout programs and estimating substantial damage.

The spirit of collaboration has continued. AECOM used the results in Flood Insurance Study (FIS) updates in both Davidson County and Sumner County, Tennessee. Metro Nashville, FEMA, the USACE, and the National Weather Service continue coordinated meetings to ensure all modeling efforts are reflected properly in the updated flood insurance rate maps.

REAL-TIME FLOOD-INUNDATION MAPPING TOOLS FOR THE CUMBERLAND RIVER NEAR NASHVILLE, TENNESSEE

Shannon Williams [1]

The May 2010 flood in Middle Tennessee revealed a critical need to improve the accuracy and timeliness with which government agencies alert the public to flood risks along the Cumberland River and its tributaries. Three key requirements are (1) improved understanding of the relation between river stage and flood depth areal extent , (2) a method to apply that understanding to produce detailed projections of flooding, and (3)a system to make such projections available to the public in a manner that is accurate, timely, and readily accessible.

In November 2010, the USGS entered into an agreement with Metro-Nashville to develop a system for accurately extrapolating flood depth and extent, based on real-time or projected river stage, and for publishing maps of extrapolated inundation surfaces in a format that is readily accessible to community planners, emergency responders, and the general public. The geographic scope of the investigation is the main channel of the Cumberland River and adjacent land between Old Hickory Lake and Bordeaux. The investigation also includes improvements to the hydrologic monitoring network. Several stream gages will be installed along the Cumberland River and major tributaries which were not monitored before the May 2010 flood. Additional improvements include installing real-time gages in the headwaters of local tributaries which are susceptible to flash flooding.

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SESSION 3B

SEDIMENT & GEOMORPHOLOGY II
8:30 a.m. – 10:00 a.m.

Surrogate Sediment Substrates: Revisiting Artificial, Formulated and Synthetic Sediment
Adrian M. Gonzalez

Hydrology and Geomorphology of a 500-Year Flood, Blackburn Fork, Putnam-Jackson Counties, 18 August 2010
Evan A. Hart and Dana C. Jolley

Work in Progress, 2011 – Development of Assessment and Modeling Guidance on Estimating Reliable Bed-Material Transport Rates for Gravel-Bed Streams in Tennessee
Patrick McMahon, John S. Schwartz, and Eric Chance

SURROGATE SEDIMENT SUBSTRATES: REVISITING ARTIFICIAL, FORMULATED AND SYNTHETIC SEDIMENT

Mr. Adrian M. Gonzalez [1]

Over 2,300 literature references have been reviewed and mined for prior work related to surrogate sediment substrates (i.e., synthetic, formulated or artificial sediment). This literature mining effort confirmed that development progress has stagnated. The more substantial contribution of this literature review effort is to identify and integrate a substantial body of work from other scientific research to provide a set of tools and a strategy for advancing the formulation of surrogate sediment substrates. After a brief review of the work done to bring synthetic sediment substrate formulations to its current state-of-the-art, the efforts of the early pioneers in this field are summarized and acknowledged, along with the limitations they encountered and addressed through their work. This presentation presents possible criteria for improving synthetic sediment substrate formulations, and proposes a general framework for meeting those criteria. The presentation concludes with a proposed methodology for creating surrogate sediment substrates that are reliable with regard to data quality objectives and that closely mimic the realism of their natural sediment counterparts. The focus of the proposed framework is on the carbon component of the solid phase and the ionic composition of the pore water phase. The methodology's flexibility and adaptability would be applicable to sediment geochemistry studies, sediment bioassays supporting remediation efforts, or macro-benthos organism studies, for example. Substrates created by this methodology would reduce uncertainty in sediment data obtained from field sediment by minimizing test-effect differences caused not by treatment variables but by sediment composition effects.

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HYDROLOGY AND GEOMORPHOLOGY OF A 500-YEAR FLOOD, BLACKBURN FORK, PUTNAM-JACKSON COUNTIES, 18 AUGUST 2010

Evan A. Hart[1*] and Dana C. Jolley[1]

On 18 August 2010, a historic flood occurred along Blackburn Fork, Spring Creek, and Roaring River in Putnam, Overton and Jackson counties. Total 2-day rainfall amounts in the watershed were in excess of 11 in, however, reports indicate that most of this fell within a 12-hour period. Rainfall frequency statistics for the area computed by NOAA indicate a 2-day, 500-yr rainfall of 10.9 in and a 12-hour, 1000-yr rainfall of 8.7 in. Thus, the annual return interval of the 18 August rainfall event is at least 500 yr, and possibly greater than 1000 yr. Since no gauging stations area currently in operation along the rivers affected by flooding, we estimated flood discharge using the slope area method and other methods, based on the size of the boulders that were moved in the flood. We conducted field work shortly after the flood to determine high water marks and channel geometry. These estimates indicate that peak discharge along Blackburn Fork was at least 20,000 cfs, equivalent to a 500 to 1000 yr flood, according to USGS Stream Statistics for ungauged basins. The geomorphic impact of the flood was also considerable. The upper reaches of Blackburn Fork, including Cummins Falls, a proposed state natural area, were scoured to bedrock. Thousands of mature trees were uprooted and deposited one mile downstream on floodplains. Grassy floodplains were covered with gravel and cobble deposits several feet thick, and bank erosion triggered landslides. The flood fundamentally altered the morphology of Blackburn Fork and surrounding floodplains.

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WORK IN PROGRESS, 2011 - 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 Eric Chance[3]

Successful design and construction of dynamically stable 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 the restoration design of gravel bed-streams under changing land use conditions, obtaining this balance is often difficult. This project focuses on improving the restoration design process by evaluating and or developing practical solutions for assessment of sediment supply and transport capacity relations. Outcomes of the project will provide design practitioners detailed guidelines for estimating bed material transport in East Tennessee and geologically similar regions.

The primary research site for this project is located on Little Turkey Creek in Farragut, Tennessee. The study reach is typical of a post-disturbance, dynamically stable, stream in a partially urbanized watershed. The watershed is approximately 4.5 square miles and contains suburban and commercial development with large pockets of open spaces and forest.

Within the study reach, a series of four pit traps has been installed, spanning nearly the full wetted width of the stream. The pit traps have been instrumented with load cells and stage recording equipment in order to facilitate testing and calibration of existing bedload transport models contained in the BAGS (Bedload Assessment in Gravel Bed Streams) modeling package. Bedload transport predictions made using results from the pit trap battery are compared to predictions made using practitioner grade (small scale) bedload traps in order to: 1) evaluate the practicality of using the BAGS model with practitioner grade equipment, 2) establish clear protocols for using practitioner grade equipment coupled with BAGS, and 3) to estimate the uncertainty in bedload predictions made using practitioner grade equipment coupled with BAGS. Further, data collected at the research reach will be used to evaluate existing, and or develop new, tools for estimating bedload supply in partially urbanized watersheds.

This presentation covers the overall project objectives, illustrates the design and construction of the bed-material sediment collection station, and presents some of the preliminary results obtained from this research station.

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SESSION 3C

KARST
8:30 a.m. – 10:00 a.m.

Characterization of Karst Systems to Support EIS Decisions
Ann Epperson, Berny Ilgner, and Richard Lounsbury

Using a Combination of Geographic Information System Techniques and Field Methods to Analyze Karst Terrain in the Red River Basin, Tennessee and Kentucky
David E. Ladd

Bacteria Models, Source-Tracking, and Transport in the Fall Creek Watershed and Upper Duck River
Anne Choquette, Alice Layton, William Wolfe, and James Farmer

CHARACTERIZATION OF KARST SYSTEMS TO SUPPORT EIS DECISIONS

Ann Epperson[1], Berny Ilgner[2], and Richard Lounsbury[2]

ABSTRACT

To relieve traffic congestion in south Knoxville, the Tennessee Department of Transportation (TDOT) is evaluating, through an Environmental Impact Statement (EIS), various alignment options for extension of a major bypass; the James White Parkway. The project area includes the Toll Subwatershed of the Tennessee River Watershed, which is situated in well-developed karst terrane. Regulatory concerns were raised regarding bypass development through a karst region, including potential impacts to the threatened Berry Cave Salamander. To help address concerns, TDOT retained ARCADIS to characterize area hydrogeologic conditions and to determine whether specific karst features/sinkholes within, and immediately around, the Toll Subwatershed are likely connected directly to Meades Quarry Cave, containing the largest known Berry Cave Salamander population. Challenged with this technical objective, a work-plan was designed to focus on upfront detailed geologic definition and development of a Conceptual Site Model (CSM), such that a focused and cost effective injection program could be implemented without sacrificing karst site characterization. The trace included injecting fluorescein, eosine, Rhodamine WT, and pyranine into strategic sinkholes following background monitoring. After injection, periodic samples from 14 stream/spring locations were analyzed for the presence of dyes for 7 weeks. Positive traces were identified for each of the four injection sites showing a strong strike-oriented flow component within the karst aquifer, some of which were across previously established watershed boundaries. One trace also identified a direct sinkhole connection to Meades Quarry Cave. These findings were consistent with the original understanding of the hydrogeologic system and were used to refine the CSM. This project demonstrated that a robust upfront geologic analysis and CSM development will result in cost savings by knowing early in the process the level of uncertainty in hydrogeologic conditions, and allowing the design of an appropriate trace that is cost effective. TDOT, armed with this knowledge, can then integrate these findings into their EIS process and identify proposed alignments that will potentially impact the karst system.

INTRODUCTION

In the spring of 2009, a hydrogeologic and dye trace study was conducted by ARCADIS in the south Knoxville area for TDOT as related to potential future development of the proposed James White Parkway extension. The proposed extension will start near the southern terminus of the existing parkway, and likely extend to the south-southeast and reconnect with John Sevier Highway and ultimately U.S. Highway 441. The final preferred roadway alignment will not be determined until an EIS is completed by Parsons, and review and concurrence has been reached by a multi-agency Tennessee Environmental Streamlining Agreement (TESA) group as part of the National Environmental Policy Act (NEPA) process.

The primary objective was to determine whether karst features/sinkholes within and immediately around the Toll Subwatershed likely connect and drain stormwater directly into the Meades Quarry Cave system. This work was conducted to:

- Provide sufficient information to allow TDOT to select a roadway alignment that would avoid certain karst features to minimize potential impact to the karst aquifer.

- Respond to the Tennessee Wildlife Resources Agency (TWRA) and the U.S. Fish and Wildlife Service (USFWS) concerns regarding future road construction with respect to potential impacts to the threatened Berry Cave Salamander species, the most robust population of which is reportedly present within the Meades Quarry Cave system.

The early hypothesis was that several sinkholes located near initial proposed roadway alignments would in fact connect directly with the Meades Quarry Cave system based on the physical location/proximity of these features with respect to known caves and underlying geologic strata. As such, the primary project goal was to conduct a sufficiently thorough and cost effective hydrogeologic study/tracing effort that will reduce uncertainty in site conditions by determining direct sinkhole to cave connections.

Photo Caption: View from southwestern end of Meades Quarry Lake facing northeast, with major spring resurgence just out of view at photo right.

The project area is located in south Knoxville and is generally situated between the Tennessee River and Chapman Highway (U.S. Route 441), and includes the more rural area to the southeast of South Young High School and the residential Island Home area. More specifically, the area of interest includes the Toll Subwatershed (Figure 1 - below) of the Tennessee River Watershed, which is hereafter referred to as “the Site.” The eastern side of the Toll Subwatershed is demarcated by a watershed divide between the Tennessee River and French Broad River Watersheds. The Site is situated in an area of mature karst geology with many significant karst features.

PROJECT APPROACH

The overall strategy for this project was to manage uncertainty. That is, balance the scope of the dye trace and its associated cost, with adequate site characterization that will allow project objectives to be achieved. This was accomplished by initially developing a preliminary CSM that recognized and took advantage of the east Tennessee structural geologic setting that "packages" carbonate units between clastics, and thereby focuses flow conditions along geologic strike.

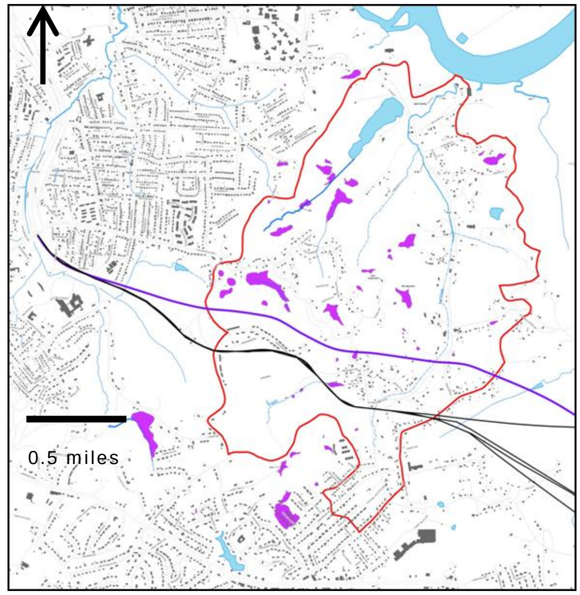


Figure 1: View of Toll Subwatershed boundary with respect to the Tennessee River (top right) and initial proposed roadway alignments.

This first step included a robust desktop review of available geologic and hydrogeologic literature. Using high resolution topographic data, all sinkholes/closed depressions and other karst features, such as springs and caves, were identified during the desktop review, which were then field inspected during a focused karst inventory. A cave trip into the Meades Quarry Cave system with the original cave mapper was also completed to further understand karstic conditions within the study area. Based on the results of this robust up-front work, a preliminary CSM was developed and incorporated into a detailed Dye Trace Work Plan prepared for multi-agency review as part of the overall EIS/TESA process for this project. The four sinkholes selected for injection were based on proximity to the proposed roadway alignments, area land use, watershed boundaries, and preliminary CSM findings with respect to local geology (i.e., two distinct conduit networks).

Geologic Setting

The study area is located in the Valley and Ridge Physiographic Province, where the strike of the sedimentary rock beds is generally oriented southwest-northeast (DeBuchananne, and R.M. Richardson, 1956). The Valley and Ridge is characterized by distinctive stratigraphy and structure where the dipping geologic formations result in "packaging" of karstic units by bounding them with less transmissive and less (or no) karst development (e.g.., shales and sandstones). This "packaging" also results in karst development along strike (northeast to southwest) within carbonate units. Groundwater flow within these karstic formations is further controlled by the surface topographic watersheds. As such, the overall movement of groundwater in East Tennessee (and at the Site) is highly dependent on this "packaging," the local geologic structure, and stratigraphy.

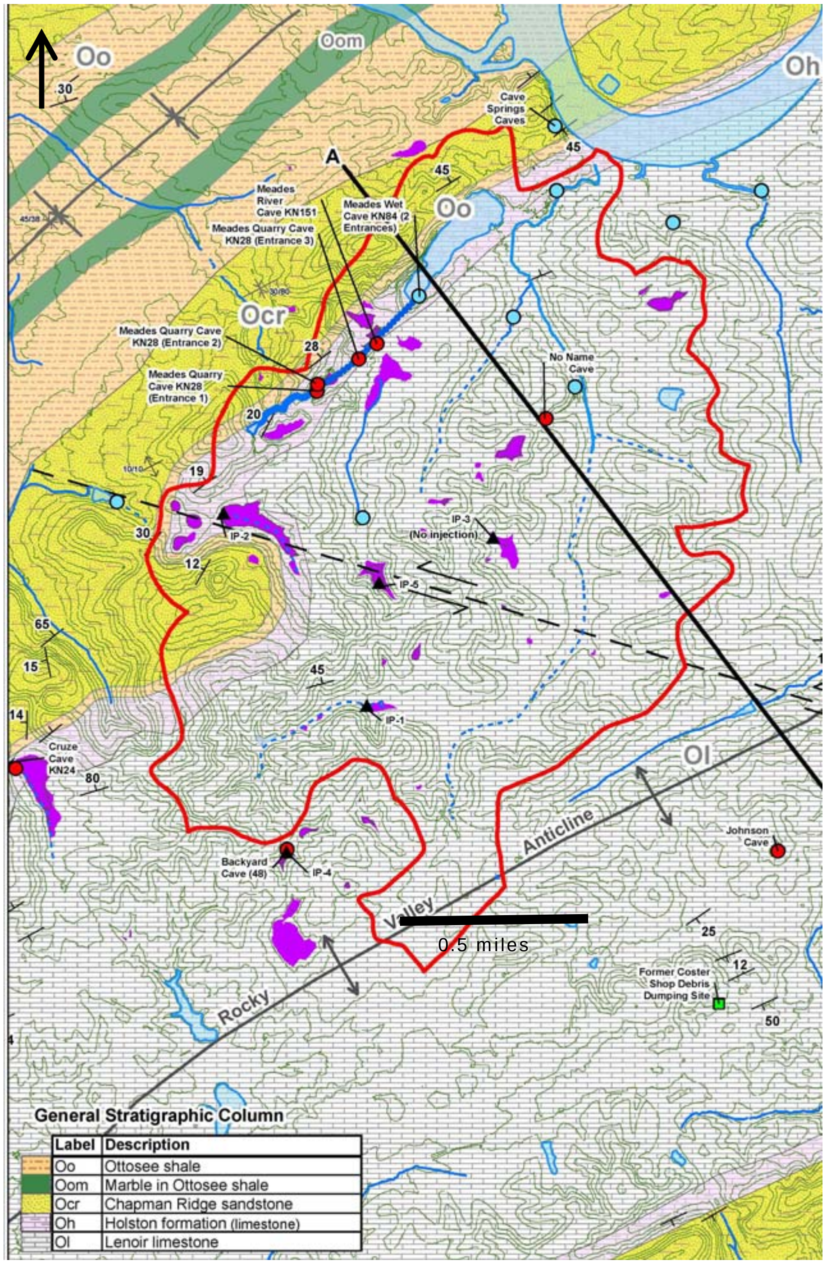


Figure 2: View of bedrock geology underlying the Toll Subwatershed and immediate surrounding area with axis of Rocky Valley Anticline in bottom half of figure.

Four geologic formations of middle Ordovician age immediately underlie the Toll Subwatershed, which is situated along the western margins of the Rocky Valley Anticline and results in generally northwest dipping beds in the majority of the Toll Subwatershed. These four formations are members of the Chickamauga Group and include from youngest to oldest: the Chapman Ridge sandstone (Ocr); the lower tongue of the Ottosee shale (Oo); the Holston limestone (Oh); and the Lenoir limestone (Ol).

The Lenoir limestone underlies the majority of the Toll Subwatershed footprint (Figure 2). The Lenoir is an argillaceous or silty, fossiliferous limestone that is known to contain relatively small caves. Older exposures exhibit moderate near surface weathering along bedding and joints. Beds weather nodular or cobbly because clay and silt impurities are concentrated along irregular bedding planes (Milci 1973). Regionally, the thickness of the Lenoir limestone ranges from 120 to 600 ft (Milci 1973).

The westernmost fringes of the Toll Subwatershed are underlain by relatively narrow bands of the Holston formation, Ottosee shale, and Chapman Ridge sandstone, which are all oriented in a northeast to southwest configuration along regional bedrock strike. Directly to the northwest of the Lenoir limestone is a narrow band of the Holston formation, which consists of an un-metamorphosed, but generally dense coarsely crystalline limestone known as “Tennessee Marble” (Milci 1973). The Holston formation has been quarried extensively for Tennessee Marble, both on and near the study area, and in East Tennessee in general. Weathering characteristics commonly include irregular top of rock, cavities, and sinkholes (Kellberg 1973). The Holston contains numerous clean, sharp, reverse faults gently curved both vertically and horizontally (Cattermole 1955). Based on exposures in quarries, small scale faulting can cause abrupt changes in thickness (Cattermole 1958), which is estimated to be approximately 250 ft the study area. Narrow bands of the lower tongue of the Ottossee shale [a heterogenous shale estimated to be less than 30 ft in the study area (Cattermole 1955)] and the Chapman Ridge sandstone (which forms the resistant ridges along the western margin of the Toll Subwatershed) are located to the northwest of the Holston. The Chapman Ridge sandstone and the lower part of the Ottosee shale inter-tongue and the contacts between them may be sharp or gradational (Cattermole 1955).

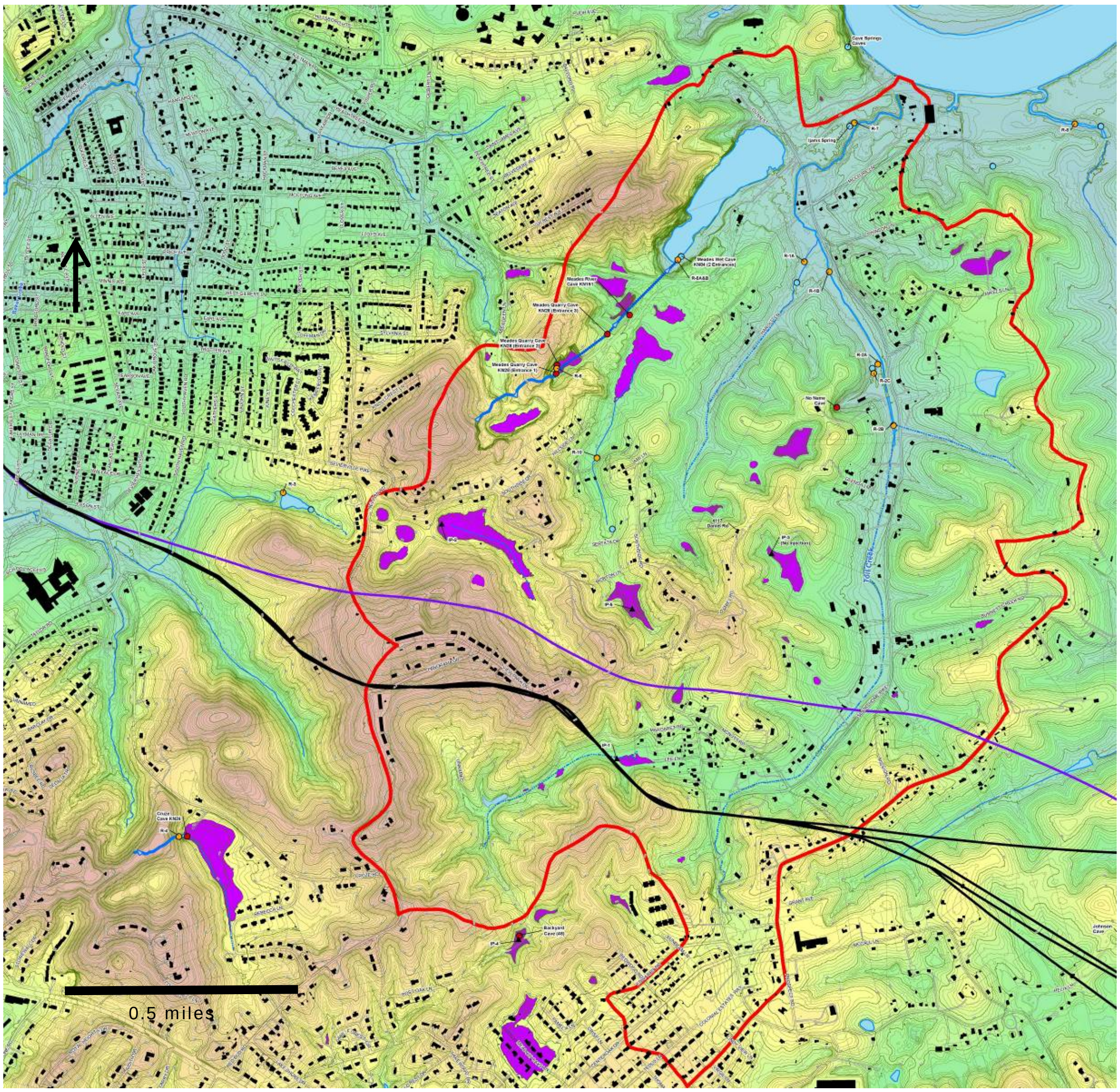


Figure 3: View of digital elevation model and significant karst features (dark purple color) such as known caves, springs, and sinkholes within the study area.

Development of the preliminary CSM revealed that the site is situated in an area of mature karst terrane with numerous significant karst features (Figure 3 – previous page). This includes several known caves, numerous sinkholes/closed depressions, several disappearing streams/swallets, and springs. Significant mapped caves (including known cave streams and springs) have formed within the Holston Formation, as associated with Cruze Cave to the southwest, and the Meades Quarry Cave system. Furthermore, these caves have generally developed in a linear pattern along a northeast to southwest trend parallel to regional bedrock strike. Several large sinkholes and small caves have also formed within the Lenoir limestone. However, published literature (Moore 1973) indicates that the Holston Formation is one of the more soluble formations in the Knoxville area, as demonstrated by the greatest number of penetrable caves and wells/springs per square mile. Further information from Moore (1973) confirms that caves within the Holston Formation are generally formed parallel along strike joints, and contain shorter connecting passages perpendicular to strike along dip joints.

Dye Trace Execution

Following multi-agency approval of the dye trace Work Plan (ARCADIS 2009), various notification activities for dye trace execution were initiated in March 2009. Approximately 2 weeks prior to the initial proposed injections, the dye trace was registered with the Tennessee Department of Environment and Conservation (TDEC) - Division of Groundwater Supply, Groundwater Management Section. Several other notifications were also completed prior to injections, in the event that visible dye became present within the study area. These notifications included the TDEC Local Field Office, Homeland Security, Knoxville Police and Fire Departments, Knoxville Emergency Medical Services, Local Non-Emergency 911, and property owners where dye injections were planned. Public notification signs were also prepared and posted in advance at key areas in the field visible to the public. These signs included general information regarding the nature of the dye trace study, in addition to contact information for any individuals that had concerns about the dye trace being conducted. This aggressive notification process seemed very helpful as no calls regarding the trace were received during the project, even with visible dye present within surface waters shortly following injections.

After the installation/setup of monitoring locations, a four week long background monitoring period was initiated. This included the placement, retrieval, and analyses of activated carbon passive dye receptors (PDRs) at 14 stream/cave/spring locations at approximate one to two week intervals. The results of the background monitoring did not preclude the use of any of the proposed dyes; however, fluorescein was detected in the Meades Quarry Cave System at moderate levels, likely due to pre-existing conditions in the area.

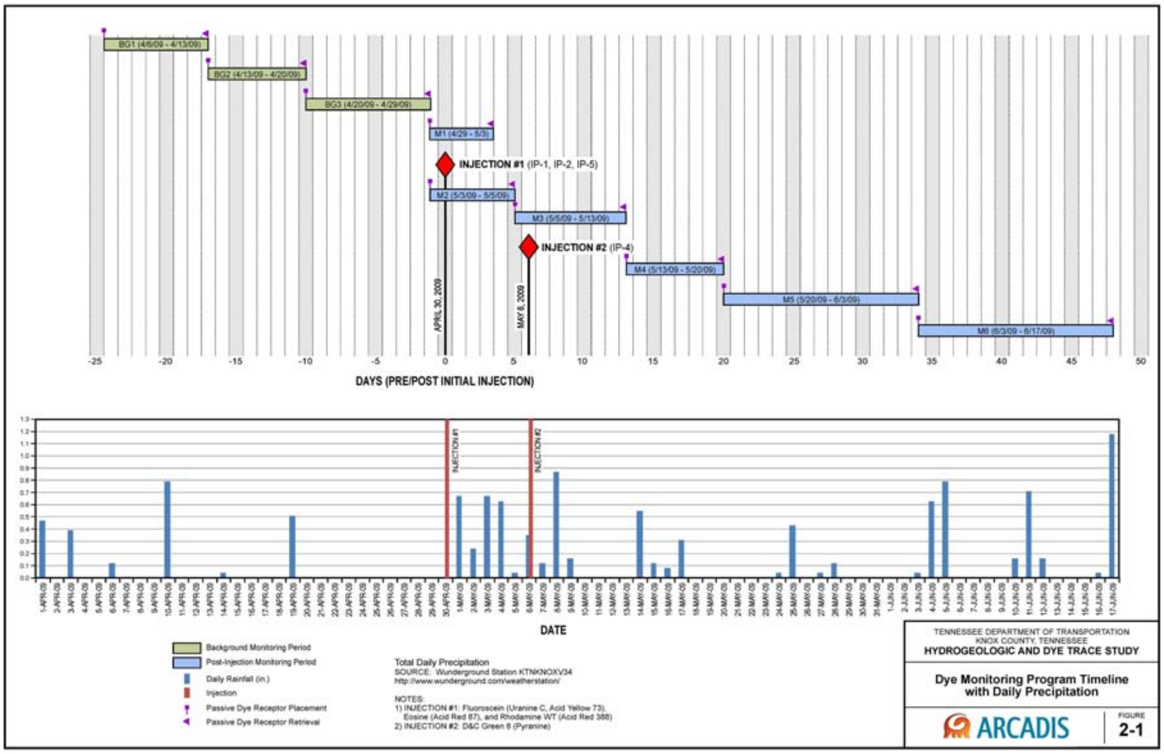
Four dyes (fluorescein, rhodamine-WT, eosine, and pyranine) were injected using a phased-injection approach into separate and distinct sinkholes within the study area in the spring of 2009. This included the pre-wetting of sinkhole features to minimize dye loss followed by post-injection flushing with water. Dye types, injection amounts, and pre- and post-injection slug amounts are summarized on Table 1 below.

Table 1. Summary of Dye Injection Points, Dye Types and Quantities, and Pre-/Post-Injection Wetting Amounts

Injection Point	Dye Type	Estimated Quantities	Pre-Wetting Amount (gals)	Post-Injection Slugs (gals)
IP-1	Rhodamine-WT (AR-388)	2 lbs 20% (0.4 lbs total mass)	500	2700
IP-2	Fluorescein (AY-73)	1 lb	500	1135
IP-4	Pyranine	1 lb	0	0
IP-5	Eosine (AR-87)	1 lb	500	2770

Following injections, a 7-week long dye monitoring period was initiated at the 14 monitoring locations. During this period, PDRs were collected, replaced, and analyzed generally on a weekly basis and rigorous quality-assurance and quality control (QA-QC) measures were taken. This included following USFWS-established decontamination procedures for cave gear used during the retrieval of PDRs placed at the two in-cave locations to protect against the spread of white nose syndrome, a disease decimating bat populations. A fixed-based laboratory equipped with a Shimadzu RF-5301 spectroflourophotometer was utilized for all dye analyses. The overall dye monitoring project timeline illustrating the duration of the background and monitoring periods, injection dates, and precipitation is presented on Figure 4.

Figure 4: Dye Monitoring Program Timeline with Daily Precipitation



PROJECT FINDINGS

The dye monitoring results for this project identified positive traces for all four injected dyes. This included visual and laboratory detections of fluorescein in the two Meades Quarry Cave monitoring locations, and the presence of the three other dyes (rhodamine-WT, eosine, and pyranine) at the Big Spring monitoring location. No dyes were detected at monitoring stations located outside the Toll Subwatershed. The Rhodamine-WT and eosine were detected both visually and through laboratory analyses. Rhodamine-WT and eosine were also confirmed (visual and laboratory) in an approximate 150-ft-deep private water well (non-drinking water) located northeast of the dye injection points for these dyes. Positive traces are illustrated on Figure 5.

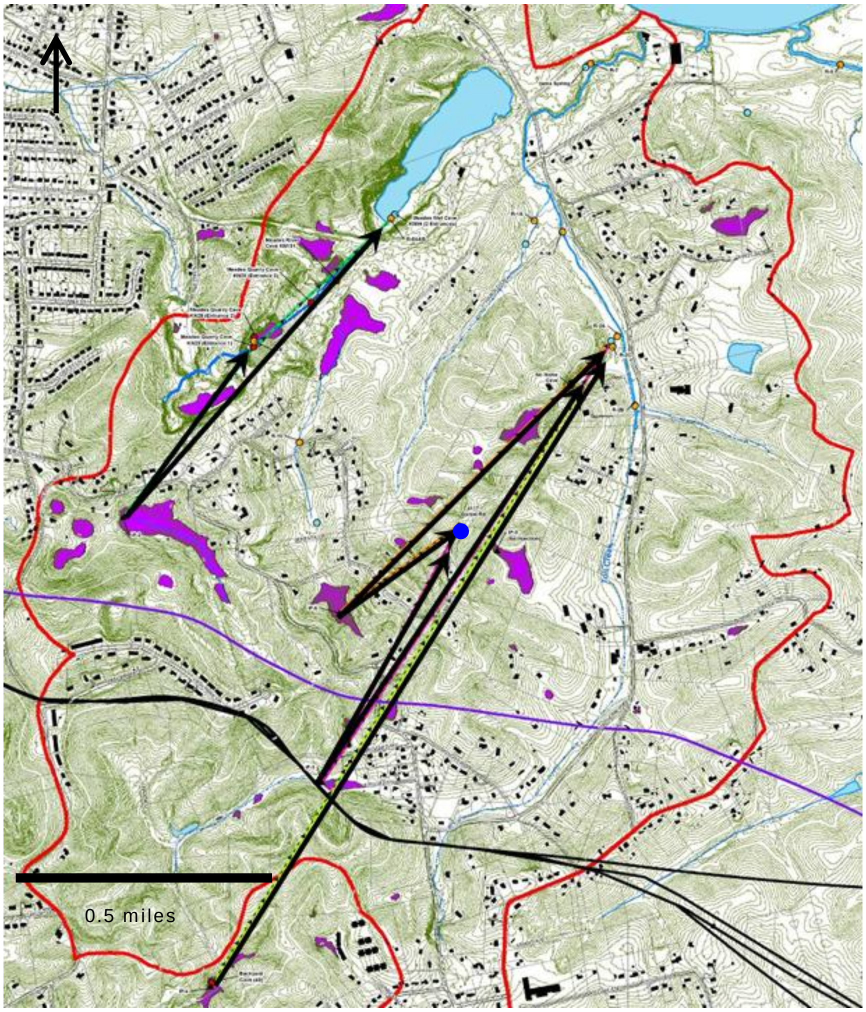


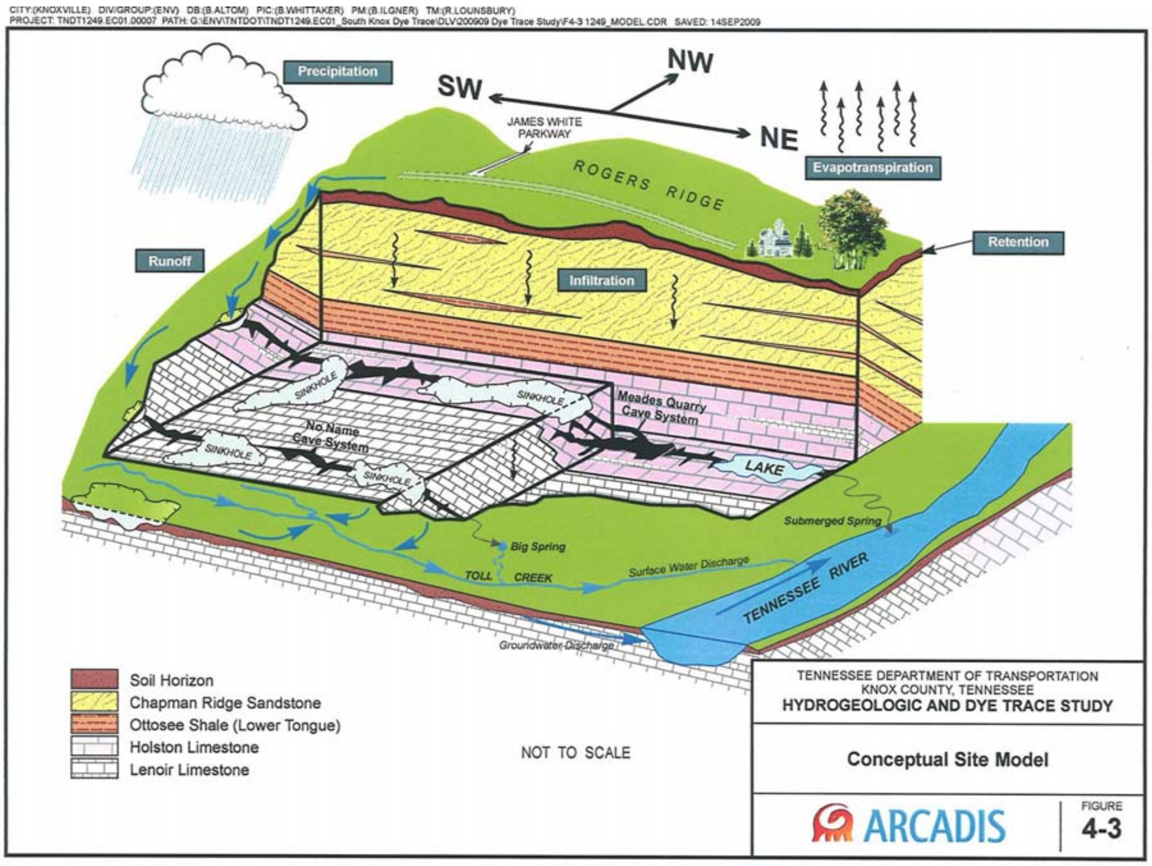
Figure 5: Map showing inferred tracing vectors within the study area.

The results of this groundwater study confirm the presence of a mature karst system with two distinctly separate conduit flow networks, the Meades Quarry Cave and No Name Cave systems. This is confirmed through a variety of findings including direct sinkhole to cave connections, rapid dye movement within these conduits (on the order of several thousand feet per day), and an overall groundwater flow within these conduit networks in a northeasterly direction towards the Tennessee River. Also, identified during this study was groundwater movement across topographic watershed boundaries, which is not uncommon in karst terranes.

The dye trace results were ultimately used to project which sinkholes in the Toll Subwatershed are connected into existing cave systems. Ultimately, those sinkholes located along the northwestern margins of the Toll Subwatershed and within the Holston formation were predicted to connect to the Meades Quarry Cave system; other sinkholes situated within the central portion of the Toll Subwatershed were predicted to connect to the No Name Cave system. Following this work, the CSM (Figure 6) was refined to incorporate findings identified during the trace, which included the addition of two distinctly separate conduit flow networks oriented northeast to southwest along geologic strike with northeasterly groundwater flow.

CONCLUSIONS

Figure 6: Final Conceptual Site Model



The main conclusions that can be drawn from the work completed are as follows:

- Groundwater tracing is an effective tool that can be used to characterize karstic flow systems, including the identification of sensitive sinkholes that should be avoided during selection of a proposed road alignment, and/or identification of engineering designs protective of these sensitive natural drainage features.
- A robust hydrogeologic study conducted upfront for development of a preliminary CSM will result in a thorough and cost effective dye trace design.
- Careful consideration to the optimal number of monitoring points should always be given, perhaps erring on the conservative side (i.e., overabundant number of samples) where appropriate to ensure a successful trace.
- By addressing karst early during the NEPA process, alignment and design considerations can be integrated into the selection process that minimize impact to the hydrogeologic system.
- Proper and thorough attention to notifications and signage is critical to good public relations.

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USING A COMBINATION OF GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES AND FIELD METHODS TO ANALYZE KARST TERRAIN IN THE RED RIVER BASIN, 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 flow, groundwater recharge and flow, and contaminant transport. In karst areas, some component of surface-water runoff is diverted to closed depressions that recharge groundwater at various rates, thus affecting the amount of direct runoff reaching streams and providing potential pathways for contaminant entry to a groundwater system.

The U.S. Geological Survey (USGS) Tennessee Water Science Center (WSC), in cooperation with the Tennessee Department of Environment and Conservation (TDEC), is applying GIS terrain analysis along with field data-collection methods to identify karst features, characterize their surface-water/groundwater connectivity, and 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.

The analysis focuses on quantifying the number, locations, catchment areas, storage capacities, and drainage rates of closed depressions in this watershed. The results are incorporated into analytical, statistical, and conceptual models to explore the role of numerous closed depressions and their internal drainage characteristics as controls on basin-scale hydrologic response and contaminant delivery to streams.

Calculations of depression water storage volume and catchment area provide estimates of the rainfall required to fill a closed depression. If the amount of rainfall 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 reject storm flow and re-divert it to runoff. Depressions with low storage capacity will flood and overflow quickly if poorly connected to the groundwater system. Depressions with these characteristics are less likely to route contaminated runoff to groundwater during storm events. In contrast, depressions with high storage capacity are less likely to overflow regardless of their ability to transmit runoff as recharge to a groundwater system. These depressions have the potential to collect more runoff than low-storage capacity depressions, and they may recharge a groundwater system relatively rapidly if they are hydraulically well connected to the subsurface.

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BACTERIA MODELS, SOURCE-TRACKING, AND TRANSPORT IN THE FALL CREEK WATERSHED AND UPPER DUCK RIVER

Anne Choquette[1,2], Alice Layton[3], William Wolfe[1], and James Farmer[4]

ABSTRACT

Fecal bacteria are the current regulatory standard used to indicate pathogen risk in U.S. waters. Potential fecal bacteria sources include human wastewaters, livestock, and wildlife, but the relative importance of these sources is commonly unclear, particularly in areas of mixed land use where all of these contaminant sources are present. In regions of karst geology, complex hydraulic connections between the surface and subsurface, and rapid groundwater transport through conduits add to this uncertainty.

The USGS, in cooperation with the Duck River Agency, investigated several types of fecal bacteria sources through periodic sampling for bacteria and water quality, molecular source-tracking, and monitoring streamflow and inorganic water-quality constituents. The objectives of the study were (1) to generate real-time estimates of *E. coli* concentrations from flow and turbidity and (2) to better understand bacterial sources and transport processes. The study area included six sampled sites in the Fall Creek watershed, which drains into the Duck River downstream of Shelbyville, Tennessee, and two sites on the Duck River, upstream and downstream of the Shelbyville wastewater treatment plant. Drainage areas of the Fall Creek tributary sites ranged from about 3 to 36 mi^2.

Water samples were collected at each site over a range of flow conditions. Samples were analyzed for *E.coli*, *enterococci*, *Bacteriodes* sp., turbidity, major water-quality constituents and nutrients. Continuous measurements of streamflow and turbidity were recorded over a period of six months at the tributary sites and for two years at the Duck River sites. Additionally, limited reconnaissance included sampling for select pathogens associated with bacteria, for bacteria in poultry litter and bovine manure runoff, and for anthropogenic trace organic chemicals.

Linear regression models were developed for *E. coli* concentration as functions of turbidity and streamflow and then applied to the continuous-monitoring records. The results of the models can provide information on the duration and exceedance probabilities of *E.coli* concentrations and loads at the sampled sites. The models indicate the potential for turbidity or streamflow to be used to estimate real-time *E.coli* concentrations in streams in this region. The continuous-record estimates of *E.coli* concentrations were used to assess variabilty across seasons and flow conditions, and the periods over which water-quality standards were exceeded. Host-associated *Bacteroides* assays were evaluated as markers of human and bovine sources. Results found markers for both human and bovine sources at the sampled sites. Relative contributions from these sources varied with flow conditions and may reflect the transport processes delivering bacteria to the streams. One or more of four pathogen genes tested (*Salmonella*, and *E. coli eae*, *stx*I and *stx*II) were detected in about 26 percent of 46 stream samples tested. *E.coli, enterococci,* and *Bacteroides* were evaluated in eight poultry litter and manure samples;

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Bacteroides were present in all of the poultry litter and manure samples, and *E.coli* and *enterococci* were present in most (75 and 85 percent, respectively) of the samples; *enterococci* concentrations were typically 100 to 1000 times greater than *E.coli* concentrations in these samples. Reconnaissance sampling for anthropogenic trace organic chemicals included four of the tributary sites. Six of the 69 analyzed chemicals were detected among the sampled sites, and the herbicide atrazine was the most commonly detected chemical.

PROFESSIONAL POSTERS

Community Outreach—Empowering Elementary Students to Protect our Water Resources
Celeste M. Barry

Variation in Raw Water Quality Information Related to Long-Term Water Resource and Water Supply Issues
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Weighing the Evidence—How Ecological Risks are Being Assessed for the TVA Kingston Ash Recovery Project
Suzy Young, Daniel Jones, and Neil Carriker

Impacts of Nonpoint-Source Pollution on Diatom Community Structure and Oxygen Metabolism in the Red River Watershed of North-Central Tennessee
Jefferson G. Lebkuecher, Stacy M. Rainey, Chelsea B. Williams, and Alex J. Hall

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Gregory H. Nail and Raymond J. Kopsky

Water Demand Projections to 2030 for the Southern Cumberland Plateau and North Central, Tennessee
John A. Robinson and W. Scott Gain

COMMUNITY OUTREACH – EMPOWERING ELEMENTARY STUDENTS TO PROTECT OUR WATER RESOURCES

Celeste M. Barry

CH2M Hill has participated in the annual World Water Monitoring Day (WWMD) event since 2003. WWMD is an international effort hosted by the Water Environmental Federation and the International Water Association to raise the public awareness of protecting our water resources. Last year over 120,000 people in 81 countries conducted basic monitoring of their local streams and lakes. The CH2M Hill Knoxville office visits two area elementary schools each fall to interact and teach the students the importance of maintaining safe water quality levels. Students are teamed with CH2M Hill professionals and guided through testing the water quality of samples from several area lakes. Through the process students become aware of the importance of maintaining safe levels of these parameters for providing safe drinking water as well as maintaining healthy plant and animal populations.

An expanded program was conducted this year by teaming with the Tennessee Valley Authority (TVA) and the Knoxville Utilities Board (KUB) to provide students two additional learning opportunities. TVA brought their Enviroscape 3-D model of a typical watershed including a factory, houses, farmland, construction areas, roads, streams, and a lake. Students learned about the importance of watersheds and how rain and pollution can interact to end up in local streams and lakes. KUB shared an interactive slide-show illustrating the path a drop of water takes from stream through treatment facility to our homes for everyday use. CH2M Hill plans to continue to provide this outreach event and help inspire future generations to be good water stewards.

VARIATION IN RAW WATER QUALITY INFORMATION RELATED TO LONG-TERM WATER RESOURCE AND WATER SUPPLY ISSUES

Randy M. Curtis[1]*

ABSTRACT

The State of Tennessee mandates the tracking of physical and chemical characteristics of raw water supplies by water treatment plant operators. This information is documented on a monthly operations report form submitted to the State for each raw water source supplying finished water to the public. This documentation could also be used to track long term variation of temperature, pH, alkalinity, free CO_2, iron, manganese, and fluoride in rivers or aquifers. Turbidity measurements also supply a large existing data set that can be used to evaluate basin scale changes due to development or road building projects. Representative samples from municipal water supplies including surface water sources, springs, and wells, can be used to conduct spot checks of water quality in various geological settings within the State of Tennessee. Illustrations of various time series and graphical statistical methods are used to highlight significant variations in these basic measurements. Annual cycles and longer term persistent shifts in water quality may be useful for defining basic hydrologic cycle interactions as well as evaluating sustainable development options at the local scale. The local environmental field offices of the Tennessee Department of Environment and Conservation, Division of Water Supply, frequently maintain up to five years of these monthly operator forms for each water treatment plant in their area.

THE RAW DATA

The Tennessee Code Annotated, in §68-221-103 (a) states that the Department of Environment and Conservation shall exercise general supervision over the operation of public water supplies, including all features which do or may affect the quality of the water supply. The quality of the raw water is tracked as a means of documentation that proper treatment methods have been employed for compliance with the law. The high frequency of sampling and the high number of surface water intakes generate a large amount of raw water quality data. Figure 1 illustrates the scatter of surface water treatment facilities in the cataloged water basins in the State. When wells and spring intakes are added, some type of basic, reproducible and frequent water quality information is available for over 300 locations. The groundwater and spring water sources may not include as many tests, owing to the lesser degree of variation and the higher inherent raw water quality. The monthly forms are submitted to the State and retained in the public record for a minimum of five years. Longer periods of record may be available at the site of operation, where the retention of the reports depends on local preferences and space allotments.

INTRINSIC VALUE AND VARIATION

The raw water quality is measured and recorded in order to meet set treatment standards. Evaluation of the data is guided by whether the facility is in compliance with those standards or not. The intrinsic value of this data is the opportunity it represents for finding signals from underlying physical processes by evaluating the long term variation present in the information. These large daily records represent an opportunity to examine real world variation within watersheds and determine how much real change is present within the normal variation. In other words, because so many measurements are taken for comparison to a critical target value, the quality of the measurements may be relied on, and the shear

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numbers present an opportunity to separate long terms signals by identifying normal 'noise'. Every data set contains noise, and some data sets contain signals. To detect the signals, find a way to filter the noise.

TEMPERATURE

Figure 2 illustrates the raw water temperature data from an intake on the Nolichucky River is East Tennessee from 1994-2005. There is a distinct sinusoidal pattern as the seasonal air temperatures affect the surface water. The highest summer temperatures are held for only a few days, and then the water temperature gradually declines until the coldest part of winter, usually in February. However, the daily variation over ten years from 1995-2005 indicates an apparent trend in that the coldest temperatures for each year gradually rose. Figure 3 illustrates a similar data set from 2002-2010 in the Collins River in the transition from the Cumberland Plateau to the Highland Rim. The seasonal pattern is again evident, with the temperature in a state of flux, either up or down, instead of long periods of steady state at either high or low temperatures.

TURBIDITY

Figure 4 illustrates the raw water turbidity values from two treatment plants in Warren County, Tennessee, compared to the United States Geological Survey stream gage located downstream of both. The gage is on a highway bridge over the Collins River, just downstream of the confluence of the Barren Fork and Collins Rivers. The Collins river water intake is about a mile upstream of the gage and the Barren Fork intake is about two miles upstream. The water quality information from streams with only occasional water quality measurements by State or Federal regulators could be supplemented with daily turbidity data when examining sediment impacted watersheds.

Figure 5 illustrates another potential asset of raw water turbidity data, namely, tracking long term changes for Total Maximum Daily Load information. The surface water intake on the Nolichucky River for the city of Jonesborough's plant is downstream of the portion of the watershed containing Interstate 26. The Tennessee portion from the Nolichucky River to the North Carolina border generally followed South Indian Creek and its tributaries. Construction on the Tennessee portion of I-26 was nearly complete in 1995. The turbidity values from 1994 through 2002 show an obvious improvement in raw water turbidity at the intake, about two miles below the confluence with South Indian Creek. Long term raw water quality data could serve as an independent check for Total Maximum Daily Load evaluations on sediment impaired streams when tracking load reductions or plan effectiveness.

SURFACE WATER / GROUNDWATER INTERACTIONS

Raw water sources span a continuum from the rivers to creeks to springs to wells. Seasonal variation in the raw water parameters could indicate when baseflow groundwater affects surface water quality, or, when surface water affects groundwater quality through variations in recharge. Figure 6 shows a gradual rise in fluoride values in the Collins River in the early winter through spring, 1999-2000. The water temperature plot falls at the same time. The fluoride values may reflect baseflow at time when streambank vegetation is not intercepting water in the hyporheic zone. Hardness values for raw water over several years at the same intake, shown in Figure 7, show abrupt shifts near the end of the water year, usually in October but sometimes as late as November or as early as September. This either reflects an increase in relative groundwater inflow, or, some biogeochemical process which can be detected as hardness.

Figure 8 shows how surface flow in the form of stormwater infiltration, may affect groundwater. The data is for turbidity measurements at a shallow well on the southern Highland Rim in middle Tennessee, coupled with daily rainfall amounts from a nearby station in the southern Regional Climate Center.

Intense rainfall events, such as the storm in early May 2010, result in a pulse of turbidity measurable within a few days. This turbidity pulse could be used to ascertain rudimentary travel time for surface recharge in the wellhead protection area. Note that the degree of turbidity, the reason driving the frequent measurements of this parameter at this point, does not approach a level of concern. The water remained clear in terms of human perception. The information related to physical processes associated with recharge to this well become perceptible only after investigation.

DEEP GROUNDWATER VARIATIONS

Several years of data from two utilities in west Tennessee were compiled to evaluate the degree of variation in groundwater withdrawn from the same Tertiary sand aquifer in two fields separated by a few miles. One is in a topographically higher setting, the north field, while the other is adjacent to the incised valley containing one of the areas larger trunk stream channels. Because the intake depths are in the same regional aquifer, the deeper overburden at the northern field and the nearby surface water / groundwater interaction zone are the main variables relating to recharge. Table 1 compares the average daily raw water quality data for these two systems from December 2004 to July 2010. Non-detects were replaced with a random number between zero and the reported detection limit, and missing data was omitted from the calculation of averages.

Table 1: Average Raw Water Quality, West Tennessee Tertiary Sand Aquifer

Parameter	South Field	North Field
Turbidity in NTU's	0.19	0.09
pH	5.78	5.43
Alkalinity	30.69	13.59
Hardness	53.14	13.84
Carbon Dioxide	83.45	59.72
Iron	0.22	0.02
Manganese	0.05	0.01

There are obvious differences in the average values, but not from a water treatment standpoint. Both well fields supply good quality water which is easily treated before distribution by the utilities. Figure 9 illustrates one component of the raw water quality information which hints at the variation over time. The scatter plot compares the iron vs. turbidity values for the 2004 and 2010 databases for raw water from the northern field. The scatter shows an increase in the number of higher than average iron values in 2009. The higher iron detections are sporadic and the levels are negligible in terms of day to day treatment operations, but the data hints at a gradual change in the process feeding water to this well field.

The differences in the raw water quality at these two well fields may be supplying information regarding the abstraction process. When a well is put on-line as a utility supply, there are only three possible sources of water to replenish that which is withdrawn: increased recharge to the aquifer, decreased discharge from the aquifer, or removal of water from long-term storage in the aquifer. Withdrawal of water from storage is manifested as a cone of depression in the water table surrounding the well, the geometry of which is fixed by the aquifer's physical capability to transmit water to the pump. The volume of unsaturated, or de-saturated, sand within the cone adjacent to the well bore is no longer subject to lateral water movement. Instead, the vertical recharge in the immediate vicinity of the well has to flow through a greater thickness of sand before mingling with the water in the aquifer. This effect may account for the slight shift in iron detection in the north field exhibited by Figure 9, gradual shifts in the recharge process over time.

Abstraction from the southern field may involve induced infiltration from the river's bank filtration zone as the cone of depression is replenished by water which would ordinarily be going towards the river's baseflow area.

RECOMMENDATION

The collection of data to determine whether it meets a standard is necessary and appropriate documentation to evaluate management success for operation of a water treatment plant. Currently, government oversight in the State of Tennessee tracks whether drinking water is up to standards, whether there is risk from water pollutants, the amount of depletion of regional aquifers, and the potential ecological impact of new surface water source withdrawals. The raw water quality data from treatment plants is also a window into basic physical processes of recharge and groundwater/ surface water interaction. To address the core question of sustainability of Tennessee's water resources, an effort should be made to retain and evaluate the data source represented by the raw water quality information. This data should not be purged from the State files after a few years when it could provide researchers or regulators the key to answers about the hydrologic system's future behavior.

Future behavior of a system can only be predicted if there exists adequate physical knowledge of the structure of the system as well as observational knowledge about the system's behavior. The raw water quality data represents a resource which could provide the latter and proper evaluation by academia or governmental agencies could lead to the former.

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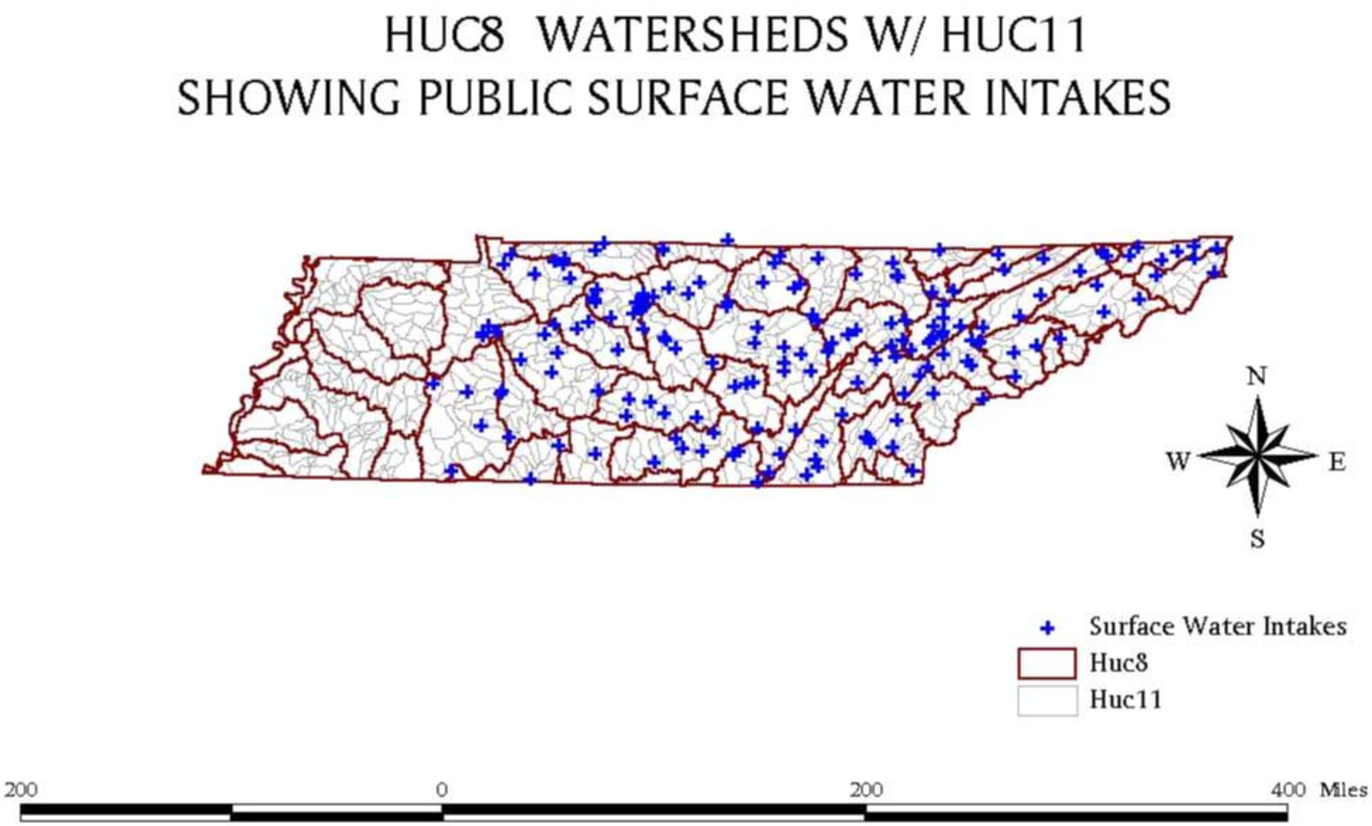
HUC8 WATERSHEDS W/ HUC11
SHOWING PUBLIC SURFACE WATER INTAKES
N
W
E
S
Surface Water Intakes
Huc8
Huc11
200
0
200
400 Miles

Figure 1

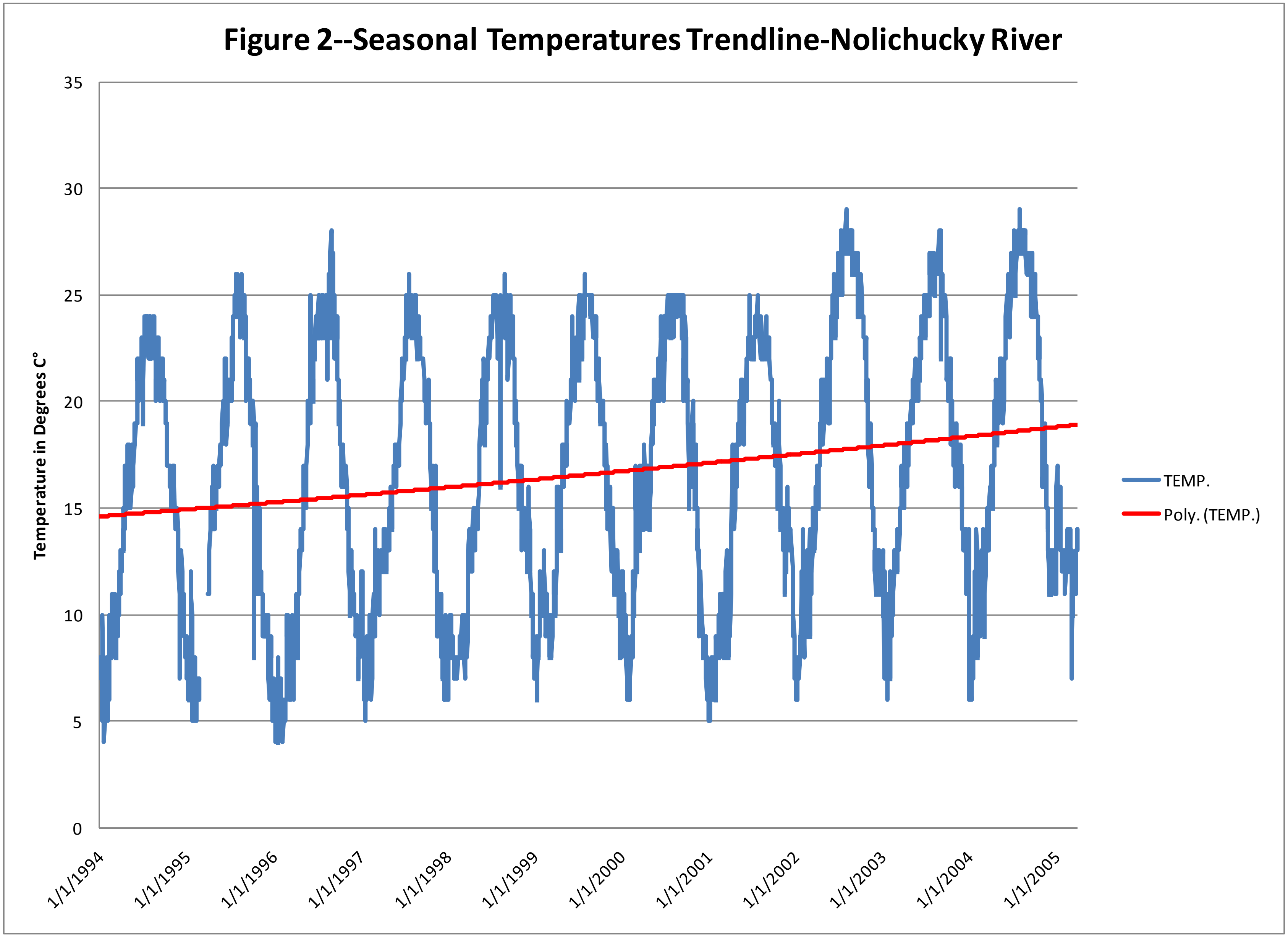

Figure 2--Seasonal Temperatures Trendline-Nolichucky River
Temperature in Degrees C°
35
30
25
20
15
10
5
0
1/1/1994
1/1/1995
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
TEMP.
Poly. (TEMP.)

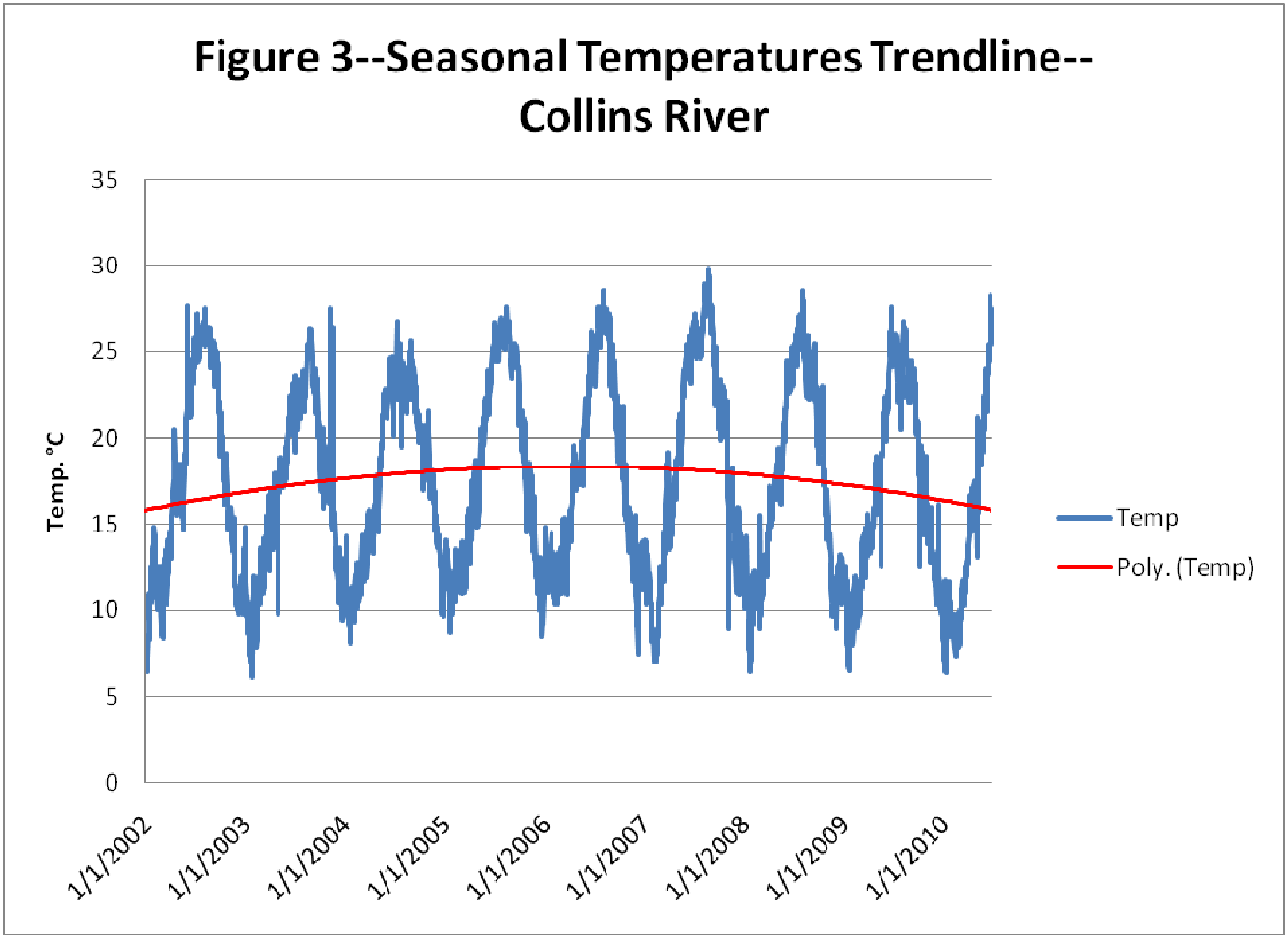
Figure 3--Seasonal Temperatures Trendline--
Collins River
Temp. °C
35
30
25
20
15
10
5
0
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
Temp
Poly. (Temp)

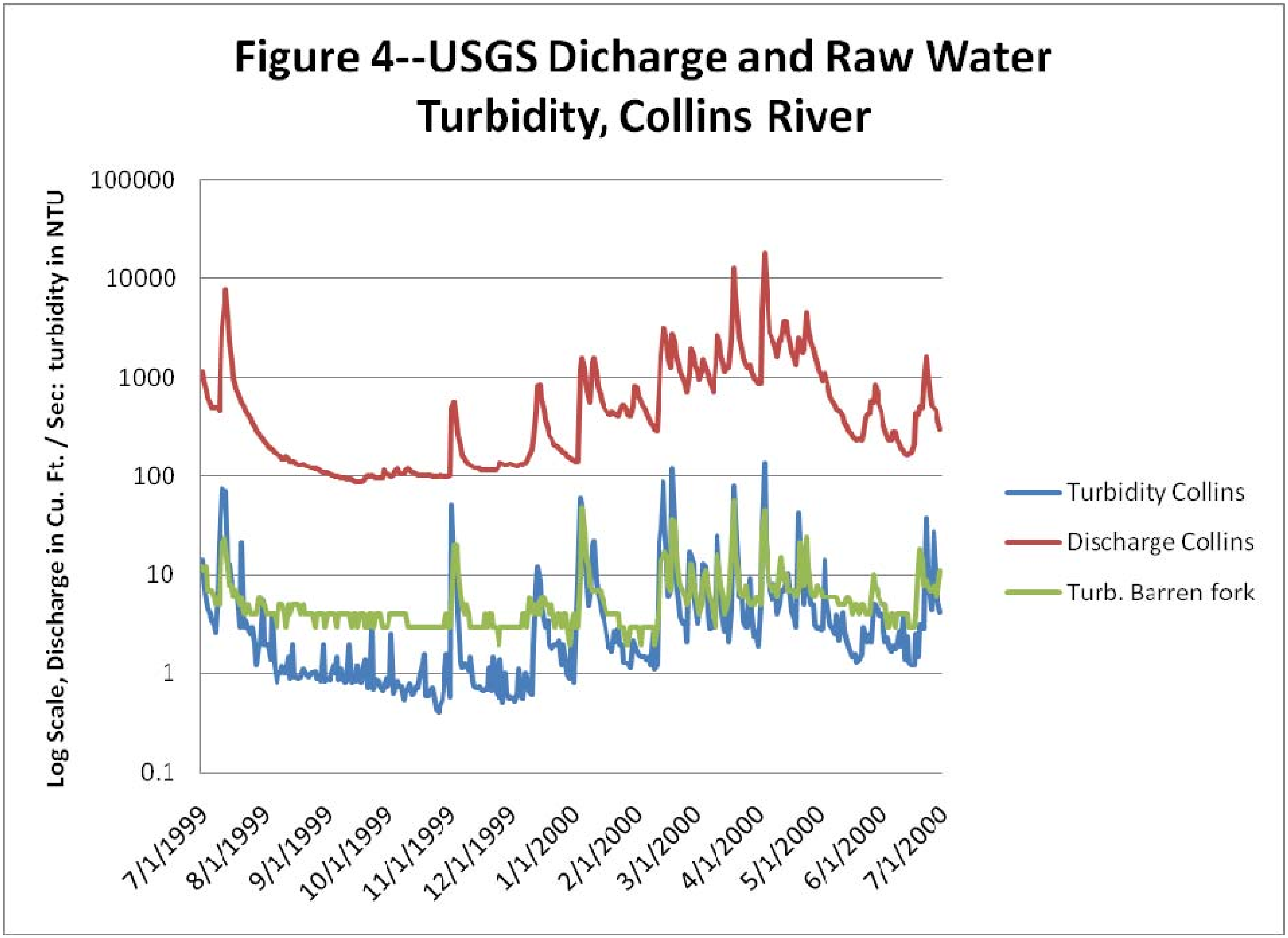
Figure 4--USGS Dicharge and Raw Water Turbidity, Collins River
Log Scale, Discharge in Cu. Ft. / Sec: turbidity in NTU
100000
10000
1000
100
10
1
0.1
7/1/1999
8/1/1999
9/1/1999
10/1/1999
11/1/1999
12/1/1999
1/1/2000
2/1/2000
3/1/2000
4/1/2000
5/1/2000
6/1/2000
7/1/2000
Turbidity Collins
Discharge Collins
Turb. Barren fork

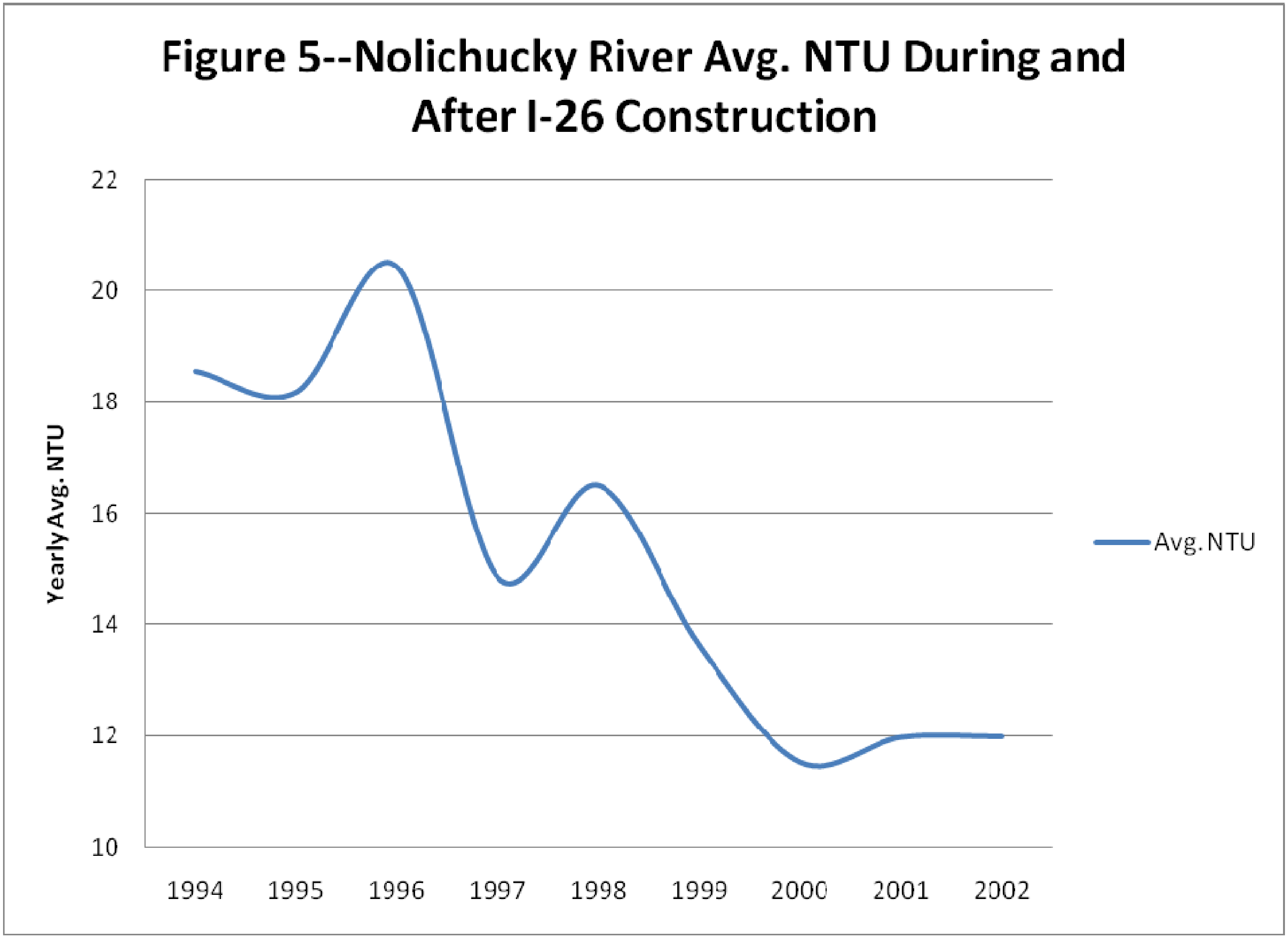
Figure 5--Nolichucky River Avg. NTU During and After I-26 Construction
22
20
18
16
14
12
10
Yearly Avg. NTU
1994
1995
1996
1997
1998
1999
2000
2001
2002
Avg. NTU

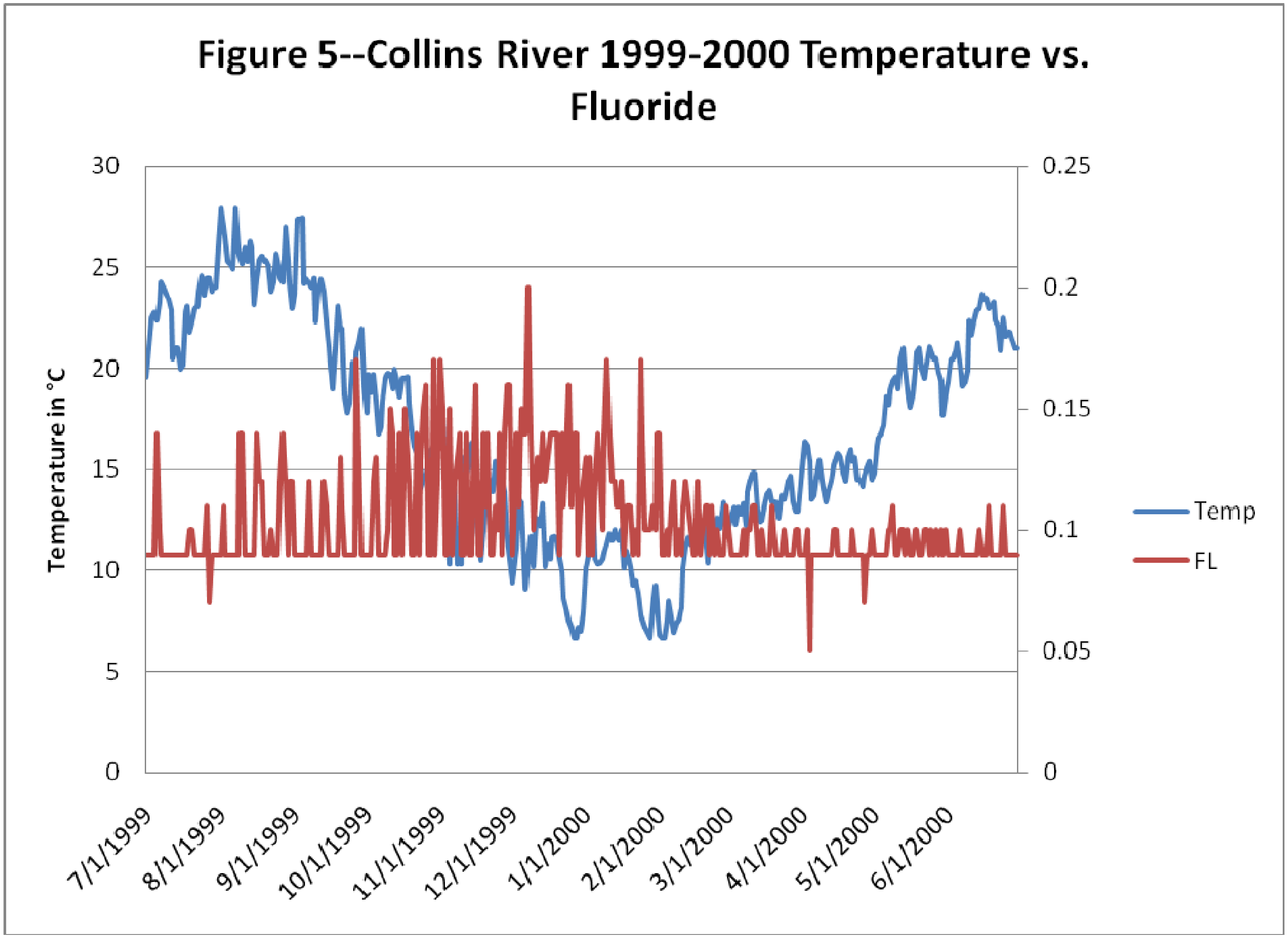
Figure 5--Collins River 1999-2000 Temperature vs. Fluoride
Temperature in °C
30
25
20
15
10
5
0
0.25
0.2
0.15
0.1
0.05
0
7/1/1999
8/1/1999
9/1/1999
10/1/1999
11/1/1999
12/1/1999
1/1/2000
2/1/2000
3/1/2000
4/1/2000
5/1/2000
6/1/2000
Temp
FL

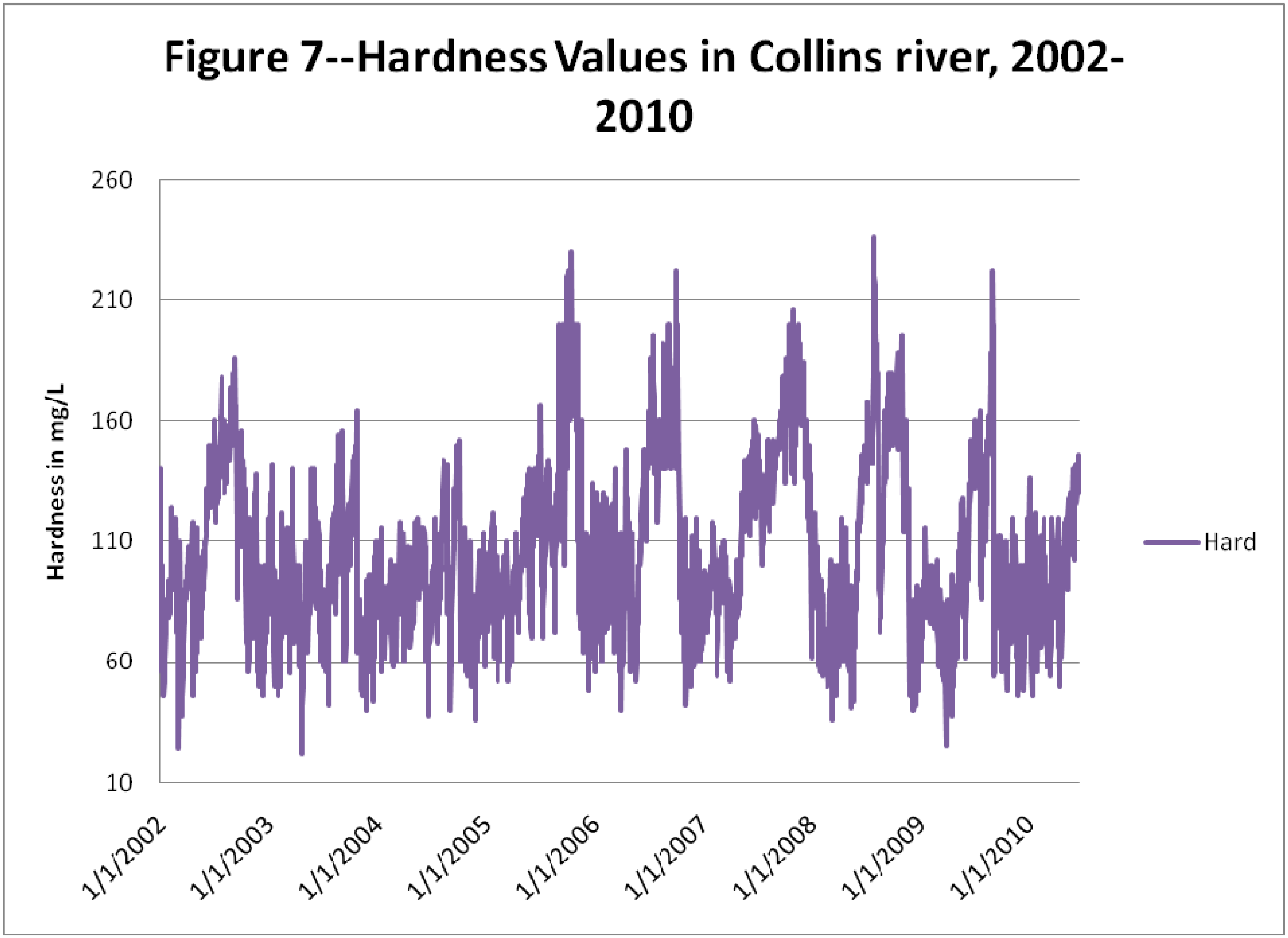
Figure 7--Hardness Values in Collins river, 2002-2010
260
210
160
110
60
10
Hardness in mg/L
Hard
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010

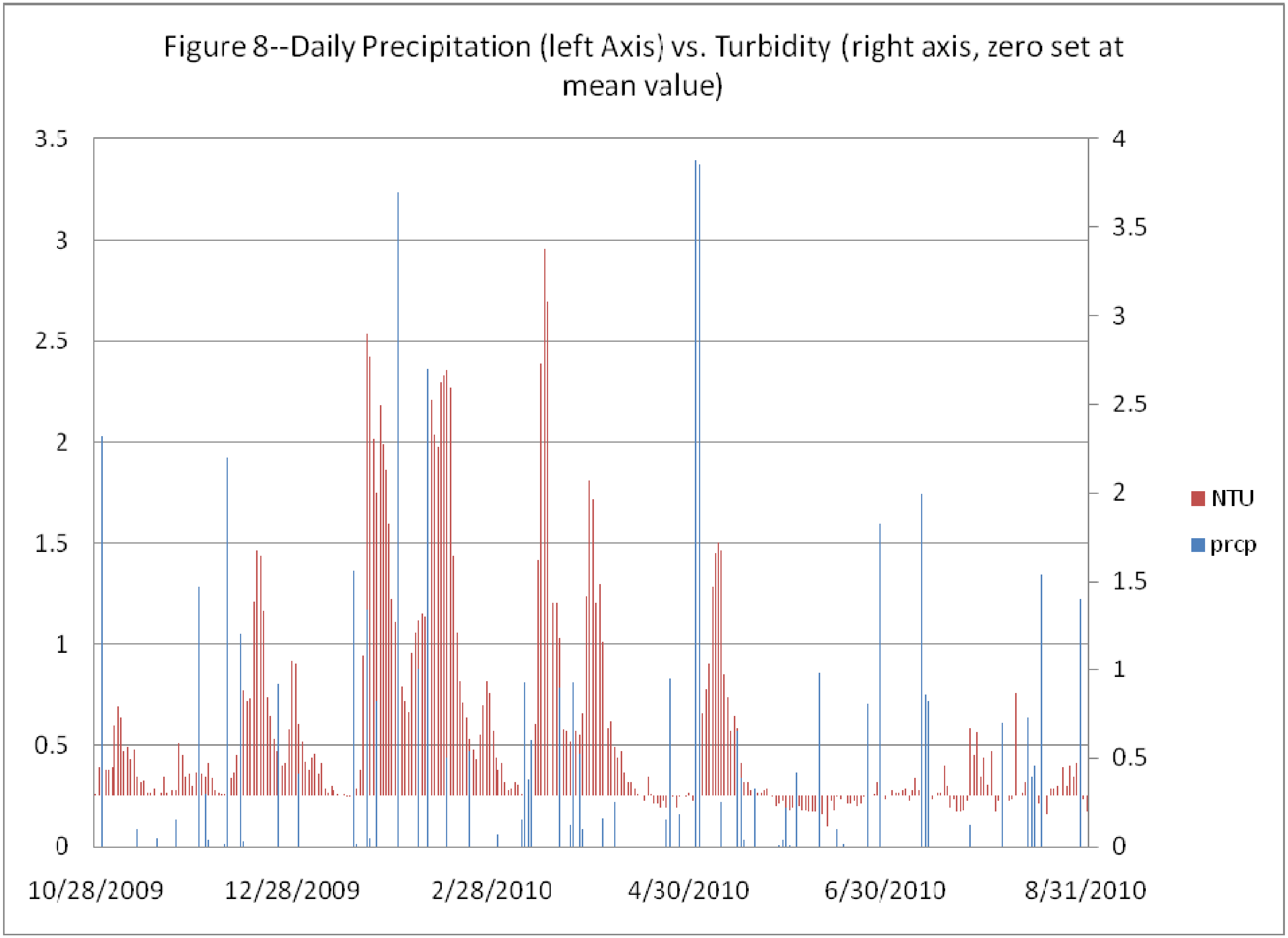
Figure 8--Daily Precipitation (left Axis) vs. Turbidity (right axis, zero set at mean value)
3.5
3
2.5
2
1.5
1
0.5
0
4
3.5
3
2.5
2
1.5
1
0.5
0
NTU
prcp
10/28/2009
12/28/2009
2/28/2010
4/30/2010
6/30/2010
8/31/2010

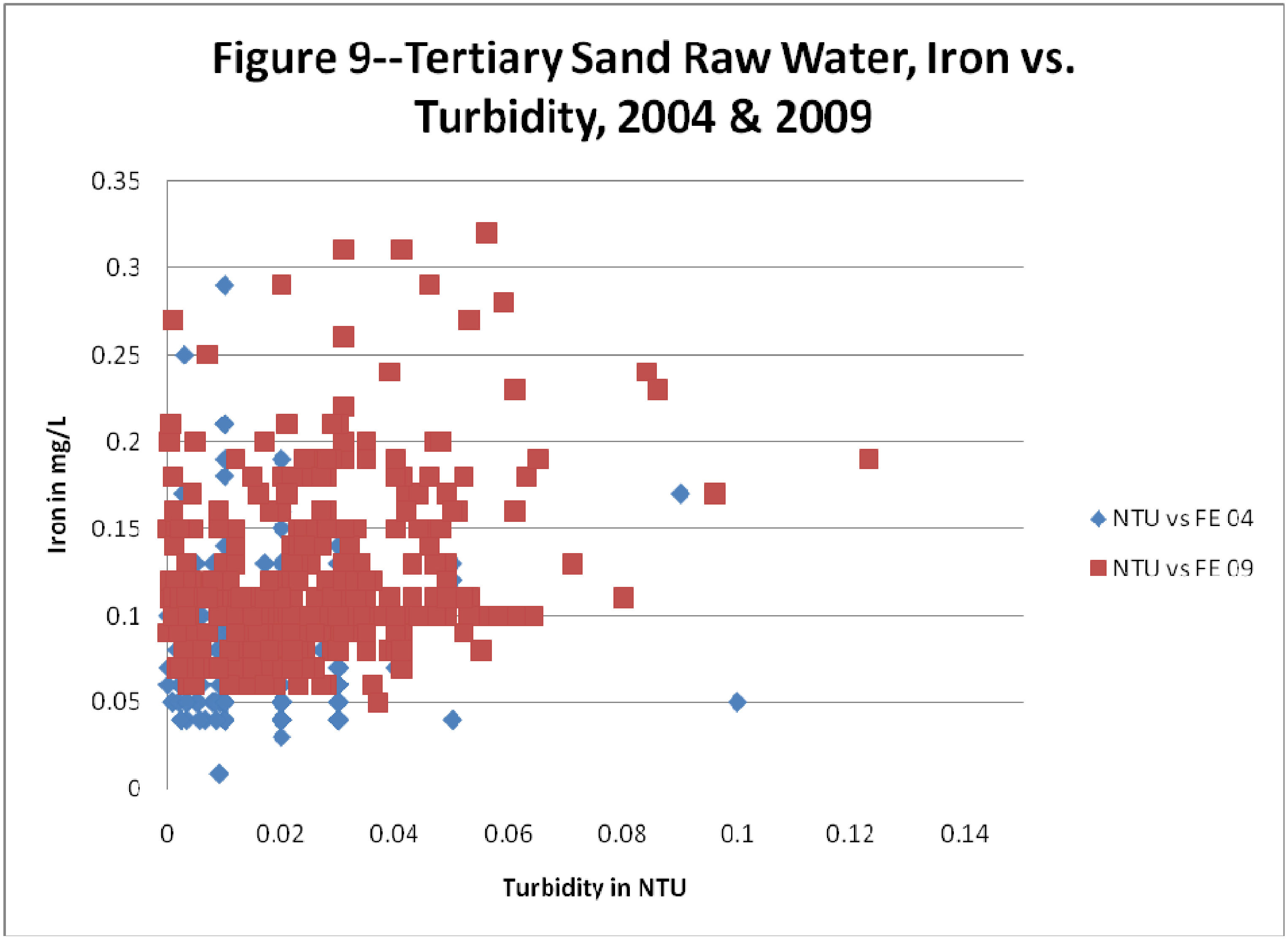
Figure 9--Tertiary Sand Raw Water, Iron vs. Turbidity, 2004 & 2009
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Iron in mg/L
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
Turbidity in NTU
NTU vs FE 04
NTU vs FE 09

WEIGHING THE EVIDENCE – HOW ECOLOGICAL RISKS ARE BEING ASSESSED FOR THE TVA KINGSTON ASH RECOVERY PROJECT

Suzy Young[1], Daniel Jones[1]*, and Neil Carriker[2]

The release of fly ash at the Tennessee Valley Authority (TVA) Kingston Fossil Plant on December 22, 2008 discharged approximately 5.4 million cubic yards of coal ash slurry into the adjacent aquatic and terrestrial systems. The initial response focused on public protection and stabilization of the released ash, but rapidly evolved to include comprehensive monitoring of ambient media and ecological receptors. Metals and metalloids are the primary constituents of potential concern for fly ash. A Conceptual Site Model (CSM) was developed to summarize and illustrate the ecological receptors and potential exposure pathways associated with the release.

The Screening Level Ecological Risk Assessment (SLERA) indicated that a Baseline Ecological Risk Assessment (BERA) is warranted for the River System. The direct exposure pathways being evaluated for the River System include exposures to ash as sediment, sediment porewater, groundwater discharging to surface water, surface water, and seasonally-exposed sediment. Dietary exposures are also a concern for some ash-related constituents, including arsenic and selenium. The ecological receptors for which bioaccumulation and food web pathways are being studied at this site include fish, benthos, emergent insects, piscivorous birds and mammals, aerial-feeding insectivores, herbivorous birds, omnivorous mammals, amphibians, reptiles, and others. The BERA strategy presented in this poster was used to develop data quality objectives for the River System Investigation and identify additional data needs. The CSM and BERA Strategy were then used to refine the numerous field and laboratory studies being performed or supported by TVA.

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IMPACTS OF NONPOINT-SOURCE POLLUTION ON DIATOM COMMUNITY STRUCTURE AND OXYGEN METABOLISM IN THE RED RIVER WATERSHED OF NORTH-CENTRAL TENNESSEE

Jefferson G. Lebkuecher[1], Stacy M. Rainey[1], Chelsea B. Williams[1], and Alex J. Hall[1]

Six streams in the Red River Watershed were sampled to evaluate the impacts of nonpoint-source pollution on the structure of benthic diatom assemblages and whole-stream oxygen metabolism. The three most abundant taxa sampled in the watershed were *Nitzschia linearis* (16.4 %), *Navicula reichardtiana* (15.4 %), and *Navicula tripunctata* (7.2 %). These taxa are tolerant of habitat degradation due to excessive sediments and nutrient enrichment. Poor quality water in all six streams is indicated by: (1) high Siltation Index values for diatom assemblages which reveal loss of biotic integrity as a result of erosion, (2) high rates of whole-stream oxygen metabolism characteristic of eutrophic conditions, and (3) low ratios of whole-stream gross primary production to respiration typical of heterotroph-dominated habitats associated with poor quality water. The diatom assemblage at Sulphur Fork Creek is most impacted as indicated by the lowest Shannon Diversity Index, highest Siltation Index, and lowest Pollution Tolerance Index. High rates of whole-stream oxygen metabolism and high abundances of diatom taxa tolerant of sediments and eutrophication are hallmarks of stream impairment by erosion and nutrient enrichment. The results reveal the negative impacts of nonpoint-source pollution on the ecological integrity of diatom communities and oxygen dynamics in streams of the southern portion of the Interior Plateau Level III Ecoregion.

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GIS INUNDATION MAPPING RESULTS FROM AN UNSTEADY FLOW APPLICATION OF HEC-RAS TO AN EMERGENCY OGEE SPILLWAY

Gregory H. Nail, Ph.D., P.E.[1] and Raymond J. Kopsky, Jr., P.E., P.H.[2]

The widely accepted Hydrologic Engineering Center – River Analysis System (HEC-RAS) software has been used to model unsteady flow scenarios over the emergency Ogee spillway of Wappapello Dam, Missouri. This HEC-RAS model was developed by synthesizing actual surveyed stationing and elevation data together with stationing and elevation data obtained electronically via ArcGIS software. Results include inundation mapping downstream from the spillway, for both historical and hypothetical flows.

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WATER DEMAND PROJECTIONS TO 2030 FOR THE SOUTHERN CUMBERLAND PLATEAU AND NORTH CENTRAL, TENNESSEE

John A. Robinson[1] and W. Scott Gain[2]

Future water demand was estimated for the Southern Cumberland Plateau and North Central Tennessee through 2030. Water demand models were developed using published data sets of projected population and water use. The population projections were developed for counties in Tennessee for the years 2010, 2020, and 2030. The population served by each public water supply system was projected as a fixed portion of the population of the county in which the water supply system is located. Water-use data from 2005 were compiled from the monthly operation reports and water system surveys by the Tennessee Department of Environment and Conservation. Commercial withdrawals were projected as a ratio of residential withdrawals, which varied with county population density and converged on1:1 at a density of about 1000 persons per square mile.

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STUDENT POSTERS

Hydraulic Gradients and Groundwater Flow at Tennessee State University, Nashville, Tennessee
Aras Barzanji, Alex Morris, Mike Bradley, and Tom Byl

Fertilizer Usage and Nutrient Leaching in the Richland Creek Watershed, Nashville, Tennessee
Isaiah W. Bolden, DeAndre Q. Baynham, Katherine M. Roland, Anna C. Brakefield, Christopher T. Peek, and Alan U. Hererra

Groundwater Recharge in an Urban, Karst Terrain
Carlton Cobb, Lonnie Sharpe, Dafeng Hui, and Tom Byl

Graphical Residence Time Distribution Model for Karst Systems Using Matlab® and GNU Octave Derived from Independent Gamma Distributions of Tracer Travel Distance and Linear Velocity
Irucka Embry and Roger Painter

Using Soil Survey to Access Land Management Practices on Soil and Water Quality
Joy Hall, Warren Anderson, and Jason McAfee

Hydrogeologic Controls on Water Quality at a University Dairy Farm
Larry McKay, Robert W. Hunter, and Jaehoon Lee

Hydrologic Analysis of a Rare Flood in Jackson County, Tennessee
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Transport of Explosive Residue Surrogates in Saturated Porous Media
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BPA and Other Plasticizers as Organic Markers for Near-Term Dating of Sediments from Urban Runoff
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Effect of the 2010 Flood Event on Surface and Ground-Water Quality and a Wetland Ecosystem in Nashville, TN
Victor Roland

Aromatic-Ring Biodegradation in Soils from a Crude Oil Spill on Clear Creek, Obed Wild and Scenic River National Park
Loreal Spear, Aaron Williams, Jaala Brooks, Carlton Cobb, Brandon Cobb, Marquan Martin, Patrice Armstrong, Mike Bradley, and Tom Byl

Application of Bioluminescent Yeast-Based High Throughput Bioassay for Monitoring Endocrine Active Compounds in Wastewater
Jun Wang, Melanie DiClaudio, Alice Layton, and G.S. Sayler

Geospatial Assessment of Threats to Mussel Diversity within the Upper Duck River Watershed
Tyler Skelton

Radon Levels and Geochemistry Associated with Three Unique Springs in Bon Aqua, Tennessee
Karla Ward, Terreka Hart, and Orville N. Bignall

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

HYDRAULIC GRADIENTS AND GROUNDWATER FLOW AT TENNESSEE STATE UNIVERSITY, NASHVILLE TENNESSEE

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

Groundwater flow paths are difficult to determine in karst terrains due to the anisotropy openings in the subsurface. Nonetheless, using three or more wells, one can calculate the general direction and magnitude of hydraulic gradients using the triangulation method. The objective of this research was to determine the hydraulic gradient of a limestone-bedrock aquifer approximately 0.5 mile east of the Cumberland River near Tennessee State University (TSU; near river mile 185) as an indicator of groundwater flow direction. Three deep (200-250 feet below land surface) wells located along the Cumberland River floodplain on TSU's research farm were monitored for this study. These four-inch wells were cased to top of rock and were open borehole in the bedrock below. Geophysical logging placed the top-of-bedrock at approximately 40 to 60 feet below ground surface and found two openings in the bedrock at approximately 72- and 108-feet below ground surface. Water levels were measured repeatedly over time using an electric tape and ranged from 6 to 22 feet below land surface, depending on the well and weather conditions. Continuous water levels were monitored in one well using a pressure transducer and data recorder. Results indicate that rain rapidly influenced the hydraulic gradient and flow directions. For example, in less than 24 hours after a 1.5 inch rain, the potentiometric water levels rose between 1 and 3 feet, in the various wells, changingthe direction of flow and increasing the magnitude of the hydraulic gradient by 11 percent. Additional work is needed to better understand the relation between the Cumberland River and water levels in the wells.

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FERTILIZER USAGE AND NUTRIENT LEACHING IN THE RICHLAND CREEK WATERSHED, NASHVILLE TN

Isaiah W. Bolden, DeAndre Q. Baynham, Katherine M. Roland, Anna C. Brakefield, Christopher T. Peek, Alan U. Hererra

Nitrogen-containing fertilizers used in households across America contribute to nitrous oxide emissions. Because nitrous oxide is 300 times more potent than carbon dioxide, small quantities of nitrous oxide emissions from lawn care practices can comprise a significant portion of US greenhouse gas emissions (GHG). The effect of nitrous oxide emissions on the total US GHG is unknown, and options for cost effective emissions reductions have not been fully explored. The EPA Inventory of US Greenhouse Gas Emissions and Sinks includes estimates of household nitrous oxide emissions; however, these are not based on comprehensive data and do not take alternative emission-affecting factors into account. We carried out a lysimeter-based study in which we directly sampled and measured the nitrate and ammonium variability of the soil solution in households along the Richland Creek watershed in Nashville, TN. Twenty lysimeter sites were chosen based on fertilizer application rate as determined from a previous survey of 260 households in the watershed. Results were analyzed in terms of spatial and temporal variability as related to variations in soil physical and chemical properties using multiple linear regression modeling. The data will help to form the basis of a numerical model, which will describe NOx emissions at the watershed scale.

GROUNDWATER RECHARGE IN AN URBAN, KARST TERRAIN

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

Karst aquifers in urban locations are particularly vulnerable to contamination for three reasons. First, karst features and hydraulic processes tend to promote rapid movement of surface waters into the sub-surface with little or no filtration. Second, urban settings tend to have a higher density of contaminant sources. Third, urban settings have extensive areas of impervious surfaces that commonly direct surface runoff to sinkholes or losing streams with no filtration. The objective of this project was to better understand the vulnerability of Nashville's shallow groundwater to contamination as indicated by residence time and though put in the shallow karst aquifer underlying the city. Temperature and conductivity were monitored continuously for 2 years at Tumbling Rock Spring, located on the Tennessee State University campus in Nashville. Synoptic sampling augmented the continuous monitoring. The samples were analyzed for turbidity, pH, and concentrations dissolved oxegen, nitrate, sulfate, iron, discharge and turbidity. Groundwater discharging from the spring maintained a nearly constant temperature of 17.5^{o} C, plus or minus1 degree year round. Specific conductance generally decreased during drier summer months and increased during wet winter months. This pattern was punctuated by sharp upward departures following rain events.

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GRAPHICAL RESIDENCE TIME DISTRIBUTION MODEL FOR KARST SYSTEMS USING MATLAB(R) AND GNU OCTAVE DERIVED FROM INDEPENDENT GAMMA DISTRIBUTIONS OF TRACER TRAVEL DISTANCE AND LINEAR VELOCITY

Irucka Embry[1] and Roger Painter[1]

The Residence Time Distribution (RTD) is the time that a particle will take to complete its path from the injection to the exit point in a closed system. Most RTD models have used the advection dispersion equation (ADE) for tracer breakthrough curves for karst systems. ADE solutions for tracer breakthrough curves exhibiting near plug flow behavior are usually Gaussian (normally distributed) in nature. This symmetric solution often predicts finite tracer concentrations at zero time and this is not often shown in tracer breakthrough curves, which frequently are characterized by relatively long upper tails. There are few quantitative tracer studies modeling karst systems that have tracer concentrations normally distributed about the mean residence time and few of these models graphically display this distribution. The objective of this project was to create an M-file language computer algorithm in MATLAB® Version 6.5.1 and GNU Octave Version 3.2.4 that combined both the numerical and visual aspects of karst tracer studies. This project used the transformed residence time distribution function using the independent gamma distributions of tracer travel distance and linear velocity. This algorithm computes the transformed RTD function from the time inputs and then displays the RTD function versus Time graph, the Tracer Concentration versus Time graph, and the graph of the tracer concentration normally distributed about the mean residence time.

Acknowledgement: Tom D. Byl[1,2]

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USING SOIL SURVEY TO ACCESS LAND MANAGEMENT PRACTICES ON SOIL AND WATER QUALITY

Joy Hall[1], Dr. W. Anderson[2], and Jason McAfee[3]

Land use and water quality are public concerns in Tennessee. How can soil and water quality assessed? USDA-NRCS has outlined a unique way to assess the interaction of land management and these quality concerns using the soil survey.

The ABAS 4350, SOIL SURVEY AND LAND USE classes of fall 2009 and 2010 were assigned a 20 acres study site in the Stones River watershed. The study site is on the east fork of the Stones River. Their assignment has been to use the soil survey to assess the effects of land use practices on soil and water quality. Land management uses assigned to the site is as pasture land and vegetable garden.

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HYDROGEOLOGIC CONTROLS ON WATER QUALITY AT A UNIVERSITY DAIRY FARM

Larry D. McKay[1], Robert W. Hunter[1], Jaehoon Lee[2]

Dairy farms typically produce large quantities of manure and other waste products which are often stored or treated in lagoons and then applied to local fields as fertilizer. Contamination of nearby streams by dairy farm wastes through surface runnoff, drainage tile discharge, direct release of wastes or inundation of waste storage facilities during seasonal flooding have long been recognized as major environmental concerns. However, much less attention has been paid to fate and transport of dairy wastes in the subsurface and their potential impact on water quality in aquifers or in groundwater discharge to streams. One of the challenges in evaluating the environmental impact of dairy operations is that there are relatively few field research sites where all of the potential pathways for waterborne transport of dairy wastes are monitored and quantititatively evaluated. There are even fewer sites where extensive baseline water quality monitoring programs were established prior to operation of the dairy. This is essential to distinguish between environmental impacts from dairy operations and other nearby sources, such as beef production and human sewage from septic fields. This presentation describes the development of a an integrated hydrogeologic/hydrologic site assessment and groundwater/surface water quality monitoring program at the University of Tennessee – Little River Dairy Farm, located near Townsend, TN. The dairy is currently under construction and the first cows are expected to arrive in late 2010. Hydrologic/hydrogeologic investigations of streams and groundwater at the site have been underway for more than 3 years, and these are expected to provide background data for assessing impacts of dairy wastes and for testing the effectiveness of different management practises. The lower half of the ~180 ha site consists of low-relief fields used for row crops, which are underlain by 4 – 8 m of alluvial deposits (mainly interbedded silt and fine-grained sands) on top of by black shale or limestone. Several active sinkholes are present in the portion of the fields underlain by limestone. The fields are bounded on two sides by the Little River, a popular recreational river, and on the third side by Ellejoy Creek, which is on the state's 303(d) list for impairment by nutrients, sediment and fecal microorganisms, which are derived from upstream agricultural and rural residential development. These fields will be fertilized with treated dairy wastes and are the main area of concern for offsite migration of contaminants through groundwater, drainage ditches and (eventually) a tile drain system. A secondary area of concern is the dairy waste treatment pond which is located, along with the dairy barns, on the upland portion of the site, which is underlain by 1-2 m of clay-rich residual soils developed on fractured shale bedrock. Long term water quality monitoring of runnoff, streams, drainage ditches and groundwater is planned, with the intent of measuring environmental impact of dairy operations and testing the effectiveness of different management practices.

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HYDROLOGIC ANALYSIS OF A RARE FLOOD IN JACKSON COUNTY, TENNESSEE

Dana C. Jolley[1] and Korey T. Harvey[1]

On August 18, 2010 a stationary front dumped up to 11 in of rain on parts of the Blackburn Fork watershed in Jackson County, TN. The resulting flood scoured stream channels, transported large boulders and trees, and destroyed several structures. Since no gauging stations exist on Blackburn Fork, several indirect methods were used to estimate the discharge of the event. First, we used the slope-area method to estimate discharge. This method uses high water marks to estimate channel dimensions and slope. Secondly, we used a form of the bedload transport formula to estimate velocity from boulder size. Finally, we also estimated discharge of the flood from model predictions using the TR-55 runoff model. To evaluate the reasonableness of these estimates we compared them with flood frequency curves from gauged streams in the region and with flood frequencies predicted by the USGS program StreamStats. Preliminary results indicate that this flood had an annual recurrence interval between 500 and 1000 years.

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TRANSPORT OF EXPLOSIVE RESIDUE SURROGATES IN SATURATED POROUS MEDIA

Beth Lavoie[1], Melanie A. Mayes[2], Steven C. Minkin, Jr.[3], and Larry D. McKay[1]

Contamination of soils by munitions constituents is pervasive on Department of Defense operational ranges. Low-order detonations result in the heterogeneous distribution of explosives residues (ER) at shallow depths (Clausen et al., 2006). At a limited number of ranges ER contamination of groundwater has been observed.

Previous studies have shown that the downward migration of colloid-sized contaminants can significantly impact groundwater quality (McCarthy and McKay, 2004). The goal of this study was to investigate if colloid transport plays a role in the migration of ER contaminants. The main objective was to determine the transport potential of fine (<5 µm) ER particles in saturated, granular media of varying size.

A series of saturated transport experiments were conducted in columns (2x20 cm) packed with clean, Ottawa sand (median grain diameter 0.4 or 1.0 mm) or glass beads (4.0 mm). Particulate 2,6-Dinitrotoluene was used as a surrogate for ER. A sodium bromide tracer was also used to characterize nonreactive transport. Particulate tracers were applied directly to the top layer of sand in the columns to represent field conditions. Experimental results indicate that DNT movement through the columns occurred as a combination of solid and dissolved phase transport. Concentration differences between unfiltered and filtered samples indicate that particulate DNT accounted up to 40% of the total mass recovered in the effluent. The particulate fraction recovered in the effluent increased with increasing grain size. This suggests that the transport of particulate DNT might be enhanced by the presence of macropores found in many soil types.

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BPA AND OTHER PLASTICIZERS AS ORGANIC MARKERS FOR NEAR-TERM DATING OF SEDIMENTS FROM URBAN RUNOFF

Akannaya Omelogu

Bisphenol-A (BPA) along with similar phenols and other plasticizers such as methylphenols (MP) and chlorophenols (CP) are pollutants commonly found in our environment. Because these compounds do not occur in nature and are stable in nature, they are good candidates for use in dating sediments resulting from urban runoff. As a possible means of near-term dating of sediments, we are determining phenolic xenoestrogens and other plasticizers that may be present in successive layers of sediment from Capshaw Cave in Cookeville, Tennessee. This project is being conducted in conjunction with research by Dr. Evan Hart, who is analyzing metal concentrations in the Capshaw Cave sediment layers.

We are using headspace solid-phase microextraction (HS-SPME) with gas chromatography-mass spectrometry (GC-MS) to analyze plasticizers in extracts of the sediment. Our procedure is based on that of Liman et al. (*Intern. J. Environ. Anal. Chem*. 2010, 90(3-6), 230-244.) In our method, we extract the compounds with methanol and dichloromethane. We analyze the samples by headspace SPME, using PDMS-DVB fiber. Our instrument is the Varian CP-3300 GC Saturn 2200 mass spectrometer. In this poster, we will present the analytical methods we are using to determine phenolic compounds in cave sediments.

We will present the results of our study of these compounds in Capshaw Cave sediments, and how these findings can help date the sediment layers.

EFFECT OF THE 2010 FLOOD EVENT ON SURFACE AND GROUND-WATER QUALITY AND A WETLAND ECOSYSTEM IN NASHVILLE, TN

Victor Roland[1]

On May 2 and 3, 2010, middle Tennessee received 13-15 inches of rain, the result was a 100-year flood event on the Cumberland River. Much of Nashville flooded over a 2-5 day period. The flooded areas included sewer lines, sewage treatment facilities, stalled vehicles, fuel storage tanks, and stock-piled chemicals, releasing raw sewage and chemicals into the Cumberland River at multiple points. The objective of this research project was to document the water-borne contaminants around the flooded areas of Tennessee State University (research farm, main campus) during and after the flood. This included collecting surface and groundwater samples. The samples were analyzed for dissolved metals (ICP method), organic compounds (GC instrument), turbidity (turbidimeter), and fecal bacteria (m-coliblue® membrane filtration method). Mud left on the vegetation after flood waters receded was also analyzed for bacteria. Continuous water-quality monitoring stations set up prior to the flooding were used to document abnormalities or hydrologic changes caused by the flood waters. The results show a temporal and spatial effect during the flood event; surface water samples collected closer to the Cumberland River were 2-10 times higher in turbidity and *E. coli* than the backwaters in the neighborhoods. Zinc concentration was below detection in pre-flood waters and rose to 10-30 micrograms per liter in the flood waters. Mercury levels spiked to 30 micrograms per liter in some of the flood waters as compared to less than 5 micrograms per liter in pre-flood waters. Nitrogen was below 10 mg/L during the flood but increased 3-fold as waters receded. The mud left by the flood waters had elevated *E. coli* counts for four weeks after the water receded. Fuel was detected in recession waters collected near a fuel storage facility. A groundwater well that was covered by 15 feet of flood waters had elevated turbidity and greater than100 *E. coli* colony forming units/100 mL2 weeks after the flood receded. A comparable well 125 yards away that was not covered by flood waters had no turbidity and no *E. coli* detections. This indicates that the wells covered by the flood waters were prone to contamination. The main environmental stress on the wetland ecosystem was the inundation itself and not the contaminants. The 4-day inundation killed cattails and released a pulse of nitrate into receding waters. Fortunately, periphyton living in the wetland rapidly absorbed the nitrate and kept it from entering the Cumberland River. Beavers living in the wetland suffered a reduction in numbers and habitat, but appear to have recovered 6 months later and are actively expanding their dams.

Acknowledgement: Tom Byl[1,2]

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AROMATIC-RING BIODEGRADATION IN SOILS FROM A CRUDE OIL SPILL ON CLEAR CREEK, OBED WILD AND SCENIC RIVER NATIONAL PARK

Loreal Spear[1], Aaron Williams[1], 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 located in areas bordering the Obed WSR and some of these areas are targeted for a significant increase in exploratory drilling. During July, 2002, an exploratory drilling operation near the boundary of the WSR encountered a highly pressurized petroleum zone and released an estimated 12,000 barrels of oil in 24-hours. The spilled crude oil flowed down the embankment and percolated down into the subsurface. After 7 years, oil is still seeping out into the creek. The objective of this project was to identify contaminated seeps, characterize the microbial community and measure the rate of natural bioremediation. Several new seeps were identified and located with GPS. Subsurface bacteria from clean and contaminated sites along the creek found Pseudomonds, 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. The more efficient heterotrophic aerobic and iron-reducing bacteria were present, but in smaller proportions. Microcosms were established using 40 cm^3 of sediment collected from contaminated seepson White Creek. The concentration of aromatic petroleum compounds was measured using a fluorometer. The half life for aromatic rings in un-amended soils was 583 days. Adding peroxide and vitamin B_{12} enhanced the rate of biodegradation and reduced the half-life to 163 days.

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APPLICATION OF BIOLUMINESCENT YEAST-BASED HIGH THROUGHPUT BIOASSAY FOR MONITORING ENDOCRINE ACTIVE COMPOUNDS IN WASTEWATER

J. Wang, M.L. DiClaudio, A.C. Layton, G.S. Sayler

Bioluminescent *Saccharomyces cerevisiae* strains BLYES, BLYAS, and BLYR were developed to detect the presence of potential environmental estrogenic, androgenic, or toxic compounds, respectively. These strains contain the bioluminescent lux*CDABE* genes from *Photorhabdus luminescens* and the *frp* gene from *Vibrio harveyi*, which are expressed on two plasmids either under the control of estrogen response elements (*S. cerevisiae* BLYES), androgen response elements (*S. cerevisiae* BLYAS), or are constitutively expressed for the detection of toxicity (*S. cerevisiae* BLYR). In the presence of estrogenic or androgenic compounds, *S. cerevisiae* BLYES and BLYAS produce bioluminescence, respectively, while *S. cerevisiae* BLYR produces light except in the presence of toxic substances. Bioassay using these bioreporter strains has been demonstrated as a high throughput, inexpensive and rapid screening system for determining potential endocrine disruptive chemicals (EDCs). Recently, this bioassay system has been applied in monitoring the removal of EDCs in wastewater treatment process. By using lab-scale bioreactors recruiting activated sludge biomass from Hallsdale-Powell Wastewater Treatment Facility in North Knoxville, continuous Fill & Draw experiments were performed for 7 days simulating wastewater treatment process. Samples collected from bioreactors were concentrated by solid phase extraction and tested by Bioluminescence Yeast Reporters to determine whether estrogenic or androgenic activity changed with treatment. Bioluminescence Yeast Reporters successfully demonstrated decrease of total endocrine disruptive activity and toxicity in treated wastewater, proving that yeast-based bioluminescent assays can rapidly and effectively gauge whether wastewater treatment methods have modified or removed endocrine-active or toxic compounds.

GEOSPATIAL ASSESSMENT OF THREATS TO MUSSEL DIVERSITY WITHIN THE UPPER DUCK RIVER WATERSHED

Tyler Skelton[1]

Conservation of biodiversity is critical in maintaining healthy ecosystems. The Duck River of Tennessee is considered one of the most biologically diverse freshwater systems in North America according to the US Geological Survey. With over 500 species of aquatic plants, over 140 species of fish, 55 species of mussels, and 25 varieties of snails, the Duck River watershed is teeming with life (Niemiller, Matthew L, 2005). Many of the species found within the watershed are endemic. A keen understanding of what threatens this vast range of biodiversity is critical in preserving the flora and fauna within the watershed. Mussel populations are particularly sensitive to pollution and are key indicators of water quality and were the focus of this project. A geospatial information system (GIS) was developed to identify the spatial location of stressors and the magnitude of stress in relation to mussels and mussel host fish occurrences. The GIS allows for the prioritization of conservation now and in the future. Threats assessed included non-point source pollution from runoff, point source pollution from Water Pollution Control (WPC) permits, and dams and their potential for population fragmentation and alteration of stream flow. An assessment of population distribution of individual mussel species and their host fish identified the relationship of threat and mussel shoals. Riparian health was determined by locating banks with non-natural land cover. The GIS developed in this project will be applied in the decision making process to identify locations of threats, and potential reintroduction sites for mussels.

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RADON LEVELS AND GEOCHEMISTRY ASSOCIATED WITH THREE UNIQUE SPRINGS IN BON AQUA, TENNESSEE

Karla Ward[1], Terreka Hart[1], Orville N. Bignall[1]

The John Noel State Natural Area located on the western Highland Rim near Bon Aqua, Tennessee has a unique hydrologic setting. The area was named Bon Aqua (French for "good water") by early settlers because there are springs with different chemical properties located within close proximity to each other. The chemistry of the spring waters varies from relatively fresh water, with low specific conductance, to mineral sulfur-water with high conductivity. The objective of this research was to analyze isotopes and geochemistry associated with 3 springs in the area that represents a range of geochemical properties. The three springs chosen for this study were within a few hundred yards of each other and designated Springs 1, 2, and 3. Spring 1 emerged from a small cave-like opening near the road and had a specific conductance of 269 micro-Siemens per centimeter (µS/cm), and average radon levels in the water of 11 pico-Curies per liter (pCi/L). The soil in the cave had an average radon level of 0.3 pCi/L of soil gas. Spring 2 was slightly lower in elevation, emerging from a bedrock opening at the base of the hill. Water in Spring 2 had a specific conductance of 328 µS/cm and average radon level of 127 pCi/L. Spring 3 water emerged from the base of the historic bath house and had a strong hydrogen sulfide odor. The specific conductance of Spring 3 water was 1078 µS/cm, with an average radon level of 319 pCi/L. Alluvial soils near Spring 3 had an average radon level of 380 pCi/L of soil gas. The pH values of the waters were 7.8, 7.5, and 6.4 in Springs 1 – 3, respectively. The results show that radon is more prevalent in the mineral waters of Spring 3. Additional geochemistry and isotope analysis is needed to develop a conceptual model of radon transport from the subsurface and distribution in the soils.

Acknowledgement: Mike Bradley[2], and Tom Byl[2,3]

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

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Mammoth Cave is home to many unique animals that could be harmed by contaminants carried into the cave system during storm events. This project was conducted to determine if leaf-pack filter systems attenuated storm runoff at seven parking lots in Mammoth Cave National Park. Grab samples were collected at the inlet and outlet of the filter systems, and analyzed for oil and grease, sediment, turbidity, gasoline compounds, nitrate, ammonia, fecal bacteria, dissolved iron, and chemical oxygen demand (COD). For the first sampling round, the filters had not been serviced for 8 years and did very little to remove contaminants. The contaminant concentrations at the outlet were similar to those at the inlet, with the exception of removing 20-70 percent of the oil and grease. After replacing leaf packs and cleaning out debris, the re-conditioned filters did not remove oils and greases and did little to remove copper and ammonia from runoff waters. However, the re-conditioned filters removed up-to 99% of the benzene, toluene, ethyl-benzene and xylene, and, up to 90% of the turbidity, *E. coli*, chemical oxygen demand and iron from the storm runoff. These results indicate that well-maintained filtration systems are more effective than clogged filters at removing many but not all contaminants from parking lot runoff.

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