



Proceedings of
**The Sixteenth Tennessee
Water Resources Symposium**

April 19-21, 2006

Proceedings from the

**Sixteenth Tennessee
Water Resources Symposium**

Montgomery Bell State Park
Burns, Tennessee

April 19-21, 2006

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Division of Water Pollution Control
Symposium Contest Question: Name the Stream.



PREFACE

The State of Tennessee relies heavily on its abundance of fresh water--both surface water and ground water. Unfortunately, overuse and contamination are becoming greater threats to these valuable natural resources, thus, endangering the long-term sustainability of their quantity and quality. The Tennessee American Water Resources Association (TN AWRA) is proud to host a forum through which water-resource managers, federal, state and local governmental agencies and officials, and academics are able to exchange ideas and share innovations. This year, we celebrate the Sixteenth Tennessee Water Resources Symposium.

We have a wide-ranging venue of topics that include surface-water quality, ground-water contamination, source water, GIS, and watershed planning, to name a few. Because of the great success of last year's exhibitor demonstrations, exhibitors will again be showcasing their products during an outdoor session.

In keeping up-to-date in a rapidly changing digital world, we are providing this year's proceedings to all of the conference participants as an Adobe PDF in addition to the printed copy. We will be asking for your opinion on whether we should provide future proceedings only in PDF format and limit the printed copies to individual requests. Adobe PDF format will allow for simple queries, the inclusion of color illustrations, and greater flexibility on extended abstract page restrictions.

Each TN AWRA conference relies on the abilities of the planning committee to make the conference a success. These volunteers work behind the scenes, generously contributing their time and effort. I personally thank the committee members (listed on Page v of these proceedings) for their commitment and dedication. I would like to extend a special thanks to Lori Crabtree for her guidance. I also extend a warm thank you to our sponsors and exhibitors for your generosity and participation.

We welcome you to the Sixteenth Tennessee Water Resources Symposium.



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1:30 – 3:00 p.m.
Wednesday, April 19

Keynote Address by David DeWalle, National AWRA President
The Pennsylvania State University

*Meeting the Future Needs of Water Resources Professionals:
The AWRA Perspective and Beyond*

12:30 – 1:30 p.m.
Thursday, April 20

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SESSION 1A

SURFACE-WATER QUALITY I

3:30 p.m. – 5:00 p.m.

Preliminary Evaluation of Sediment Toxicity on Mussel Populations in the Clinch, Powell, and Big South Fork Basins in Tennessee, Virginia and Kentucky

Greg C. Johnson, Steve R. Alexander, Steve Bakaletz, and Dr. Don S. Cherry

Fate of Herbicides Used in Pine Plantations on the Cumberland Plateau

John J. Harwood and Rong Jiang

Regional Characterization of Streams in Tennessee with Emphasis on Diurnal Oxygen, Nutrients, Habitat, Geomorphology and Macroinvertebrates

Rebecca James

PRELIMINARY EVALUATION OF SEDIMENT TOXICITY ON MUSSEL POPULATIONS IN THE CLINCH, POWELL, AND BIG SOUTH FORK BASINS IN TENNESSEE, VIRGINIA AND KENTUCKY

*Greg C. Johnson¹, Steve R. Alexander², Steve Bakaletz³, and Dr. Don S. Cherry⁴

The U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, National Park Service, Virginia Tech, and Office of Surface Mining, collected bed-sediment and interstitial water samples for toxicity testing and chemical analysis from 2004 to 2005. Sites were selected to represent a gradient of freshwater mussel productivity in streams affected by coal mining and oil production activities, and were classified qualitatively into groups reflecting mussel reproductive success (good, fair, poor, and none) based on field surveys of mussel size distribution. Samples were collected at 21 sites in Tennessee, Virginia, and Kentucky, at 12 sites in the Big South Fork of the Cumberland River, and at 9 sites in the Clinch and Powell Rivers. Bed-sediment and interstitial water samples were analyzed for concentrations of selected metals, polycyclic aromatic hydrocarbons (PAHs), major ions, and nutrients. Bed sediment and interstitial water also were used for toxicity testing on two daphnids (*Ceriodaphnia dubia* and *Daphnia magna*), and two juvenile mussels (*Villosa iris* [rainbow mussel] and *Epioblasma capsaeformis* [oyster mussel]).

Coal composition of the bed material ranged from 0.2 to 47.7 percent at the sites and was found to be highly variable, depending upon which depositional zone was sampled. Preliminary analyses of metals in bed sediments using acid volatile sulphide / simultaneous extracted metals analysis (AVS/SEM) indicate higher concentrations for sites qualitatively rated as poor or none as compared with sites rated as good or fair, based on mussel reproductive success. Concentrations of PAHs in a number of bed-sediment samples exceeded Canadian chronic and acute guidelines for aquatic organisms. Reproduction of *Daphnia magna* (10-day sediment toxicity test) was lower for samples from sites where total PAHs in bed-sediment samples normalized for organic content were high, while samples from sites with higher *Daphnia magna* reproduction had lower normalized total PAHs values. Elevated levels of copper, arsenic, and ammonia were detected at Indian Creek, a tributary to the Clinch River in Virginia, where one of the last remaining populations of *Epioblasma walkeri* (tan riffleshell) has been documented.

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FATE OF HERBICIDES USED IN PINE PLANTATIONS ON THE CUMBERLAND PLATEAU

John J. Harwood*¹ and Rong Jiang^{1,2}

STUDY OVERVIEW

A privately owned tract on Gross Ridge (35° 50' 12"N, 85° 18' 01"W), directly east of Virgin Falls Pocket Wilderness in White County, TN, was chosen as our study site. Sixty acres of the tract were clearcut in 2002 and planted with pine in late spring 2004. Two herbicides, Arsenal (imazapyr) and Escort (metsulfuron-methyl), were aerial sprayed for pine release in late September 2004. Vacuum soil lysimeters were installed at the site prior to herbicide application, and samples of soil water, water in intermittent streams draining the site, and the receiving stream Big Laurel Creek were collected and analyzed following rain events for a period of over one year following herbicide application.

Our study of herbicide fate includes computer modeling and chemical analysis of samples taken from the study area. Computer modeling with the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) is based on site-specific field. Water samples were analyzed by inline pre-concentration HPLC method.

FATE CHARACTERISTICS OF IMAZAPYR AND METSULFURON-METHYL

Imazapyr (Arsenal) is slowly degraded by microbial process and can be relatively persistent in soils (1). Because it does not bind strongly with soil or sediment, imazapyr can be highly mobile in the environment and therefore may contaminate water. Reported soil half-lives of imazapyr range from 1 - 5 months. Imazapyr has been found both in surface and ground water following forestry application (2, 3). Imazapyr undergoes photodegradation in aqueous solutions with a half-life of 2 days.

Metsulfuron-methyl (Escort) is broken down through chemical hydrolysis (4). It is stable to hydrolysis at neutral and alkaline pH. Reported soil half-lives of metsulfuron-methyl range from 14 - 180 days. The water solubility of metsulfuron-methyl is increased at higher pH (pH = 4.6, 270 mg/L; pH = 5.4, 1750 mg/L; pH = 6.7, 9500 mg/L). Thus, metsulfuron-methyl is more mobile and more stable in alkaline soils than in acidic soils. It is classified as highly mobile in soil.

ANALYSIS OF FIELD SAMPLING AND ANALYSIS

Three small stainless steel vacuum lysimeters (Model SW-074, Soil Measurement Systems, Tucson, AZ), fitted with Teflon tubing, were installed September 1, 2004. The lysimeters were set at different depths in augured holes (Eijelkamp Edelman one-Piece Auger, 2 3/4" diameter). Slurries of the original soil layers were used to imbed the lysimeters; the holes were plugged at the top with 10 cm layer of bentonite slurry. The lysimeters were set at the bottom of individual

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soil layers as indicated by the augured soil cores. The depths of the bottoms of the lysimeters are Lys 1 – 60 cm, Lys 3 – 40 cm and Lys 4 – 25 cm. (A fourth lysimeter, “Lys 2”, failed to yield any sample.) Lys 1 and Lys 3 were positioned adjacent to one another, 1.5 m apart, in a clear area; Lys 4 was placed about 4 m from these two, in an area which retained low vegetation.

Herbicides were applied by helicopter on October 5, 2004. The total area treated was about 24 hectare (60 acres) on the top of Gross Ridge. The application rate was 0.84 kg active ingredient per hectare (kg a.i./ha) of imazapyr and 0.07 kg a.i./ha of metsulfuron-methyl.

Three small intermittent streams, labeled CS1, CS2, CS3 (see Figure 1), and one large surface stream, Big Laurel Creek (LC), were selected for surface water grab sampling. The CS sites are intermittent streams contained in uncut forest catchments produced by drainage from the

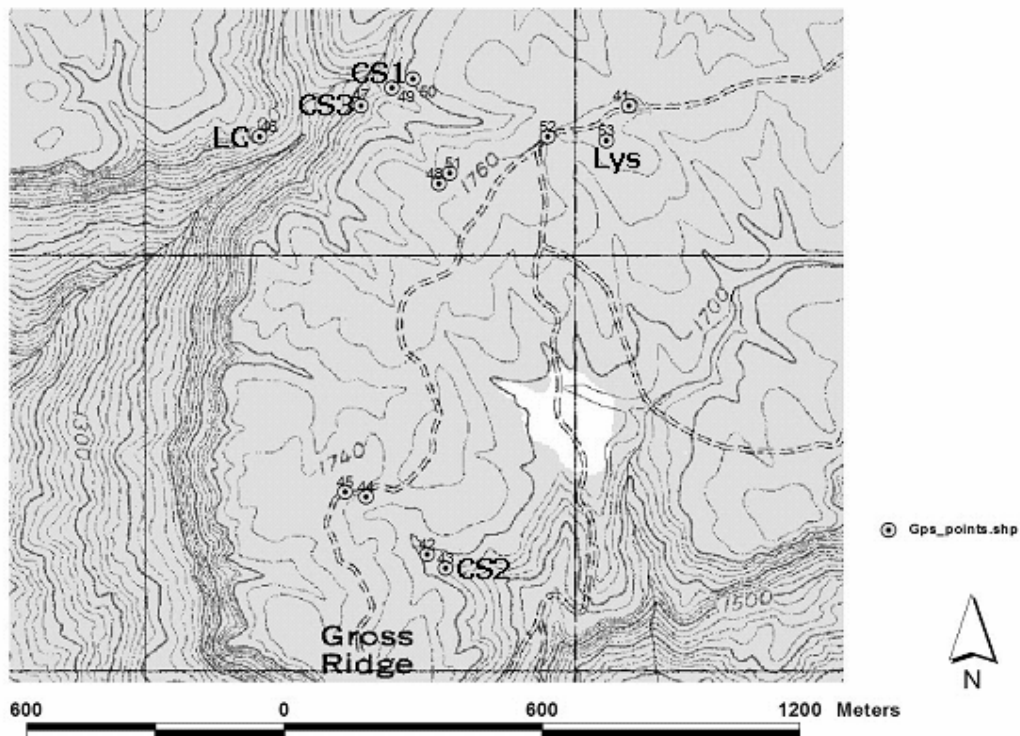


Figure 1. Map of field sampling sites

clearcut areas. The uncut “streamside management zones” of these catchments are ample, about 50 meters in width. Big Laurel Creek is at the base of a naturally wooded ravine along one side of the clearcut area. The herbicide treated area extends from approximately 1760 feet to 1720 feet elevation.

Samples were collected in 250 mL amber glass bottles with Teflon faced PE-lined caps (Fisher Scientific). The bottles containing sample were stored for transport in a cooler chilled with cool packs.

Spiked samples were prepared on-site by adding sample to aliquots of stock solutions transported to the site in the sample bottles. Lab blank and lab spike samples (Milli-Q water) were brought to the field and taken back to the lab in the whole sampling procedure without opening.

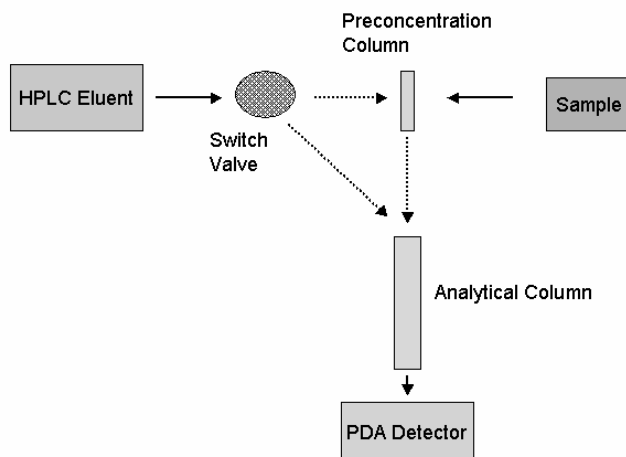


Figure 2. HPLC inline pre-concentration and analysis method

The first stream sampling was on September 18, 2004, and the first lysimeter sampling was on October 15, 2004. Sampling was generally weekly, on the day following each successive rain event. Approximately 1 inch of rainfall was found necessary to allow subsequent collection of sufficient water from the lysimeters for analysis.

In the laboratory, sample pH was measured, and samples were syringe-filtered through 0.45 μm PTFE filter (FisherBrand) into Teflon-lined capped vials and stored in the refrigerator until analysis. All samples were analyzed within three days after sampling and preparation.

Samples were analyzed with an inline pre-concentration HPLC method developed for the study (Figure 2). Chromatography was performed on a Varian ProStar HPLC-Photodiode Array HPLC. A delivery pump (Beckman, Model 110A) was used to deliver samples to the pre-concentration column. The pre-concentration column used was a Synergi 4 μ Hydro-RP 80A (4 μm particle diameter, 30 \times 4.60 mm) column (Phenomenex). Both the Spherex 5 C18, (5 μm , 250 \times 4.60 mm) (Phenomenex), and the μ Bondapak C18, 125 \AA , (10 μm , 300 \times 3.9 mm) (Waters Corporation) analytical columns were found suitable in separating the herbicides for analysis. Five mL samples were loaded onto the pre-column at a flow rate of 2.5 mL/min prior to analysis. Analysis was performed with a mobile phase of 45% acetonitrile and 55% 0.2% (V:V) concentrated phosphoric acid with a flow rate of 1.5 mL/min. An analytical wavelength of 230 nm was used. The detection limit for both herbicides using this method is estimated to be 2 $\mu\text{g/L}$.

Soil texture was determined by the ASTM D 422 hydrometric method (5). Soil organic matter (SOM) was determined by redox titration following digestion of soil with dichromate (6).

FIELD RESULTS

Neither of the applied herbicides was found in any stream water sample.

The measured maximum concentrations of herbicides in soil water (lysimeter) was less than 0.3 mg/L in the beginning of application, and decreased to below 0.05 mg/L two months after application for both herbicides.

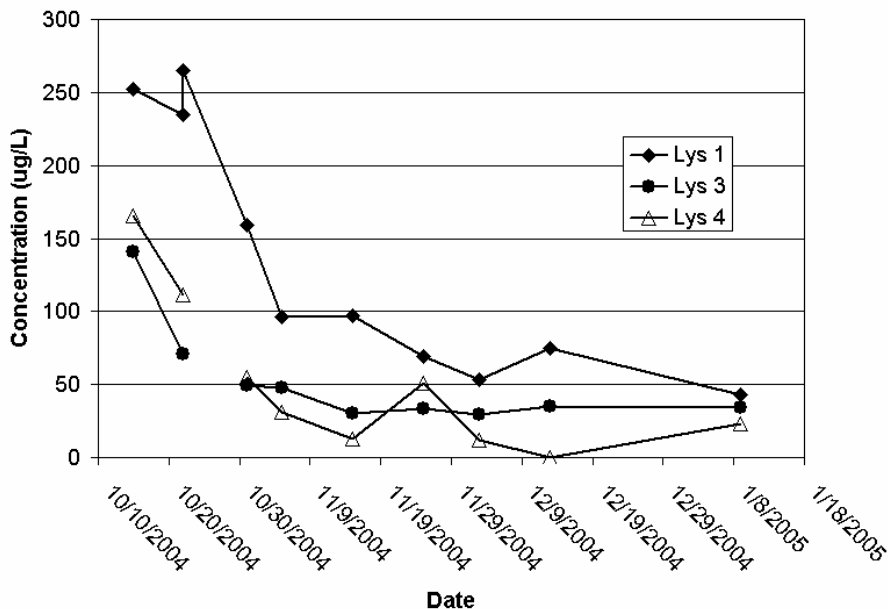
Figure 3 shows the concentrations of herbicides in soil water samples over time. The herbicides in all three lysimeters generally declined over time. Concentrations of both herbicide residues in soil water dropped significantly within the first two months after application in each lysimeters. Imazapyr was in higher concentration in soil water than was metsulfuron-methyl. The depths of lysimeters were in the order of Lys4 < Lys3 < Lys1. Lys3 had the lowest residues for both herbicides in the beginning after application. Lys1 had the highest herbicide levels during the entire sampling period.

Scheduling conflicts and dry weather prevented sampling during much of 2005. Samples were collected on 11/17/2005 and 12/1/2005; neither herbicide was detected in either of these samples.

The pH of soil water samples was higher than that of the surface water samples. With the exception of one Big Laurel Creek sample, which had a pH of 6.38, surface water pH ranged between 4.05 and 5.50. Lys 1 and Lys 2 soil water pH ranged between 5.80 and 6.69; Lys 4 soil water samples had higher pH, between 7.10 and 7.68.

The concentrations of metsulfuron-methyl in soil water samples were much lower than those of imazapyr. This is expected because the application rate of imazapyr was 12 times higher than that of metsulfuron-methyl. Also, as noted above, imazapyr is more persistent in than is metsulfuron-methyl (soil half-life 1 - 5 months and 14 - 80 days, respectively).

Imazapyr in Percolation Water



Metsulfuron-methyl in Percolation Water

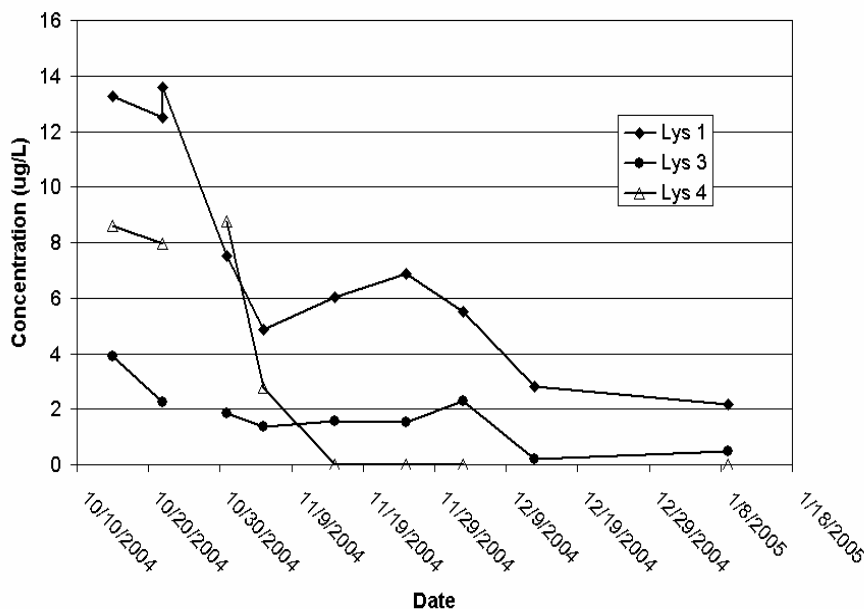


Figure 3. Concentration of herbicides in lysimeter samples over time

MODELING RESULTS

Our GLEAMS computer simulation was based on Lys1 soil (Table 1). The precipitation and other climatic parameters were obtained from the Crossville, TN weather station.

Table 1. Soil texture of Lys 1 soils

Layer	Depth (cm)	Silt %	Clay %	Sand %	Texture	SOM %
Core1-1	10	39.0	13.8	47.2	Loam	2.90
Core1-2	21	42.9	15.8	41.3	Loam	1.45
Core2	42	45.5	18.8	35.7	Loam	0.51
Core3	63	23.4	49.5	27.1	Clay	0.35

GLEAMS predicted that storms produced 63.2% percolation water and 3.85% runoff during the study period.

The total predicted losses of imazapyr are 378 g/ha, 45.2% of application. Most of these losses are in percolation water, 374 g/ha (44.6% of application). Only 5.02 g/ha (0.6% of application) loss is predicted to occur in runoff loss, and 0.302 g/ha (0.04% of application) in eroded sediment.

The total predicted losses of metsulfuron-methyl were 17.4 g/ha, 24.9% of application. 17.2 g/ha loss (24.6% of application) was in percolation, only 0.165 g/ha (0.24% of application) in runoff, and 0.0035 g/ha (0.005% of application) in sediment.

ACKNOWLEDGEMENTS

Guy Zimmerman, Manuel Campoamor, Larry Tankerseley, Jerry Prater and Hong Zhang graciously contributed help in this project.

REFERENCES

1. Tu, Mandy, Hurd, Callie and Randall, John M., "Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas - Imazapyr", <http://tncweeds.ucdavis.edu/products/handbook/17.Imazapyr.pdf>, version date: April 2001.
2. Michael, J. L., and Neary, D. G., "Herbicide dissipation studies in southern forest ecosystems," *Environmental Toxicology and Chemistry*, 1993, 12, 405-410.
3. Cox, C., "Herbicide Factsheet, Imazapyr," *Journal of Pesticide Reform*, Fall 1996, 16(3), 16-20.
4. "EXTOXNET - Pesticide Information Profile - Metsulfuron-methyl", Cooperative Extension Offices of Cornell University, Michigan State University, Oregon State University, and University of California at Davis, <http://pmep.cce.cornell.edu/profiles/extoxnet/metiram-propoxur/metsulfuron-methyl-ext.html>, publication date: 9/93.
5. "ASTM D 422 Test Method for Particle-Size Analysis of Soils", ASTM International, 2002.
6. Radojevic, Miroslav and Bashkin, Vladimir, "Practical Environmental Analysis," Royal Society of Chemistry: Cambridge, UK, 1999, 325-330.

REGIONAL CHARACTERIZATION OF STREAMS IN TENNESSEE WITH EMPHASIS ON DIURNAL OXYGEN, NUTRIENTS, HABITAT, GEOMORPHOLOGY AND MACROINVERTEBRATES

Rebecca James*¹

ABSTRACT

The Division of Water Pollution Control was awarded a 104(b)(3) grant in 2002 to investigate natural diurnal fluctuations of dissolved oxygen levels in 15 ecological subregions in Tennessee. Historic daylight readings were used to supplement this information and to evaluate dissolved oxygen patterns in 10 additional subregions. The results of that initial study were published in January 2003 (Arnwine and Denton, 2003).

The Division was awarded another 104(b)(3) grant in 2004 to expand the original study. The results of this study were published in September 2005 (Arnwine et.al., 2005). The 2004 study was designed to provide additional information in eight subregions where preliminary data suggested statewide criteria of 5ppm may need to be raised and in two ecoregions where lower DO levels might be supportive of fish and aquatic life. The 2004 project was also designed to characterize streams based on geomorphology, periphyton, and nutrients. Ninety-nine sites were selected for monitoring for this project (Figure 1).

The geomorphology of 33 existing reference streams and 24 test streams found in 19 ecoregions was defined using the Rosgen classification system. The classification system is based on physical processes and assumes that stream morphology depends on the stream's landscape position (Rosgen, 1996). There are four hierarchical levels of the Rosgen classification system. The first level describes a stream's geomorphologic characterization. The second level is a morphological description of the stream's characteristics. The third level assesses the stream condition and its stability. The fourth level is a confirmation of predictions made in Level III. Streams in this study were classified to Level II.

Another goal of this project was to characterize periphyton abundance in 30 ecoregion reference streams where existing data were not available. Additionally, there was a desire to evaluate algal abundance in 31 test streams in ecoregions where nutrient levels are generally elevated. Due to the sedentary nature of periphyton, abundance is sensitive to changes in water quality. Typical background levels of periphyton were estimated for 19 ecological subregions.

There were two goals for nutrient data collection. One was to increase the reference database, to further refine numeric nutrient criteria. The second goal was to test the reliability of using nitrate probes that could potentially cut monitoring time and analysis costs while providing diurnal nutrient information. The nitrate probes proved impractical. Due to their difficulty holding calibration, they tended to be unstable and imprecise, and once calibrated would begin to drift.

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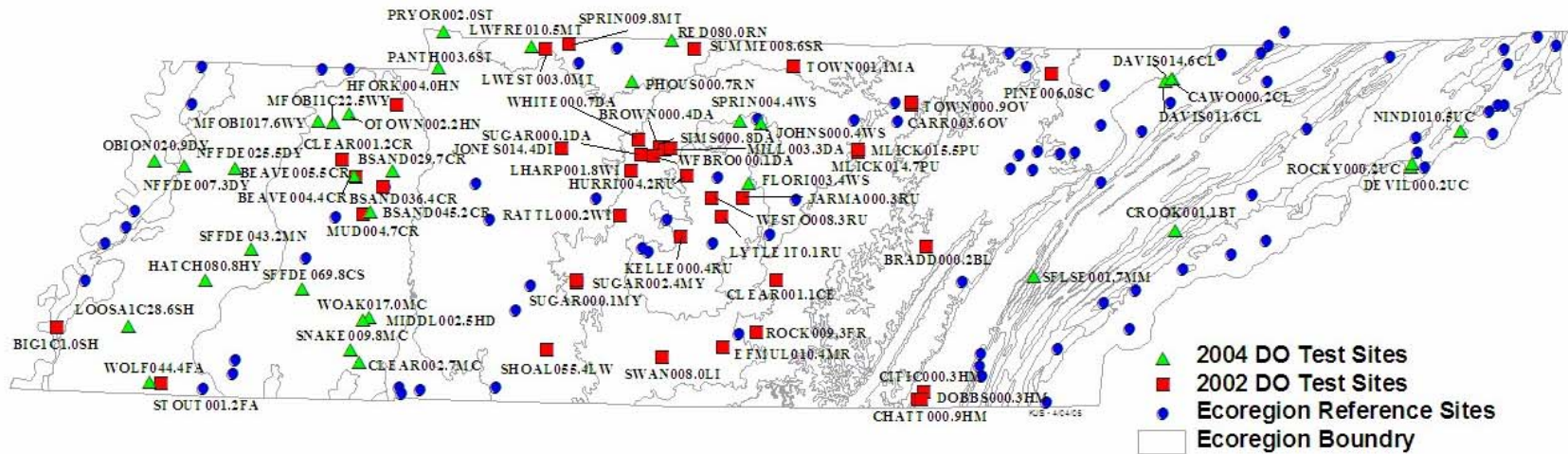


Figure 1: Location of reference and test sites where diurnal DO and nutrient monitoring was conducted August – October 2002, and July – November 2004.

Benthic macroinvertebrate samples were collected using a semi-quantitative single habitat technique per the Division's QSSOP for Macroinvertebrate Stream Surveys (TDEC, 2003). Samples were collected at 24 sites where continuous monitoring probes were deployed. Habitat assessments were conducted at sites where macroinvertebrate samples were collected following high gradient or low gradient protocols (TDEC, 2003).

The final goal of this study was to characterize non-wadeable streams that cross ecoregions in west Tennessee. Biological, habitat, and nutrient guidelines have already been developed for wadeable streams that are 80% contained within the Southeastern Plains and Hills (65e) and the Loess Plains (74b). Since all reference sites in the Mississippi Alluvial Plain (73a) are non-wadeable, guidelines are already developed for non-wadeable streams 80% within this ecoregion. However, five non-wadeable rivers, including several large forks, originate in the Southeastern Plains, cross into the Loess Plains, and enter the Northern Mississippi Alluvial Plain on their way to the Mississippi River. These include the Obion, Forked Deer, Hatchie, Loosahatchie, and Wolf River systems. Results of the non-wadeable stream monitoring indicated that data were generally not directly comparable to existing wadeable stream guidelines. It is likely that separate biological and nutrient criteria will need to be developed for these stream types.

REFERENCES

- Arnwine, D.H. and G.M. Denton. 2003. *Evaluation of Regional Dissolved Oxygen Patterns of Wadeable Streams in Tennessee Based on Diurnal and Daylight Monitoring*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.
- Arnwine, D.H., James, R.R., and K.J. Sparks. 2005. *Regional Characterization of Streams in Tennessee with Emphasis on Diurnal Dissolved Oxygen, Nutrients, Habitat, Geomorphology and Macroinvertebrates*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.
- Rosgen, Dave. 1996. *Applied River Morphology*, Wildland Hydrology, Pagosa Springs, Colorado.
- Tennessee Department of Environment and Conservation. 2002. *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water*. Division of Water Pollution Control, Nashville, Tennessee.

SESSION 1B

GROUND-WATER/SURFACE-WATER INTERACTION

3:30 p.m. – 5:00 p.m.

Pesticide and Degradate Concentrations in a Closely Linked Ground Water–Surface Water System in a Sand Aquifer: Initial Comparisons

Anne F. Choquette and Sharon E. Kroening

Surface-Water and Ground-Water Interactions in the Upper Duck River Watershed, Tennessee

Rodney R. Knight

Water Chemistry and Quality Changes in the Rockhouse Cave System, Carter County, Tennessee

Yongli Gao, Nikki Gibson, Taylor Burnham, and Brian Evanshen

PESTICIDE AND DEGRADATE CONCENTRATIONS IN A CLOSELY LINKED GROUND WATER–SURFACE WATER SYSTEM IN A SAND AQUIFER: INITIAL COMPARISONS

Anne F. Choquette*¹ and Sharon E. Kroening²

Significant hydraulic exchange occurs between ground water and lakes on the Lake Wales Ridge, a 700-square-mile region in central Florida that contains more than 200 seepage lakes³. Due to seasonally high precipitation, extensive citrus agriculture, and highly permeable sandy soils, the Ridge is particularly vulnerable to leaching of agrichemicals. Pesticide concentrations in both ground- and surface-water in this region relative to national monitoring data confirm this vulnerability. Sampling of four Ridge lakes in 2003 and 2004 and of ground water (surficial aquifer) from 31 wells from 1999 through 2004 indicated regional patterns in concentrations of several pesticides, including simazine, norflurazon, and aldicarb, and their degradates. Median concentrations of both pesticides and degradates were typically lower in lakes than in ground water. This pattern is likely due to increased opportunity for biogeochemical degradation (including photolysis), sorption, and dilution of pesticides within the lakes compared to the ground-water system. The ratios of pesticide degradate-to-parent concentrations were higher in lakes than in ground water, which is consistent with degradation occurring as ground water moves through the subsurface into the lakes and with chemical breakdown and sequestration within the lake systems. Consistent detections of parent compounds in the lakes indicate incomplete chemical breakdown in the lake systems, relatively rapid ground water transit times, and possible atmospheric deposition. The next phase of study will include quarterly sampling in additional lakes to further explore the seasonal and spatial consistency of these relations in the Ridge ground water – lake systems.

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³ Lakes which are fed predominantly by ground-water inflow as opposed to surface-water inflow.

SURFACE-WATER AND GROUND-WATER INTERACTIONS IN THE UPPER DUCK RIVER WATERSHED, TENNESSEE

Rodney R. Knight

The U.S. Geological Survey, in cooperation with the Duck River Development Agency, collected streamflow data, ground-water level data, and discharge data for selected springs to characterize the temporal and spatial distributions of water resources and to identify reaches of streamflow gains and losses in the upper Duck River watershed (UDRW) in south central Tennessee. The UDRW study area encompasses the Duck River at Normandy Dam (river mile 248) to the Duck River at Columbia (river mile 132.8). Streamflows in the UDRW during the study period from May 2003 to September 2005 were near long-term averages.

Continuous streamflow data and baseflow synoptic investigations indicate that watersheds in the southern and western parts of the basin yield more water than other areas in the watershed. Flow-duration analysis of continuous streamflow data for two tributary watersheds, Big Rock Creek and Fountain Creek, indicates that a sustained baseflow (ground-water discharge) though Big Rock Creek may also be affected by some sustained wastewater-treatment discharge. Flow-duration analysis for tributaries in the northern and eastern parts of the UDRW, such as North Fork Creek, Wartrace Creek, and Flat Creek near Shelbyville, shows a relatively low flow rate in the frequency range of baseflows, indicating somewhat lower ground-water contributions than in other areas of the watershed. In contrast, baseflow synoptic investigations completed in November 2003 and May 2004 indicate that those tributaries in the southern and western parts of the UDRW have higher than average baseflows when compared with tributaries in the northern and eastern parts of the watershed.

A streamflow accounting of discharge at four streamgages on the Duck River indicates that direct ground-water discharge to the river channel accounts for a substantial portion of the total flow during these periods of recession. Estimates of ground-water discharge to the Duck River were made by subtracting the various contributions to the total flow, such as measured tributary inflows, releases from Normandy Dam, and wastewater-treatment discharge, from the streamflow measured at the four streamgages along the mainstem of the Duck River at Shelbyville, above Milltown, at Pottsville, and at Columbia. Calculations made using these data during periods of extended recession in late summer 2003 and early fall 2004 indicate that the portion of the total flow contributed by direct ground-water discharge to the channel increased progressively downstream. The largest sub-reach increase in ground-water discharge occurred between Pottsville and Columbia (a length of approximately 33 river miles). The drainage area contributing to this sub-reach represents only one-eighth of the total drainage area of the Duck River, but produces almost one-third of the total ground-water discharge to the Duck River above this point (an average of 30 million gallons per day). This sub-reach of the Duck River where direct ground-water discharge to the river is increased coincides with the area where increased ground-water contributions to tributaries and high baseflow yields in tributary watersheds were observed.

WATER CHEMISTRY AND QUALITY CHANGES IN THE ROCKHOUSE CAVE SYSTEM, CARTER COUNTY, TENNESSEE

Yongli Gao¹, Nikki Gibson^{1*}, Taylor Burnham^{1*}, and Brian Evanshen²

INTRODUCTION

The Rock House Cave stream served as a water supply for the community of Milligan until the system was taken over by the City of Elizabethton in the late 1960 or early 70's. In the late 1980's the city decided to stop using the cave stream and utilize the facility for a pump station only. Recent dye tracing test in this area indicates that surface water in Dry Creek sinks down and then the groundwater flows westward through Rock House Cave, Salt Peter Cave, and then flows through Cave Spring Cave as a spring to be merged into Buffalo Creek (Gao et al., 2006). Figure 1 shows the locations of Dry Creek, Rock House Cave and Buffalo Creek. This is a very active karst aquifer system. Karst aquifers are highly vulnerable to rapid ground-water contamination (ASTM, 1995; U.S. Environmental Protection Agency, 1997). Surface and subsurface contaminants can enter the aquifer system within days or even minutes in a karst terrain. Contamination can then quickly spread through the groundwater system along solution conduits and pollute the aquifer (Gao 2002).

This is the second of a series of two papers describing preliminary scientific investigations of the Rock House Cave system. This paper introduces a preliminary study to investigate the water chemistry and water quality changes in the Rock House Cave System. The long-term objectives of this study are as follows:

1. Describe, simulate, and document groundwater recharge, flow, mass transport, and basin outlines in this area since this area has unique karst features and accessible aquifer test facilities.
2. Develop a hydrologic model and test the model with groundwater tracing, water chemistry, aquifer test, recharge and discharge data.
3. Investigate the impact of urbanization and human activities on landscape and water quality changes.
4. Provide the community with essential information about the vulnerability of groundwater water sources.

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* Student Author

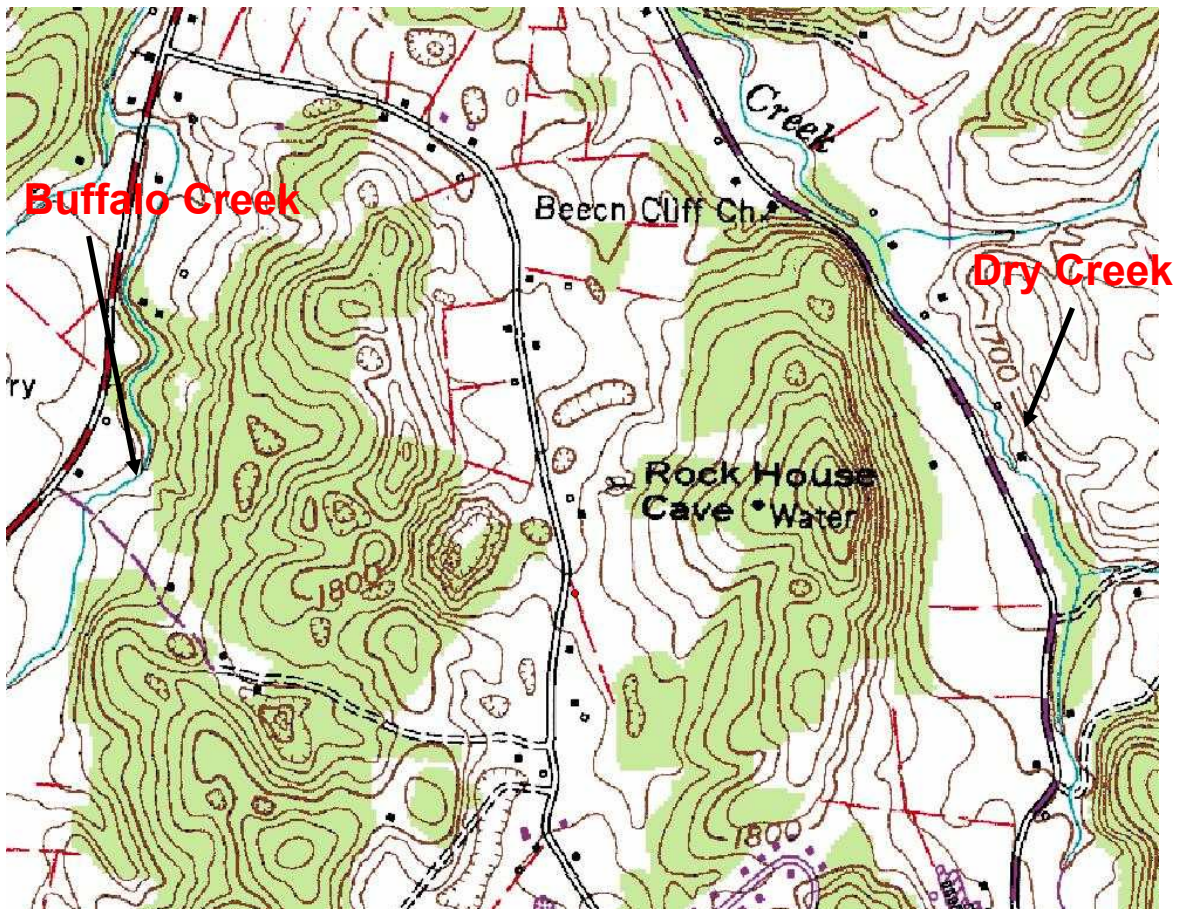


Figure 1. Locations of Dry Creek, Rock House Cave, and Buffalo Creek in the study area (notice that the Rock House Cave system connects Dry Creek and Buffalo Creek, The map is from the Johnson City Quadrangle, Tennessee, USGS 7.5 minute series topographic map, 1959 - photo revised 1968. The horizontal distance across this figure is approximately 2 kilometers.)

METHODS

Surface water and groundwater samples were collected on November 19 and December 14 in Dry Creek, Buffalo Creek and the three caves. Water samples collected on December 14 were analyzed and stabilized within 6 hours and therefore produced relatively more reliable water chemistry data.

All water samples were analyzed in the Environmental Health laboratory at East Tennessee State University. Alkalinity, hardness, phosphate, and nitrate were analyzed using HACH analytical procedure. Total coliforms and *E. coli* were analyzed using standard Colilert Most Probable Number (MPN) method.

RESULTS AND DISCUSSION

Table 1 lists the results of our preliminary water chemistry for water samples collected on December 14. Comparing with drinking water standards (U.S. Environmental Protection Agency, 1976), The total coliforms and *E. coli* for all water samples are above the Maximum Contaminant

Level (MCL) for drinking water. Hardness of these water samples ranges between moderately hard water and hard water. Hardness and alkalinity in Dry Creek are relatively lower and then increase in the groundwater system because of carbonate rock dissolution. Buffalo Creek has the highest hardness and alkalinity and the concentration in the downstream water is slightly lower because of the mixing between upstream water and groundwater. Nitrate and Phosphate are not significantly high in all water samples, which indicate no direct agriculture impact in the vicinity of the Rock House Cave area.

Total coliforms and E. coli in Surface water are significantly higher than groundwater under low flow conditions. Potential sources of the bacteria could be from septic tank leakage or animal fecal waste. Buffalo creek has the highest levels of alkalinity, hardness, and coliforms and E. coli. Analytical data in Table 1 shows that Dry Creek and Rock House Cave system do not contribute to the contamination of Buffalo Creek. The surrounding are near Rock House Cave has experienced substantial urban development and expansion. It is important to trace the sources of the contaminant to protect water resources in this area.

Table 1. Water chemistry in surface water and groundwater of the Rock House Cave area

Name	Dry Creek	Rockhouse conduit	Rockhouse water pool	Cave Spring	Buffalo Creek (upstream)	Buffalo Creek (downstream)
Unique #	DK-1	RC-1	RC-2	CS-1	BF-2	BF-1
Hard. (as CaCO ₃ mg/l)	110	128	135	116	174	163
Alk. (as CaCO ₃ mg/l)	59	94	106	99	151	134
NO ₃ -N (mg/l)	1.2	1.8	1.4	1.2	1.8	1.3
PO ₄ -P (mg/l)	0.26	0.22	0.11	0.19	0.35	0.22
Total Coli. (MPN/100ml)	920.8	410.6	410.6	517.2	>2419	>2419
E. Coli. (MPN/100ml)	128.1	4.1	5.2	8.4	313	360.9

SUMMARY

Our preliminary water chemistry data indicates that surface water especially in Buffalo Creek is severely contaminated with fecal bacteria. Coliforms and E. coli are also detected in the groundwater of the Rock House Cave system. Rock House Cave, Salt Peter Cave and Cave Spring Cave are within one mile to a losing stream, Dry Creek. There are over a dozen caves within a 10 km² area around Rock House Cave. It is an ideal natural karst laboratory for future karst studies.

In many communities of Eastern Tennessee, drinking water sources are springs or wells drilled into carbonate aquifers. Groundwater system in this area is poorly understood. Planners and water users have limited knowledge about how vulnerable the aquifers are to rapid contamination. The state of Kentucky has begun a statewide program that collects aquifer data and Tennessee should start a similar program to protect vulnerable groundwater resources.

REFERENCES

ASTM, 1995, Standard Guide for the Design of Ground Water Monitoring Systems in Karst and Fractured-Rock Aquifers, American Society for Testing and Materials, Annual Book of Standards, D5717-95.

Gao, Y., 2002, Karst Feature Distribution in Southeastern Minnesota: Extending GIS-Based Database for Spatial Analysis and Resource Management. [Ph.D. thesis] University of Minnesota, 210 p.

Gao, Y., Benfield, R., Jones, S., Gibson, R., and Burnham, T., 2006, Groundwater Tracing in the Rockhouse Cave System, Carter County, Tennessee, The Sixteenth Tennessee Water Resources Symposium, in press

U.S. Environmental Protection Agency, 1976, Quality criteria for water: Washington, D.C., U.S. Environmental Protection Agency, Office of Water Planning and Standards, EPA 440/9-76/023, 537 p.

U.S. Environmental Protection Agency, 1997, Guidelines for Wellhead and Springhead Protection Area Delineation in Carbonate Rocks, United States Environmental Protection Agency, EPA 904-B-97-003

SESSION 1C

GEOMORPHOLOGY

3:30 p.m. – 5:00 p.m.

Predicting the Distribution of Gravel Bars in Tennessee Streams

Simon M. Mudd, Ben R. Iobst, and David J. Furbish

Evaluation of the Importance of Channel Processes in Evaluating Suspended-Sediment Yields in CEAP-Watershed Studies

Andrew Simon

Spatial and Temporal Variability of Turbidity and Suspended Sediment in Southwest Williamson County, Tennessee

Tim Diehl and Shannon Williams

PREDICTING THE DISTRIBUTION OF GRAVEL BARS IN TENNESSEE STREAMS

Simon M. Mudd¹, Ben R. Iobst², and David J. Furbish²

Gravel bars in streams play an important role providing habitat for aquatic species. Hyporheic flow through these bars also influences stream chemistry. The spatial distribution of gravel bars in streams has been hypothesized to have a significant influence on stream chemistry, nutrient spiraling, and stream biota. Here we report on a method for predicting the extent and distribution of gravel bars in streams using topographic analysis based on field measurements taken in the Land Between the Lakes National Recreation Area in Northwest Tennessee.

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EVALUATION OF THE IMPORTANCE OF CHANNEL PROCESSES IN EVALUATING SUSPENDED-SEDIMENT YIELDS IN CEAP-WATERSHED STUDIES

Andrew Simon¹

Sediment is one of the principle pollutants of surface waters of the United States. Efforts by the U.S. Department of Agriculture to quantify and control sediment erosion have historically focused on fields and upland areas. There is a growing body of evidence in agricultural areas of the mid-continent that the locus of sediment erosion has shifted from fields and uplands to edge of field gullies and channels. This is due in part to successful conservation efforts and the natural attenuation of erosion processes with time. Sediment, eroded historically from fields and uplands, was deposited in valley bottoms, filled channels, and accumulated on flood-plain surfaces, causing severe drainage problems. To convey floodwaters and to alleviate flooding problems, channels throughout the mid continent were dredged and straightened, resulting in de-stabilization of entire river systems, severe bank erosion and dramatic increases in erosion rates. This rejuvenation of channel systems results in a systematic series of processes and channel forms that can be identified as *stages of channel evolution*. Today, these channel-erosion processes are still active and can account for up to 85% of the suspended-sediment load in streams, much of this, from streambank failures. A reconnaissance study of about 2,500 km of streams in western Iowa showed that 80% of the observed stream reaches were experiencing streambank failures (Hadish, 1994). Similar studies in southeastern Nebraska and western Tennessee showed that about 75% and 60% of stream reaches had unstable streambanks, respectively (Simon and Rinaldi, 2000; Bryan *et al.*, 1995).

Rapid geomorphic assessments (RGAs) of benchmark watersheds in the Conservation Effects Assessment Program (CEAP) are used to determine the degree of instability and stages of channel evolution throughout the channel systems. The distribution of stages throughout the channel network identify local versus systematic disturbances and whether channels are important contributors of sediment. Stable, reference conditions are identified from stages I and VI and used as a means of comparing suspended-sediment yield data from the CEAP watersheds to regional values. Data from more than 2,900 sites across the United States were analyzed in the context of estimating flow and suspended-sediment transport conditions representing average, annual and at the 1.5-year recurrence interval ($Q_{1.5}$) discharge. Data were sorted into the 84 Level III ecoregions to identify spatial trends in suspended-sediment concentrations and yields. Suspended-sediment yields for stable streams are used to determine “background” or “reference” sediment-transport conditions and to compare with values obtained from the monitored CEAP watersheds.

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SPATIAL AND TEMPORAL VARIABILITY OF TURBIDITY AND SUSPENDED SEDIMENT IN SOUTHWEST WILLIAMSON COUNTY, TENNESSEE

Tim Diehl¹ and Shannon Williams²

In 2004, the U.S. Geological Survey, in cooperation with the Tennessee Department of Transportation, began monitoring turbidity and suspended sediment in outfalls and streams draining small basins on or near the segment of State Route 840 extending about 10 km southeast from Highway 100 (SR840). Land uses in these basins include forestry, grazing, and hay production. Some of these basins include construction areas that have been temporarily stabilized.

Preliminary analysis of data collected after temporary stabilization of the initial construction areas, and before resumption of construction, shows that construction-area outfalls and streams affected by past construction activities on this section of SR840 did not have distributions of turbidity or suspended-sediment concentration (SSC) elevated above distributions at non-construction sites. Some basins affected by grazing appear to have had higher turbidity and SSC than the other non-construction sites.

Continuously monitored turbidity in the study area was below 10 FNU (Formazin Nephelometric Units) during baseflow, but exceeded 1000 FNU for brief periods during storm-runoff events. Discrete sampling of turbidity appeared to miss temporal changes that continuous monitoring revealed. Although the precision of estimates is poor at low turbidity, turbidity can be used to estimate SSC during storm runoff when turbidity is high.

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SESSION 2A

SURFACE-WATER QUALITY II

8:30 a.m. – 10:00 a.m.

Effects of Water Chemistry and Watershed Characteristics on Populations of Trout in the Great Smoky Mountains National Park

Karen Jackson, Bruce Robinson, Steve Moore, and Matt Kulp

Status of Water Quality in Tennessee 2006 305(b) Report

Paul E. Davis and Kim Sparks

2005-2006 Triennial Review of Water Quality Standards

Gregory M. Denton

SURFACE-WATER QUALITY III

10:30 a.m. – 12:00 p.m.

Natural Solutions for Stormwater and Water Quality Management

G. Dodd Galbreath

Heavy Metal Record in Corbicula Shells Near a Former Industrial Site

Kaye Savage

Construction Storm Water Compliance (or the Lack Thereof) in the Memphis Area—What is TDEC/WPC Doing to Enlighten Responsible Parties?

Terry R. Templeton

REGULATION AND POLICY MANAGEMENT

1:30 p.m. – 3:00 p.m.

ARAP and Economic Evaluation of Alternatives: New Piney River 2.6 MGD Intake and Treatment Plant January 6, 2006

William W. Wade

The Tennessee Stream Mitigation Program (TSMP) Tennessee's In-lieu-fee Program

Joey Woodard

Of Dead Cows and Soda Straws

Tom Moss

REMEDIATION TECHNIQUES

3:30 p.m. – 5:00 p.m.

An Economical In-situ Alternative for Treatment of Nitrate Contaminated Groundwater

Katherine Y. Bell, William P. Hamilton, and John Haselow

Quantifying Peroxide-Enhanced Benzene and Toluene Biodegradation in a Single-well Injection

Lashun King, Roger Painter, Gregg Hileman, and Tom D. Byl

North Potato Creek In-pit Water Treatment Plant at the Copper Basin Mining Site
Griff Wyatt and Franklin Miller

EFFECTS OF WATER CHEMISTRY AND WATERSHED CHARACTERISTICS ON POPULATIONS OF TROUT IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Karen Jackson¹, Bruce Robinson², Steve Moore, and Matt Kulp

INTRODUCTION

Acid deposition is believed to play a role in altering aquatic ecosystems. The Great Smoky Mountains National Park (GRSM) is noted for having some of the highest acid deposition rates of any national park. The objective of this study is to combine fish, water quality, and watershed data bases in order to determine what relationships exist between fish health and density and water quality, especially pH. The results of this analysis will hopefully be used to identify specific environmental factors that may limit the distribution of trout species and affect the composition of fish communities in the GRSM.

METHODOLOGY

Statistical correlations were used to identify relationships between the biomass and condition factors for trout as a function of observable water chemistry variables and watershed characteristics. The data set consists of GRSM data collected on 37 stream sites during 1993-2003. Three of the 37 sites have no fish present and are located on Shutts Prong, Porters Creek, and Walker Camp Prong. Park-wide water quality monitoring consisted of quarterly sampling and analysis for pH, acid neutralizing capacity (ANC), conductivity, major cations, and major anions. The sites are distributed throughout the GRSM in the following ten different watersheds: Abrams Creek, Bunches Creek, Cataloochee Creek, Cosby Creek, East Prong Little River, Hazel Creek, Indian Camp Creek, Middle Prong Little Pigeon River, Middle Prong Little River, and West Prong Little Pigeon River. Sampling sites range in elevation from 335 to 1,469 meters above mean sea level and include areas with various land uses, geologic formations, and vegetation types. Basin characteristics were obtained from topographical maps and a GIS database. Annual or biannual fish population surveys conducted by the National Park Service included the use of backpack electrofish shockers in order to obtain estimates of biomass (kg/ha) and condition factors ($\text{g}/\text{mm}^3 * 10^6$) for each of the three trout species (brook, brown, and rainbow).

RESULTS AND DISCUSSION

In order to determine what relationships exist between fish health and watershed characteristics and water quality a preliminary correlation analysis of all variables was performed. Variables with a Pearson correlation coefficient having a p-value less than 0.05 were identified as having significant relationships. The following Table 1 shows significant correlations between trout biomass (kg/ha) and the three predictor variables of elevation, pH, and % anakeesta. Trout biomass data has been split into the two categories of adult and young-of-year (YOY) in order to better explain fish health. The variable of elevation refers to the elevation of the fish sample site above mean sea level (ft). In this data set, yearly median pH from quarterly baseflow grab samples was used for 1993 to 2003. The variable % anakeesta refers to percent of the contributing area to the sample site that is covered by this geology type.

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Table 1: Correlations Between Biomass and pH, Elevation and % Anakeesta.

		Brook Trout YOY Biom (kg/ha)	Brook Trout Adult Biom (kg/ha)	Brown Trout YOY Biom (kg/ha)	Brown Trout Adult Biom (kg/ha)	Rainbow Trout YOY Biom (kg/ha)	Rainbow Trout Adult Biom (kg/ha)
Fish Elevation (ft)	Pearson Correlation	0.495	0.534	-0.452	-0.697	-0.427	-0.226
	Sig. (2-tailed)	0.000	0.000	0.021	0.000	0.000	0.002
	N	152	155	26	29	188	195
Median pH	Pearson Correlation	0.292	0.314	0.541	0.742	0.528	0.591
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	184	187	58	61	220	227
% Anakeesta	Pearson Correlation	-0.248	-0.392	-0.588	-0.617	-0.397	-0.480
	Sig. (2-tailed)	0.001	0.000	0.000	0.000	0.000	0.000
	N	184	187	58	61	220	227

The results from Table 1 demonstrate how brook trout biomass has a significant positive correlation with elevation while brown and rainbow trout have significant negative correlations. Brook trout typically occupy small, swift, high elevation mountain streams while brown and rainbow trout seem to prefer large low elevation streams. From the data used for this analysis it has been found that brook trout are present at elevations between 2120 and 4820 ft in the GRSM. Brown trout are present at elevations between elevations between 1700 and 2420 ft and rainbow trout are present at elevations between 1100 and 4010 ft. The following Figure 1 helps show the elevation ranges for each of the three trout species and instances where their habitats overlap.

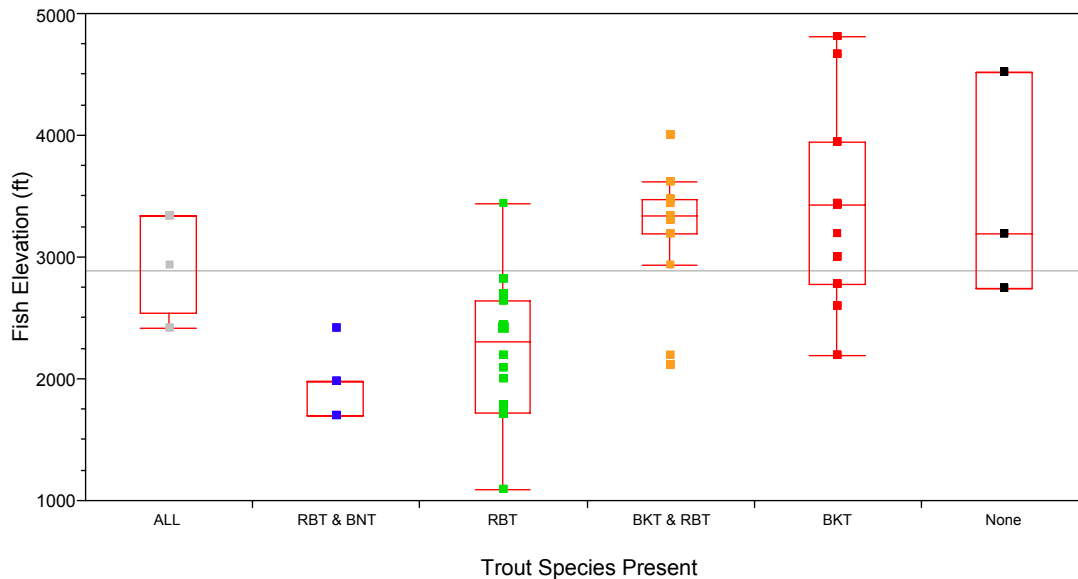


Figure 1: Fish Elevation vs. Trout Species Present

Acidification can affect fish populations by a variety of mechanisms ranging from increased mortality and emigration to decreased food supplies (Baldigo 2001). Mountain streams like those in the GRSM are more sensitive to acidification due to their lower buffering capacities. The

results in Table 1 show that all three trout species have a significant positive correlation with median stream pH. However, each of the three species have different acid tolerances. Native brook trout are the most acid tolerant species in the GRSM. Brown trout, which have been introduced from Europe, are only intermediate in acid tolerance. Lastly, rainbow trout, which have been introduced from the western United States, are the most sensitive of the three trout species (Bulger 1998). The following Figure 2 better demonstrates the pH ranges preferred by each of the trout species within the GRSM. From this figure it appears that brook trout can survive at pH values ranging from 5.71 to 6.7. Rainbow trout are present at pH values from 5.68 to 8.24 and brown trout at pH values from 6.26 to 7.10. The three sites that have no fish present maintain stream pH values between 4.73 and 5.99.

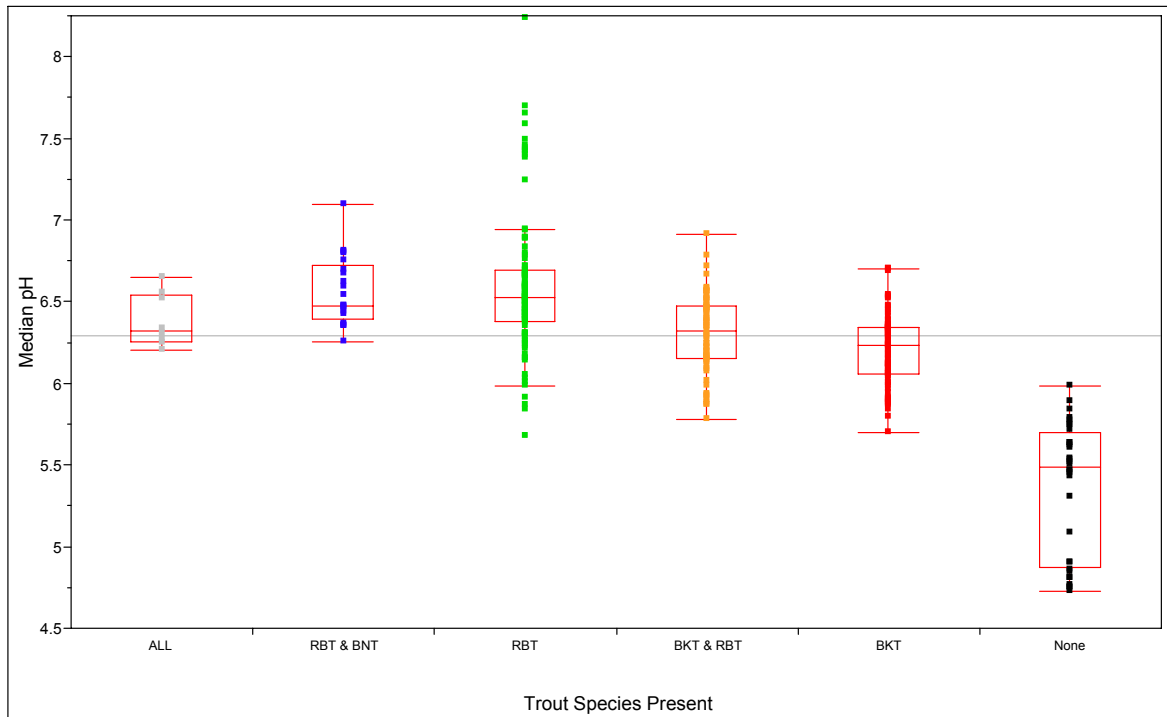


Figure 2: Median pH vs. Trout Species Present

Anakeesta is a geologic formation commonly found within the GRSM, which contains pyrite (Fe_2SO_4). Whenever rock from this formation is disturbed a harmful chemical reaction takes place. Rainwater and seepage flow move across and through the broken rock producing iron oxide (Fe_2O_3) and sulfuric acid (H_2SO_4). The resulting iron oxide produces an orange-yellow runoff which coats rocks and soils downstream. The sulfuric acid moves downstream sterilizing all streams into which it drains. The results in Table 1 show the expected significant negative correlation between fish biomass and percent of contributing site area covered by anakeesta.

REFERENCES

Baldigo, Barry P.; Lawrence, Gregory B. **Effects of Stream Acidification and Habitat on Fish Populations of a North American River.** *Aquatic Sciences* (2001), 63, 196-222.

Bulger, Art; Cosby, Jack; Webb, Rick. **Acid Rain: Current and Projected Status of Coldwater Fish Communities in the Southeastern US in the Context of Continued Acid Deposition.** A Coldwater Conservation Fund Report. Trout Unlimited (1998).

STATUS OF WATER QUALITY IN TENNESSEE 2006 305(B) REPORT

Paul E. Davis¹ and Kim Sparks²

WATERSHED MONITORING

Tennessee is fortunate to have abundant water resources with over 60,000 miles of streams and rivers and over 500,000 acres of reservoirs and lakes. Protecting these resources is one of TDEC's greatest challenges. A watershed monitoring approach is used to help organize monitoring activities and resources. Tennessee's 54 watersheds are organized into 5 groups that are assessed on a 5-year cycle (Figure 1).

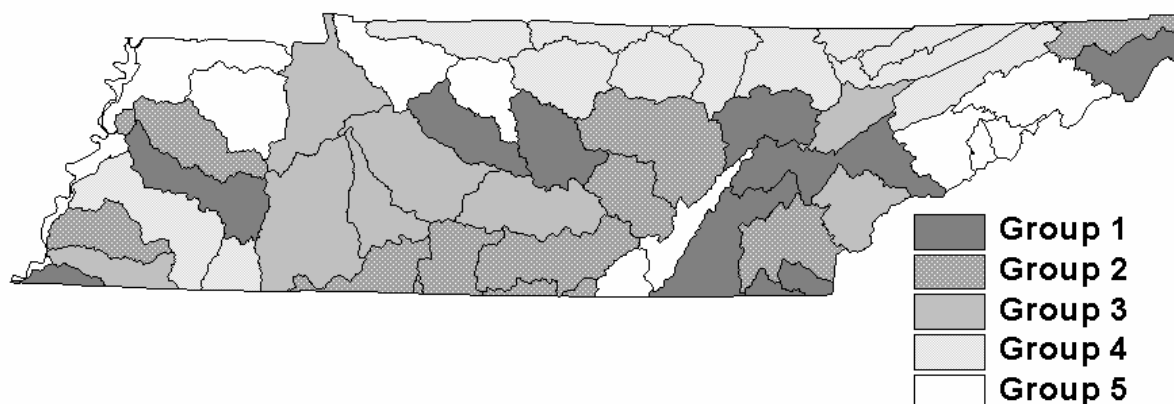


Figure 1: Watershed Cycle Monitoring Groups

The watershed approach serves as an organizational framework for systematic assessment of streams, rivers, reservoirs, and lakes in the state. By viewing the entire watershed, the Department is better able to address water quality problems. This approach allows for an in-depth study of each watershed and encourages coordination of public and governmental organizations.

The first year of the cycle involves planning watershed activities, gathering existing data and locating other resources in the watershed. In the second year waterbodies in the watershed group are monitored and in the third year they are assessed to determine if they meet water quality standards. Group 3 watersheds were assessed in 2005 and group 4 watersheds were monitored. In the fourth year Total Maximum Daily Load (TMDL) are developed to identify continuing pollution problems. In the fifth year of the watershed cycle draft National Pollutant Discharge Elimination System (NPDES) permits are issued.

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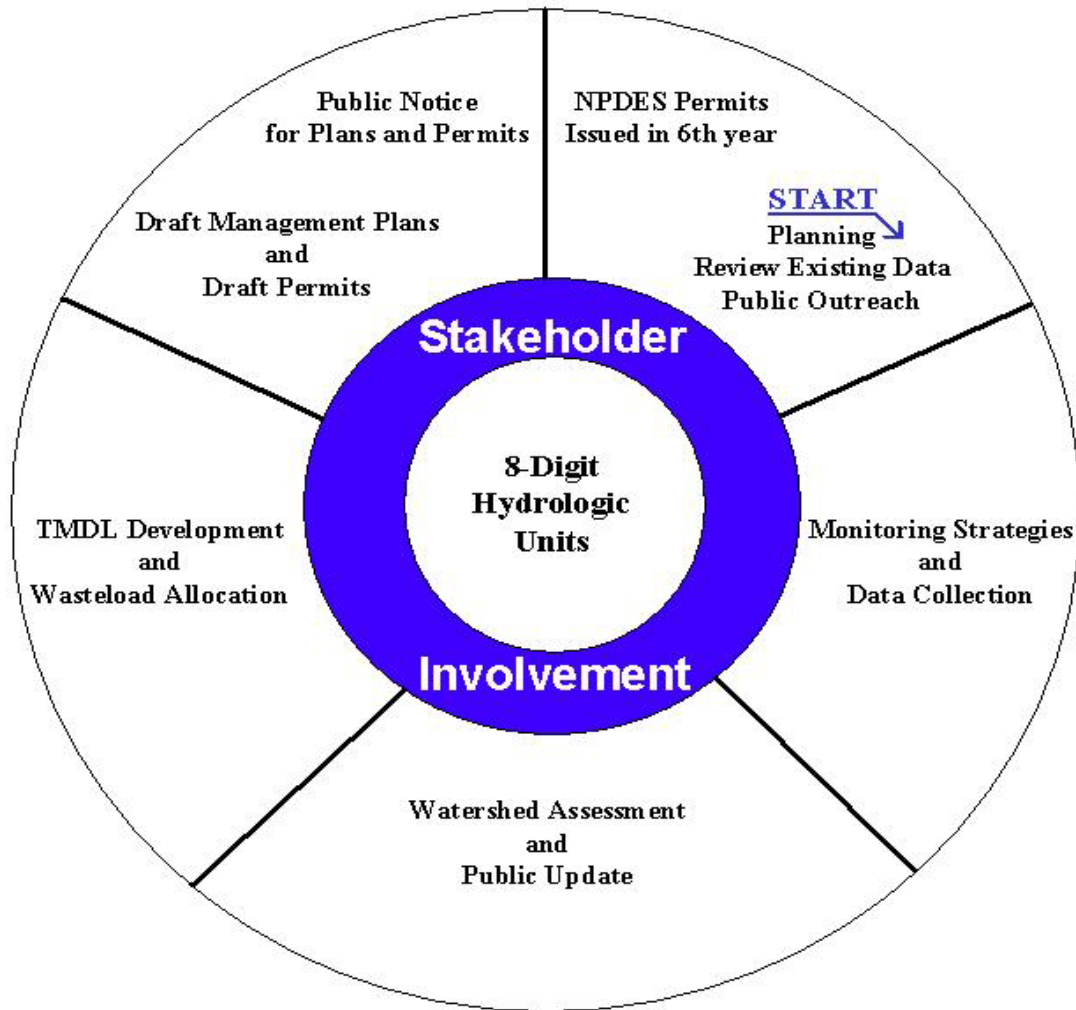
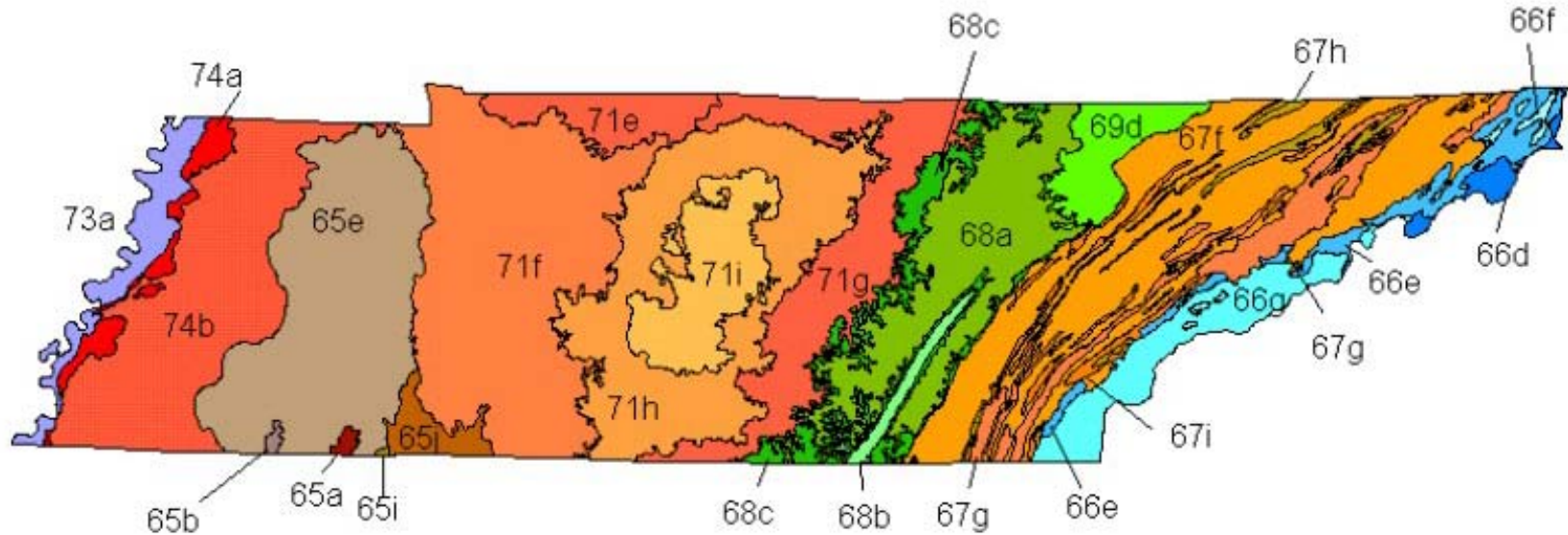


Figure 2: Watershed Cycle

ECOREGIONS

In order to accurately assess stream biological health and water quality, a regional approach proposed by EPA has been adopted by the state. Ecoregions are relatively homogeneous areas with similar climate, landform, soil, vegetation, hydrology, and other ecologically relevant variables. As the watershed approach serves as an organizational structure, the ecoregion approach is a geographical framework for establishing water quality expectations.

Tennessee was divided into 25 Level IV subcoregions (Figure 3). Within each of the Level IV subcoregions, the least impacted yet representative waterbodies or ecoregion reference streams have been monitored for a decade. Data from these reference sites are used to establish regional water quality expectations and refine Water Quality Standards within Level IV subcoregions.



65a Blackland Prairie	67f Southern Limestone/Dolomite Valleys and Low Rolling Hills	71e Western Pennyroyal Karst
65b Flatwoods/Alluvial Prairie Margins	67g Southern Shale Valleys	71f Western Highland Rim
65e Southeastern Plains and Hills	67h Southern Sandstone Ridges	71g Eastern Highland Rim
65i Fall Line Hills	67i Southern Dissected Ridges & Knobs	71h Outer Nashville Basin
65j Transition Hills	68a Cumberland Plateau	71i Inner Nashville Basin
66d Southern Igneous Ridges and Mtns	68b Sequatchie Valley	73a Northern Mississippi Alluvial Plain
66e Southern Sedimentary Ridges	68c Plateau Escarpment	74a Bluff Hills
66f Limestone Valleys and Coves	69d Cumberland Mountains	74b Loess Plains
66g Southern Metasedimentary Mountains		

Figure 3: Level IV Ecoregions in Tennessee

WATER QUALITY ASSESSMENT CATEGORIZATION

The Water Quality Standards determine designated uses for Tennessee’s waterways, define criteria for each designated use, and provide an antidegradation policy to protect existing uses. Tennessee’s water quality standards have seven use classifications. Specific designated Use Classifications for Surface Waters in Tennessee are listed in Rules of TDEC, Chapter 1200-4-4 and numeric and narrative criteria for each designated may be found in the Rules of TDEC, Chapter 1200-4-3. These rules may be viewed on TDEC’s website at <http://www.state.tn.us/environment/wpc/publications>.

Monitored waters are compared to the most restrictive water quality standard to determine if they support their designated uses. Generally, the most restrictive criteria are for recreational use and support of fish and aquatic life. Each river, stream, lake, and reservoir is assessed to determine if it meets use support designation. Waterbodies are then placed in the appropriate use support category (Table 1).

Table 1: Category Classifications

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

Each river, stream, reservoir or lake has been placed in the appropriate use support category. The 2005 group 3 watershed assessments will be included in the 2006 305(b) Report. An interactive map of water quality assessments is available on TDEC’s website at <http://www.state.tn.us/environment/water.php>.

The 2004 305(b) Report The Status of Water Quality in Tennessee³ may be viewed on TDEC’s website at <http://www.state.tn.us/environment/wpc/publications> or a printed copy maybe obtained by contacting Kim Sparks. The 2006 305(b) Report is currently under final review and will soon be available at the above website.

³ Denton, G.M., K.J. Sparks, D.H. Arnwine and L.K. Cartwright. 2004. 2004 305(b) Report – The Status of Water Quality in Tennessee. Tennessee Department of Environment and Conservation, Division of Water Quality Control. Nashville, TN.

2005-2006 TRIENNIAL REVIEW OF WATER QUALITY STANDARDS

Gregory M. Denton¹

Water quality standards are goals for surface waters such as streams, lakes, and wetlands. Each state develops its own standards that must include at a minimum three parts: stream use classifications, general water quality criteria, and an antidegradation policy. Tennessee periodically reviews its water quality standards in order to insure that the most recent science and research has been incorporated into our water quality goals.

A review of water quality standards began in 2005 and will be completed in 2006.

Stream use classifications are beneficial public uses that have been assigned to each waterbody in the state. Tennessee currently specifies a set of seven designated uses: fish and aquatic life protection, recreation, domestic water supply, industrial water supply, irrigation, livestock watering and wildlife, and navigation. Some streams or lakes are specifically named in the regulation (Chapter 1200-4-4). However, since it is not possible or desirable to list every stream in the state, the regulation also contains “catch-all” statements that assign a set of uses to streams within each basin that have not been specifically named.

General water quality criteria are descriptions of the level of water quality required to sustain each of the designated uses. Many criteria are numeric while others are narrative. Narrative criteria are verbal descriptions of conditions associated with pollution and are frequently crafted as “free from” statements.

The Antidegradation Policy establishes the circumstances in which degradation can and cannot be allowed in Tennessee waters. The Policy also describes “high quality waters” and authorizes the Tennessee Water Quality Control Board to designate Outstanding National Resource Waters (ONRWs). Tennessee currently has seven designated ONRWs: Abrams Creek, Little River, West Prong Little Pigeon River, Little Pigeon River, Obed River, Big South Fork of the Cumberland, and Reelfoot Lake.

The combination of a set of designated uses, the criteria assigned to those uses, and the antidegradation status of a specific stream combine to create the water quality standard for that stream. For application of the standards, including water quality assessment and permitting, the most stringent criteria apply.

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In Tennessee, promulgation of water quality standards is a responsibility of the Water Quality Control Board. The general makeup of the Board is established by the Water Quality Control Act. It is currently set at ten members with three of the members representing the Departments of Environment and Conservation, Public Health, and Agriculture, respectively. Other members represent conservation interests, agriculture, small business, municipalities, industries, county governments, and the public-at-large.

The Division of Water Pollution Control provides technical support to Board members and holds public hearings on behalf of the Board.

Several things normally happen during a triennial review.

- Numeric criteria are updated, based on the results of EPA's most recently published national guidance. Any newly adopted MCLs for drinking water are incorporated into the criteria for protection of domestic water supplies.
- The Antidegradation Policy is updated, if needed.
- Coordination takes place with the U. S. Fish and Wildlife Service staff to ensure that water quality standards are protective of species with special status.
- Once a draft regulation has been published, public hearings are held in numerous places across the state. The Board formally responds to comments received during the formal comment period.
- Stream-use classifications are updated as needed. While not officially a stream-use classification, the list of trout streams and naturally reproducing trout streams is also updated.
- As EPA approval is required before new standards can be implemented, Division staff will work very closely with EPA's regional office in Atlanta.

Public hearings for the 2005-2006 triennial review were held in January, 2006. Proposed changes to the regulations include updates to the stream-use classifications, revised numeric criteria, and clarifications for the antidegradation policy.

NATURAL SOLUTIONS FOR STORMWATER AND WATER QUALITY MANAGEMENT

G. Dodd Galbreath¹

The presentation begins with a brief review of landscape based hydrologic functions (the water cycle, infiltration, surface water runoff, groundwater recharge, the affects of forests and corresponding stream flow/water quality influences). Then it will briefly contrast traditional approaches and emerging innovations in stormwater management. The presentation will then highlight numerous examples of high quality innovations in stormwater management from around the nation. Examples include the award winning Seattle, Washington's Public Works Department "Natural Drainage Project". Other residential bio-retention projects will be shown from Burnsville and Maplewood, Minnesota; Prince George's County, Maryland and Somerset, Maryland. The presentation will include examples of green roofs, pervious paving and water harvesting. Lastly, the presentation will close with examples of seven different bio-retention sites that have been constructed and landscaped with native plants on the 200 acre Ellington Campus in Nashville, TN.

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HEAVY METAL RECORD IN *CORBICULA* SHELLS NEAR A FORMER INDUSTRIAL SITE

Kaye Savage¹

ABSTRACT

Corbicula fluminea shells collected along the Harpeth River in the vicinity of a former Pb smelter show elevated concentrations of Pb and Cd relative to shells collected upstream and downstream. Spatially resolved analysis of the shells using laser ablation ICP-MS shows that metals are primarily associated with the periostracum; Pb and Cd are concentrated in the outermost layer while other metals are present through the entire periostracum thickness. Shell growth bands did not provide a record of the timing of exposure to metals.

INTRODUCTION

Bioavailability of heavy metals is an issue of wide concern, particularly in stream settings where transport processes can act over long distances and contaminants affect sensitive ecological communities. *Corbicula* clams have been the subject of a variety of related investigations because of their broad distribution and the record of metal uptake in their tissues. Their survival in response to heavy metal exposure has been correlated with survival of sensitive indicator organisms such as *Ephemeroptera* (Souceck et al., 2001), but because of their annual growth cycles and longer lifespans they may provide longer-term records of metal exposure. Most studies on *Corbicula* sp. have focused on living organisms and their physiological response to stressors in the environment. Baudrimont et al. (2003) found that the half-life of Cd and Zn in *Corbicula fluminea* soft parts were 500 and 40 days, respectively. Adverse impacts to *Corbicula* sp. from metal and uranium exposure have been reported, such as inhibition of valve closure (Liao et al., 2005), and uptake in organs and gills (Simon and Gamier-LaPlace, 2004; Legeay et al., 2005). The uptake mechanisms are not well resolved; Croteau and Luoma (2005) found dietary pathways more important than direct dissolved uptake of copper, but Tran et al. (2002) reported the opposite for cadmium uptake. Metal-bearing suspended sediment as a direct source of metals to *Corbicula* soft tissues has not been verified (Bilos et al., 1998; Ciutat and Boudou, 2003).

The purpose of this study was to test whether the shell material of *Corbicula Fluminea* could provide a record of metal exposure. The study site is adjacent to a former Pb smelting facility in an upper reach of the Harpeth River near College Grove, TN. Remediation activities were in progress at the site during and after sample collection, but remediation of the stream bank was not complete at the time samples were collected.

SETTING

The Harpeth River is a tributary to the Cumberland River in middle Tennessee draining primarily carbonate rock terrain. However, sediment inputs from erosion, particularly during storm events, are significant (Wilson and Lockwood, 2005). The river drains an area of approximately 860 square miles; the drainage area upstream of the study site is approximately 35 square miles. Most of the reaches in these headwaters have been designated on the 2004 draft Tennessee 303d list as

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impaired. Causes of impairment include siltation, alteration in streamside or littoral vegetative cover, high levels of *E. Coli* and/or total fecal coliform bacteria, and low dissolved oxygen. The reach near the smelter facility is indicated on the 303d list as impacting 2.7 stream miles with Pb, via contaminated sediment (Tennessee Department of Environment and Conservation, 2004). Prior studies (U.S. EPA, 1998; TDEC, 2002) showed elevated Pb in sediment but not river water in this area.

METHODS AND MATERIALS

Samples

C. fluminea shells were collected at 16 sites upstream and downstream of the industrial facility on several occasions in 2003 and 2004. Up to about twenty shells were collected at each site. None of the shells were supporting live organisms at the time of collection.

Shell dissolution & analysis

Prior to crushing, shells were rinsed with DI water and lightly scrubbed to remove attached sediment. Approximately 12-26 g shell material from each site was crushed in a porcelain shatterbox which was decontaminated between samples by grinding silica sand and rinsing with a weak detergent, deionized water, and ethyl alcohol. Subsamples (~0.25g) were dissolved in 0.5 M Ultrex grade nitric acid over 24 hours on a rotary shaker. Solution aliquots were filtered to 0.45 μm , diluted 10x and analyzed by ICP-MS using a Perkin Elmer Elan DRC II system. Quality control measures included matrix spikes, acid blanks, and duplicate samples.

Laser ablation ICP-MS

Individual shells were rinsed with DI water, dried, mounted with putty and placed into the sample chamber of a New Wave UP213 laser ablation unit coupled to the Perkin Elmer Elan DRC II ICP-MS system. The sample chamber was purged with Ar gas after loading. Samples were moved beneath the 60 - 80 μm diameter laser beam and location was tracked with a microscope as Ar gas flowed through the chamber, carrying ablated material to the ICP-MS. The beam energy was approximately 9 J cm⁻².

Isotopes shown in the accompanying figures were chosen as analytes on the basis of their isotopic abundances and the likelihood of interferences from monatomic or polyatomic species. ⁴³Ca, with 0.14% isotopic abundance, was used to monitor calcium concentration because, in a high-Ca material such as shell calcite, choosing an abundant isotope would saturate the MS detector. Furthermore ⁴⁰Ca overlaps in mass with ⁴⁰Ar, present in the plasma. ⁵⁷Fe was chosen to monitor iron in preference to ⁵⁶Fe or ⁵⁴Fe which can show interference from ⁴⁰(Ar,Ca)¹⁶O and ⁴⁰(Ar,Ca)¹⁴N, respectively. Interferences with ⁵⁷Fe, while possible, would arise from combinations of less abundant isotopes or from triatomic rather than diatomic combinations. In other cases, where interferences are less problematical, the most abundant isotope is shown, e.g. ⁶³Cu, ²⁰⁸Pb, although data were collected for multiple isotopes.

Several strategies were used to qualitatively determine the elemental distribution in the shells: ablating one spot and collecting data as a function of ablation depth; ablating along growth bands in the shell, ablating across growth bands in the shell, and ablating the shell interior surface. Selected shells were cut in half using a low speed saw and ablated in cross-section.

RESULTS AND DISCUSSION

Dissolved shells

Pb and Cd are highly correlated in *Corbicula fluminea* shell material from powdered, composite samples ($\rho = 0.91$), and the pair display a local maximum in samples collected near the smelter facility (Figure 1). Transition metals are moderately correlated to one another ($\rho = 0.4 - 0.7$) but do not display a distinct trend with distance from the facility.

Shell LA-ICP-MS

The major trend to emerge from laser ablation ICP-MS data is that metals, including Pb and Cd, primarily reside in the periostracum of *C. Fluminea*. Figure 2 shows the distribution of elements along shell growth bands, highlighting the contrast between exposed shell material and the periostracum, a thin proteinaceous layer on the shell exterior. Both ablation patterns were collected using the same laser and detector settings; the path length represented in each graph is approximately 1.8 mm. The low signals at the start of the scans (left) were collected without the laser on, to record instrument background conditions. In the exposed shell material (Fig. 2a), the signal is dominated by ^{43}Ca . On the band with remaining periostracum (Fig. 2b), the ^{43}Ca is much lower and metal signals are increased. (Note that, because only single isotopes are shown, the values are *not* directly proportional to elemental concentrations.)

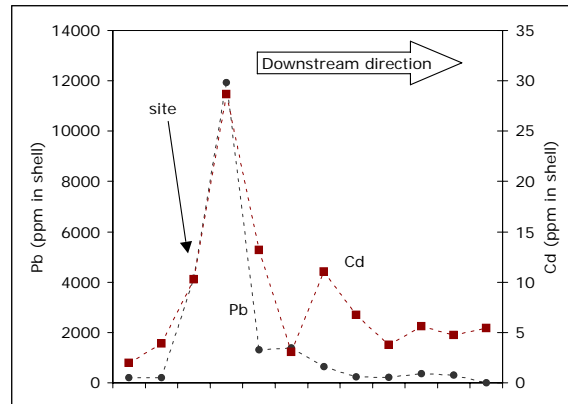


Figure 1. Pb and Cd content of shells, calculated from ICP-MS data

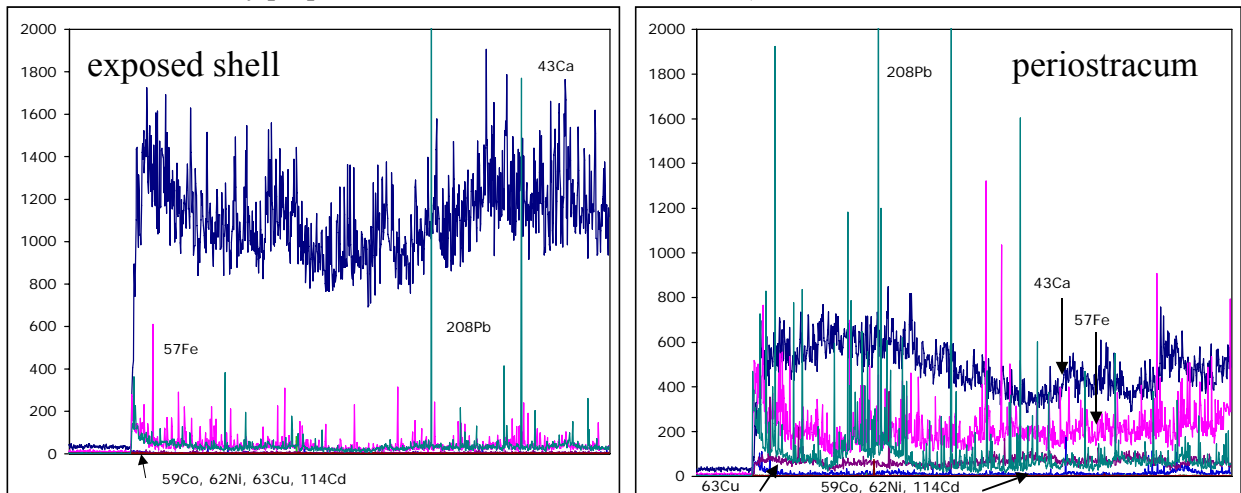


Figure 2. Laser ablation ICP-MS data along exposed shell growth band (left) and periostracum-covered growth band (right). Metals are associated with the periostracum. Sharp rise corresponds to the laser beam activation; left of the rise is background signal.

Figure 3 shows a transects through a cross-section of shell, proceeding from the shell interior towards the exterior. Here too, the compositional change is pronounced as the laser crosses the boundary between shell calcite and periostracum. The total path length is approximately 1.8 mm; the thickness of the periostracum appears to be approximately 200 μm .

Figure 4 shows LA-ICP-MS data that were collected by making five passes with the laser along a single line across the exterior of a shell, crossing two growth bands over a distance of

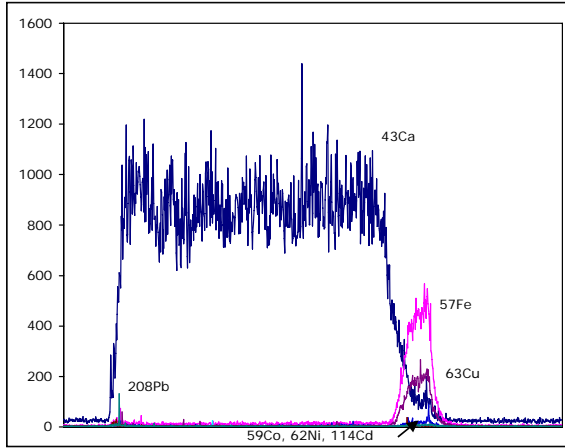


Figure 3. LA-ICP-MS on cross-section of shell, from interior (left) to exterior (right). The rise in Fe and Cu corresponds to the periostracum.

approximately 1.8 mm. The first pass therefore predominantly samples the periostracum, ablating it away such that subsequent passes predominantly sample the calcite shell substrate. In the first pass, shell ridges where the periostracum is thin are indicated by relatively high Ca and low Fe and Cu. In the second pass, and subsequently, Ca is increased over the entire pattern, and Cu and Fe are reduced as the periostracum is progressively removed by laser ablation. Pb is significant only in the first pass where the periostracum is nearly intact.

Figure 5 shows an example of a spot ablation. Proceeding left to right across the figure corresponds to depth from the shell surface. In this figure, analyzed values have been adjusted

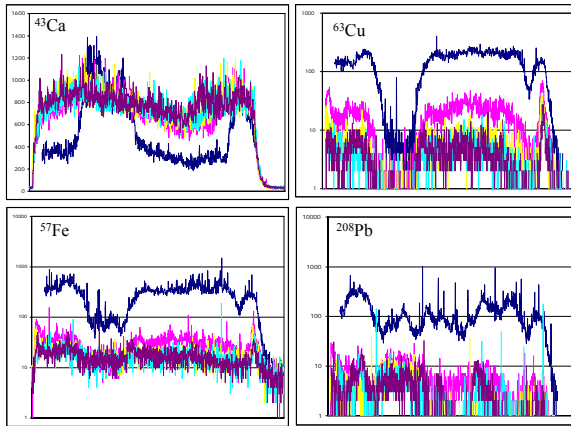


Figure 4. Successive scans along the same line, crossing two growth bands. Each graph represents a single element (Ca, Cu, Fe, Pb; see text).

to reflect the isotopic abundance for the measured isotope, so values should approximately correspond to the total elemental concentrations. Elements are shown on different axial scales to highlight the trends. Note the inverse relationship between calcium and all of the other metals. The left part of the graph, where most elements peak, represents the periostracum. As the periostracum is ablated away, the underlying shell calcium is exposed. Fe and Cu are present throughout the periostracum, whereas Cd, Co and Pb are only in the outermost layer and are ablated away almost immediately.

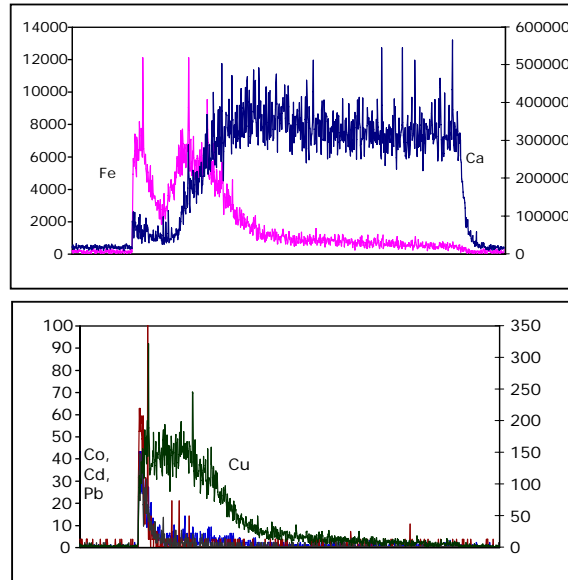


Figure 5. Results of laser ablation at a spot, “drilling” down into the shell from the surface. Elements are shown on separate graphs with different scales to emphasize correlations.

CONCLUSIONS

Metals in *Corbicula fluminea* shells were associated primarily with the periostracum rather than shell material, and there was no trend in metal concentrations along growth bands. Pb and Cd are

correlated well with each other, and are most concentrated in shells collected near the former battery recycling site. They are also most concentrated in the outermost part of the periostracum, whereas other metals (Fe, Cu) are distributed through the whole thickness of the periostracum. The periostracum of *C. Fluminea* appears to serve as a record of exposure to environmental metals, but the timing of exposure and manner of uptake are not evident from this study.

ACKNOWLEDGEMENTS

Thanks to David Wilson for collecting the initial set of shell samples and helpful discussions initiating this project. Thomas Steinwinder and Ben Iobst also collected shell samples, and helped with sample preparation and laser ablation ICP-MS. Rossane DeLapp optimized the LA-ICP-MS for our use.

REFERENCES

- Baudrimont, M.; Andres, S.; Durrieu, G.; Boudou, A. *Aquatic Toxicology* 2003, 63, 89-102.
- Bilos, C.; Colombo, J. C.; Presa, M. J. R. *Environmental Pollution* 1998, 99, 1-11.
- Ciutat, A.; Boudou, A. *Environmental Toxicology and Chemistry* 2003, 22, 1574-1581.
- Croteau, M. N.; Luoma, S. N. *Environmental Toxicology and Chemistry* 2005, 24, 2871-2878.
- Legeay, A.; Achard-Joris, M.; Baudrimont, M.; Massabuau, J. C.; Bourdineaud, J. P. *Aquatic Toxicology* 2005, 74, 242-253.
- Liao, C. M.; Jou, L. J.; Chen, B. C. *Environmental Pollution* 2005, 135, 41-52.
- Simon, O.; Gamier-Laplace, J. *Aquatic Toxicology* 2004, 68, 95-108.
- Soucek, D. J.; Schmidt, T. S.; Cherry, D. S. *Can. J. of Fisheries and Aquatic Sciences* 2001, 58, 602-608.
- Tennessee Department of Environment and Conservation, Division of Water Pollution Control: Nashville, TN 2004, 303d List.
- Tennessee Department of Environment and Conservation, 2002, TMDL for metals in the Harpeth River Watershed
- Tran, D.; Boudou, A.; Massabuau, J. C. *Environmental Toxicology and Chemistry* 2002, 21, 327-333.
- U.S. EPA. Region 4 Science and Ecosystem Support Division, Hazardous Waste Section, Athens, GA, 1998. SESD Project No. 98-0557
- Wilson, D. J.; Lockwood, R. E.; Harpeth River Watershed Association; Cumberland River Compact, 2005.

CONSTRUCTION STORM WATER COMPLIANCE (OR THE LACK THEREOF) IN THE MEMPHIS AREA - WHAT IS TDEC/WPC DOING TO ENLIGHTEN RESPONSIBLE PARTIES?

Terry R. Templeton¹

WHAT'S THE BIG DEAL ABOUT SILT?

The Division of Water Pollution Control in the Memphis Environmental Field Office (MEFO) currently has approximately 1300 sites permitted for discharge of storm water from construction activities. More than 400 applications for coverage under the General NPDES (National Pollutant Discharge Elimination System) Permit for Discharges of Storm Water Associated with Construction Activities (CGP) were received in Memphis in 2005. Impairment by siltation is one of the leading causes of surface water pollution in Tennessee. So what's the big deal about silt? Siltation causes impairment to waters by altering the physical, chemical, and biological properties of water in a stream. The division seeks to minimize the impact of siltation on waters of Tennessee by regulating the discharge of storm water from land disturbance at construction sites. A regulated activity, which is covered by a general permit, can be conducted provided the terms and conditions of the permit are met. The purpose of the CGP can be summarized by saying that pollution from storm water discharges at construction sites should be eliminated by the use of an appropriate set of erosion prevention and sediment controls, collectively called Best Management Practices (BMPs), that are specifically designed, installed, and maintained for each site.

EROSION PREVENTION AND SEDIMENT CONTROLS – WHAT WE WANT VS. WHAT WE GET

For several years, staff at the MEFO have regularly attempted to educate the regulated community, including their engineers, consultants, and contractors, about the requirements of the CGP. MEFO personnel have given presentations to a number of groups on repeated occasions, including homebuilder and developer organizations, professional engineering organizations, and other similar groups. These presentations serve as refreshers on CGP requirements. One of those requirements is that a site-specific Storm Water Pollution Prevention Plan (SWPPP) be prepared for every site before permit coverage can be granted. Successful creation and implementation of the SWPPP is the key to what we want to find at a site when we conduct an inspection. We want the SWPPP to be a site-specific plan that details how the permittee will prevent pollution at a site, not simply a statement that says they will prevent pollution and follow the permit - don't just quote the CGP in the SWPPP! This presentation is a summary of the message we present to the regulated community in an attempt to help permittees understand both the regulatory context of the CGP and the Best Management Practices (BMPs) that they are required to implement at every site. We discuss several important things that the CGP states must be included in the SWPPP. We caution permittees to remember that the division does not perform an engineering review of the SWPPP and does not certify whether the SWPPP adequately provides for the pollution prevention requirements at the site as described in the General Permit. We also remind them that it is the responsibility of all site operators to design, implement, and maintain measures that are sufficient to prevent pollution at a site, and to remain in compliance with the terms and conditions of the General Permit.

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We include in our presentation examples of the results we often find at actual project sites. Here are some of the photographs of bad examples that we share.



How not to install silt fence!

BEST MANAGEMENT PRACTICES – WHAT THEY ARE AND WHAT THEY'RE NOT

We also discuss BMPs that should be used at sites. We commonly see BMPs that are poorly designed, located and installed incorrectly, and poorly maintained. As a result, sediment is often transported off-site, which is a permit violation. We remind permittees that BMPs must be used correctly. One commonly used BMP, silt fence, is often used inappropriately, and not maintained correctly. We will discuss the principles of proper silt fence use. This photograph illustrates a typical failure that has resulted from the use of too little slope at a construction site.



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In conclusion, we remind the regulated community that the problem of erosion and sedimentation is a big one, and that regulatory efforts to manage the problem will continue. With the advent of NPDES Phase II in 2003, there will be more regulation by local municipalities, as well. The CGP expires and is reissued every five years, and public hearings are held on proposed changes. We encourage the regulated community and all stakeholders to make themselves aware of permit requirements and offer comments on issues of interest.

**ARAP AND ECONOMIC EVALUATION OF ALTERNATIVES:
NEW PINEY RIVER 2.6 MGD INTAKE AND TREATMENT PLANT
JANUARY 6, 2006**

William W. Wade, Ph.D.¹

PROPOSED ARAP RULE CHANGE INVOKES ECONOMIC RIGOR

TDEC's Aquatic Resource Alteration Permit (ARAP) establishes the permitting process for physical alteration of waters of the state. Chapter 1200-4-7 of the rules of the Tennessee Department of Environment and Conservation (TDEC) --ARAP -- governs activities that would alter state streams by withdrawal, discharge, wetlands drainage, etc. ARAP §1200-4-7-.04 (5)(c) 2 states that “. . . [P]ermit conditions shall protect the source stream's resource value[s],” where §1200-4-7-.03 (29) defines resource values as the benefits provided by the water resource. . . . [B]enefits include, but are not limited to, the ability of the water resource to:

- (a) filter, settle and/or eliminate pollutants;
- (b) prevent the entry of pollutants into downstream waters;
- (c) assist in flood prevention;
- (d) provide habitat for fish, aquatic life, livestock and water fowl;
- (e) provide drinking water for wildlife and water fowl;
- (f) provide and support recreational uses; and
- (g) provide both safe and adequate quality and quantity of drinking water.

ARAP requires an applicant for a permit to withdraw water from a Tennessee stream to describe the proposed activity with all the necessary technical information for the Commissioner to make a determination, including an assessment of the practicable alternatives for a planned activity. Evaluation of either changes in resource values or assessment of alternatives has been given little attention at TDEC. The agency's capabilities are mostly physical science-based to the exclusion of economics. This orientation away from economics by TDEC has left the evaluation of alternatives with no objective criteria by which to measure the economics of alternatives that might satisfy an agency's needs. But this is about to change.

TDEC's currently proposed ARAP rule-change adds explicit clarity to the assessment of practicable alternatives. “When a proposed activity may result in degradation of waters, the alternatives analysis . . . shall include a discussion of the **feasibility of all potential alternatives, plus the social and economic considerations and environmental consequences of each consistent with the requirements of Chapter 1200-4-3-.06.**”

http://www.state.tn.us/environment/wpc/publications/2005RuleAmend1200_04_07.pdf

New language at §1200-4-3-.06 (3) a.2. defines alternatives for water withdrawals as “water conservation, water reuse or recycling, off-stream impoundments, water harvesting during high flow conditions, regionalization, withdrawing water from a larger water body, use of ground water, connection to another water supply with available capacity, and pricing structures that

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encourage a reduction in consumption.” The proposed ARAP changes require financial and economic analysis of alternatives that conforms to EPA’s 1995 guidance document entitled Interim Economic Guidance for Water Quality Standards: Workbook (EPA 823/B-95-002) (Economic Guidance) – or submittal of equivalent information. This new guidance fills the need for standards by which to evaluate alternatives.

ECONOMIC EVALUATION OF ALTERNATIVES WITHIN ARAP REQUIRES EMPIRICAL ANALYSIS

A 2004 application filed by a small rural water district to double its withdrawal from the Piney River in Middle Tennessee provides a very good basis to illustrate TDEC’s quandary in dealing with evaluation of alternatives without economic standards. Without clear criteria by which to evaluate alternatives, the assessment of “all practicable alternatives” is little more than window dressing with no policy significance. In the Piney River example, opposition to the permit application led to the author’s involvement to evaluate the economic feasibility of the proposed alternative in comparison with other alternatives. This evaluation revealed deficient and missing objective empirical analysis of the alternatives available to the water district. Regardless of impacts on resource values of the Piney River, available alternatives dismissed in the applicant’s submittal were shown to be substantially more economic than doubling the intake from the Piney River.

The first problem was the submitted demand forecast, which was the basis for the Purpose and Need for the project. The water district’s engineer submitted the demand forecast shown in Chart 1, which showed a sharp rise in the District’s customer connections to 7,100 by 2025. Examination of this forecast revealed it to be unsupported by any population forecast. In fact, the rural area population served by the district is expected by the UT Center for Business and Economic Research to continue slow growth. (The County is not in a rapidly growing area of Middle TN.) Chart 2 shows the author’s growth forecast, which reaches only 4,400 customer connections by 2025, based on CBER’s rural county population forecast. Whether or not CBER’s forecast anticipated growth that might be catalyzed by completion of SR-840 was unknown to the engineer and the author; nonetheless, the engineer’s forecast included no empirical support.

The engineer’s forecast emphasized that the water district was nearing its permitted withdrawal capacity of 1.3 mgd, which justified its application to double the intake. Evaluation of data contained in the submittal revealed that while this was true, the district’s average amount of water sold was under 0.6 mgd in recent years, less than half of permitted capacity. Both trends are shown on Chart 3. Chart 4 emphasizes the district’s actual problem: water loss. The district’s water losses averaged more than 40% 2000 – 2004, improving slightly to 38% for twelve months ending February 2005.

The engineer’s water withdrawal forecast shown on Chart 5 implies that requirements will exceed permitted withdrawal amounts before the end of the decade. However, this forecast is flawed by two shortcomings:

- 1 it begins from and embeds in the forecast a constant 38 percent loss factor;
- 2 the forecast is unsupported by any empirical basis.

The engineer’s solution to this problem was to double the permitted withdrawal amount and build a state of the art \$4.85 million membrane filtration plant. Neither of the alternative demand

forecasts based on UT's population forecasts done by the author exceeds existing permitted withdrawal amounts during the planning horizon. If the water district can improve its leak detection and management from 38% to 15% water loss – in line with good management performance – the existing permitted cap is not exceeded on peak days until late in the next decade. Ninety million gal/year could be saved in 2005 rising to 120 million gallons for the author's forecast, assuming the 15% benchmark loss rate. Treating and losing 90 million gallons cost the water district \$80,000 in 2005 at \$0.85 per 1000 gpd. The present value of the money saved by improved leak detection over the planning horizon is \$1.14 million.

The engineer's Alternative Analysis included three alternatives: (1) No Action; (2) Buy water from a nearby water system; (3) Build the new intake facilities with the water treatment plant. Reducing water losses was not among the alternatives. TDEC did not direct the district to consider the high water losses as a remedy for the district's perceived impending water shortage. Yet, improved leak detection alone is consistent with no needed action until late into the next decade when something will have to be done to accommodate peak day requirements.

The Alternatives analysis within the engineer's report comprised three pages of prose unsupported by any data and analysis that ruled out the do nothing and purchase water alternatives. Under EPA's Economic Guidance document, a small utility with existing bonded debt less than the \$4.85 million new project would have to show substantial and far-reaching social and economic impacts to the community served by not undertaking the project before the new project could be approved. The cost of alternatives to avoid such a large addition of debt to ratepayers would be a legitimate policy question important to regulatory oversight.

Chart 6 shows the author's financial analysis of the alternatives. Leak detection is clearly the best policy, saving over \$1 million in present value 2005 dollars, with either the UT forecast or the unsupported high engineer's forecast. Buying water incrementally as needed to meet out year peak day demands is a low cost option, \$330,000, if future growth follows the UT population forecast, or \$2.9 million following the engineer's forecast. Buying water incrementally as needed is clearly a substantially better alternative than building and operating a new sophisticated membrane plant, the present value cost of which is shown as \$9.5 million, including capital and operating costs, plus periodic membrane replacement.

Another alternative considered for the small water district was to shut down and buy all water from a nearby larger water district with a new treatment plant, excess capacity, and substantially more management expertise – including a well-developed and low cost leak detection program. This alternative is shown costing between \$7.0 and \$8.98 million present value 2005. These costs represent the present value of the price per 1000 gallons offered by the selling water district to the small rural water district. Shutting down made more economic sense than building the new treatment plant.

IMPLICATIONS OF PINEY RIVER APPLICATION TO PROPOSED CHANGES IN ARAP

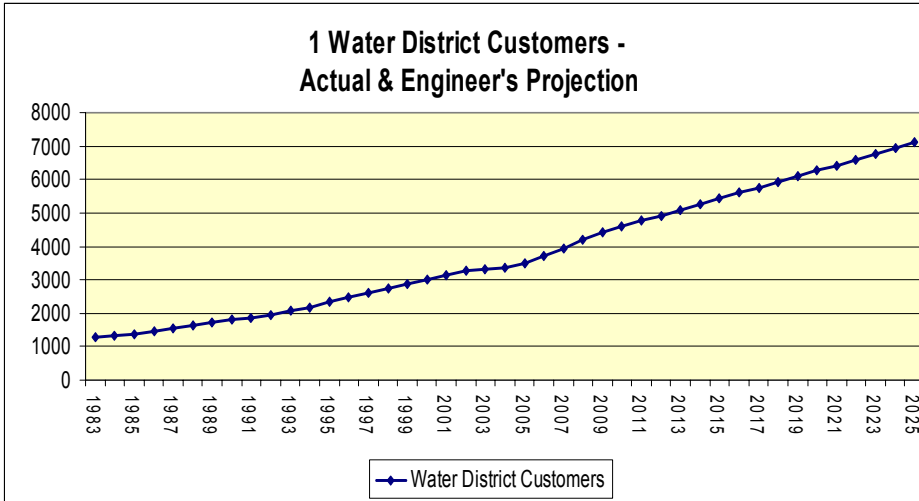
When provided with the author's showing that the applicant's desire to double the Piney River withdrawal amount and build a new treatment plant was neither needed nor made good use of the ratepayers' money, TDEC found itself concerned about the implications of the information in both the author's and engineer's reports. The engineer was invited to respond, but submitted no written rebuttal or reconsideration of its initial report. TDEC found the district's withdrawal of 1.3 mgd to have a *de minimus* impact on Piney River stream flows. But for the rigorous

evaluation of alternatives, the project might have gone forward to the detriment of the district's ratepayers – and to the perceived detriment of other interested Piney River stakeholders.

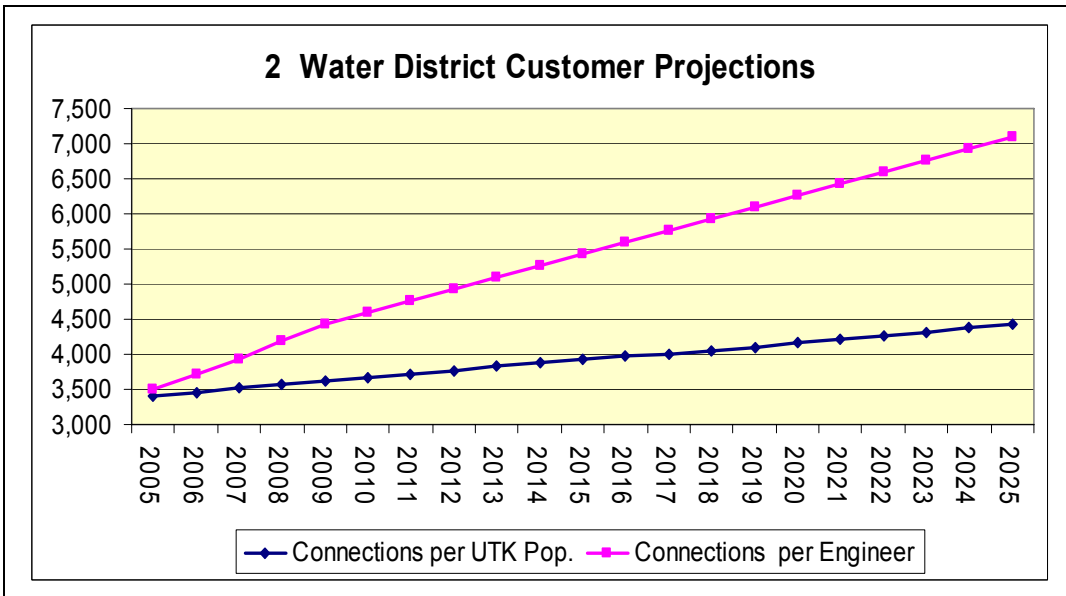
The water district, when provided an objective analysis of the benefits of the buy water alternative, chose to do so. The applicant withdrew its permit application. Negotiations are in progress in January 2006 to contract to buy water from the nearby agency. TDEC did not have to evaluate formally the alternatives on their merits and decide whether or not the intake and treatment alternative was unneeded and uneconomic. The engineer did not get to build the \$4.85 million plant.

TDEC's proposed new ARAP rules impose economic rigor into the evaluation of "all practicable alternatives" and provide criteria to support decision making. The proposed changes to ARAP are much needed and will improve the evaluation process. Applicants will be required to provide rigorous analysis or alternatives. The agency will need to develop expertise to evaluate whether the proposed alternative is both needed and consistent with good use of the rate payers' money, benchmarked to EPA's criteria. Proposed ARAP changes to incorporate the financial and economic impacts of alternatives will affect the regulatory outcome.

State water policy supports regionalization efforts that include cost sharing by using or enhancing existing developed water resources to avoid new impacts to rivers and the environment. The buy water alternative, which was dismissed in three paragraphs by the engineer, is consistent with Tennessee's regionalization directive. With ARAP's enhancement of economic evaluations of alternatives, TDEC will have the tools to better evaluate and balance the needs of off takers with instream resource values.

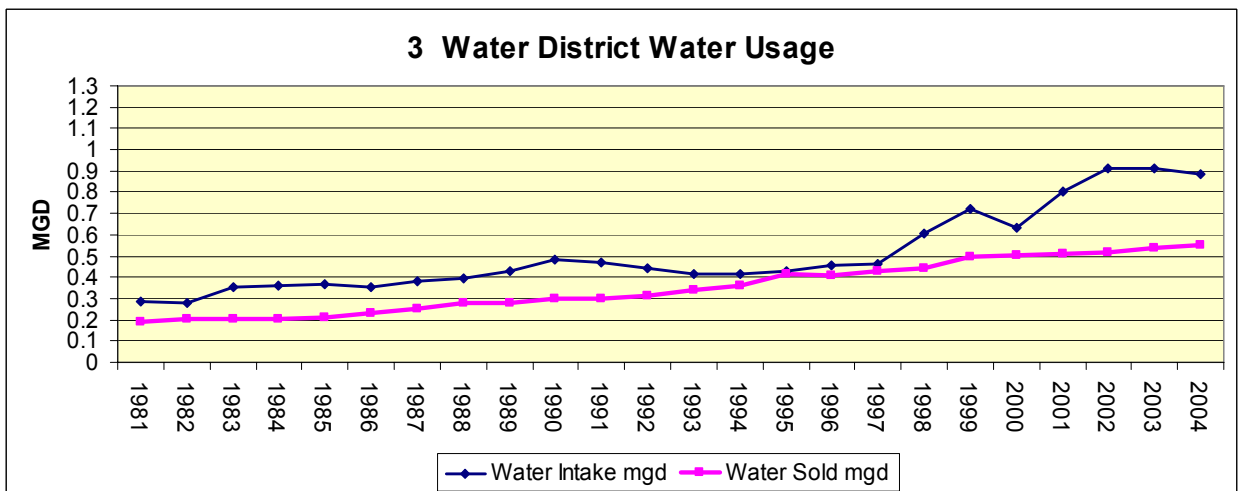


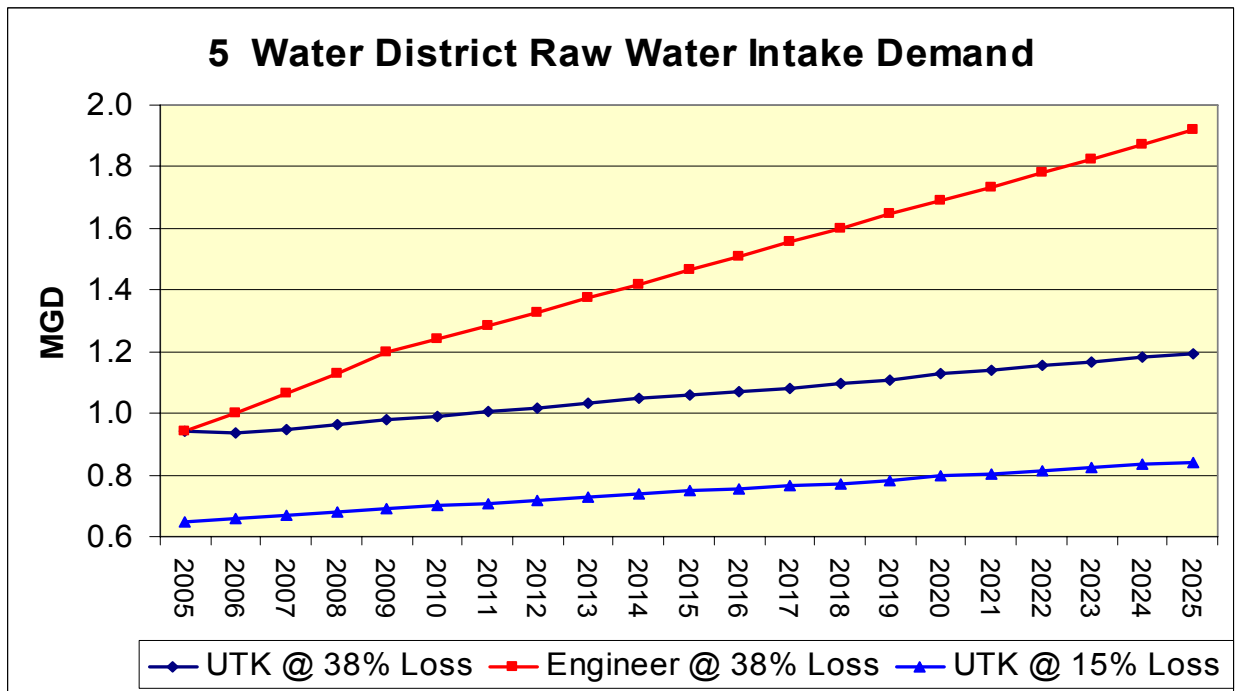
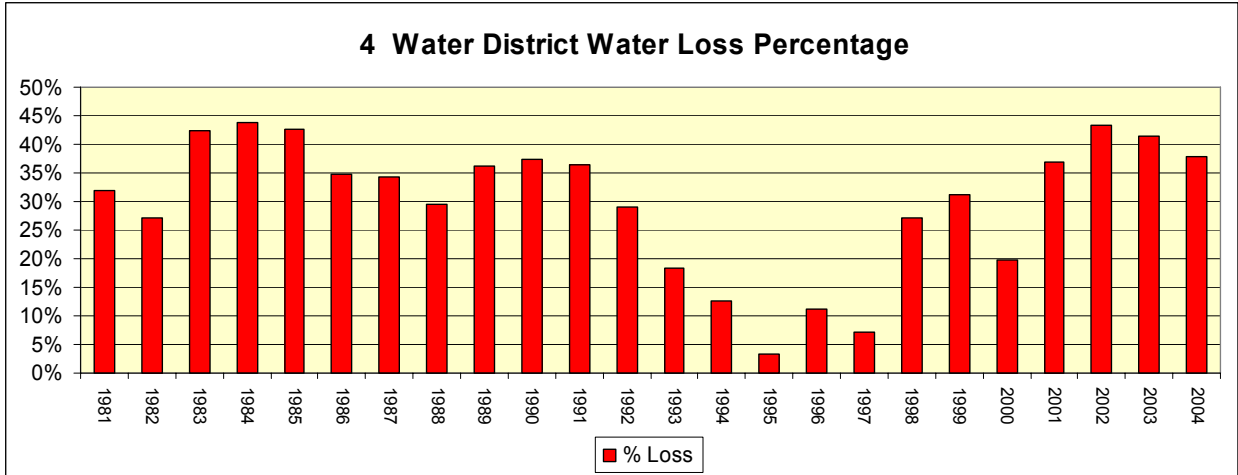
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4400





6 Comparison of Alternatives	PV 2005 \$ Million
PV Savings to reduce to 15% loss rate - UT Forecast	\$1.14
PV Savings to reduce to 15% loss rate - Engineer's Forecast	\$1.52
PV Cost of purchased Incremental water - UT Forecast	(\$0.33)
PV Cost of purchased Incremental water - Engineer's Forecast	(\$2.95)
PV Buy All Water from DWA @ \$1.71 per 1000 gal. - UT Forecast	(\$7.04)
PV Buy All Water from DWA @ \$1.71 per 1000 gal. - Engineer's Fcst	(\$8.98)
PV Cost of Membrane Intake Project	(\$9.50)

THE TENNESSEE STREAM MITIGATION PROGRAM (TSMP) TENNESSEE'S IN-LIEU-FEE PROGRAM

Joey Woodard¹

BACKGROUND

Compensatory mitigation for permitted activities that result in unavoidable impacts to aquatic resources is required by both federal and state law. Compensatory mitigation projects are designed to replace aquatic resource functions and values that are adversely impacted under regulatory programs. In-lieu-fee mitigation occurs in circumstances where a permittee provides funds to an in-lieu-fee provider instead of either completing project-specific mitigation or purchasing credits from an approved mitigation bank. Developed in accordance with Federal Guidance on the Use of In-Lieu-Fee Arrangements for Compensatory Mitigation under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, the Tennessee Stream Mitigation Program (TSMP), was established in 2002 as Tennessee's first in-lieu-fee program.

The TSMP is administered by the Tennessee Wildlife Resources Foundation (TWRf). The TWRf is a 501(c)(3) non-profit that was established in 1999 to support the programs of the Tennessee Wildlife Resources Agency (TWRA). Just a few of the TWRf's goals are to ensure public hunting lands for Tennessee's sportsmen, to reintroduce fish species to Tennessee's rivers and lakes and to provide habitat for Tennessee's non game species. The TWRf is the sole member of the TWRf, LLC, a non-profit limited liability corporation created specifically for the purpose of administering the TSMP. A Memorandum of Agreement (MOA) between the U.S. Army Corps of Engineers and the TWRf, LLC establishes an interagency Stream Mitigation Review Team (SMRT) composed of representatives from the Tennessee Department of Environment and Conservation (TDEC), U.S. Army Corps of Engineers (Nashville District), U.S. Army Corps of Engineers (Memphis District), the Tennessee Valley Authority (TVA), the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and the Tennessee Wildlife Resources Agency (TWRA) to oversee the development, operation, and management of the TSMP.

PURPOSE

With oversight from the SMRT, the TSMP's primary objective is to provide cost-effective, meaningful compensatory mitigation for unavoidable impacts to Tennessee's aquatic resources. The TSMP is one alternative available to permittees for providing off-site mitigation. Although federal guidance clearly establishes a preference for on-site or near-site compensatory mitigation where applicable, it allows for the use of a mitigation bank or in-lieu-fee mitigation in situations where there is no practicable opportunity for on-site compensation, or when the use of a mitigation bank or in-lieu-fee mitigation is deemed environmentally preferable to on-site compensation. The availability of the in-lieu-fee mitigation alternative allows for the use of funds derived from multiple permitted impacts within a given geographic area to be consolidated and focused to achieve restoration at locations determined to have the greatest need, thereby maximizing the ecological effectiveness of the mitigation.

In order for an applicant to participate in the TSMP, the applicant must make application with the appropriate state and federal regulatory agencies. During the permitting process, the applicant

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must first attempt to avoid and then minimize the impact. If the impact cannot be avoided then the applicant is given the opportunity to mitigate for the impact either on-site or near-site. If on-site or near-site mitigation is not viable, the applicant may chose to use a mitigation bank or an in-lieu-fee program such as the TSMP. Once an applicant pays the TSMP the set rate of \$200.00 per each linear foot of mitigation required, the TSMP accepts full responsibility for fulfilling the compensatory mitigation requirement specified by the regulatory agencies.

PROCESS AND PROCEDURE

The TSMP is responsible for providing compensatory mitigation for permitted impacts across the state of Tennessee. In accordance with the MOA and TDEC's Tennessee Stream Mitigation Guidelines (Guidelines), acceptable mitigation measures can include stream restoration as well as enhancement activities such as bank stabilization, riparian buffer establishment, and livestock exclusion. As further stipulated in the MOA and the Guidelines, a proposed TSMP mitigation project must meet specific qualifying criteria. A project should be located within the same EPA Level III Ecoregion, ideally within the same USGS 8-digit hydrologic unit, and generally should be located on streams within one stream order as the impacted stream(s) for which it is intended to provide mitigation. The ratio of urban to rural streams impacted should be generally replicated during the selection and implementation of mitigation projects. Additionally, with all other factors being equal, priority should be given to 303(d) listed streams for which the mitigation efforts may provide a means to alleviate the causes or sources of water quality and/or habitat impairment.

TSMP projects are identified through the dedicated efforts of both TSMP staff and the involvement of partner agencies and organizations located throughout the state. To date, TSMP projects have been identified, developed, and implemented with the active participation of federal, state, and local agencies as well as resource-oriented non-profit organizations. The successful accomplishment of individual projects and the achievement of the TSMP's goals and objectives are fueled by these critical partnerships. Collaboratively, these efforts are focused on restoring, enhancing and thus improving water quality and aquatic/riparian habitat in each of the state's 13 major river basins.

Mitigation sites can be on public or private lands. Participation in the TSMP is entirely voluntary and offers stewardship-minded landowners with an additional option for achieving desired resource improvements and protections. As the property stays in the landowners hands, landowners maintain a voice during project development and implementation. Landowner commitment and acceptance is critical in achieving long-term project success. Unlike some short-term programs that provide cost-sharing assistance only, the TSMP fully funds all of the work associated with developing, designing, implementing, and monitoring its projects. Therefore, no matching funds are needed from the landowner.

In exchange, landowners who desire to have work performed on their property must agree to ensure the long-term protection of the affected stream channel and the re-established riparian area through the institution of a perpetual land preservation agreement. The agreement serves to permanently protect projects by restricting uses that would damage restoration work while allowing the landholder to retain ownership of the project area for continued enjoyment and use for such purposes as hunting, fishing, and other types of recreation. Landowners are also asked to provide access to the work area for project implementation and ongoing monitoring. However, the agreement does not allow for public access to the protected area.

The TSMP places a strong emphasis on using the science of fluvial geomorphology and the application of natural channel design methodologies to accomplish its stream restoration projects. This approach focuses on reestablishing bed and bank stability, floodplain function, sediment transport capability, and aquatic and riparian habitat function using data gathered from healthy streams and properly functioning floodplains as the basis for redesigning and restoring the impaired channel. This process-based approach is founded on a commitment to relying on naturalized techniques of restoration, stabilization, and protection. It mandates abandoning traditional methods that incompletely consider flow dynamics, sediment transport, or habitat needs and that typically rely upon tactics that harden our streams through the use of materials such as rip rap, concrete, and gabion baskets.

The TSMP restoration process starts with intensive preliminary evaluations of a potential project site including detailed assessments of existing morphological, habitat, and functional conditions to characterize the level of stream degradation, instability and impairment. During this comprehensive pre-screening, definitive criteria are used to evaluate the potential of the proposed project to provide ecological benefits in a cost effective manner. Projects must improve an aspect of water quality (e.g., reduce sedimentation, habitat impairment or nutrient loading). Other factors considered during the initial assessment process include the presence of existing constraints (e.g., utilities, structures, cultural resources, threatened and endangered species), constructability and construction access, and cost/credit benefit ratios which can all affect on overall project cost and effectiveness. Examples of viable mitigation site characteristics include stream segments that have been previously straightened or channelized, are experiencing bank failure due to erosion, are lacking riparian vegetation, are void of aquatic habitat, or have been encased in pipes or culverts that can be removed and the stream restored.

Based upon the preliminary evaluations, a determination is made regarding the most appropriate course of action to follow. Given the level of degradation, channel evolution stage, and projected costs, the most beneficial mitigation approach can be as simple as excluding livestock, planting trees, and allowing the stream to naturally achieve stability. Conversely, the conditions could warrant totally reconstructing a stable stream channel with improved floodplain functionality and instream habitat. Reestablishing a stable stream system typically requires restoring a meandering pattern and a profile with bedform diversity as well as a cross-sectional dimension capable of handling the flows and transporting the required sediment loads dictated by the watershed. Natural instream and bank structures such as vanes, cover logs, rootwads and native vegetation are commonly used to maintain bedform, provide habitat and augment bank stability. Restoration projects also involve the reestablishment of native riparian buffers, typically a minimum of 50 feet wide. The goal is to create a self-sustaining stream ecosystem.

Restoration of a stable, functioning stream with improved habitat is no small undertaking. It requires considerable expertise and proven ability in a variety of engineering and environmental disciplines. To accomplish the further assessment, design and implementation of such projects, the TSMP utilizes the services of the most highly experienced consultants and contractors in the region that specialize in stream restoration.

Following implementation, monitoring is required for all TSMP mitigation projects. The objective of this monitoring is to assess conditions in order to quantify the success of a project and provide for evaluations of approaches, methods and techniques in order to facilitate continual process improvement. Monitoring serves to determine whether an improvement to channel stability, sediment transport, riparian and aquatic habitat and overall function of a significantly degraded stream was achieved. The monitoring protocol used by the TSMP includes assessments of measurable attributes of stream dimension, pattern and profile, sediment competence and

capacity, bed aggradation and degradation, lateral and vertical stability, riparian forest growth, structure and diversity, and assessment of in-stream habitat.

ACCOMPLISHMENTS

To date, the TSMP has completed 29,869 linear feet of stream mitigation providing 7,864 feet of mitigation credit. Additionally, seven projects totaling approximately 80,712 linear feet have been approved and are in different phases of assessment, design or implementation. These projects are expected to produce an additional 38,265 feet of mitigation credit. Collectively, these projects will produce 110,581 linear feet of restored and/or enhanced stream for a total of 46,129 feet of mitigation credit. This represents 51% of the 91,153 linear feet of current TSMP mitigation obligation. Additionally, 81% or 37,317 feet of the total credit being generated by these projects is occurring on 89,281 linear feet of 303(d) listed impaired streams. These projects will also fulfill current mitigation requirements in six different USGS 8-digit hydrologic units, as well as 85% of the TSMP's current obligation in the Ridge and Valley Level III Ecoregion, 42% in the Interior Plateau Level III Ecoregion, 11% in the Mississippi Valley Loess Plains Level III Ecoregion and 78% of the current obligation in the Southeastern Plains Level III Ecoregion.

This progress did not happen overnight. It has taken a little more than three years to build the TSMP from the ground up – going from a mere concept to a fully functioning organization that is implementing meaningful stream mitigation projects. The TSMP continues to refine and streamline its processes and procedures to increase efficiency and cost-effectiveness while achieving viable restoration results. By continuing to use the best available science, partnering with other committed organizations, encouraging landowner stewardship, and hiring the most experienced consultant/contractors, the TSMP is optimally positioned to lead the way in providing successful and meaningful mitigation to improve degraded stream resources in Tennessee. For more information about the TSMP, please stop by our display during the conference or visit our website at www.tsmp.us.

OF DEAD COWS AND SODA STRAWS

Tom Moss



What does a dead cow have to do with protecting public water supplies? More than you might think in Tennessee. The frustrations of dealing with a dead cow led to a change in the law protecting public water systems and culminated in changes in the Water Supply Rule that took effect on October 29, 2005. Tom Moss, Tennessee's Source Water Protection Coordinator was contacted by Tennessee Association of Utility District staff in May of 2001 regarding a concern of water system personnel. A farmer had intentionally dumped a dead cow out above their water intake as a part of ongoing feud with the system. The water system personnel asked for assistance in getting the carcass removed. Tom Moss contacted numerous state and local agencies with very little success. The carcass was finally removed by an enterprising local deputy sheriff. At the time, there was a provision of the Tennessee Safe Drinking Water Act that prohibited dumping sewage above a public water supply intake, but only sewage. In the following legislative session, the Department of Environment and Conservation was asked by the legislature if there were any amendments it would like to propose. The Tennessee Safe Drinking Water Act was already up for an amendment due to an EPA reporting requirement changes, making an additional change more viable. The Division of Water Supply proposed that the prohibition be expanded to include "any other waste or contaminant" and that "intake" be expanded to include "well or spring." This amendment was made in 2002. In 2004, Tennessee was chosen as one of five states across the country for the EPA Inspector General's Office to visit for success stories in Source Water Protection primarily based on the "dead cow amendment" and the accompanying changes that were underway in the Drinking Water Supply Rules.

With this new authority to protect water supply sources within the Act, the Division of Water Supply recently promulgated regulations to add complimentary language to the former Wellhead Protection Rule 1200-5-1-.34. The Rule is now titled "Drinking Water Source Protection" and includes contaminant inventory and emergency operation requirements for water systems using

surface water intakes in addition to the wellhead protection requirements for ground water systems that were present previously. There has also been language that gives the Division authority to address certain high risk activities in the vicinity of water supply intakes, wells and springs that might otherwise be unregulated. With these changes, Tennessee is a leading state in Source Water Protection nationwide. And it all started with a dead cow...

AN ECONOMICAL *IN-SITU* ALTERNATIVE FOR TREATMENT OF NITRATE CONTAMINATED GROUNDWATER

Katherine Y. Bell^{1*}, William P. Hamilton², and John Haselow³

INTRODUCTION

Nitrate pollution of groundwater, which arises from a wide range of point and non-point sources, may have potential effects on human health and the environment; thus, reducing nitrate concentrations in groundwater has been a topic of much interest. One of the potentially most cost-effective approaches of treating nitrate contaminated groundwater is biological denitrification. This process has been used in wastewater treatment because it is highly selective with efficiencies approaching 100%. Although it has not historically been used as a method to treat groundwater, denitrification has been shown to occur in aquifer systems; however, without addition of electron donor, the reaction may proceed very slowly.

This paper presents a case study for the conceptual design of a denitrification wall that has been approved by the state of North Carolina to treat groundwater contaminated by release of urea from a former fertilizer plant. Design parameters and potential process limitations are discussed.

TECHNICAL BACKGROUND

Most biological denitrification is carried out by heterotrophic bacteria that derive their energy from oxidation of organic carbon. Biological conversion of nitrate (NO_3^-) to nitrogen gas (N_2) involves several steps ($\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$) with many bacteria only capable of performing one or two of the steps; thus, the microflora that perform denitrification must be considered as a group. Although denitrification is a four step process, it is modeled well using a first order expression for the conversion of nitrate directly into molecular nitrogen⁴.

$$[\text{NO}_3^-]_t = [\text{NO}_3^-]_0 e^{-kt}$$

Because denitrification depends on a number of factors, reaction kinetics will vary depending on conditions under which the reaction occurs. There are, however, numerous reports of first-order kinetic constants for denitrification in soils. Some of the reported ranges of these constants are shown in Table 1. Note that systems with a supplemented carbon source tend to exhibit higher rates of denitrification.

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³ Environmental Engineer, Ph.D., P.E., Redox Tech, LLC., 1006A Morrisville Parkway, Morrisville, NC 27560, haselow@redox-tech.com

⁴ dos Santos, S.G.; Varesche, M.B.A; Zaiat, M.; Foresti, E. Comparison of methanol, ethanol, and methane as electron donors for denitrification, Environ. Eng. Sci. 2004, 21, 313-320.

Table 1. Kinetic Constants for Denitrification in Soils

Rate Constant (1/hr)	Condition	Reference
0.1 – 0.4	Petroleum contaminated aquifer	Schroth et al., 1998
0.2 – 0.3	Petroleum contaminated aquifer	McGuire et al., 2002
~0.2 – 0.6	Denitrification wall with carbon source	Schipper et al., 2005
0.01 – 0.2	River plain, no carbon supplement	Sjodin, et al., 1997
0.01	In-stream sediment in agricultural watershed, no carbon supplement	Böhlke et al., 2004

A number of factors are important in controlling the kinetics of denitrification including oxygen, nutrient availability, temperature, pH, and the presence of inhibitory compounds. Because NO_3^- serves as the terminal electron acceptor, denitrification requires anoxic conditions and an oxidation-reduction potential (ORP) of approximately 750mV or lower; oxygen, which competes with nitrate as an electron acceptor in the energy metabolism of cells, can have an inhibitory effect.

Denitrification has been shown to occur in natural aquifer systems^{5, 6, 7} although, without addition of electron donor, the reaction may proceed very slowly. Investigators have shown that the injection of various substrates and nutrients into aquifers can enhance *in-situ* biological denitrification^{8, 9}. A review of enhanced *in-situ* denitrification projects found that although significant denitrification can be achieved, the rates of nitrate removal can be slow. Additionally, it may be difficult to control injection of solutions in aquifers that lack homogeneity and isotropy¹⁰. These difficulties can be overcome by intercepting the nitrate plume and denitrifying the groundwater in an anoxic denitrifying wall (or trench). This technology has been used to remove nitrate from shallow groundwater underlying land where spray irrigation is used for final disposition of treated wastewater effluent¹¹.

Although rate constants have been reported for subsurface denitrification, removal rates are more widely used for designing denitrification walls. These values are used to estimate residence times for design of denitrification walls because for specific types or mixtures of wall materials. Denitrification rates for natural systems and anoxic walls using various carbon sources are shown in Table 2.

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- 5 Addy, K.; Gold, A.; Nowicki, B.; McKenna, J.; Stolt, M.; Groffman, P. Groundwater denitrification in a New England Fringing Salt Marsh. *Estuaries*. Submitted.
- 6 Smith, R.L.; Böhlke, J.K.; Garabedian, S.P.; Revesz, K.M.; Yoshinari, T. Assessing denitrification in groundwater using natural gradient tracer tests with ^{15}N : In situ measurement of a sequential multistep reaction. *Water Resour. Res.* 2004, 40, W07101.
- 7 Tesoriero, A.J.; Liebscher, H.; Cox, S.E. Mechanism and rate of denitrification in an agricultural watershed: Electron and mass balance along groundwater flow paths. *Water Resour. Res.* 2000, 36, 1545-1559.
- 8 Mercado, A.; Libhaber, M.; Soares, M.I.M. In-situ biological groundwater denitrification concepts and preliminary field tests. *Wat. Sci. Technol.* 1988, 20, 197-209.
- 9 Janda, V.; Wanner, R. J.; Marha, K. In-situ denitrification of drinking water. *Wat. Sci. Tech.* 1988, 20, 215-220.
- 10 Matějů, V.; Čížinská, S.; Krejčí, J.; Janoch, T. Biological water denitrification – A review. *Enzyme Microb. Technol.* 1992, 14, 170-183.
- 11 Schipper, L.A.; Barkle, G.F.; Vojvodic-Vukovic, M. Maximum rates of nitrate removal in a denitrification wall. *J. Environ. Qual.* 2005, 34, 1270-1276.

Table 2. Denitrification Rates in Anoxic Walls using Various Carbon Sources.

System and Location	Residence Time (days)	Nitrate Input	Denitrification Rate (gN/m ³ ·d)	Reference
Riparian Zone Aquifer Rhode Island, USA	Not Reported	Not Reported	3.5	Tesoriero et al., 2000
Agricultural Aquifer, Canada	Not Reported	< 30 mg/L	3.8	Addy et al., 2002
Sawdust Wall (30%) New Zealand	1 – 10	5.9 gN/m ³	0.014 – 0.43	Schipper and Vojvodic-Vukovic, 2001
Sawdust Wall (20%) Canada	10 – 13	34 gN/m ³	2.4	Robertson et al., 2000
Sawdust Wall (15%) Canada	17 – 40	57 gN/m ³	2.6	Robertson et al., 2000
Sawdust Wall (15%) Canada	15 – 30	1.2 gN/m ³	0.7	Robertson et al., 2000
Garden Mulch (100%) Canada	0.01 – 0.03	4.8 gN/m ³	5 - 30	Robertson et al., 2000
Woodchip Wall (100%) Iowa, USA	Not Reported	25 gN/m ³	0 – 0.24	Jaynes et al., 2002
Sawdust Wall (30%) Australia	3 – 7	62 gN/m ³	15	Fahrner, 2002

CURRENT SITE CONDITIONS AND ANALYSIS

A Comprehensive Site Assessment was performed at the Almont Shipping Terminal Site (the Site), located in Wilmington, NC. Some of the important geologic properties of the underlying aquifer relevant to conceptual design of a denitrification trench are summarized below.

- Average Hydraulic Conductivity = 1.22 ft/d generally in the SW direction
- Vertical Gradient = 0.0066 and 0.0077 ft/ft, measured in May 2005 and June 2005, respectively
- Horizontal Gradient = 0.022 and 0.023 ft/ft, measured in May 2005 and June 2005, respectively

Monitoring well data collected in May 2005 are shown in Table 3. Because total nitrogen concentrations reported for groundwater are comprehensive of all forms of nitrogen, these results were used to estimate concentration isopleths for the contamination plume (Figure 1). Assuming that the nitrogen contours reflect concentrations through approximately 10 feet of groundwater in a sand aquifer with porosity (*n*) of approximately 0.2, the plume area and total nitrogen mass were estimated. From this model, the nitrogen plume was estimated to be approximately 1500 feet long (N to S) and 900 feet wide (E to W) covering approximately 26 acres; the total nitrogen mass in the plume was estimated to be approximately 77,000 lbs. Approximately 75 % of the plume is concentrated in 5 acres immediately downgradient of the release area. The location of a proposed denitrification wall, located between Brunswick Street and Harnett Street approximately 75 feet west of Nutt Street (Figure 1), is approximately at the 2500 mg/L total nitrogen isopleth.

Table 3. Results for Groundwater Sampling Conducted in May 2005.

Monitoring Well Location	Ammonia (mg/L NH ₃ ⁺ as N)	Chloride (mg/L as Cl)	Nitrate + Nitrite (mg/L NO ₃ ⁻ +NO ₂ ⁻ as N)	Phosphorus (mg/L as P)	Sulfate (mg/L as SO ₄ ²⁻)	Total Kjeldahl Nitrogen (mg/L as N)	Total Nitrogen (mg/L as N)
MW-1	8.4	9.5	ND	0.94	58	91	91
MW-2	0.6	10	1.54	2.57	106	4.5	6
MW-3	86.2	135	59.1	0.49	538	115	184
MW-4	1,123	245	59.1	4.51	620	1,154	1,213
MW-5	0.7	2,185	0.64	0.48	302	3.9	4.5
MW-6	24.1	1,354	ND	0.72	29	44.8	44.8
MW-7	7.6	3,491	0.05	1.73	ND	8.4	8.4
MW-8	4.6	20,901	ND	0.35	260	10.6	10.6
MW-9	2.2	290	ND	1.65	128	6.7	6.7
MW-10	1,820	712	27	5.07	585	2,100	2,244
MW-12	35.6	428	44	0.13	94	37.8	88.1
MW-13	284	6,888	28.7	0.16	730	297	344
MW-14	2,919	7,838	614	0.91	1,710	3,332	4,285
MW-15	3,180	14,726	317	5.21	2,790	3,920	4,250
MW-16	23.9	176	ND	2.5	158	29.1	29.1
LM-13	0.4	18.5	3.15	0.94	33	2	5.2
DW-1	1.7	89	ND	0.15	16	6.2	6.2
DW-2	2,394	2,209	188	3.49	392	3,780	4,075

Design of a denitrification wall is dependent primarily upon the hydraulic detention time required to meet the desired removal of nitrate. A first order reaction rate model can be used to derive the design parameters for a denitrification wall for a given set of conditions. In this conceptual design, both the total mass of nitrate to be treated and the influent or initial nitrate concentration were estimated from monitoring well data collected in May 2005. If all of the nitrogen in the plume can be converted to nitrate, upgradient of the proposed location for the denitrification wall, then it may be assumed that the total nitrogen values can be used to approximate the mass and initial concentration of nitrate to be treated at a denitrification wall. Thus, the assumption that 77,000 lbs total nitrogen mass will require treatment with an initial concentration of 2500 mg/L nitrate.

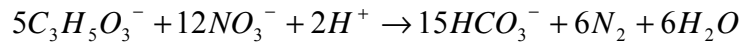
Understanding that rate constants for very high initial nitrate concentrations have not been reported, midrange kinetic constants will be used to estimate required reaction times for a denitrification wall at the Almont Site. Using the initial concentration of 2500 mg/L and a final concentration of 10 mg/L nitrate and a kinetic constant of 0.4/hr which is a midrange value reported for denitrification¹², the required reaction time in a denitrification wall should be on the order of 14 hours. Using the same approach, a matrix of conditions was evaluated; results are shown in Table 4, yielding a range of values of 2 – 55 hours. The reaction times, calculated using a first-order kinetic model, are consistent with residence times reported for denitrification walls in Table 2.

¹² Schipper, L.A.; Barkle, G.F.; Vojvodic-Vukovic, M. Maximum rates of nitrate removal in a denitrification wall. J. Environ. Qual. 2005, 34, 1270-1276.

Table 4. Summary of Reaction Times in a Denitrification Wall

Initial Nitrate Concentration (mg/L)	Final Nitrate Concentration (mg/L)	Kinetic Constant (hr ⁻¹)	Reaction Time (hr)
2500	10	0.4	14
2500	2	0.4	18
2500	1	0.4	20
2500	10	0.1	55
2500	10	1	5
250	10	0.1	32
250	10	1	3
100	10	0.1	23
100	10	1	2

The total mass of nitrogen present in the Site plume has been estimated at just over 77,000 lbs. If the entire mass of nitrogen can be converted into nitrate, then the stoichiometric amount of carbon (based on sodium lactate as the carbon source) will be approximately 264,000 lbs of sodium lactate.



Because this is a large amount of sodium lactate, it may be most cost effective to utilize a solid carbon source in the denitrification wall (e.g., sawdust, straw bales, soybeans, mulch); however, provision will be required for external dosing of carbon due to the fact that the solid carbon in the trench will degrade over time. In addition to reducing the amount of sodium lactate solution required for nitrate conversion, use of a carbon source can provide a buffer for potentially inhibitory compounds.

Because nitrate is nonsorptive, it does not exchange on sediment surfaces in the vadose zone and has a low probability of retardation onto soil colloids, thus, it tends to move unhindered through a soil profile¹³. The result is that nitrate solutions move through soils at virtually the same rate as the wetting front in the vadose zone or with groundwater flow. In order to prevent short-circuiting of the reactive wall, a material with a higher hydraulic conductivity than the surrounding aquifer material should be used to construct the wall. In practice, installation of permeable reactive barriers as horizontal layers in the shallow water table zone do not necessarily have to penetrate the full depth of a contaminant plume to be effective¹⁴.

CONCEPTUAL DESIGN

The final recommendation for treatment of the Site is design and construction of a carbon amended denitrification wall (Figure 2) in conjunction with carbon pretreatment of the nitrified contaminant plume. Although there have not been reports of *in-situ* treatment of the high

¹³ Bohn, H.; McNeal, B.; O'Connor, G. 1979. Soil Chemistry. John Wiley & Sons, New York, NY.

¹⁴ Robertson, W.D.; Blowes, D.W.; Ptacek, C.J.; Cherry, J.A. Long-term in-situ barriers for nitrate remediation. Ground Water, 2000, 38, 689-695.

concentrations of nitrate that would potentially be encountered at the Site, there is evidence that high concentrations are not inhibitory to denitrification occurring in bioreactors^{15, 16, 17, 18}. Additionally, some researchers provide evidence that chemically, the denitrification rate would be more favorable at higher initial concentrations of nitrate. In general, studies that evaluated higher initial concentrations of nitrates did report that the reaction kinetics were increased when compared to lower initial concentrations¹⁹. Pretreatment of high nitrate concentration areas via injection of a carbon amendment should initiate denitrification in upgradient portions of the plume; interception of the plume by the denitrification wall would allow for the anoxic trench to be used as a “polishing” step.

The primary design parameters and potential process limitations for the denitrification trench proposed for the Almont Shipping Terminal Site are summarized below.

- Provide for $7 \geq \text{pH} \geq 8$ in the denitrification wall
- Provide a minimum C:N ratio > 1 via a combination of solid carbon in the trench and liquid dosing in the denitrification wall; excess carbon (20 – 40%) may be necessary to ensure that conditions in the wall are anoxic, i.e., $\text{ORP} \leq 750 \text{ mV}$
- Construct the denitrification wall with a hydraulic residence time ≥ 3 days
- Potential inhibitory effects that should be a consideration based on site conditions are listed below presence of sulfides;
 - presence of high salinity;
 - presence of hypochlorous acid (which could form if peroxide is used to convert urea to nitrate) can limit denitrification due to direct lethal effects to microorganisms or reduction in pH;
 - denitrification may slow or stop if the reaction becomes carbon limited; and,
 - short-circuiting may limit denitrification if the denitrification wall becomes clogged due to swelling of solid carbon source material or biofouling.

ADDITIONAL APPLICATIONS FOR DENITRIFICATION TRENCH TECHNOLOGY

Passive denitrification systems are currently used to treat nitrate contaminated water from shallow groundwater underlying land where spray irrigation is used for final disposition of treated wastewater effluent. If it can be demonstrated that this same technology can address nitrate contamination at concentrations present at the Almont Shipping Terminal Site, then this type of low cost system could be used to treat contaminated groundwater from other sources such as Confined Animal Feeding Operations (CAFOs) which have limited economical methods for dealing with high nutrient wastes.

¹⁵ Glass, C.; Silverstein, J. Denitrification of High Nitrate, High-Salinity Wastewater. *Wat. Res.*, 1999, 33, 223–229.

¹⁶ Glass, C.; Silverstein, J. Denitrification kinetics of high nitrate concentration water: pH effect on inhibition and nitrite accumulation. *Wat. Res.*, 1998, 32, 831–839.

¹⁷ Veydovec, W.; Silverstein, J.; Cook Jr., N.; Figueroa, L.; Hund, R.; Lehmkohl, G. 1994. Denitrification Inhibition by High Nitrate Wastes. Proceedings of the ASCE National Environmental Engineering Conference. New York, NY, 415–422.

¹⁸ Chen, S.; Juaw, C.; Cheng, S. Nitrification and denitrification of high strength nitrite wastewater with biofilm reactors. *Wat. Sci. Tech.*, 1991, 23, 1417–1425.

¹⁹ Robertson, W.D.; Cherry, J.A. In situ denitrification of septic-system reactive porous media barriers: field trials. *Ground Water*, 1995, 33, 99-111.

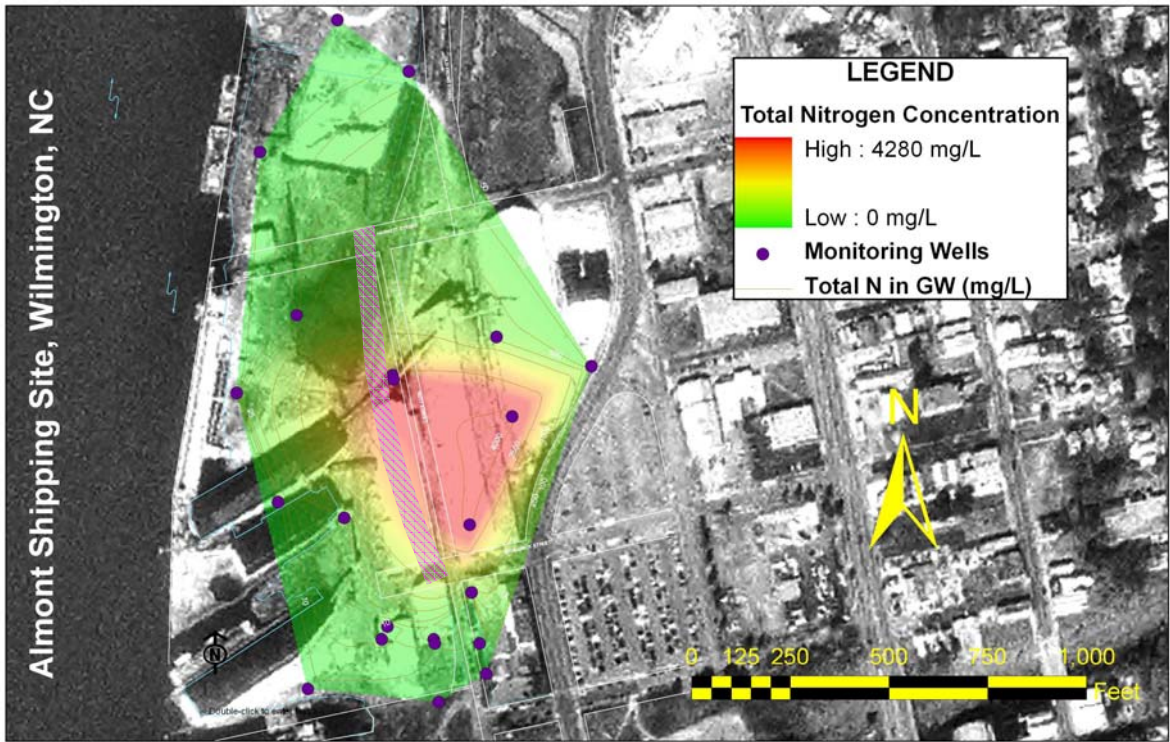


Figure 1. Almont Shipping Terminal Site

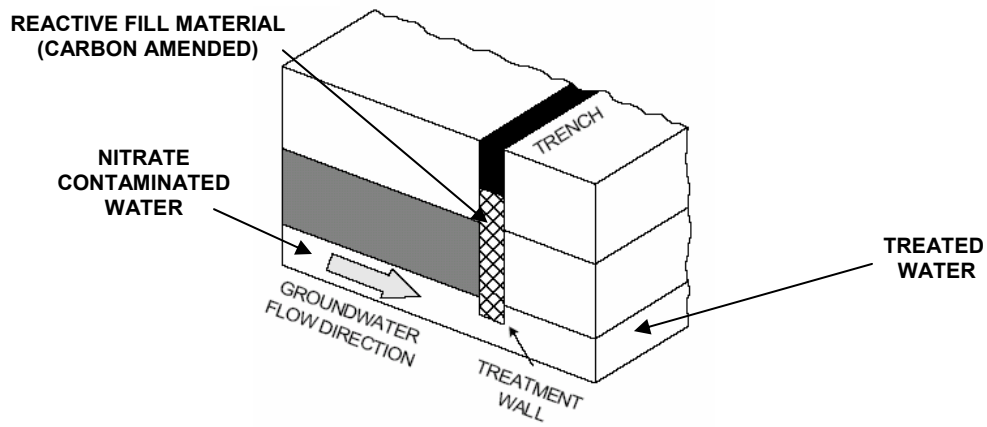


Figure 2. Conceptual Design of *In-Situ* Denitrification Trench

QUANTIFYING PEROXIDE-ENHANCED BENZENE AND TOLUENE BIODEGRADATION IN A SINGLE-WELL INJECTION

Lashun King^{1*}, Roger Painter¹, Gregg Hileman², and Tom D. Byl^{2,1}

Published research has shown that that anaerobic biodegradation of toluene is generally 50 times slower than aerobic biodegradation. Because of the potential for the rapid transport of dissolved contaminants in karst conduits, aerobic conditions are needed to enhance bioremediation. This study was divided into three phases. The objective of the first phase was to evaluate oxygen-release compounds (ORCs) to enhance fuel biodegradation by free-living bacteria found in karst aquifers. The objective of the second phase was to develop a numerical method to quantify the rate of enhanced biodegradation using a single well for injection and monitoring. The third phase applied the findings of phase 1 and 2 to a field trial.

In the first phase of this study, the ORCs evaluated were hydrogen peroxide (H_2O_2), calcium peroxide (CaO_2), and magnesium peroxide (MgO_2). The H_2O_2 molecules break down into oxygen (O_2) and water (H_2O). The CaO_2 and MgO_2 break down in the presence of water into O_2 and either $CaOH$ or $MgOH$, respectively. In this study, 2.25-liter liquid-karst microcosms (for example, flasks containing water and free-living karst bacteria) were spiked to 100 micrograms per liter ($\mu g/L$) toluene, and different ORC concentrations were added. Sterile controls were established with toluene and ORCs to verify that toluene removal resulted from biological processes. Additional controls with live bacteria, but no ORC supplements, also were established for comparison. Microcosms enriched with 3 milligrams per liter (mg/L) H_2O_2 , CaO_2 , or MgO_2 all showed greater than 95 percent toluene removal in 7 days, as compared to 45 percent removal in live microcosms with no ORCs. When the microcosms were enriched with 300 mg/L H_2O_2 , CaO_2 , or MgO_2 , only the H_2O_2 treatment elicited a reduction in toluene of greater than 99 percent in 7 days. The other peroxide treatments had slightly enhanced toluene removal compared to the live control, but generally were not effective at this higher concentration. The decline in MgO_2 and CaO_2 performance possibly was caused by the simultaneous release of hydroxide that has been found to inhibit biodegradation processes.

In the second phase of the study, a numerical method capable of quantifying biodegradation was developed by coupling the equation for residence-time distribution (RTD) to a first-order rate of biodegradation (k'). This numerical method was evaluated in a laboratory simulation. The simulation included a single-well injection of H_2O_2 and sodium chloride (conservative tracer) into a 5-gallon carboy containing karst water with 100 $\mu g/L$ toluene. The carboy was connected to a pump that delivered a constant flow of fresh bacteria-containing karst water (3 milliliters per minute) through the 5-gallon carboy, thereby diluting and transporting the conservative tracer from the carboy. The toluene also was diluted and transported from the carboy, but was subject to biodegradation processes since it is a non-conservative chemical. The rate of toluene removal predicted by the numerical model and the observed rate of removal in the experiment were within close agreement (18 percent), confirming the numerical approach.

The third phase of this study was conducted to determine if a numerical model incorporating RTD coupled to a k' could be used to quantify toluene and benzene removal from a karst aquifer using a single well injection system. This study involved injecting sodium chloride ($NaCl$) as a

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conservative tracer, as well as H_2O_2 , to enhance aerobic biodegradation. The RTD-biodegradation formula predicted benzene and toluene concentration in the well through time to within 1 $\mu\text{g/L}$ of the actual concentration.

NORTH POTATO CREEK IN-PIT WATER TREATMENT PLANT AT THE COPPER BASIN MINING SITE

Griff Wyatt, P.E.¹ and Franklin Miller, P.E.²

INTRODUCTION

The Copper Basin Mining Site is the site of extensive metals and copper mining and sulfuric acid production dating back to the mid-1800s. These historic mining and related activities have resulted in environmental degradation in the Basin. Although various government agencies and private parties have taken steps to revegetate the area, the Copper Basin continues to be affected by the presence of mining materials and mineral processing by-products, and continued releases of acidic, metal-laden water. In order to address these environmental concerns, OXY USA, Inc. and its subsidiary Glenn Springs Holdings, Inc. (OXY/GSH), the US Environmental Protection Agency (USEPA), and the Tennessee Department of Environment and Conservation (TDEC) agreed to conduct a cooperative, voluntary environmental remediation and redevelopment of the Copper Basin as outlined in an Agreement on Consent (AOC).

Part of this agreement was to develop and implement interim actions reducing contaminant loading to the Ocoee River so that immediate progress in improving ecological health could be realized while a phased approach of long-term remedial actions are identified and implemented in upper parts of the watershed. OXY USA, Inc. is conducting removal actions to reduce contaminant discharges from the creeks draining the two watersheds comprising the Site. One such action is construction of an innovative in-pit lime treatment facility designed to treat North Potato Creek (NPC) flows prior to its confluence with the Ocoee River.

The NPC Water Treatment Plant (NPCWTP) was constructed to address and alleviate contaminant discharge from NPC into the Ocoee River while long-term work and study are proceeding upstream in the NPC Watershed. The NPCWTP was designed and constructed based on results of an Engineering Evaluation/Cost Analysis (EE/CA)³ prepared pursuant to an AOC between USEPA Region 4 and OXY/GSH. In the EE/CA, flow measurements, field parameter measurements, and sampling were performed to characterize NPC and the South Mine Pit (SMP). Following site characterization, alternatives for addressing the objectives of the AOC were developed and evaluated. This paper describes the design, operation, and performance results of the selected alternative, in-pit treatment, for the NPCWTP.

SITE DESCRIPTION

The Copper Basin is comprised of two watersheds, the North Potato Creek and Davis Mill Creek (DMC) Watersheds, both of which confluence with the Ocoee River. NPC drains approximately 9,700 acres and flows through the SMP, located 0.4 mile above the confluence of the NPC with the Ocoee River. The SMP is an abandoned surface mine with a surface area of approximately 20 acres. The SMP is approximately 1,800 feet long by 480 feet wide and has a maximum depth of

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³ Barge, Waggoner, Sumner, and Cannon; MFG – Shepherd Miller; Edge Group, 2003, Final Engineering Evaluation / Cost Analysis for North Potato Creek Watershed Ducktown, Tennessee.

approximately 200 feet with an estimated water volume of 550,000,000 gallons. In 1991, NPC was routed through the SMP; this was done to allow sediments to settle in the pit before the NPC entered the Ocoee River.

The annual average flow of NPC, including base and storm flows, at the inlet and outlet of the SMP is 8,160 gpm and 8,920 gpm, respectively. The difference in flow between the inlet and outlet can be attributed to groundwater, rainfall, and surface runoff. The 10-year, 24-hour storm flow for NPC at the inlet of the SMP is 436,000 gpm. Water quality parameters of NPC at the inlet of the SMP have average values of 5 s.u. for pH, an acidity of 23 mg/L (as CaCO₃) and dissolved iron of 10 mg/L; corresponding values at the SMP outlet are 3.3 s.u., 37 mg/L and 3.6 mg/L, respectively. Other dissolved metals present in NPC at lower concentrations include aluminum, cadmium, cobalt, copper, lead, manganese, zinc.

Water quality in the SMP varies with depth. The upper layer is characterized by a low density, low specific conductance water. At lower depths, the water has a higher density and higher specific conductance. The specific conductance throughout the depth of the pit is depicted in Figure 1. This figure depicts the existence of a chemocline at a depth of 23 to 26 feet. This narrow layer of water shows a sharp change in specific conductance indicative of the marked differences in chemistry between the upper and lower layers of the pit. Coincident temperature stratification has also been measured. The pH, acidity, and dissolved iron in the upper layer of the pit were found to be 3.4 s.u., 37 mg/L, and 3.7 mg/L, respectively; values for these parameters measured at the outlet of the pit into NPC are essentially the same as those in the upper layer. The pH, acidity, and dissolved iron values in the lower layer of the pit were found to be 4.7 s.u., 870 mg/L to 1,270 mg/L, and 530 mg/L to 640 mg/L. The potential of the South Mine Pit to turn over or become mixed was a major consideration in the design of the NPCWTP because a loss of stratification could potentially result in degradation of water quality in North Potato Creek below the pit and downstream in the Ocoee River⁴.

NPCWTP DESIGN AND OPERATION

The NPCWTP design and operation is described in this section and is depicted schematically in Figure 2. The NPC pump station, located upstream of the SMP, pumps 3,000 gpm of NPC flow to the rapid mix tank where hydrated lime is added to raise the pH of the water. Following lime addition, the 3000 gpm of water from the rapid mix tank discharges into NPC downstream from the NPC pump station and combines with the remaining NPC flow. The NPC pump station, rapid mix tank, and lime silo are shown in Figure 3. Lime is added to the rapid mix tank at sufficient rates to raise the pH of the combined NPC flow to a pH that will precipitate iron and other dissolved metals. Mixing and flocculation occur as the combined rapid mix tank discharge and NPC water flow 800 feet downstream and discharge into the north end of the SMP. The SMP serves as a large settling pond where precipitated solids settle prior to discharge from the south end of the SMP. Laboratory and full-scale field studies conducted prior to construction of the NPCWTP indicated that the SMP would remain stratified after treatment began creating a high pH layer of treated water overlying the lower pH and high dissolved solids water in the lower layer of the pit. Studies also confirmed that precipitated solids would settle through the

⁴ Colarusso, L.A., J.A. Chermak, J.C. Priscu, and F.K. Miller. 2003. "Modeling pit lake water column stability using Ce-Qual-W2." In Proceedings of the Tenth International Conference on Tailings and Mine Waste. Vail, Colorado. October. A.A. Balkema, Rotterdam.

chemocline. The geochemical reactions occurring during laboratory and field treatment studies are further described by Chermak, et. al.⁵.

In addition to lime feed, high dissolved solids water pumped from the lower layer of the SMP may be added to the rapid mix tank as seed water for iron flocculation. Although sufficient dissolved oxygen is typically present in the NPC flow to oxidize the dissolved iron in NPC, a cascade aerator is incorporated into the design at the discharge from the rapid mix tank into NPC. Additionally, a blower is available to provide oxygen to the rapid mix tank during periods of low flow and/or dissolved oxygen in NPC.

Rapid Mix Tank

The rapid mix tank uses a tangential feed configuration. Water from the NPC pump station is tangentially discharged into the base of the rapid mix tank at high velocity that causes centrifugal mixing in the tank. Water discharges from the top of the rapid mix tank through a pipe to NPC. Although not normally required, the blower is available to supplement mixing in the tank.

Lime Feed System

Lime is fed by volumetric feeders in the lime silo. NPC water is utilized for dissolving the hydrated lime. A pipe branches from the NPC pump station discharge prior to the pipe connection to the rapid mix tank. The branch pipe carries 200 gpm of NPC water to the lime dissolving tank located in the lime silo. NPC water continually discharges at the 200 gpm flow rate into the lime dissolving tank where hydrated lime is fed at varied rates as required to raise the pH in NPC. The resulting lime solution overflows the lime dissolving tank and flows into a trough that discharges into the rapid mix tank. The trough discharges into a vertical pipe that feeds lime solution into the base of rapid mix tank at the NPC pump station discharge pipe location. The high velocity of the NPC pump discharge into the rapid mix tank causes the lime solution to be mixed in the lower portion of the rapid mix tank.

pH Control System

The pH control system for the NPCWTP is designed to be operated either manually or automatically. The lime feed rate is based on maintaining set pH values at two locations, monitoring station SW8 at the SMP inlet and monitoring station SW9, at the discharge from the SMP. Because the upper layer of the pit is chemically homogeneous, pH values and dissolved metals concentrations in the upper layer of the pit are the same as at monitoring station SW9.

The pH and acidity in NPC upstream of the SMP varies widely, depending upon several factors but primarily on NPC flow. During precipitation events, pH in NPC initially decreases and the acidity increases. Consequently, lime feed must be increased to maintain the desired pH as storm flows increase. High storm flows in NPC create the greatest demand for lime to maintain the desired pH at both monitoring locations. The pH may increase rapidly at SW8 during rain events; however, due to the large buffering capacity provided by the 200 million gallon volume in the upper layer of the SMP, pH at SW9 does not increase as rapidly and the lime feed rate can be adjusted to maintain a relatively constant pH from the pit discharge and consequently from NPC to the Ocoee River.

⁵ Chermak, J.A., B. Wielinga, G. Wyatt, and J. Taylor. 2004. "Cost-effective acid rock drainage water treatment applied to mining-impacted watersheds." The American Society of Mining and Reclamation.

Contingency Measures

As previously discussed, destratification was a concern in the design of the NPCWTP. Although laboratory and pilot studies indicated that the pit stratification should remain stable, concerns regarding adverse impacts from discharge of deep pit water to the Ocoee River necessitated development of contingency measures. Contingency measures included construction of a diversion ditch, which would allow the NPC to flow around the SMP, and a means to halt discharge from the pit. Additionally, contingency measures include a pump system to recycle pit water from the discharge end of the pit back to the treatment plant for additional treatment. During normal operations, NPC water flows through the diversion structure located in NPC. During contingency operations, the sluice gates at the diversion structure are closed, diverting water around the SMP, and the recycle system pumps water back to the treatment plant for additional treatment. This measure is kept in place until water quality in the upper layer of the pit is of acceptable quality to resume discharge from the south end of the pit.

System Monitoring

The NPCWTP monitoring system is a PLC-based system including flow and water quality measurement equipment. The system provides continuous measurement of a number of parameters and includes alarm functions when selected parameters fall outside a desired range. Flow is measured at the inlet and outlet of the SMP, at the discharge to the rapid mix tank, and from the pump discharge from lower layer of the SMP to the rapid mix tank. Specific conductivity and pH are measured at SW8 and SW9. The NPCWTP system also monitors water quality parameters in upper and lower layers of the SMP. This system features two Hydrolab® sondes that provide continuous measurement of pH, specific conductance, oxidation-reduction potential, temperature, and dissolved oxygen. Each Hydrolab® is suspended from a buoy; one sonde is suspended in the upper layer and the other in the lower layer of the pit. Continuous Hydrolab® measurements are transferred to the control room at the NPCWTP by solar powered radio transmitters on each buoy. This portion of the monitoring system is designed to monitor the SMP for changes in water quality that may indicate pit destratification. Figure 4 depicts pit configuration and monitoring locations.

Construction and Operation and Maintenance Cost

The construction cost, operation and maintenance cost, and the treatment cost per 1000 gallons for the NPCWTP are provided in Table 1. The estimated cost for a conventional water treatment plant to accomplish comparable treatment of NPC is also provided.

Table 1. Water Treatment Costs

COST	NPCWTP and Infrastructure	Conventional WTP
<i>Construction Costs</i>	\$4,000,000	\$25,000,000
<i>Annual O&M Cost</i>	\$400,000	\$1,300,000
<i>Treatment Cost per 1000 Gallons</i>	\$0.085	\$0.24

PERFORMANCE RESULTS

Operation of the NPCWTP began January 10, 2005. Daily field measurements of dissolved iron have been performed at the pit discharge since plant operations began. These results are shown in Figure 5. Samples were also collected for laboratory analysis at two week intervals. Results for aluminum and zinc are presented in Figures 6 and 7, respectively. Removal rates of copper, cadmium, manganese, lead and cobalt are shown in Table 2. The largest NPC storm flow treated

to date by the NPCWTP is 48,000 gpm. The concentrations of each constituent are compared to the average concentrations measured during the EE/CA conducted during 2001 and 2002.

Based on the laboratory results at monitoring location SW9 and the average annual flow rates measured during the EE/CA, loading removal calculations were performed and are presented in Table 2. These loading calculations indicate that dissolved metals daily average loading reductions to the Ocoee River of 790 lbs. per day and over 290,000 lbs. annually are being achieved.

CONCLUSIONS

The in-pit treatment system utilized at the North Potato Creek site has proven to be a cost effective alternative to conventional lime treatment for treatment of large and highly variable acid mine drainage flows. The treatment system accomplishes a high level of treatment for large acid mine drainage flows without construction of the large infrastructure typically necessary to treat such large flows. The design concepts and construction details utilized may have applicability for addressing other acid mine drainage flows.

ACKNOWLEDGEMENTS

This work, including initial studies, engineering design, and construction was funded by Glenn Springs Holdings, Inc., a subsidiary of Occidental Petroleum.

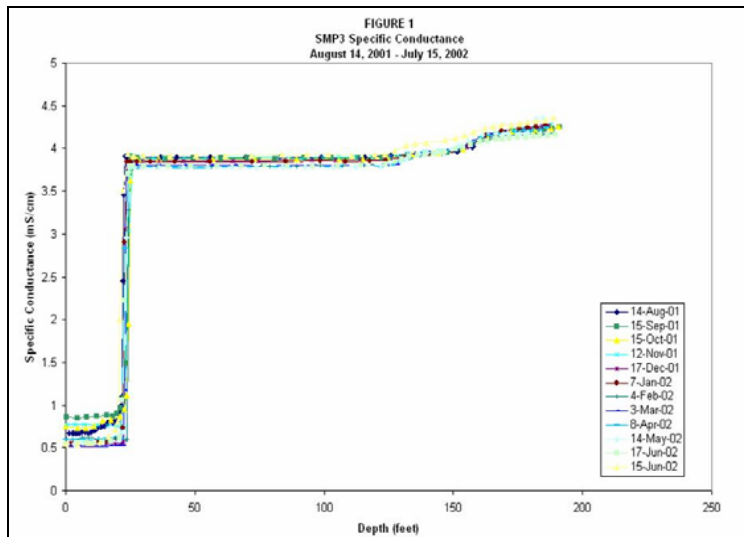


Figure 1. SMP Specific Conductance, August 2001 – July 2002



Figure 3. NPC Water Treatment Plant

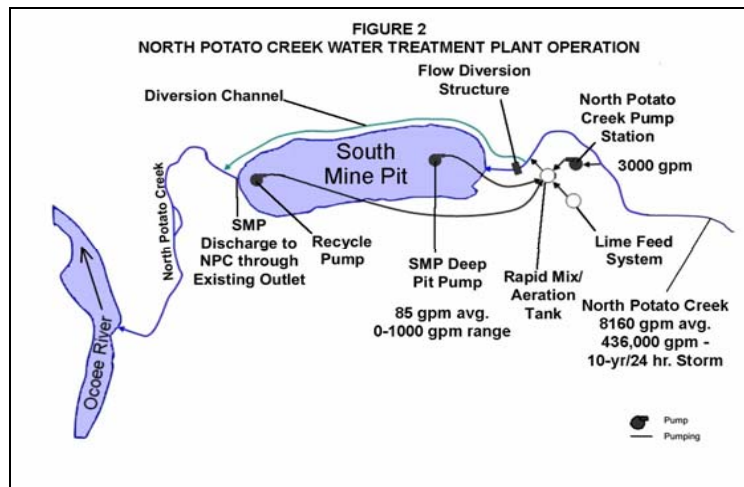


Figure 2. Conceptual Design of NPCWTP Operation



Figure 4. SMP Monitoring Locations

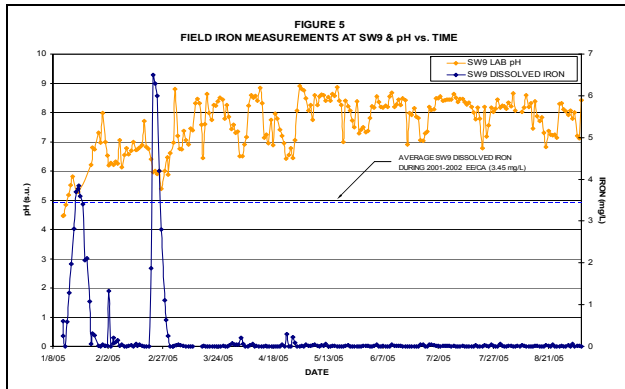


Figure 5. Field Iron and pH at SW9

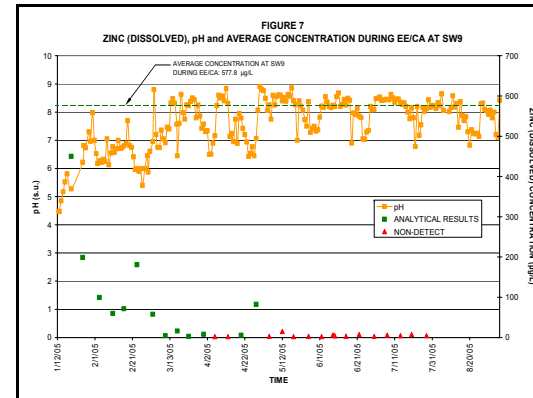


Figure 7. Zinc (Dissolved), pH and Average Concentration during EE/CA at SW9

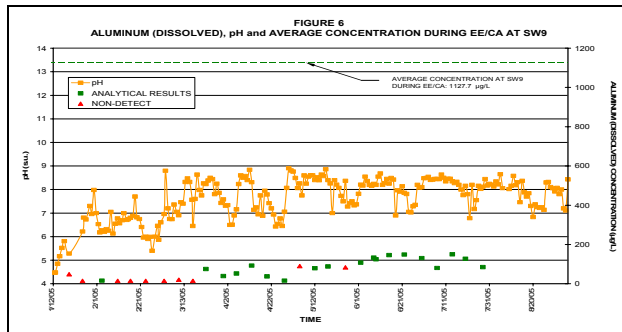


Figure 6. Aluminum (Dissolved), pH and Average Concentration during EE/CA at SW9

Table 2. Loading Reductions at SW9

Dissolved Analyte	Average Concentration at SW9 (µg/L)		Removal (%)	Loading Reduction at SW9 based on Average Flow	
	During EE/CA	After Start-Up		Daily (lbs)	Annual (lbs)
Aluminum	1100	74	93.4	130	47,000
Copper	110	1.0	99.0	13	4,700
Iron	3,500	43	98.8	420	150,000
Zinc	580	26	95.6	68	25,000
Cadmium	0.70	0.08	88.7	0.10	28
Manganese	2,500	1,200	52.8	160	58,000
Lead	5.7	0.06	98.9	0.70	250
Cobalt	24	5.5	77.3	2.3	840
Total				790	290,000

SESSION 2B

WATERSHED INVESTIGATIONS

8:30 a.m. – 10:00 a.m.

Implementation of the Corps Water Management System (CWMS) in U.S. Army Corps of Engineers, Nashville District
William R. Barron, Jr.

Descriptive Statistics for Raw Water Data from Water Treatment Facilities in the Nolichucky River Basin, Northeast Tennessee
Randy M. Curtis

Impacts of Urbanization on Habitat Quality and Fisheries in a Ridge and Valley Watershed: Implications for Stream Rehabilitation Planning
Robert L. Sain and John S. Schwartz

WATERSHED PARTNERSHIPS I

10:30 a.m. – 12:00 p.m.

Tennessee Valley Authority's Water Quality Initiatives Process
Tom McDonough

Addressing Water Quality Issues of Oostanaula Creek Through Water Resource Partnerships
Linda B. Harris

Boone Initiative: A Watershed Approach to Improve Reservoir Health
T. Shannon O'Quinn

WATERSHED PARTNERSHIPS II

1:30 p.m. – 3:00 p.m.

The Beaver Creek Watershed Partnership Overview and Watershed Plan
Roy A. Arthur and Liz Bouldin

The Beaver Creek Watershed Partnership: Education and Outreach
Ruth Anne Hanahan

Use of a Dynamic Sediment Delivery Model for Watershed Planning in Beaver Creek, Knox County, Tennessee
Shannon E. Bennett and John S. Schwartz

WATERSHED PARTNERSHIPS III

3:30 p.m. – 5:00 p.m.

Little River Watershed Initiative
Tom McDonough and Eric Henry

The Stock Creek Watershed Restoration Plan
Roy Arthur, Jim Hagarman, and Alice Layton

Bullrun Creek Restoration Initiative
Todd L. Reed and Melinda A. Watson

IMPLEMENTATION OF THE CORPS WATER MANAGEMENT SYSTEM (CWMS) IN U.S. ARMY CORPS OF ENGINEERS, NASHVILLE DISTRICT

William R. Barron, Jr.¹

ABSTRACT

Nashville District is in the process of implementing the Corps Water Management System (CWMS). The Corps Water Management System is the data acquisition, management, modeling, and decision support system that assists the Corps in its water management mission of regulating more than 500 dam and reservoir projects. CWMS is a nationwide integrated system of hardware, software, and other resources that acquires, analyzes, and stores data; develops decision support information; and allows user access to any data and information on the system.

This paper will describe the progress that Nashville District has made in implementation of CWMS. Major emphasis will be placed upon the modeling portion of the implementation, but some emphasis will be placed upon the data acquisition and management part of the software.

Data acquisition is real-time. Data dissemination uses web based technology. The database consists of Oracle and Data Storage System (DSS) files. Forecasting is based upon National Weather Service, Nexrad, Stage3 rainfall radar. The meteorological model and the hydrological model (HEC-HMS) are grid based models that are tied to geographic information system (GIS) data. Operation of the dams is done within a model called the Reservoir Simulation System (ResSim). Flow is routed using the River Analysis System (HEC-RAS), unsteady flow model. Inundation mapping is created based upon the HEC-RAS water surface elevations. Flood damage impacts are determined from first floor elevations of structures in the floodplain.

CWMS is an integrated, active suite of software. It is designed to provide the user with a multitude of graphical options for making operational decisions.

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DESCRIPTIVE STATISTICS FOR RAW WATER DATA FROM WATER TREATMENT FACILITIES IN THE NOLICHUCKY RIVER BASIN, NORTHEAST TENNESSEE

Randy M. Curtis, R.P.G.*

INTRODUCTION

Water Treatment Plants are required to collect and record information on raw water quality, prior to treating drinking water for public consumption. Typically, measurements are made of temperature, turbidity, pH, and alkalinity on a daily basis. Other measurements may include iron, manganese, fluoride, and hardness concentrations in untreated water. The raw water quality data from several water treatment plants in the Nolichucky River basin in Northeast Tennessee was transferred to an electronic format for statistical evaluation. The extensive and long term nature of the raw water quality data make them an ideal source of information for the evaluation of seasonal and long term water quality trends, station to station comparisons within the surface water basin, and the degree of historical variation present within the basin.

DATA SOURCES

The Tennessee Division of Water Supply is responsible for the supervision of public water systems in the State. Under their rules and regulations, all community water systems and those non-community water systems classified as a surface source must compile and maintain accurate daily operating records of the water works systems on forms prepared and furnished by the Tennessee Department of Environment & Conservation. The form 'Monthly Operations Report' (MOR) is submitted to the local field offices (not the Nashville Central Office) by the certified operator of each water system. The form, in addition to information regarding the amounts of water pumped each day, tracks the chemical and physical characteristics of the raw and finished water, the chemicals used in treatment, calculated dosages, jar test data, and filter operation data. The basic regulatory requirements of the current rule were emplaced in August, 1977. The data from MOR forms from the Town of Erwin, Town of Jonesborough, City of Greeneville, and the North Greene Utility District were used to compile raw water data from 1994 through 2004 into an EXCEL electronic workbook.

METHOD

The files for the water systems in upper east Tennessee are located in the Johnson City Field Office of the Tennessee Department of Environment & Conservation. Files from four water systems within the Nolichucky River surface water basin were examined to determine the common aspects of the data contained within the MOR's. For example, some of the physical and chemical characteristics of the raw water are not monitored unless there is a direct need related to plant operations. Data from the year 2004 was transferred to an electronic data format in order to compare and evaluate the most commonly monitored raw water parameters: pH, total alkalinity, turbidity, and temperature. The Erwin Utilities O'Brien Spring (PWSID # 0000231) in Unicoi County is a groundwater supply treated at the head of the spring. The spring is within the Valley and Ridge physiographic province at the base of the Blue Ridge Mountains and provides around 230,000 gallons per day to the utility. The Nolichucky River is the main source of water for the Town of Jonesborough (PWSID # 0000338) in Washington County and the intake is located just downstream of the United States Geologic Survey gauging station at Embreeville, Tennessee. The river at that point drains an area of about 804 square miles and has an average discharge of 1317 cubic feet per second. The Jonesborough plant treats about 2.75 million gallons per day.

The City of Greeneville's water intake is on the Nolichucky about 28 river miles downstream of the Jonesborough intake. The withdrawal at Greeneville is via a pre-sedimentation basin, and the water plant there treats about 7.5 million gallons per day. The North Greene utility intake at Lick Creek in northern Green County treats about 500,000 gallons per day. Lick Creek eventually joins the Nolichucky River about 57 miles below the City of Greeneville intake. Lick Creek's drainage area is exclusively within the Valley and Ridge physiographic province. The 2004 year data for all three surface water points showed significant variation on a yearly basis. The O'Brien Spring groundwater data was fairly consistent, with no temperature variation and very little turbidity. The O'Brien data for 2004 was sufficient to show how a groundwater influx component to the Nolichucky might be manifested, and no further data from that point was examined. Copies of MOR's from 1994 to 2003 for the three surface water plants were purchased from the Johnson City Filed Office files and transcribed to an electronic format.

DESCRIPTIVE STATISTICS

Tables 1 through 4 contain the statistical information for each water intake, including the average or mean, median, minimum, maximum, standard deviation, trimmed mean (upper and lower 5% of extreme values removed and remainder averaged), the number of values, the number of missing values, skewness (a measure of asymmetry) , and kurtosis (difference in distribution from a normal curve). The raw water pH is a measure of the raw water chemistry's acid/base reaction potential. It is needed for the dosage calculations involved in the water treatment. The pH did not show a definitive seasonal trend, though some shifts over time were apparent.

Table 1—Raw Water pH Values Measured From 1994 to 2004 at Public Water Treatment Plants in the Nolichucky Basin

Statistic	Town of Jonesborough	City of Greeneville	North Greene Utility	O'Brien Spring (2004 only)
Number of Samples	4015	3956	3972	50
Missing Values	3	62	46	316
Mean	7.3904	7.6882	7.7974	7.76
Median	7.4	7.7	7.7	7.8
Minimum	*5.4	7.1	6.2	7.6
Maximum	8.8	8.8	8.6	7.9
Stand. Error Mean	0.00565	0.00335	0.00503	0.00948
Standard Deviation	0.3578	0.2109	0.3170	0.0670
Trimmed Mean	7.3945	7.6795	7.7015	7.7591
Skewness	-0.25	0.72	-0.30	-0.17
Kurtosis	0.63	1.27	0.83	-0.02

*Note that Tennessee Fish and Aquatic Life Criteria, for larger rivers, list a pH range of 6.5 to 9.0 pH units.

The lowest pH, 5.4 occurred on two consecutive days in August, 1998 at the Jonesborough intake. The values were clearly anomalous, which raises the issue of when or whether raw water parameters should be viewed as indicators of anomalous conditions in the source. In order to evaluate the low pH readings in light of what should be expected from that source in August, the data from 1994-1997 pH values at the Jonesborough facility were used to establish an August

background for an individual values control chart. This graphical device takes the historical average and the standard deviation of the data to determine upper and lower bounds to the range of expected variation. The monthly pH data had an approximately normal distribution, so the control chart approach is valid. Figure #1 demonstrates the anomalous nature of the August 1998 low pH and the visual utility of the approach.

Table 2—Raw Water Temperature Values Measured From 1994 to 2004 at Public Water Treatment Plants in the Nolichucky River Basin

Statistic	Town of Jonesborough	City of Greeneville	North Greene Utility	O'Brien Spring (2004 only)
Number of Samples	3978	3956	3987	366
Missing Values	40	62	31	0
Mean	16.743	16.016	14.383	14
Median	17	16	15	14
Minimum	4	1	1	14
Maximum	29	29	25	14
Stand. Error Mean	0.0996	0.122	0.0897	*
Standard Deviation	6.283	7.697	5.661	*
Trimmed Mean	16.774	16.121	14.481	14
Skewness	-0.09	-0.11	-0.16	*
Kurtosis	-1.19	-1.35	-1.19	*

* Parameters without a variation component cannot be calculated.

The surface water temperatures displayed a clear pattern of seasonal variation, with lows and highs occurring about two months after the winter and summer solstices, respectively. Lick Creek is small enough that a significant amount of its channel may be shaded by vegetation where the banks are wooded. This accounts for the Lick Creek high temperatures being somewhat lower than the Nolichucky River maxima. For the low temperatures, the greater volume of flow in the Nolichucky obviates against approaching the freezing point as easily as the water in Lick Creek. The seasonal variation in the Jonesborough raw water is illustrated by Figure #2. A linear trend line has been added to show that the average temperatures have been increasing since 1994, mainly because of the cold weather minimums not dropping as much in the colder months in recent years. This pattern was not seen in the North Greene or City of Greeneville temperature data, perhaps because of the lower volume of Lick Creek and the apportionment of Nolichucky River water into the relatively smaller volume of the pre-sedimentation basin prior to measurement at the City of Greeneville intake.

Alkalinity is defined as the sum of the bases titrated by strong acid to a defined end point. In natural waters in carbonate rock terrains this is frequently assumed to be due to the major mineral species of the carbonate system and it is important in dosage calculations to be able to account for the correct amounts of chemicals to add if pH adjustment is necessary. Another way to define alkalinity is in terms of electroneutrality, or the charge balance of the chemical species in the water: alkalinity equals the sum of the cation equivalents minus the sum of the anion equivalents, including organic anions. The second definition is mentioned because the amounts of alkalinity measured at the various points appears to have a seasonal component, but there are variations which apparently arise from processes other than mineral weathering or dissolution combined

with precipitation effects. Nitrate assimilation or denitrification, iron or sulfur reduction in channel bed deposits, or precipitation of organic acids could generate alkalinity. Figure #3 illustrates the time series plot of raw water alkalinity for the surface water intakes. Figure #4 takes the data for the North Greene alkalinity values and plots them against the median alkalinity value for the 1994-2004 North Greene data in order to highlight the variations above and below the median.

Table 3—Raw Water Alkalinity Values (mg/l) Measured From 1994 to 2004 at Public Water Treatment Plants in the Nolichucky River Basin

Statistic	Town of Jonesborough	City of Greeneville	North Greene Utility	O'Brien Spring (2004 only)
Number of Samples	4012	3956	3972	51
Missing Values	6	62	46	315
Mean	23.024	59.728	187.37	87.882
Median	23	60	191	88
Minimum	12	22	50	75
Maximum	43	118	269	103
Stand. Error Mean	0.0588	0.208	0.358	0.570
Standard Deviation	3.724	13.064	22.56	4.068
Trimmed Mean	22.927	59.318	189.22	87.956
Skewness	0.46	0.46	-1.50	0.11
Kurtosis	0.54	0.27	3.65	4.38

The turbidity measurements are made as a baseline determination before filtration procedures are applied. The slight variations in turbidity at the groundwater source, O'Brien Spring, still were not great enough to exceed the lowest measurements made at the surface water sources. Lick Creek appears to be more susceptible to frequent muddying, and the pre-sediment basin at the City of Greeneville apparently fulfills its function well, based on the turbidity maxima recorded.

Table 4—Raw Water Turbidity Values (in NTUs) Measured From 1994 to 2004 at Public Water Treatment Plants in the Nolichucky River Basin

Statistic	Town of Jonesborough	City of Greeneville	North Greene Utility	O'Brien Spring (2004 only)
Number of Samples	4015	3956	3986	366
Missing Values	3	62	32	0
Mean	15.774	5.496	35.393	0.3556
Median	5	4	19	0.29
Minimum	0.9	1	2	0.12
Maximum	680	130	960	1.56
Stand. Error Mean	0.604	0.0733	0.904	0.0108
Standard Deviation	38.297	4.609	57.044	0.2058
Trimmed Mean	9.499	5.024	25.956	0.3307
Skewness	7.26	8.55	5.57	2.35
Kurtosis	75.53	165.76	47.89	7.51

CONCLUSIONS

This study was undertaken as a way to advertise the existence of the raw water data base in existence in the Tennessee Government files and to explore the variations inherent in some of that data over time. The apparent upward trend of the Jonesborough raw water temperature in the past ten years was somewhat alarming and merits further study. The turbidity data, over time, might have some utility in assessing total maximum daily limits emplaced by the Division of Water Pollution Control. The author wishes to thank the Johnson City Field Office staff for their valuable assistance in the preparation of this paper.

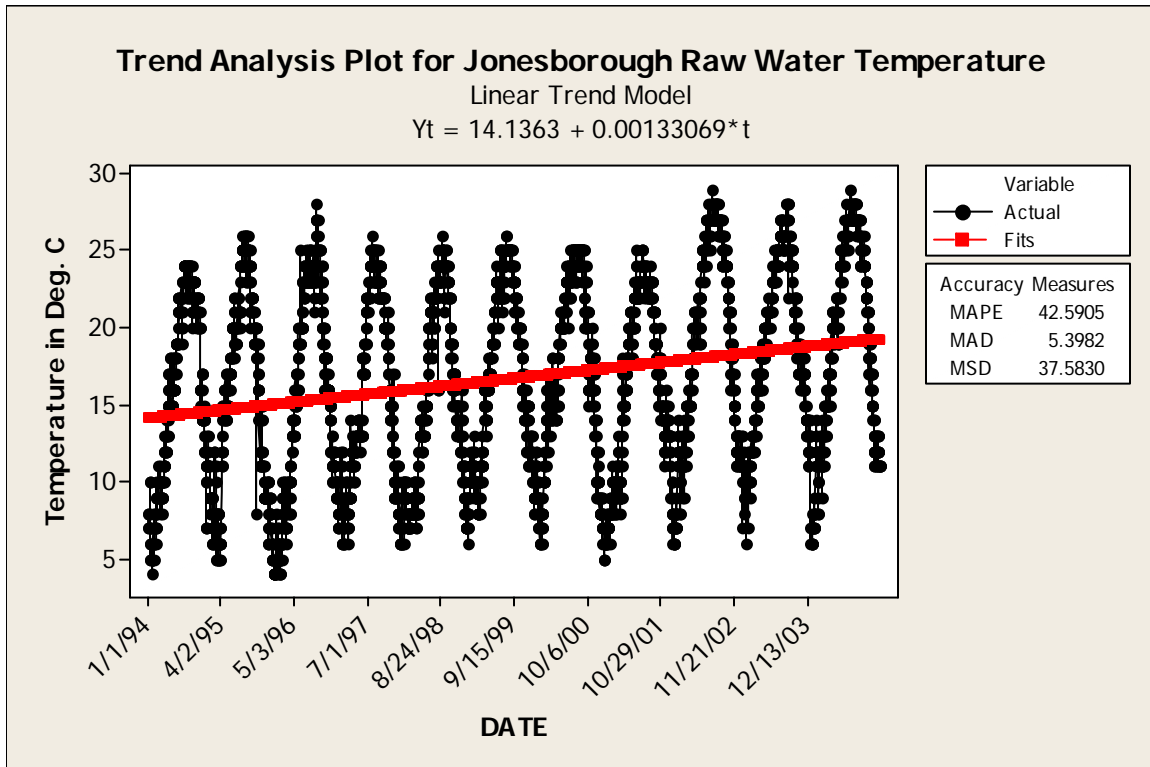


Figure 1. Time Series Plot with Linear Trend Line Overlay, Jonesborough Raw Water Temperature

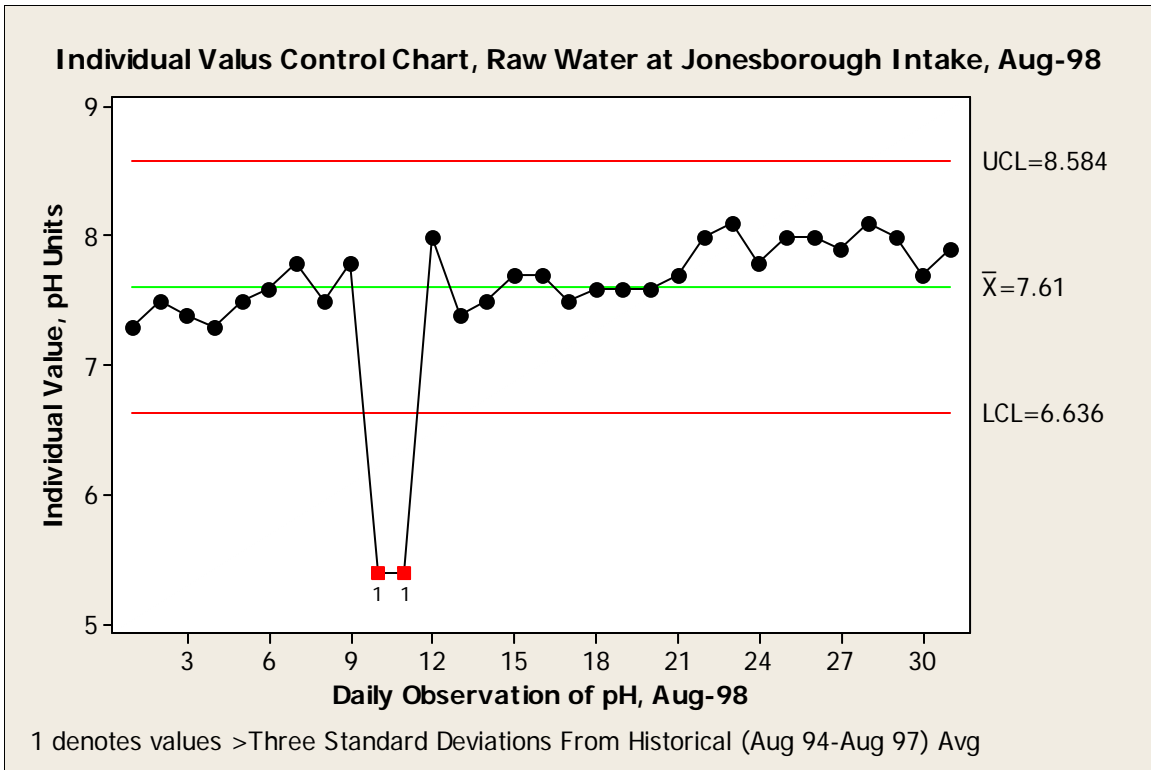


Figure 2. Control Chart Illustrating Measured August 1998 pH Values Against Expected pH Ranges

Figure #3--Daily Raw Water Alkalinity Measurements From the Jonesborough, North Greene, and Greenville Water Intakes

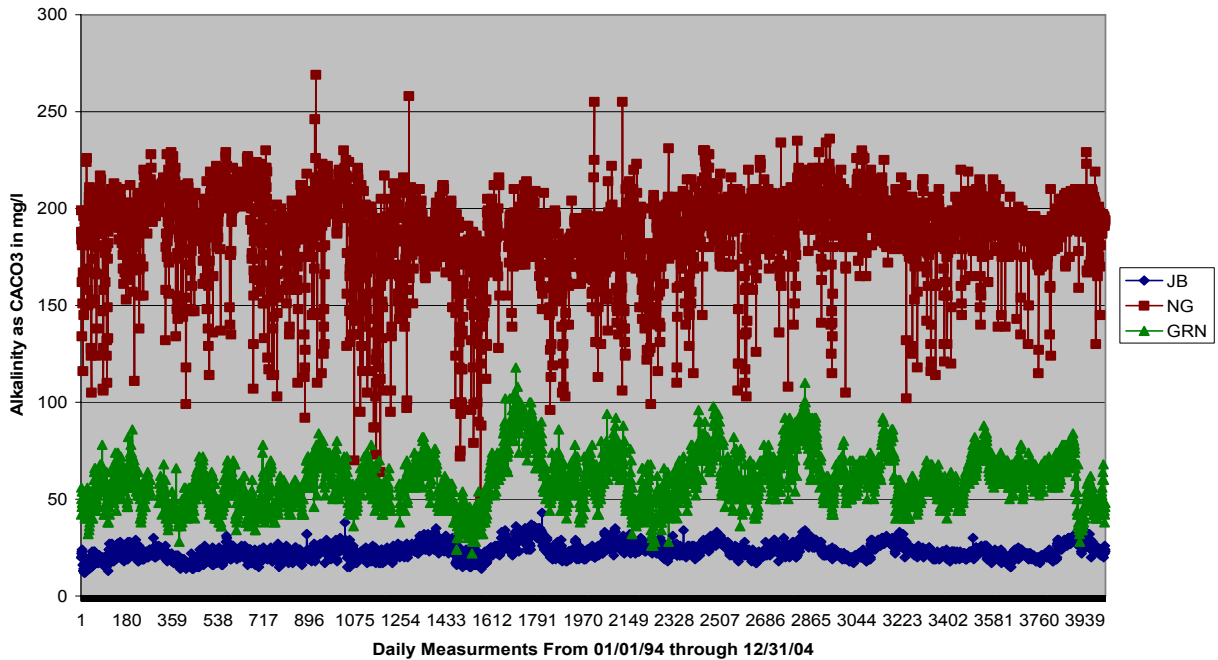
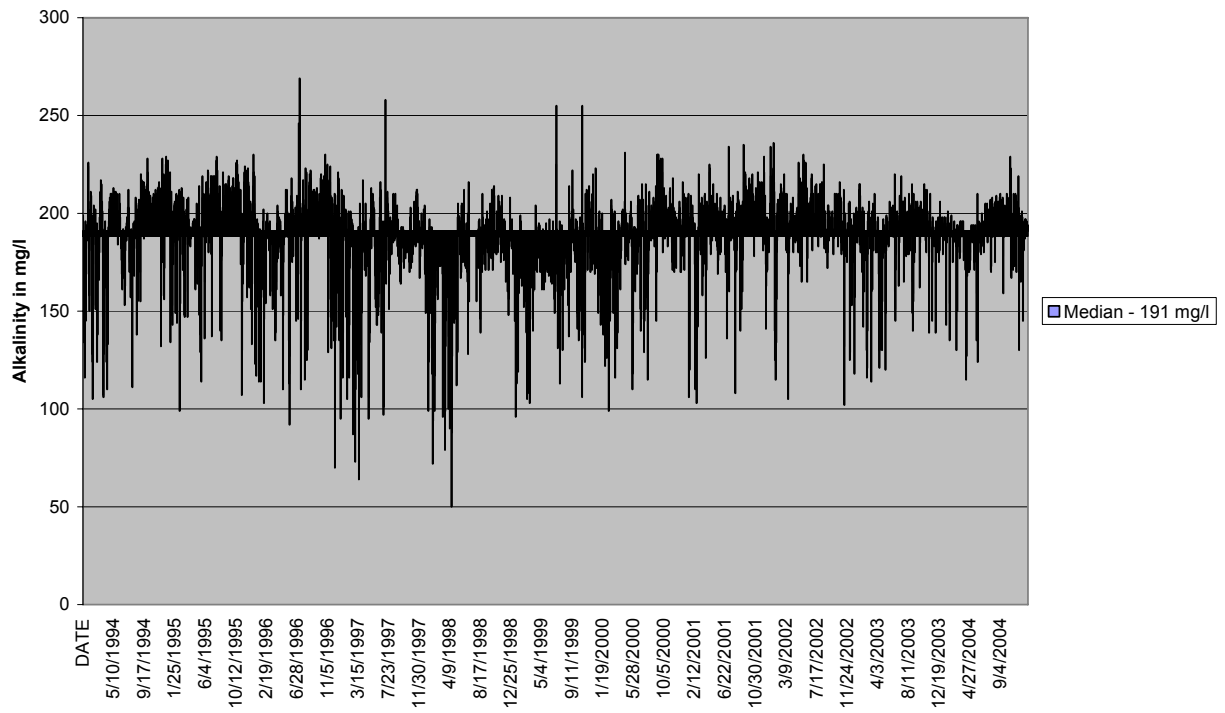


Figure #4--North Greene Utility Raw Water Alkalinity Values Plotted Against the Median Alkalinity for the Period 1994-2004 at Lick Creek



IMPACTS OF URBANIZATION ON HABITAT QUALITY AND FISHERIES IN A RIDGE AND VALLEY WATERSHED: IMPLICATIONS FOR STREAM REHABILITATION PLANNING

Robert L. Sain¹ and John S. Schwartz²

Numerous case studies have shown that urbanization tends to degrade physical habitat in streams and lower the biological integrity. Impacts to biota occur when a watershed becomes modified with about 10% to 25% impervious surface from urban development. Impervious surface changes the natural runoff patterns, increasing frequency and magnitude of peak events, and stormflow volumes. Its measure also functions as a surrogate to other possible environmental stressors such as habitat alteration, non-point pollution, and elevated summer temperatures, all of which can affect fish community structure. In contrast to other biota, fish can seek refugia in high quality reaches from stressed environments if movement corridors are not impinged. Watershed connectivity is key to maintaining biological integrity of fish communities, in which scale-dependent habitat patches and corridor quality between patches define connectivity. Our understanding of connectivity as a function of watershed urbanization is limited, both in terms of the spatial mosaic of land development in the uplands and infrastructure encroachment in riparian areas. In the Beaver Creek watershed, Knox County, Tennessee, 24 study sites were assessed for habitat quality, geomorphic structure, and fish biological integrity during July to September 2005. The study sites included four sites per six subwatersheds varying in levels of urban development. A statistical ordination technique was used to observe patterns in fish community structure orientated along watershed- and reach-scale parameter vectors to identify governing environmental factors. Results were integrated with ecological information on fish traits to illustrate how planning for stream rehabilitation in urban watersheds can be improved.

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TENNESSEE VALLEY AUTHORITY'S WATER QUALITY INITIATIVES PROCESS

Tom McDonough¹

Tennessee Valley Authority has 7 multidisciplinary Watershed Teams that assist communities across the Tennessee Valley develop and implement protection and restoration initiatives in their local watersheds. These teams work in partnership with business, industry, government agencies, and community groups to manage, protect, and improve the quality of the Tennessee River and its tributaries. A systematic process is followed that include the following components: identifying causes and sources of pollution, building interagency and citizen partnerships, engaging stakeholders in determining strategies, writing watershed plans to address identified problems, and securing funding to implement solutions, and managing improvement projects.

This process begins with project selection. First, teams determine where improvement is needed based on water quality monitoring data. Then they rate prospective projects based on partnership potential, stakeholder support, and overall chance for success. Selected projects are implemented in four sequential phases spanning the project duration: explore, build/prepare, implement, and transition to maintenance. Each phase has specific objectives, which focus on key elements needed for success: cause/source identification, local ability to act, communication and marketing, and action plan development and implementation. Finally, teams identify actions necessary to achieve each objective, including a timeline. Plans are updated annually to reflect progress, adjust to changing circumstances, and ensure that all actions align with the objectives for each phase. The planning process is documented in flow charts and written instructions. An online planning system ensures consistency and allows for review and comparison, sharing of lessons learned, and identifying opportunities for improvement. TVA currently supports a total of 36 initiatives throughout the Tennessee Valley.

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ADDRESSING WATER QUALITY ISSUES OF OOSTANAULA CREEK THROUGH WATER RESOURCE PARTNERSHIPS

Linda B. Harris¹

A fecal coliform TMDL (total maximum daily load) was developed by the Tennessee Department of Environment and Conservation Division of Water Pollution Control for Oostanaula Creek in 2002, requiring a 98% reduction of pathogens at the mouth. Through utilization of Tennessee Valley Authority's Integrated Pollution Source Inventory, causes and sources of the impacting pollutants were analyzed and prioritized subwatersheds were targeted for improvement. In support of TMDL implementation, effective partnerships were forged to address various agricultural and urban components of the implementation plan. Examples of these partnerships include:

- Utilization of a Unified Watershed Assessment grant from Tennessee Department of Agriculture (TDA) to assess agricultural operations in upper Oostanaula Creek and improve water quality through improved planning and funding of best management practices. Participating agencies are TDA, TVA, and USDA Natural Resources Conservation Service,
- Funding by TVA to the Athens Utility Board for installation of 3 new stream gauges,
- Cooperative public outreach and education efforts through the cooperation of Athens Public Works, Athens Utility Board, Keep McMinn Beautiful, McMinn County Planning, and TVA.

Data collected after the original TMDL analysis were used for comparison to the original TMDL by Load Duration Curve analysis, clearly showing significant improvement has been achieved for pathogen loading in Oostanaula Creek, with loading apparently reduced by nearly an order of magnitude. Due to availability of this new data, a new TMDL for pathogens has been drafted in 2005.

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BOONE INITIATIVE: A WATERSHED APPROACH TO IMPROVE RESERVOIR HEALTH

T. Shannon O'Quinn¹

Boone Reservoir is located in northeast Tennessee near the cities of Kingsport, Tennessee; Johnson City, Tennessee; and Bristol, Tennessee/Virginia. It is a multiple purpose reservoir built and operated by the Tennessee Valley Authority (TVA) for flood control, navigation, recreation, aquatic life uses, and hydro power generation. Since its impoundment in 1952, Boone Reservoir has struggled with a variety of water quality issues. Historical problems from point source pollution discharges are now regulated through the 1972 Clean Water Act. More recently recognized and documented problems are associated with non-point source pollution. Assessments conducted by TVA and the Tennessee Department of Environment and Conservation reveal that Boone Reservoir and many of its tributaries suffer from nutrient enrichment, excessive sediment, elevated bacteria concentrations, and aquatic habitat loss due to urban and agricultural runoff. These pollution sources are being addressed through collaborative efforts such as the Boone Watershed Partnership's (BWP) Boone Initiative. The BWP is an alliance of concerned citizens and natural resource agencies working together to protect and improve the health of Boone Reservoir and its tributaries. The Boone Initiative focuses improvement efforts in twelve impaired tributary watersheds that significantly influence reservoir conditions. In each watershed, the approach is to build and strengthen watershed coalitions and partnerships, assess watershed conditions, implement outreach strategies, leverage funding, and develop Watershed Action Plans (WAP). For example, the Sinking Creek (one of the twelve tributaries) WAP has been developed and serves as a guide for project implementation. The Boone Initiative will provide benefits such as documenting water quality improvements; building consensus among stakeholders; reducing public health risks; promoting economic development; changing community perceptions of Boone Reservoir; and creating a model for reservoir improvement. This presentation will supply more detailed information regarding Boone Reservoir and watershed conditions, the Boone Initiative, and the Sinking Creek WAP.

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THE BEAVER CREEK WATERSHED PARTNERSHIP OVERVIEW AND WATERSHED PLAN

Roy A. Arthur^{1*} and Liz Bouldin²

The 86 square mile Beaver Creek Watershed is a subshed of the Lower Clinch Watershed and is located entirely within Knox County, Tennessee. It is a rapidly urbanizing watershed with five distinct communities and approximately 70,000 residents. All 44 miles of its main stem are on the Tennessee 303d list. The primary pollutants are sediment, nutrients, pathogens, and habitat alteration. In 1998 the Beaver Creek Task Force was formed. This partnership includes Knox County Stormwater Division, TVA, University of Tennessee, TN WRRC, TDEC, the local utilities, the Beaver Creek Watershed Association, EPA, Region 4, Water Management Division, and others. A flood study, visual stream and land use assessments, updated GIS land use layer, stream sampling and analysis, new Knox County Smart Growth Stormwater Ordinances, and a Green Infrastructure land use planning tool have been completed. A comprehensive watershed education program is in place and retrofit BMPs are being installed. AnnAGNPS for sediment and HSPF for nutrients are the models being used to develop a comprehensive watershed restoration plan. A Stakeholder Advisory Council has been formed to help the Beaver Creek Task Force choose the modeled restoration scenarios that will be most likely to succeed in the watershed. The Beaver Creek Watershed Restoration Plan will be finalized in 2006 and conform to the new EPA 319 guidelines.³

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³ Oral Presentation; Not a student; Speaker is contact person.

THE BEAVER CREEK WATERSHED PARTNERSHIP: EDUCATION AND OUTREACH

Ruth Anne Hanahan¹

In 2002, the Beaver Creek Watershed Partnership formalized a strategic education and outreach program as a part of its effort to remediate Beaver Creek, a 303d listed stream. The program was devised on a plan containing objectives, strategies for meeting these objectives including specific educational messages to be conveyed, target audiences, and timeframes for strategy implementation. Beyond providing an action-oriented structure, this plan has also provided the Education and Outreach Committee with a means for evaluating progress. The program is based on three primary sources of information:

- **results of a statistically valid survey of Beaver Creek residents' knowledge of and attitudes towards watershed concepts and issues:** The survey was administered through telephone interviews by the University of Tennessee Human Dimensions Laboratory. Key results included that the majority of respondents:
 - could not define the term “watershed”;
 - held the misconception that industrial discharge was the primary pollutant impacting Beaver Creek;
 - would like to see the creek trash and odor-free, contain healthy fish, and be clean enough that their children could swim or play in it
 - would be willing to dedicate at least four hours a year to protecting and improving the conditions of Beaver Creek.

Implication: This information has been invaluable in helping the Education and Outreach Committee to devise educational messages to address knowledge gaps and misconceptions. It also let us know that Beaver Creek residents would be willing to become involved in action-oriented programs and projects to help address water quality issues.

- **stream condition assessments.** Beaver Creek is currently listed on the 303d list for sediment, nutrients, pathogens and habitat alteration. Ongoing assessments by Tennessee Department of Environment and Conservation (TDEC), Tennessee Valley Authority (TVA) and the University of Tennessee, Knoxville (UTK) have provided the BCTF partners with sufficient information to begin quantifying pollutant input by subwatershed and identifying possible pollutant sources.

Implication: This information has been used in helping to determine the type of projects that could directly address key pollutant issues in the watershed.

- **marketing and education research.** Several key sources were directly used in formulating the BCTF's education and outreach strategies. One of those was from US EPA which contracted with LISBOA, Inc. to conduct a series of public focus groups in 2001 to better understand the public's conceptions of nonpoint source pollution and how to more effectively market/convey key educational messages (submitted by LISBOA, Inc. to US EPA Nonpoint Source Management Partnership on 11/21/01). Key relevant findings included:
 - keeping educational messages simple, limiting to two to three concepts;

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- providing specific ways citizens may take “personal responsibility” for local water quality problems;
- providing opportunities for residents to collectively address problems; and
- focusing on youth not only for their future leadership potential in the community, but also because of their current influence on the adult population

In addition, there is a wealth of research that supports the effectiveness of “place-based” teaching strategies. That is teaching watershed concepts and processes using our local community and environment; in essence using the watershed as a “living laboratory.” In addition, this approach involves keeping the learning hands-on and interactive (<http://www.peecworks.org/>).

Implication: Basing our marketing and educational strategies on sound research has increased the effectiveness of our program’s education and outreach strategies along with providing increased credibility among the business and the academic communities. As a part of our educational efforts, we have made a particular effort to involve our youth in assisting in the education of the adult population in Beaver Creek. This is in part based on their influence on adults as well as educational research that has shown one of the most effective ways to retain information is to have to teach it.

The BCTF Education and Outreach Program’s objectives include building awareness and educating target audiences on key watershed concepts and providing them opportunities to personally and collectively address watershed issues. Key messages we are currently conveying through our educational and outreach strategies include:

- A watershed is an area of land that drains to a waterbody, with the Beaver Creek Watershed draining 90 square miles.
- Activities throughout the Beaver Creek Watershed (both near and far from its creeks) can have a substantial impact on these waterways.
- Rapid development in the Beaver Creek Watershed has been impacting water quality, with increased sediment input, riparian habitat destruction, and cumulative input of household and business-generated pollutants.
- Each of us plays a part in contributing to local water quality problems and each of us can be a part of the solution.
- Here are ways you can make a difference...and here is how you can become involved.

Specific awareness and outreach strategies include:

- posting watershed entry signs along highly traveled routes going into and out of the watershed to familiar the public with the term watershed as well as provide an orientation as to the location of the Beaver Creek Watershed;
- maintaining a presence in the media; and
- conducting civic and community presentations.

The BCTF’s educational and outreach program also includes three school-based programs. All use educational strategies that are “place-based.” Two involve short, intensive educational hands-on sessions for elementary and middle school students. They are:

- **Kids-in the Creek:** This program is jointly conducted by the BCTF partners and is a day-long field event for students, providing them with an opportunity to learn about the ecology of a local creek through a series of stream assessments. Students collect and analyze creek biota, test its water quality, and find out what they can do to help keep the creek clean and healthy.

- **Water on Wheels:** This program is sponsored by the Hallsdale-Powell Utility District. Using a “Water on Wheels” mobile learning lab, HDPUD staff engages students in experiments that demonstrate how water impacts our daily lives and what can be done to conserve and protect this natural resource.

The third school-based program provides more extensive watershed education (on an average of five to seven hours of watershed education per student) and involves students in improving watershed conditions. The program, Adopt-A-Watershed (AAW), is implemented on a national basis and was established in Knox County in 1997. AAW involves students in conducting projects that address “real world” issues in the watershed. The nature of the project is generally jointly determined by teachers, BCTF partners, AmeriCorps members, and students; supports class curriculum; and culminates with the students conducting a service that work towards resolving the issue addressed by the project.

AAW currently annually involves approximately 2,000 Knox County students in 15 middle and high schools, with six of these schools located in the Beaver Creek Watershed. Twenty-five teachers and a seven-member AmeriCorps Team -- all who have received training to conduct this program – are involved in its implementation. It is supported by the Water Quality Forum (WQF), a consortium of local agencies and organizations working to protect local water quality. WQF partners provide both direct and in-kind support including helping to identify relevant water issues and needs that the students can address through their projects, serving as technical resources, and providing supplies to implement these projects.

In addition to the school-based programs, the BCTF Educational and Outreach Program includes citizen-based, action-oriented programs and projects. Adopt-A-Stream is a relatively new program being implemented in Beaver Creek that is a cooperative effort among the City of Knoxville, Knox County, and the Town of Farragut to involve citizens in stream monitoring and litter prevention. Community groups, clubs, businesses, and other citizen-based groups adopt a section of a creek, conduct quarterly visual assessments of its physical and biological conditions, and coordinate litter clean-ups two times per year. To participate in the program, representatives from each group must attend a half-day training session. After completing initial program requirements (i.e., first visual assessment and clean-up), the group will then receive a sign along their creek stretch acknowledging the group as adopting this stream section.

The BCTF Education and Outreach Committee also annually coordinates the Riparian Planting Project. This effort addresses riparian habitat destruction along Beaver Creek and involves creek-side landowners in its implementation. Approximately, 4,000 riparian seedlings purchased by TVA are distributed to these landowners for planting. AAW students are involved in both packaging the seedlings for distribution as well as developing educational materials targeted toward the land owners that include functions of vegetated riparian buffers along with the mechanics of planting. Another key benefit of this project has been the opportunity to build relationships with riparian land owners, letting them know of other creek-protection programs and projects that may be of interest to them.

A recently implemented BCTF citizen-based project involves homeowners in incorporating at least one new pollutant-reduction practice in their household. NPS educational materials from WaterWorks (<http://www.tennesseewaterworks.com>) were adapted for use in the Beaver Creek Watershed. WaterWorks is a public education program through the Middle Tennessee State University Center for Environmental Education that promotes clean water in Tennessee. Actions homeowners can take are illustrated through graphics printed on posters, brochures, and

bandanas. These materials are incorporated into school-based projects that then involve students in directly educating homeowners at community events and in their own households.

Another initiative being kicked off in 2006 is the Construction Site Education Pilot Project. Its purpose is to primarily educate subcontractors (i.e., painters, electricians, carpenters) on the importance of not damaging commonly used sediment and erosion site control best management practices (BMPs). It is being modeled after a program implemented by the City of Memphis Stormwater Pollution Prevention Program which identified that a major problem on their construction sites in maintaining commonly used BMPs (e.g, silt fences and stormdrain inlet protectors) stems from subcontractors. These workers were generally unaware of the purpose of these controls and were inadvertently damaging them with their vehicles). The implementation strategy for this project is to keep the educational messages simple and concise (e.g., purpose and importance of sediment controls; actions to be taken to deter their damage). The educational messages will be taken to the construction site and conveyed to the subcontractors on their breaks through pictorial posters. As an enticement coffee and donuts will be provided. The educational messages will be provided in both English and Spanish and can be delivered in five minutes or less. Information conveyed to the workers will be reinforced by providing each with an oil rag with the “take home message” imprinted on it.

The BCTF Educational and Outreach efforts demonstrate the many merits of partnerships – the synergy of ideas, the pooling of resources, and the attainment of mutually shared goals. Our approach has generally been for one to two partners to provide the lead on each of the programs and projects, with the remaining partners providing the support necessary for their implementation. For more information on the programs and projects being implemented by the BCTF Educational Committee, you may contact Melinda Watson at TVA at 865-632-1329 (mfandrews@tva.gov) or Ruth Anne Hanahan at (865) 974-912 (rhanahan@utk.edu).

USE OF A DYNAMIC SEDIMENT DELIVERY MODEL FOR WATERSHED PLANNING IN BEAVER CREEK, KNOX COUNTY, TENNESSEE

Shannon E. Bennett¹ and John S. Schwartz²

Beaver Creek watershed in Knox County, Tennessee has been designated as sediment and habitat impaired by the Tennessee Department of Environment and Conservation (TDEC). A draft sediment and habitat alteration Total Maximum Daily Load (TMDL) for the Lower Clinch HUC unit has been generated by TDEC for public review. The TMDL identifies that a 70% reduction in annual sediment load will be required for the Beaver Creek sections. A critical need exists to understand the current sediment conditions in the watershed. In addition, a need exists to identify the best watershed planning alternatives that can achieve the required annual sediment load reduction. Alternatives include better development planning that protects riparian corridors and effective use of erosion and stormwater runoff best management practices (BMPs) during land development. An AGNPS, a dynamic sediment delivery model, was used to estimate annual sediment loads for the current land use practices in the Beaver Creek watershed, and several planning and BMPs scenarios. Planning and BMPs scenarios were determined by an extensive community effort with watershed stakeholders. Implications of the sediment model results will be discussed, and how the Beaver Creek Task Force can use them to improve the on-going watershed planning effort.

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LITTLE RIVER WATERSHED INITIATIVE

Tom McDonough^{1*} and Erich Henry²

The Little River originates in the Great Smoky Mountains National Park. The river's water quality within the park is excellent. Downstream of the Park, the river is impacted by agricultural and development practices, and urban runoff. The quality of the river slowly degrades with increasing distance from the Park. Currently agricultural runoff is the dominant pollution source. Rapid residential and commercial development threatens to further deteriorate the quality of the Little River. The Tennessee Department of Environment and Conservation has classified the Little River as threatened [2004 305 (b) report].

In response to concerns about deteriorating water quality, local, state, and federal agencies as well as private organizations are working together to improve and protect water quality in the Little River. These efforts are being coordinated through the Little River Water Quality Forum (LRWQF). LRWQF is made up of 19 agencies and organizations that meet quarterly to plan and coordinate water quality improvement and protection initiatives. Little River Watershed Association (LRWA) is a citizen based non-profit organization dedicated to the protection and improvement of the Little River. LRWA works closely with other LRWQF members. LRWA activities include stakeholder education, volunteer monitoring, fundraising, and clean-up and restoration projects.

Partners have secured over \$2,000,000 to implement a wide variety of water quality improvement activities, including: cooperative water quality assessments; development of watershed geographic data base and pollution load model; engaged diverse stakeholders in development of watershed plan; demonstrating and promoting agricultural BMPs, providing cost-share and technical assistance; addressing urban pollution sources through planning, education, and stormwater management. An application has been submitted to EPA's Targeted Watershed program requesting funding to address agricultural and residential impacts.

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THE STOCK CREEK WATERSHED RESTORATION PLAN

Roy Arthur^{1*}, Jim Hagarman², and Alice Layton³

The 21 square mile Stock Creek Watershed, located in the southern portion of Knox County, is impaired due to bacteria and habitat alteration. In 2002 a Stock Creek Watershed Initiative partnership was formed and devised a strategy to determine causes of bacterial contamination, identify sources, and create restoration strategies to remediate impairments. A study conducted by the University of Tennessee Center for Environmental Biotechnology determined levels of *E. Coli* and sources of fecal contamination in the watershed. Grab samples were collected twelve times during a one-year period from 16 sites. *E. Coli* and total coliform were quantified simultaneously using a membrane filtration technique (Hach Co.). Total fecal concentrations for each sample were determined using a real time PCR assay designed to detect *Bacteroides* from feces of multiple animal hosts (AllBac assay). *Bacteroides* 16S rRNA gene libraries were constructed for 20 water samples to determine whether human feces were the source of contamination at sites with a low percentage of bovine fecal contamination. Sequences identified with high confidence were predominantly assigned to either humans (63%) or cattle (33%). Restoration strategies are being guided by a set of Integrated Pollutant Source Identification (IPSI) tools developed by the Tennessee Valley Authority. The tools include a non point source (NPS) inventory database in a Geographic Information System (GIS) format and a set of pollutant loading models (PLM). The IPSI inventory identifies watershed features such as land use/land cover, streambank erosion sites, and livestock operations that are known or suspected to be non-point pollution sources. The PLM uses the Universal Soil Loss Equation (USLE) for rural land uses and a washoff model for urban land uses. A new feature of the PLM is the indicator bacteria sub-model. It uses a washoff approach for all land uses, and calculates annual runoff using the curve number equation. Stock Creek was the first validation application for the bacteria sub-model in the PLM. An intensive stakeholder education process has been initiated that includes general watershed awareness through the distribution of brochures, presentations to community groups, booths at community fairs, Adopt-A-watershed program in public schools, a model farm fair, and a series of public meetings. A comprehensive Watershed Restoration Plan is being written with funds obtained through a Tennessee Department of Agriculture 319 grant.

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BULLRUN CREEK RESTORATION INITIATIVE

Todd L. Reed^{1*} and Melinda A. Watson²

The Bullrun Creek watershed drains a 104 square mile area that includes parts of Anderson, Grainger, Knox, and Union counties. Bullrun Creek is classified as impaired by the State of Tennessee [303(d) list]. Causes for this impairment are siltation, pathogens, and habitat alterations from agricultural practices, permitted industrial discharge (quarry), and a minor municipal point source.

The Bullrun Creek Partnership (BCP) was formed to coordinate efforts of 14 agencies and organizations to restore water quality in the Bullrun Creek watershed. BCP members bring a broad base of knowledge, expertise, and resources to address all aspects of watershed restoration. The partnership recently received the Tennessee Wildlife Federation's Water Conservationist of the Year Award.

Changing poor land management practices which impact water quality will take several years and will require a comprehensive program with the following elements: resource condition and pollution source assessments, community support, information/education, technical assistance, funding and BMP implementation. The partners have helped property owners improve more than 500 acres of pasture, establish or enhance 18,000 feet of riparian habitat and stabilize over 8,000 feet of eroding streambank. Quarterly water samples collected in 2004 and 2005 show reduced bacteria and total suspended solids when compared with samples collected in 2001-2002.

Clear pollution reduction goals, a diverse partnership and strong community support are key elements to making this initiative successful. BCP is committed to this watershed restoration initiative until the restoration of Bullrun Creek is complete.

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SESSION 2C

WATER RESOURCES EDUCATION IN TENNESSEE

8:30 a.m. – 10 a.m.

Hydraulics and Hydrology Course at the University of Tennessee at Martin
George H. Nail

GIS APPLICATION STRATEGIES I

10:30 a.m. – 12:00 p.m.

GIS Applications for Phase 2 Stormwater
Rick McClanahan and Todd Graves

Geographic Information System as a Tool for Data Integration and Engineering Decision Making in Watershed Restoration
Janelle L. Temple

Tennessee Streamstats: A Web-Enabled Geographic Information System Application for Automating the Retrieval and Calculation of Streamflow Statistics
David E. Ladd and George S. Law

GIS APPLICATION STRATEGIES II

1:30 p.m. – 3:00 p.m.

Spill Management Information System Version 2.0 (SMIS 2.0): New Technology for Management of Our Inland Waterways
Janey V. Smith, Eugene J. LeBoeuf, James P. Dobbins, Edsel B. Daniel, and Mark D. Abkowitz

Geographical Information System Tracking of the Effects of Storm Water Runoff and Combined Sewer Overflows on Urban Streams
Craig W. Emerson, Steven W. Hamilton, and Don C. Dailey

A Comparative Study of GIS Monitoring Techniques for Tracking Arundinaria Gigantea and Justicia Americanum Restoration Sites Used for Stream Habitat Enhancement
Jon L. McMahan, Mack T. Finley, and Andrew N. Barrass

FIELD INVESTIGATIONS-MEASUREMENTS

3:30 p.m. – 6:00 p.m.

Finding Bankfull: A Story from the Tablelands
Ray Albright and Greg Babbit

Regional Curves for the Southwestern Appalachian Ecoregion
Greg Babbit and Ray Albright

False Gages
William R. Barron, Jr.

HYDRAULICS AND HYDROLOGY COURSE AT THE UNIVERSITY OF TENNESSEE AT MARTIN

Gregory H. Nail, Ph.D., P.E.¹

OVERVIEW

Offered initially during spring 2004, a one semester undergraduate course combining survey of hydrology, basic surface water hydrology, and introduction into open channel hydraulics, has been established at The University of Tennessee at Martin (UT Martin). This paper is a summary report on the course and its content. The junior-level course is an upper division elective for engineering students with a concentration in Civil Engineering. It is a first course in hydrology for these students, and is currently offered once a year during the spring semester. Course material is organized and presented in three sections. The first section is a survey of the entire field of hydrology and focuses on the hydrologic cycle and the memorization of terms and definitions. The second section covers analyses methods used in traditional hydrology; statistical description of precipitation events, the synthetic storm, rainfall, runoff, unit hydrograph, transformation, and runoff hydrograph. The Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) is introduced near the end of this section. The third section is an introduction to open channel hydraulics. Uniform flow, derivation of Manning's equation, non-uniform flow, slope, depth, and energy considerations are presented in this section. Hydrologic Engineering Center-River Analysis System (HEC-RAS) software is introduced near the end of the course. The presentation of all material is focused on the requirement of students first using techniques with hand held calculators or spreadsheets before using HEC-HMS or HEC-RAS.

INTRODUCTION

The Engineering Department at UT Martin offers an undergraduate program leading to a B.S. in Engineering Degree with concentrations in Civil, Electrical, Industrial, or Mechanical Engineering. A sequence of lower division courses is the same for students in all four disciplines. The set of upper division elective courses varies according to discipline. Prior to 2004, students with the Civil Engineering concentration encountered hydrology only within the transportation course. The new course, Hydraulics and Hydrology, was introduced beginning spring of 2004. It is an upper division elective, available for students within the Civil Engineering concentration. Fluid mechanics is required as co-requisite. The course is divided between basic surface water hydrology followed by open channel hydraulics. Students successfully completing the course are able to begin learning how to effectively use software such as HEC-HMS or HEC-RAS, or progress to further study in specialized subjects such as ground water, storm water, unsteady flows, or water quality.

The course number appearing in the UT Martin course catalog for the new course is ENGR 353. The course description reads: *Fundamentals of open channel hydraulics and engineering hydrology. Hydrologic cycle, qualitative and quantitative hydrology, and related practical engineering computations involving precipitation, runoff, and discharge. Engineering analysis of practical open channel flows; energy, depth, slope, and transient considerations.* As described, it is an introductory course designed to combine emphasis on basics of surface water hydrology and open channel hydraulics.

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BACKGROUND

The course was designed by the instructor upon request from the Engineering Department. Educationally, the instructor has a fluid mechanics background from the Mechanical Engineering Department of Texas A&M University, having graduated with the Ph.D. in 1991. He was then employed with the U.S. Army Corps of Engineers in the Coastal and Hydraulics Laboratory (CHL)² of the Engineer Research and Development Center (ERDC)³ in Vicksburg, MS. The primary activity was that of computational hydraulics modeling, as a Research Hydraulic Engineer. The instructor was employed in this capacity at ERDC from 1991 until accepting the position at UT Martin beginning fall of 2002. Professional Registration was obtained (Civil and Mechanical Engineering) in 1998. Additional graduate level course work was taken from Mississippi State University.

At the outset, the objectives in establishing this course were twofold. The course was to provide students with enough background to be able to perform basic engineering hydrologic calculations. This provision was directed towards those students entering employment immediately upon graduation. It was also desired that students leaving the course be prepared to continue on with graduate study in the water resources field. These constraints made necessary the selection of a text which encompassed both traditional hydrology as well as open channel hydraulics. Water Resources Engineering⁴ by Wurbs and James was chosen as the text.

LEARNING OBJECTIVES

A set of learning objectives was assembled with reference to stated needs, the text, and existing courses. Similar courses at Mississippi State University and Texas A&M University were initially examined for outside input. Initially these two courses served as a starting point. Since then, similar course offerings at other schools have been examined as well. It was noted that many Civil Engineering (or Civil and/or Environmental Engineering) programs offer more than one undergraduate course in the hydrology or hydraulics area. Specifically, Texas A&M offers five such courses. Typical of many programs, the courses are arranged so that the first one is a survey course that is often titled Water Resources Engineering. Similar to Texas A&M, a first course is typically followed by a sequence of courses, each specializing in the various areas of hydrology and hydraulics, such as open channel hydraulics, surface and groundwater hydrology, computational hydraulics, and wastewater topics. It is recognized that only one course could not provide coverage or depth equivalent to several such classes. Therefore, a somewhat innovative mix of learning objectives was sought. The following set of learning objectives was adopted:

By the end of this course students will be able to:

1. Commit to memory many of the basic terms and definitions used throughout the hydrologic field.
2. Estimate total precipitation and average precipitation rate for a storm of specified length and recurrence interval.
3. For a given watershed, estimate total runoff from a storm of specified length and recurrence interval.

² Formerly known as the Hydraulics Laboratory.

³ Formerly known as Waterways Experiment Station (WES), the facility was renamed in 1999 as the Vicksburg Site of the Engineer Research and Development Center (ERDC).

⁴ Wurbs, R. A., and James, W. P., Water Resources Engineering, Prentice Hall, Upper Saddle River, NJ, 2002.

4. For a given watershed, estimate peak discharge rate resulting from a storm or specified length and recurrence interval.
5. Develop a unit hydrograph for a given watershed.
6. Develop a synthetic design storm of specified recurrence interval and length, calculating precipitation as a function of time.
7. Develop a runoff hydrograph for a synthetic design storm of specified recurrence interval and length, for a given watershed, calculating discharge as a function of time.
8. Analyze uniform or critical flow for depth, velocity, or discharge.
9. Analyze for supercritical or subcritical flow, steep or mild slopes.
10. Identify each of the six basic water surface profiles, and the existence of potential for hydraulic jump.
11. Perform the direct step and standard step calculations for water surface profiles.
12. Run HEC-HMS software for basic hydrologic calculations.
13. Run HEC-RAS software for basic hydraulic calculations.

As is expected, all areas of hydrology are not fully represented. The objectives are oriented towards enabling students to learn enough basic theory to be able to perform some basic practical calculations. The first object is intended to provide some broad exposure to many aspects of hydrology, mainly in the form of general reading, terms and definitions. Objectives two through seven, and twelve, support the traditional hydrology section with emphasis on surface water. The remaining objectives are focused on open channel hydraulics. Progress in meeting these objectives is measured in the conventional way, with students sitting for a series of three one-hour examinations during which they have limited reference materials available. The first of these examinations is entirely devoted to objective one. The second covers objectives two through seven. The third covers objectives eight through eleven. The examinations are composed of word problems or questions which directly correspond to the learning objectives list. A comprehensive final examination is administered.

TOPICS COVERED

The selection of topics was largely guided and determined by the learning objectives, and the rather severe limitations of a one semester time frame. Presentation of all topics is followed by homework assignments similar to the examples worked in class. The list of topics, in order of presentation, is as follows:

1. Overview of Hydrology
2. Hydrologic Probability Relationships
3. Intensity-Duration-Frequency Relationships
4. Watershed Characteristics
5. Rational Method
6. Synthetic Design Storms
7. Runoff and the Unit Hydrograph
8. Runoff Hydrograph
9. Uniform Flow
10. Critical Flow
11. Water Surface Profiles
12. Gradually Varied Steady Flow

Topic one parallels the overview chapter of the text (Chapter 2). It contains a broad overview of many areas and specializations within the field of hydrology. Subtopics include water, hydroclimatology, atmospheric processes, precipitation, evaporation and transpiration, units of

measure, watershed hydrology and streamflow, subsurface water, erosion and sedimentation, water quality, and climatic considerations. The chapter is structured around and order of presentation that parallels the hydrologic cycle. Students are required to read this chapter and a list of approximately ninety terms and definitions is distributed, for memorization. Examples of simple calculations involving unit conversions, discharge, etc., are worked in class.

Topics two through eight forms the hydrology section, paralleling Chapters 7 and 8 of the text. Much of the material in this section is presented in the form of short lectures on theory followed by in-class examples. The second topic is geared towards the concept of annual exceedance probability, recurrence interval, and the inverse relationship between them. Use of statistical distributions, such as log-log, log-Pearson, or Gumbel Distribution, to assign exceedance probabilities and recurrence intervals to particular hydrologic data is covered only as a description. Emphasis is placed on using the relationship between annual exceedance probability and recurrence interval.

The third topic, Intensity-Duration-Frequency relationships, is presented and actual data used for illustration. This is done both in terms of equations and charts. The concept of a precipitation rate versus total precipitation is reinforced and emphasized. Further coverage of hydrologic characteristics of watersheds, such as time of concentration and lag time, follows with the fourth topic. Adequate coverage of topics two through four allows introduction of the Rational Method, topic five, at this point. Use of the Rational Method is illustrated primarily by example, since it requires very little theoretical explanation. Emphasis is placed on the limitations inherent in use of the Rational Method, and the fact that it estimates only the peak discharge.

A progression of material beginning with the concept of total precipitation and expanding to precipitation hyetographs, synthetic design storms, including volume runoff is covered within the sixth topic. A series of examples is worked in which the National Resource Conservation Service (NRCS)⁵ techniques are used to develop a synthetic storm comprised of a precipitation and runoff hyetographs, as shown in Figure 1. The infiltration method of Green and Ampt is introduced as an alternative to the NRCS, and differences highlighted. Homework assignments require usage of these methods and development of a synthetic design storm, including precipitation and runoff hyetographs.

Topic seven is begun with a short section on theory behind the unit hydrograph. A single example featuring deconvolution and convolution is used to further the concept of the unit hydrograph. The NRCS triangular unit hydrograph is presented in detail, and the curvilinear version is also mentioned. The Clark unit hydrograph is presented as an alternative, and differences pointed out. Homework assignments incorporate development of these unit hydrograph(s) for a given watershed, corresponding to a specified duration of precipitation. Material from topics six and seven is unified in developing the storm runoff hydrograph encountered in topic eight. At this point students have manually executed all of the calculations typically done by hydrologic software, such as HEC-HMS, in homework assignments. A demonstration problem is presented allowing students to run HEC-HMS to compute a storm runoff hydrograph which is essentially identical to one previously assembled with manual calculations, as shown in Figure 2. The difference between the two hydrographs of Figure 2 arises primarily because HEC-HMS uses the curvilinear form of the NRCS unit hydrograph. Manual calculations were done with the NRCS triangular unit hydrograph. A screen capture showing the same hydrograph of Figure 2, from within a dialogue box inside HEC-HMS, is shown in Figure 3.

⁵ The Soil Conservation Service (SCS), originally begun in 1935, was replaced by the NRCS in 1994.

Order of presentation then switches to open channel hydraulics, found in Chapter 5 of the text. Students are required to memorize a derivation of Manning's Equation. Analysis of uniform flow is expanded to include prismatic channels in topic nine. Topic ten is presented by considering the concept of critical velocity and critical depth in parallel with specific energy. Analysis for critical flow in prismatic channels is considered. The concepts in topics nine and ten are utilized to introduce the idea of gradually varied steady flow, taken up in topic eleven. The work-energy equation is utilized to develop numerical methods for calculating water surface elevations for steady open channel flows. Direct step and standard step methods and illustrated by example, providing exposure to steady flow analysis of open channel hydraulics in both prismatic and irregular channels. Topics nine and ten are used to support the introduction of water surface profiles in topic eleven. These concepts are illustrated by laboratory flume demonstration. Finally, a demonstration problem is presented in which the standard step method is used to estimate the water surface elevation in an irregular channel, experiencing steady flow, simple enough to allow manual calculations. The identical problem is used to introduce HEC-RAS and the manual calculations are reproduced with the software. During spring of 2005 a section on culvert design was included.

OBSERVATIONS AND CONCLUSIONS

An undergraduate course in hydraulics and hydrology has been established at UT Martin. The course combines an introductory-level survey approach with some selected coverage of engineering hydrology and hydraulic calculations. Short sections on theory are followed by illustration via example problems, and reinforced by similar homework assignments. HEC-HMS and HEC-RAS software is introduced. Student reception of the initial and second offering of the course has been positive overall. Student evaluations for 2004 and 2005 have been 3.991 and 4.542, respectively, on a 5-point scale. The one semester time limitation is somewhat overcome, for selected students, with application of this material in a senior project. The senior project experience (spanning two semesters) allows for review of the hydraulics and hydrology course and expansion into additional material. Adjustments in order of presentation, relative time spent between topics, and depth of coverage continue to be made.

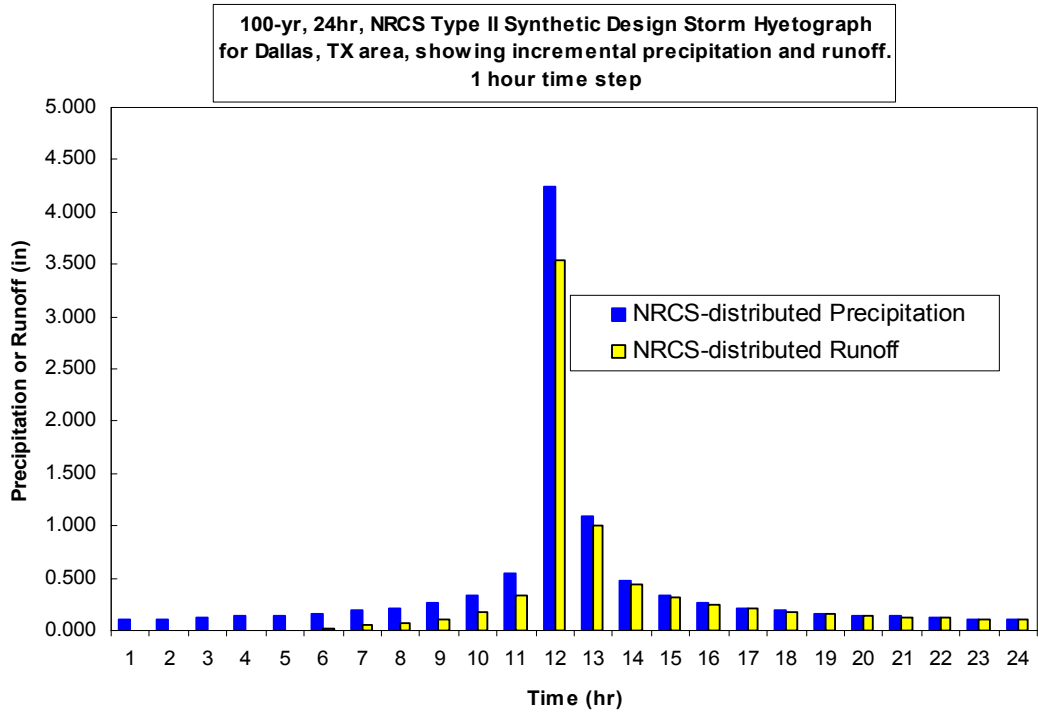


Figure 1

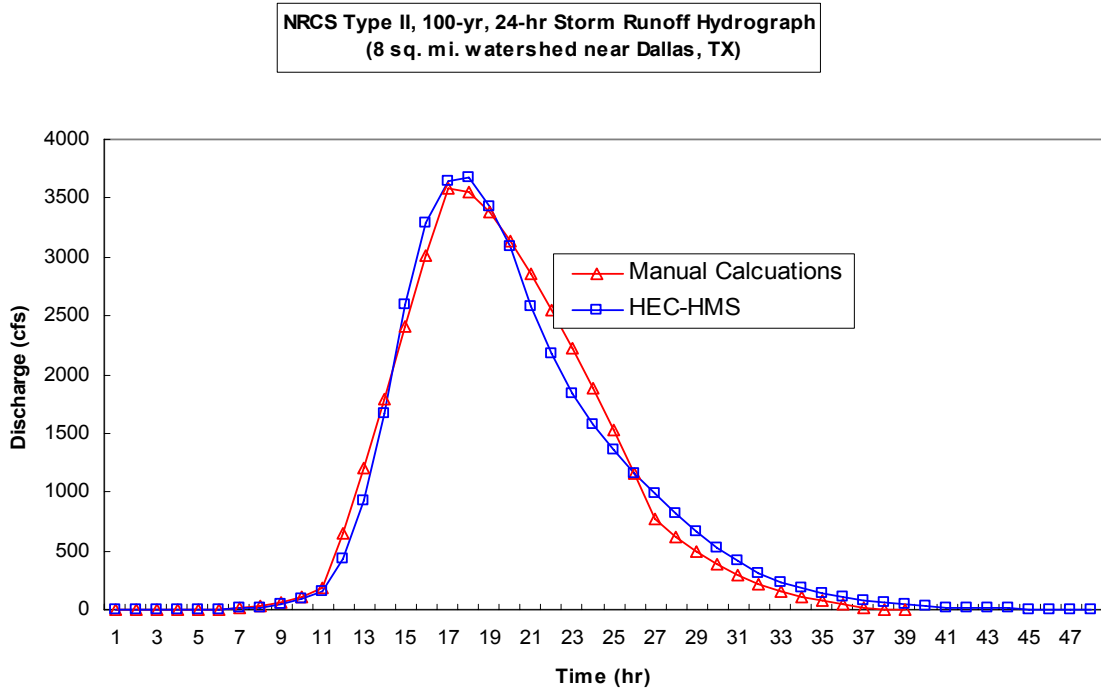


Figure 2

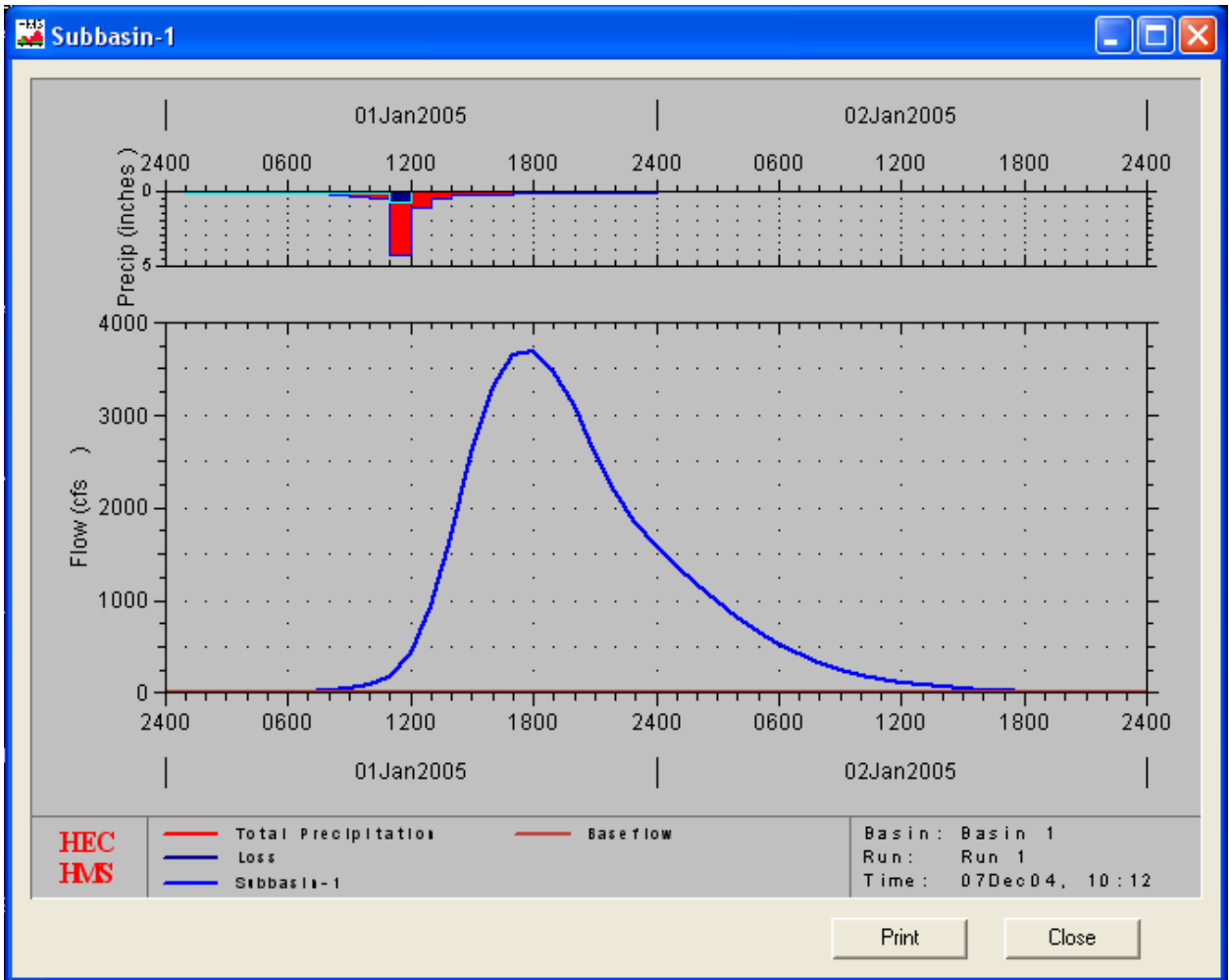


Figure 3

GIS APPLICATIONS FOR PHASE 2 STORMWATER

Rick McClanahan¹ and Todd Graves²

In order to comply with Phase 2 Stormwater requirements, many municipalities (Phase 2 MS4's) are going to be required to create drainage structure maps for their boundaries culminating in geographic data that will reveal outfall waters to the state. The ability to gather the drainage system typically would involve going in to the field with GPS data collection systems and manpower. We decided to approach the situation in a different manner. Currently, the City of Bartlett's Engineering department has scanned its complete mylar structure from 1976 to 2005 into a digital tiff format. We geo-referenced the finished scanned tiff image set of the entire city into their proper geographic locations (geo-referencing). We then were able to digitize our drainage structure in house by simply digitizing this system on top of the properly geo-referenced images. Orthoimagery and various other data layers coupled with the mylar images provided all of the data we needed to input the drainage structure. This presentation is a compilation of that work.

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GEOGRAPHIC INFORMATION SYSTEM AS A TOOL FOR DATA INTEGRATION AND ENGINEERING DECISION MAKING IN WATERSHED RESTORATION

Janelle L. Temple¹

Geographic information systems are important tools to map, display and analyze data in numerous water resources applications. In the planning stages of a Remedial Investigation/Feasibility Study for Davis Mill Creek, Copper Basin, Tennessee, a geographic information system (GIS) was used to integrate a variety of data types from multiple sources, collected over different time periods and to evaluate those data to make engineering decisions.

Various agencies, individuals and companies have been collecting data in the Davis Mill Creek watershed over many years. The data available include historical maps, analytical chemistry results from surface material, surface water, sediment and interstitial water sampling, inventory of waste materials including their estimated volumes and potential risk to the environment, field measurements of stream conditions, current aerial photographs, and topographic maps.

This paper describes how a GIS was used to compile and integrate multi-source data and develop an interactive tool for decision makers to easily and concurrently analyze recent and historical data. The tool enabled evaluation of potential point and non-point sources of contamination to Davis Mill Creek, identification of data gaps where additional information was needed to understand the impacts to Davis Mill Creek, and development of alternatives to address contamination in Davis Mill Creek.

BACKGROUND

The Copper Basin Mining Site is the site of extensive mining for copper and other metals and sulfuric acid production dating back to the mid-1800s. These historic mining and related activities have resulted in environmental degradation in the Basin. Although various government agencies and private parties have taken steps to revegetate the area, the Copper Basin continues to be affected by the presence of mining materials and mineral processing by-products, and continued releases of acidic, metal-laden water. In order to address these environmental concerns, OXY USA, Inc. and its subsidiary Glenn Springs Holdings, Inc. (OXY/GSH), the US Environmental Protection Agency (USEPA), and the Tennessee Department of Environment and Conservation (TDEC) agreed to conduct a cooperative, voluntary environmental remediation and redevelopment of the Copper Basin as described in an Agreement on Consent (AOC).

Part of this agreement was to conduct a Remedial Investigation/Feasibility Study for the Davis Mill Creek watershed. The Davis Mill Creek watershed comprises approximately 3000 acres, or 25 percent, of the Copper Basin Mining Site and produces more than 90 percent of the metals loading from the area. A number of investigations have been conducted in the Davis Mill Creek watershed providing various amounts and types of data. In order to determine what additional data were required to characterize the site and conduct a feasibility study and what additional data should therefore be collected in the remedial investigation, the existing data were evaluated.

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DATA INVENTORY

Data for the Davis Mill Creek watershed had been gathered in many forms by many different parties. The available data were assembled for analysis. Many historical maps were collected. Maps from companies that previously operated at the site included data such as topography, former industrial activities at the site, and previous alignments of Davis Mill Creek. Mining experts provided maps of areas with the potential for subsidence in the former mines.

More than 25 reports in paper or .PDF formats from USEPA and their consultants were provided presenting results of sampling at the site. Samples consisted of surface water, sediment, shallow ground water, seeps and surface materials. Maps of the sample locations were provided as well as tables of the coordinates and analytical chemistry results. An inventory of waste materials had also been conducted that provided a map of the materials, volume of the materials, and an assessment of their risk to the environment.

Current data for the site included aerial photography and topography. Analytical chemistry results of recent sampling were gathered as well as field measurements collected along the stream.

GIS INTEGRATION

Extensive data for the Davis Mill Creek watershed were compiled, but the form of the data, individual reports, maps, and files, was not conducive to comprehensive analysis. A GIS served as a useful tool to integrate all of the available information.

Current aerial photography and topography existed in an electronic format for use in a GIS and provided a backdrop for evaluating the rest of the data. Historic maps were scanned into a .TIF format and were geo-referenced by identifying common points on the paper maps and current aerial photographs. The main features of the maps were then digitized into individual featureclasses. Tables in the paper reports were converted to an electronic format and combined in an Access database. The sample locations were then converted to a featureclass so the corresponding analytical chemistry data tables could be joined or related in the GIS. A map of the inventory of waste materials was scanned and geo-referenced. Individual waste piles were then digitized into a featureclass. Associated volume and risk assessment data were included in the GIS as a table to be joined or related. Recent sampling results were in electronic format. Sample locations were recorded with handheld GPS and were easily converted to featureclasses for use in the GIS.

DATA EVALUATION

With the full set of historical and current data integrated into a GIS, the GIS became a powerful, interactive tool for evaluation. The GIS was projected on a screen during meetings among stakeholders, so all parties could view the same data during discussions. It also allowed different scenarios to be assessed and calculations to be made in real-time providing insight to further discussions and planning.

Historical and current topography were overlaid with locations of the current and former stream channel. This allowed estimates to be made of the volume of material deposited and accumulated in the stream and floodplain over the course of activities at the site. Overlaying the potential

subsidence areas on the current aerial photos was important to identify where remedial investigation or construction may not be feasible due to safety hazards.

The waste pile featureclass enabled evaluation of the potential risk of materials to the environment and their proximity to the stream. It allowed consideration of different removal scenarios and estimation of cost based on volume. For example, using the statistics tools in the GIS it was easily calculated that removal of all waste materials would require removal of 7.3 million cubic yards of material. Selection of high risk piles could be made to quickly determine that removal of only high risk piles would require moving 4.0 million cubic yards of material or that removing only high risk iron calcine would leave 170,000 cubic yards of high risk material in place.

Flow data was displayed with graduated symbols to identify significant tributaries and seeps and verify that Davis Mill Creek is a gaining stream. Analytical chemistry data was used with flow data to calculate and display metals loading in the stream, loading contributed to the stream by tributaries and seeps as well as the fraction of the total load.

The use of analytical data in the GIS also enabled evaluation of data gaps. Areas of the watershed with insufficient data were easily identified. Locations and types of data required to fill the gaps were assessed and incorporated into the data collection work plan.

CONCLUSION

A GIS enabled compilation and integration of both historic and recent multi-source data. It served as an interactive tool for decision makers to easily and concurrently analyze recent and historical data. The tool enabled evaluation of contamination to Davis Mill Creek, identification of data gaps where additional information was needed to understand the impacts to Davis Mill Creek, and development of conceptual plans for engineering actions to remediate Davis Mill Creek.

TENNESSEE STREAMSTATS: A WEB-ENABLED GEOGRAPHIC INFORMATION SYSTEM APPLICATION FOR AUTOMATING THE RETRIEVAL AND CALCULATION OF STREAMFLOW STATISTICS

David E. Ladd^{1*} and George S. Law¹

Planning, permitting, designing, and operating water-supply and wastewater-treatment facilities and hydraulic structures including bridges and culverts depend on accurate and timely estimates of streamflow statistics such as flood and low-flow frequencies and flow duration curves. Streamflow statistics are needed at both gaged and ungaged locations. The U.S. Geological Survey (USGS) periodically updates regional analyses of streamflow statistics based on a network of data-collection sites operated in cooperation with local and State agencies. These regional analyses include regression equations for estimating streamflow statistics for ungaged and unregulated streams across the State of Tennessee.

Computation of streamflow statistics using these equations for a site can be complex and require the user to provide a number of variables that may require interpretation. These may include drainage area, classifiers for physical properties, climatic characteristics, and other inputs. Obtaining these input values for gaged and ungaged sites has traditionally been time consuming, subjective, and sometimes leads to inconsistent results. Users needing streamflow statistics for ungaged sites in Tennessee must be able to accurately identify latitude and longitude, hydrologic region, contributing drainage area, and main-channel slope for each site of interest. The determination of these characteristics through manual methods may require substantial effort and personal judgment.

Use of geographic information system (GIS) technology to provide streamflow statistics, basin characteristics, and other information for gaged and ungaged sites can save substantial effort and offers potentially higher precision and consistency than can be obtained by use of manual methods. An automated, internet-based application for obtaining drainage-basin characteristics and calculating streamflow statistics at user-selected sites in Tennessee could provide information quickly and reliably without requiring users to have large investments in computer hardware and software and without requiring advanced knowledge of computer science, geographic analysis, or hydrology.

The USGS, in cooperation with Environmental Systems Research Institute (ESRI), has developed a web-enabled GIS application called StreamStats that automates the process of calculating streamflow statistics, basin characteristics, and other information for gaged and ungaged sites. StreamStats consists of five major components: (1) a user interface that displays maps and streamflow statistics based on user-selected stream locations, (2) a database that contains available streamflow statistics and descriptive information for USGS stream gaging stations, (3) a GIS database that stores base-map data needed for users to locate sites and stores other map data needed for determining basin characteristics, (4) an automated GIS process that determines drainage-basin boundaries for user-selected ungaged sites and determines basin characteristics for those sites, and (5) an automated process that solves regional regression equations to estimate various streamflow statistics for gaged and ungaged sites based on basin characteristics (Ries, K.G., III, Steeves, P.A., Coles, J.D., Rea, A.H., and Stewart, D.W., 2004, StreamStats: A U.S. Geological Survey Web Application for Stream Information: U.S. Geological Survey Fact Sheet

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FS-2004-3115, accessed December 20, 2005, at <http://md.water.usgs.gov/publications/fs-2004-3115>).

This presentation will demonstrate the use of StreamStats for a pilot area encompassing the Cumberland River basin in Tennessee. The development of StreamStats for Tennessee is a cooperative effort of the USGS and the Tennessee Departments of Conservation (TDEC) and Transportation (TDOT) and is intended to substantially reduce the effort and subjectivity involved in the calculation of streamflow statistics by many different users in the State.

SPILL MANAGEMENT INFORMATION SYSTEM VERSION 2.0 (SMIS 2.0): NEW TECHNOLOGY FOR MANAGEMENT OF OUR INLAND WATERWAYS

Janey V. Smith, Eugene J. LeBoeuf¹, James P. Dobbins,
Edsel B. Daniel, and Mark D. Abkowitz

The Spill Management information System (SMIS), developed by Vanderbilt University with support from the United States Army Corps of Engineers (USACE), provides a means to predict contaminant locations along inland water bodies to assist in either hazard planning or emergency management. The current version in use along the Cheatham Reach, Nashville, TN, includes the 2D water quality model, CE-QUAL-W2, from the USACE and the atmospheric dispersion modeling suite Computer-Aided Management of Emergency Operations (CAMEO) from the United States Environmental Protection Agency (USEPA) within a GIS coupled with a database management system (DBMS). SMIS 2.0 improves upon the previous version by integrating improved water quality modeling technology within a 3D spatial framework through the use of ArcView 9.1 and the 3D Analyst Extension (ESRI). Improvements in water quality modeling will allow for more precise determination of contaminant migration and location after a chemical incident. Three-dimensional hydrodynamic and water quality models with possibilities for use include: i. Surface-Water Modeling System (SMS) from Environmental Modeling Systems, Inc. (EMSI), ii. Environmental Fluid Dynamics Code (EFDC) from the USEPA, and iii. FLUENT, the computational fluid dynamics code software by Fluent, Inc. Use of GIS and 3D Analyst provides the capability to conduct virtual fly-over of the area and view rotations. SMIS 2.0 provides the next step in water security by providing a system that improves both hazard readiness and accident response that is applicable to any inland waterway.

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GEOGRAPHICAL INFORMATION SYSTEM TRACKING OF THE EFFECTS OF STORMWATER RUNOFF AND COMBINED SEWER OVERFLOWS ON URBAN STREAMS

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Urban landscapes are predominated in many cities by impervious surfaces to include roadways, parking areas, roof structures, and countless other structural impervious barriers. These impervious surfaces prevent infiltration of precipitation into the soil. Increased runoff from impervious surfaces creates major problems in municipal stormwater management. The impervious surfaces that prevent infiltration increase the volume of stormwater that must be processed or that drains naturally into receiving waters. Soil sediment and nutrients are carried into aquatic systems by increased natural runoff and the impervious surfaces introduce numerous pollutants to the stormwater that ultimately are introduced into the receiving bodies (U.S. Environmental Protection Agency, 1978a; 1998). The increased volume further damages the lotic ecosystems by increasing the velocity of water moving through the system. This increased velocity scours the streambed destroying habitat and macroinvertebrate communities, undercuts and erodes banks, introducing further sedimentation and nutrient inputs, and increases the ambient temperature of the aquatic system. (Brooker, 1985; Delleur, 2003; Wellborn & Robinson, 1996) The United States Environmental Protection Agency (USEPA) Stormwater Management Plan (U.S. Environmental Protection Agency, 1996) requires that all municipalities of specified populace maintain a municipal separate stormwater sewage system (MS4's). The stormwater sewage system must be separate from domestic sewage systems unless a NPDES (National Pollutant Discharge Elimination System) permit has been issued for existing combined sewer systems (U.S. Environmental Protection Agency, 1994; 2001a).

The voluminous amounts of runoff from impervious surfaces increases polluted stormwater input into storm sewer systems, receiving waters, and combined sewer systems (CSS). When combined sewer systems or MS4's are overwhelmed through precipitation events, the excess water bypasses the treatment facility and is discharged, often diluted, but generally untreated, into a receiving body (U.S. Environmental Protection Agency, 2000). Combined sewer systems offer an additional threat to surface waters in the form of combined sewer overflows (CSO). In CSO's untreated sewage mixed with storm water is discharged prior to the treatment facility through any opening in the sewer system. Discharges prior to the treatment facility often enter urban streams and rivers (U.S. Environmental Protection Agency, 1994). The introduction of polluted water into urban streams prevents the streams from supporting their designated uses and destroys aquatic fauna and flora. As the tributary carries the pollutants from stormwater runoff and combined sewer system overflows the pollutants greatly impair the quality of urban aquatic ecosystems and ultimately all surface waters ecosystems fed by the urban tributaries (U.S. Environmental Protection Agency, 2001b).

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Benthic macroinvertebrate (BMI) assemblages and fecal bacteria loads are reliable indicators that may be used for the assessment of the health of an aquatic ecosystem. Macroinvertebrate assemblages mirror the ecosystem response to pollutants. The BMI assessment accurately assesses the health of a lotic ecosystem by determining the tolerance level of the organisms collected using seven distinct biological metrics that measure tolerance values, the type and number of genera collected, and other characteristics of the sample organisms (Tennessee Department of Environment and Conservation, 2003). Fecal bacteria testing also provides vital information regarding the health of an aquatic ecosystem. Levels of fecal bacteria can indicate the effect of stormwater runoff, combined sewer overflows, septic system failures, or storm and sanitary sewage system defects (U.S. Environmental Protection Agency, 1986).

We examined two urban streams in Clarksville, Montgomery County, Tennessee. Both streams are second order tributaries of the Cumberland River located in the Western Highland Rim ecoregion (Griffith et al., 1997). Lime Kiln Hollow received urban stormwater runoff only while Gallows Hollow Branch received combined sewer outfalls and urban stormwater runoff. A local reference stream, an unnamed tributary to Passenger Creek, was also sampled. The reference stream is a second order tributary of the Red River located in rural Montgomery County, Tennessee and was sampled to control for seasonal effects.

Macroinvertebrate sampling was conducted in accordance with the Tennessee Department of Environment and Conservation's (TDEC) Quality Standard Operating Procedures (SOP) for Macroinvertebrate Stream Surveys (Tennessee Department of Environment Conservation, 2003). The study streams were sampled along 3 separate stream reaches using the modified semi-quantitative kick (MODSQKCK) method prescribed in the TDEC SOP. Samples were preserved in 10% Formalin solution in the field and transferred to the lab for processing. The samples were processed, sorted and preserved in 80% isopropanol. Macroinvertebrates were identified to the genus level for analysis. Analysis of stream systems using BMI involves the calculation of 7 biological metrics. The metrics were developed and previously tested by TDEC to be used as the statistical analysis for macroinvertebrate stream surveys. Identified differences in metric scores represent statistically significant differences. Metrics of macroinvertebrate assemblages in each stream were calculated.

Fecal bacteria loads were tested in accordance with the U.S. Environmental Protection Agency Microbial Methods for Monitoring the Environment: Water and Wastes (U.S. Environmental Protection Agency, 1978b). Water samples for fecal bacteria testing were taken from midstream sites using sterile whirl packs. Three 1 ml and three 10 ml aliquots of stream water were vacuum filtered through sterile membrane filters (0.45 µm pore size) within 6 hours of water collection. The filter membranes were then placed on FC agar plates and incubated at 44.5°C for 18 to 24 hours to test for fecal coliforms. Fecal streptococci were enumerated by preparing an identical set of membrane filters and placing them on m-Enterococcus agar followed by incubation at 41°C for 48 hours. Colony forming units (CFU) were determined for each group of fecal bacteria and were expressed as CFU's per 100 ml of water.

The data were entered into a Microsoft Excel spread sheet (Microsoft Corporation) and transferred ESRI Arcview 9 Geographical Information System Program (Environmental Systems Research Institute). A base map of the city of Clarksville was imported from the Austin Peay State University/Clarksville-Montgomery County GIS Center data server. The stream reaches were plotted using a Meridian Gold Global Positioning System (GPS) Handheld Receiver (Magellan Corporation). A separate base map of the reference stream was created using a Trimble Survey Controller GPS Receiver (Trimble Navigation Limited). The stream reach and the riparian zones were plotted using the polygon function of the Trimble GPS receiver. On the

maps of the study areas the Biological Status of the streams were indicated by color for macroinvertebrate scores and pattern for fecal bacterial numbers. Icons from the Arcview data base for bacteria and macroinvertebrates were placed beside each stream reach. These icons were hot linked to tabular representation BMI metrics and fecal bacterial load data for each stream reach. Sewer line data were provided by the Clarksville Gas and Water Department's GIS Center and plotted on the base maps. Hotlinks to photographic evidence of outfalls were placed on known outfalls along the sewer line plot.

The results of the investigation indicated that BMI assemblages in both urban streams were impacted when compared to the local reference stream. Fewer intolerant taxa were found in the urban streams and taxa richness and taxa diversity were lower in the urban streams. Fecal bacterial loading was heaviest in Lime Kiln Hollow despite the fact that this stream does not receive CSO discharges. The Benthic Macroinvertebrate Metric Scores are located in Table 1 and the Fecal Bacterial Loading data are presented in Table 2.

The data indicated an impact from urbanization on the urban streams. Specifically, the impact indicated was the result of impervious surfaces. Impervious surfaces increase the amount of stormwater that naturally drains into the lotic system by preventing infiltration (Shaver et al., 1994; Benke et al., 1981). This increased flow carries soil sediments, nutrients and other harmful pollutants from impervious surfaces as it flows into the stream. Impervious surfaces also cause CSS to become overwhelmed and to outfall prior to the treatment facility. The introduction of CSO discharges into a stream combines polluted stormwater with untreated sewage. The impervious surfaces are contributing factors to the types of pollution we examined. The increased fecal bacterial loading identified in Lime Kiln Hollow is likely the result of septic system failure but may also be the result of illegal "straight pipe" inputs. Lime Kiln Branch runs through an older part of the city and the homes in this portion of the city were once on septic systems. The estimated lifespan of modern septic systems is less than 25 years and many of the homes along Lime Kiln Branch are significantly older than 25 years. The septic systems, though no longer in use remain capable of introducing fecal bacteria into the stream. Additionally the sanitary sewer lines cross Lime Kiln Branch at several points. Failure of these older sewer lines could also contribute to the high levels of fecal bacteria encountered.

The GIS map allowed for comparison of the level of impact with proximity to points of discharge. Geographic representation clarified trends that were identified in the analysis of data. The GIS map also provided for easy conveyance of status information to the client agency. The ability to display fecal bacteria and macroinvertebrate data on the same graphic increased the productivity of the research team. Hotlinks allowed the actual data values to be displayed when desired. The GIS map will be expanded to include herpetofauna data and toxicity data before final presentation to the client agency. Using the GIS mapping applications will allow our research team to examine all of the data we have collected in one easily viewed and used format. With this information the team will be better able to recommend best management practices and will be able to assist the client in the development of the EPA mandated Stormwater Management Plan and Combined Sewer Overflow Policy for the City of Clarksville, Tennessee.

REFERENCES

Benke, A., E., Wileke, F. Parish, and D. Stites, 1981. Effects of Urbanization on Stream Ecosystems. Completion Report Project No. A-055-GA. U.S. Department of the Interior, Water Research and Technology.

- Brooker, M.P., 1985. The Ecological Effects of Channelization. *The Geographic Journal*. 151: 63-69.
- Delleur, J.W., 2003. The Evolution of Urban Hydrology: Past, Present, and Future. *Journal of Hydraulic Engineers*. 129: 563-573.
- Griffith, G.E., J.M. Omernik, and S.H. Azevedo, 1997. Ecoregions of Tennessee. EPA-600-R-97-022. U.S. Environmental Protection Agency: Corvallis, Oregon.
- Shaver, E., J. Maxted, G. Curtis and D. Carter, 1994. Watershed Protection Using an Integrated Approach. In *Sormwater NPDES Related Monitoring Needs*. American Society of Civil Engineers: Engineering Foundation. Crested Butte, Colorado.
- Tennessee Department of Environment and Conservation, 2003. Quality Standard Operating Procedure for Macroinvertebrate Stream Surveys. Division of Water Pollution Control. Nashville, Tennessee.
- U.S. Environmental Protection Agency, 1978a. Urban Runoff Control Planning. EPA-600-97-8035
- U.S. Environmental Protection Agency, 1978b. Microbial Methods for Monitoring the Environment: Water and Wastes. EPA-600-8-78-017.
- U.S. Environmental Protection Agency, 1986. Ambient Water Quality Criteria for Bacteria. EPA-440-6-84-002
- U.S. Environmental Protection Agency, 1994. Combined Sewer Outfall Control Policy. *Federal Register* 59:18688-18698.
- U.S. Environmental Protection Agency, 1996. Overview of the Storm Water Program. EPA-833-R-008.
- U.S. Environmental Protection Agency, 1998. Water Pollution Control: 25 Years of Progress And Challenges for the New Millennium. EPA-833-F-98-003.
- U.S. Environmental Protection Agency, 2000. Storm Water Phase II Final Rule: Small MS4 Storm Water Program Overview. EPA-833-F-00-002.
- U.S. Environmental Protection Agency, 2001a. Report to Congress: Implementation and Enforcement of the Combined Sewer Overflow Control Policy. EPA 833-R-01-033.
- U.S. Environmental Protection Agency, 2001b. Protecting the Nation's Water Through Effective NPDES Permits: A Strategic Plan FY 2001 and Beyond. EPA-833-R-01-001.
- Wellborn, G.A. and J.V. Robinson, 1996. Effects of Thermal Effluent on Macroinvertebrates in a Central Texas Reservoir. *American Midland Naturalist*. 136: 110-120.

Table 1. Macroinvertebrate Metrics for Gallows Hollow Branch and Lime Kiln Brach (Clarksville, Montgomery County, Tennessee) and an Unnamed Tributary to Passenger Creek (Montgomery County, Tennessee).			
Metric	Gallows Hollow	Lime Kiln	Tributary to Passenger Creek
Taxa Richness (TR)	2	2	4
EPT Richness (EPT)	0	6	4
% EPT	2	6	6
% OC	4	0	2
NCBI	4	2	4
% Dominant	4	0	6
% Clingers	4	0	4
Index Score	20	16	30
Target Score	32	32	32
Biological Status	Slightly Impaired (Partially Supporting)	Moderately Impaired (Partially Supporting)	Slightly Impaired (Partially Supporting)

Table 2. Fecal bacteria counts for Gallows Hollow Branch, Lime Kiln Branch (Clarksville, Montgomery County, Tennessee) and an Unnamed Tributary to Passenger Creek (Montgomery County, Tennessee) for two levels of precipitation. Numbers represent the average of triple aliquots and are expressed as colony forming units per 100 mL of water.				
Date	Site	Fecal Coliform	Fecal Streptococci	Precipitation Data
16 Oct 04	Gallows Hollow Branch	80	1680	Light Rain within 24 hours
16 Oct 04	Lime Kiln Branch	450	760	Light Rain within 24 hours
16 Oct 04	Unnamed Tributary to Passenger Creek	380	990	Light Rain within 24 hours
22 Nov 04	Gallows Hollow Branch	1860	1300	Heavy Rain within 24 hours
22 Nov 04	Lime Kiln Branch	860	300	Heavy Rain within 24 hours
22 Nov 04	Unnamed Tributary to Passenger Creek	830	750	Heavy Rain within 24 hours

A COMPARATIVE STUDY OF GIS MONITORING TECHNIQUES FOR TRACKING *ARUNDINARIA GIGANTEA* AND *JUSTICIA AMERICANUM* RESTORATION SITES USED FOR STREAM HABITAT ENHANCEMENT

Jon L. McMahan*¹, Mack T. Finley², and Andrew N. Barrass²

The methodology of monitoring stream bank restoration and establishment of vegetation has become dependent upon the technology of Geographic Positioning Systems (GPS) and Geographic Information Systems (GIS). Most conservation agencies utilize ArcView as a method for tracking vegetative plantings. This has become the preferred method of monitoring vegetative restoration. Large financial resources have been invested with the focus on restoring riparian zones along our waterways. Alternatively, little has been invested in the maintenance and monitoring of these restoration sites. GIS and GPS monitoring were implemented using ArcView methods compared to the newly developed program ArcGIS. Three streams were assessed for spatial distribution of River cane, *Arundinaria gigantea*, and Water willow, *Justicia americanum*, to portray the advantages of ArcGIS over the older program ArcView. The ArcGIS methods were more effective in evaluating the enhanced stream ecology of riparian sites.

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FINDING BANKFULL: A STORY FROM THE TABLELANDS

Ray Albright*¹ and Greg Babbitt²

ABSTRACT

Finding bankfull stage indicators along a stream channel is sometimes more of an art than a science. However, to be credible, one has to apply scientific methods. We developed a repeatable, systematic process to locate bankfull stage within the Level III Southwestern Appalachians ecoregion (68) in Tennessee during the summer of 2005. This ecoregion contains the Cumberland Plateau (commonly called the Tablelands), the Sequatchie Valley and the Plateau Escarpment. Our full intent was to develop regional curves of hydraulic relationships for this ecoregion, but first we had to correctly identify bankfull stage in our sample streams. We defined bankfull discharge as the effective discharge (channel forming flow). Bankfull stage was defined as the incipient point where water spreads out onto the active floodplain.

INTRODUCTION

The primary consideration when quantifying stream channel hydraulic geometry is identifying the bankfull stage. This stage of flow is best described by Dunne and Leopold (1978, pgs. 608-609) who stated that the “bankfull stage corresponding to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends or meanders, and generally doing work that results in the average morphologic characteristics of channels.”

The discharge at bankfull stage is also known as the channel-forming discharge, the effective flow and/or the dominant discharge (Leopold and Maddock, 1953; Wolman and Miller, 1960; Williams, 1978). Bankfull stage is described by most researchers as the incipient point on the stream bank where water spreads out onto the active floodplain and flooding begins (Wolman and Leopold, 1957; Emmett, 1975; Leopold *et al.*, 1964; Rosgen, 1996). Leopold (1994, pg. 90) states that “it is an empirical fact that, for most streams the bankfull discharge has a recurrence interval of approximately 1.5 years in the annual flood series.” A recurrence interval between 1 to 2 years has become the acceptable range for bankfull discharge. Knowing bankfull discharge allows a river worker to compare channel width, cross sectional area, channel depth and velocity with other stream channels at their respective bankfull stages. Finding the indicators of bankfull stage on the ground are sometimes more of an art than a science. The intent of this paper is to present a repeatable, systematic process to locate bankfull stage in the field.

RESEARCH GOALS

There were two research questions addressed. 1) Can consistent, reliable indicators of bankfull stage be identified from geomorphic features in the sampled streams of the Southwestern Appalachians ecoregion? 2) Does the typical bankfull discharge recurrence intervals of 1 to 2 years match the bankfull discharges found in the Southwestern Appalachians ecoregion?

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STUDY AREA

The study area was defined by the Level III Southwestern Appalachians ecoregion 68 in Tennessee which is composed of Level IV ecoregions Cumberland Plateau 68a, Sequatchie Valley 68b and Plateau Escarpment 68c. We chose to use the Level III ecoregion because it integrates many channel-forming variables such as precipitation, vegetation, geology, physiography and soils into a spatial framework for assessment, research, monitoring and management. The Southwestern Appalachians cover approximately 11.4% of Tennessee or roughly 5,400 square miles. The ecoregion is the source for several major rivers and their tributaries that have carved pathways through the resistant sandstone bedrock and dropping down the steeply graded escarpment to the neighboring Ridge and Valley, Sequatchie Valley and Eastern Highland Rim. The Cumberland Plateau of the Southwestern Appalachians extends 1200 to 2000 feet above mean sea level in elevation and possesses a relatively flat to gently rolling landscape commonly referred to as “the tablelands.”

The Southwestern Appalachians ecoregion is characterized by a temperate climate. The sudden rise in elevation produces an orographic effect that markedly increases precipitation volumes compared to surrounding ecoregions. The geology is an alternating layering of sandstone, siltstone and shale over a deep limestone bed. Land use across the ecoregion is still dominated by mixed mesophytic forest communities (about 70%). Agriculture is the second largest land use with pastures for cattle grazing being the primary form of agriculture with cropland to a lesser extent. Strip mining is prevalent across the Cumberland Plateau and includes primarily coal and stone mining. Urban development and urban/wildland interface has greatly increased over the last decade and is predicted to continue increasing.

METHOD

Within the Southwestern Appalachians of Tennessee, a total of 37 active and discontinued U.S. Geologic Survey (USGS) streamflow gaging stations were considered for inclusion in the study. A criterion was developed to guide site selection. After eliminating unsuitable study sites, eight USGS streamflow gaging stations and three study reaches were used in this investigation.

Geomorphic surveys were accomplished by investigators during the spring and summer of 2005. At all of the eight USGS gaged stream study reaches, a pedestrian survey was performed along the study reach upstream and downstream of the gage station to assess conditions and potential bankfull indicators. For each of the eight USGS gaging stations, a geomorphic stream survey was achieved following well-established protocol and survey procedures (Harrelson *et al.*, 1994; Leopold, 1994; Rosgen, 1996). Discharge rating tables and gage descriptions were obtained from the Nashville and Knoxville USGS offices.

Identifying bankfull stage in the field is often a formidable challenge and must be based on physical, visible indicators. The literature lists several indicators such as top of bank, floodplain break, depositional features, high scour lines, vegetation changes, substrate changes, and inflections points.

We developed five different metrics as a repeatable, systematic process to substantiate bankfull stage at each of the eleven study streams.

Bankfull stage at stream channel cross section.

At each study stream, cross sectional surveys were performed on stable, representative riffles nearest to the gaging station. Cross sectional surveys included standard readings (floodplain

elevations, left and right pins, terraces, significant breaks in slope, top of bank, left and right edge of water and thalweg) plus the elevation of bankfull stage. Bankfull stage was determined based on the indicators. Benchmarks at the gage datum were located and surveyed for reference to the stage-discharge rating tables.

Bankfull stage along the longitudinal profile.

A longitudinal profile of each study reach was conducted for a distance of approximately 20 times the bankfull width of each stream channel (Leopold, 1994). Both vertical and horizontal measurements were taken at each recognizable habitat unit such as riffle, run, glide and pool. Measurements included thalweg for bed elevation, water surface for slope, and bankfull elevation for comparison of consistent morphological indicators along the profile. Bankfull stage was determined based on the indicators.

Bankfull stage verification by a group of experts.

We enlisted the opinions from eight experienced professionals across the southeast for bankfull stage on four of the study streams. Aside from providing drainage area size onsite, all hydrologic information was purposefully withheld to reduce biased opinions. Each participant was given a pin flag and allowed to visually survey the study reach for prominent bankfull indicators. The elevation of each pin flag was surveyed for later calculation of discharge.

Graphing minimum width/depth ratio of the cross section.

We plotted width/depth ratio against stage elevation for each cross section in order to identify the minimum width/depth ratio. The point along the curve at which the width/depth ratio established a minimum was related to the elevation. This metric was used to collaborate the other metrics.

Computing the flood recurrence intervals.

Annual peak streamflow records from the 8 USGS gaging stations were obtained from the Tennessee USGS (2005) website at <http://tn.water.usgs.gov>. Recurrence intervals of the bankfull elevations were calculated by fitting the log-Pearson Type III distribution of the annual series as described in Bulletin 17B of the Interagency Advisory Committee on Water Data (1982). A modified (log base 10 transformation of the data) Excel spreadsheet originally produced by NRCS was used to compute the discharge of return intervals at 0.1 year increments between 1 and 2 years.

RESULTS AND DISCUSSION

We found that consistent, reliable indicators of bankfull stage could be identified from geomorphic features in the study streams of the Southwestern Appalachians ecoregion. We noted that the following indicators were the most useful in identifying bankfull stage: floodplain break (primary indicator); inflection point; depositional bench; and top of point bars.

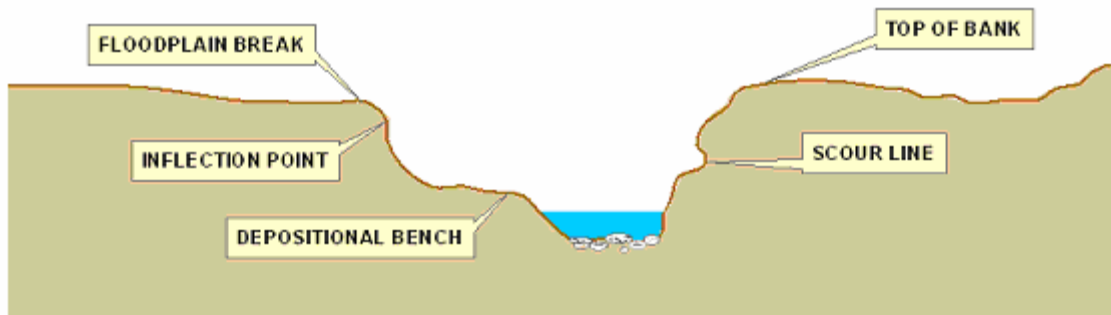


Figure 1. Typical Geomorphic Features Used as Bankfull Indicators on Streams Draining the Southwestern Appalachians of Tennessee.

The five metrics were used to substantiate the bankfull stage at each study stream. The first three metrics were field determinations. The longitudinal profile took into account many bankfull indicators along the study reach and closely agreed with the cross section bankfull elevations. The group opinions matched our own markings at all but one river, which is remarkable given the subjectivity in determining bankfull stage. The recurrence interval metric is discussed below. From the systematic process we were able to identify the bankfull elevation with high confidence.

We found that the typical bankfull discharge recurrence intervals (RI) of 1 to 2 years matched the bankfull discharges found in the Southwestern Appalachians ecoregion. We calculated that the RIs for all the study streams to be 1.1 to 1.4 years with an average bankfull discharge RI of 1.31 years (standard deviation (sd) = 0.12). This determination was comparable to the Ridge and Valley (RI = 1.36 years, sd = 0.28) and the Piedmont and Blue Ridge (RI = 1.44 years, sd = 0.22). The RI further supported our field readings for bankfull stage.

As elusive as bankfull stage may sometimes appear to be, there is a systematic way to identify it in the field.

MAIN REFERENCES

- Dunne, T. and Leopold, L.B. (1978) *Water in Environmental Planning*. San Francisco, W.H. Freeman & Company. 818 pp.
- Emmett, William W. (1975) *The Channels and Waters of the Upper Salmon River Area, Idaho*. U. S. Geological Survey Professional Paper Washington, D.C.: WPO. 870-A.: 116 pp.
- Harrelson, C.C., J.P. Potyondy, and C.L. Rawlins. (1994) *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*. General Technical Report. USDA, Forest Service, Fort Collins, Colorado. RM-245: 61 pp.
- Leopold, Luna B. (1994) *A View of the River*. Harvard Univ. Press, Cambridge, Massachusetts. 298 pp.
- Leopold, L. B. and Maddock, T. Jr. (1953) *The Hydraulic Geometry of Stream Channels and Some Physiographic Implications*. Geological Survey Professional Paper. Washington, D.C.: WPO. 252:57 pp.

Leopold, L.B., M.G. Wolman, and J.P. Miller. (1964) *Fluvial Processes in Geomorphology*. NY, New York: Dover Publications, Inc. 522 pp.

Rosgen, D. L. (2004) *River Morphology and Application Reference and Field Manual*. Wildland Hydrology. Fort Collins, Colorado.

Williams, G.P., (1978) Bank-full Discharge of Rivers. *Water Resources Research*, 14(6):1141-1154.

Wolman, M.G. and L. B. Leopold (1957) River Flood Plains: Some Observations on their Formation. *USGS Professional Paper 282-C*. 109 pp.

Wolman, M.G. and Miller, J.P. (1960) Magnitude and frequency of forces in geomorphic processes. *Journal of Geology*, 68:54-74.

REGIONAL CURVES FOR THE SOUTHWESTERN APPALACHIAN ECOREGION

Greg Babbit¹ and Ray Albright²

ABSTRACT

The purpose of this study was to develop bankfull discharge and hydraulic geometry relationships for streams draining the Southwestern Appalachians Level III Ecoregion 68 of Tennessee and compare those relationships to the Ridge and Valley of Virginia, West Virginia, and Maryland (Keaton *et al.*, 2005) and the Piedmont and Blue Ridge of North Carolina (Harman *et al.*, 1999; Harman *et al.*, 2000). Stream surveys were conducted on 11 study reaches (7 had USGS gages for calibration of bankfull) of various sized drainages across the ecoregion. Regional curves illustrate hydraulic and geomorphic relationships such as discharge versus watershed area, channel width versus channel cross sectional area and many more such relationships. The principal benefits from regional curves are their assistance in validating channel dimensions during assessment and restoration design. The marked variance in geology, climate, topography, and watershed land-uses across physiographic provinces drives the need for developing regional curves for each specific physiographic province. A comparison of the Southwestern Appalachians regional curves developed in this study to the Ridge and Valley and the Piedmont and Blue Ridge reveals distinctly different relationships. In the Southwestern Appalachians, bankfull discharge and associated cross sectional area were found to be of much greater magnitude than streams draining the other two regions.

INTRODUCTION

Streams transport water, sediment and energy while providing habitat for aquatic and terrestrial organisms. Stream channel shape, size, and pattern are a function of many physical processes and to a lesser extent, biological and chemical processes occurring simultaneously within a watershed (Emmett, 1975). Drainage basin size has been found to be highly correlated with natural channel morphology, specifically cross sectional area in many physiographic provinces throughout the U.S. (Dunne and Leopold, 1978; Harman, *et al.*, 1999; Smith and Turrini-Smith, 1999; Keaton *et al.*, 2005). Each river basin has a discharge and sediment load that are products of a number of variables interacting within a watershed, such as local climate (precipitation), geology, soils, vegetation, land use, topography, and valley morphology (Emmett, 1975; Leopold, 1994; Knighton, 1998). As noted by Montgomery (1999), differences in climate, geology and topography differ from one region to another and impose a significant influence on channel process at the reach or valley segment scale.

Hydrologic, hydraulic and resultant geomorphic processes are the dominant physical processes affecting stream channel morphology. Schumm (1960) added to the factors controlling channel shape by establishing that stream channel morphology is also a function of the composition of bed and bank materials. Leopold and Maddock (1953) pioneered hydraulic geometry relationships in the early 1950s, when they examined the width, depth, velocity, discharge and suspended sediment of natural rivers. Their quantitative examination of discharge and sediment load illustrated the dependence of channel shape on the aforementioned physical, chemical and

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biological characteristics within a watershed. The magnitude and frequency concept initially set forth by Wolman and Miller (1960) described the dependence of river floodplain and channel shape on flows of moderate magnitude occurring more frequently rather than infrequent, storm events of large magnitude. Leopold, Wolman and Miller (1964) found that stream channel shape is a function of the timing, magnitude, spatial distribution and frequency of stream discharge. Furthermore, they illustrated that the amount, size and shape of sediment transported through a reach and the composition of boundary materials within the channel help dictate channel form.

The primary consideration when quantifying stream channel hydraulic geometry is identifying the channel-forming flow because it is the discharge at which channel width, depth, area, and velocity are compared. Bankfull, effective, dominant and channel-forming discharges are terms describing a similar flow and were described by multiple scientists (Leopold and Maddock, 1953; Wolman and Miller, 1960; Kilpatrick and Barnes, 1964; Andrews, 1980; Knighton, 1998). Regional curves are a graphical method of illustrating stream channel bankfull hydraulic geometry as a function of basin drainage area within a specific ecoregion or physiographic province (Harman *et al.*, 1999). Regional curves are the product of regression analysis performed on the relationships of bankfull discharge, width, mean depth and cross-sectional area to drainage area. The dependent variables of bankfull discharge, width, mean depth and cross-sectional area can be determined from field geomorphic surveys.

METHODS

Within the Southwestern Appalachians of Tennessee, a total of 37 active and discontinued U.S. Geologic Survey (USGS) streamflow gaging stations were considered for inclusion in the study. Selected Hydrologic Unit Codes (HUCs) for the study area included: Big South Fork of the Cumberland River (05130101), Sequatchie River (06020004), the Obey River (05130105), Gunterville Lake (06030001), Upper Elk (06030003) and the Emory River (06010208). After eliminating unsuitable study sites, 11 USGS streamflow gaging stations and study reaches were used in this investigation (Figure 1).

The method of data collection followed the Level II protocol outlined by Rosgen (1996), which was built on well established geomorphic survey methodologies by others (Leopold and Maddock, 1953; Leopold *et al.*, 1964; Leopold, 1994; Harrelson *et al.*, 1994). The Level II delineative criteria describe stream channel dimension (width, mean depth, and cross-sectional area), longitudinal profile, pattern, and dominant channel material as measured in the field. The data collected on these variables are then computed and graphed to illustrate the present form of the stream channel. For the majority of streams, two channel cross-section surveys were performed on relatively stable, representative riffles closest to the gaging station as possible. According to Leopold (1994), the riffle is the most stable portion of the river. Detailed cross sections of rivers were surveyed to gather accurate channel geometry. Cross sectional surveys included floodplain elevations, left and right pins, terraces, significant breaks in slope, bankfull elevation, top of bank, left and right edge of water and thalweg.

A longitudinal profile survey of the study reach was conducted for a distance of approximately 20 times the bankfull width of each stream channel (Leopold, 1994). Both vertical and horizontal measurements were taken at each recognizable channel feature or facet such as riffle, run, glide and pool. Elevation measurements taken at each facet included thalweg for bedform, water surface for slope and bankfull elevation for comparison of consistent morphological indicators along the profile. On real-time gaging stations, river stage was recorded on the day and time of survey. Prior to beginning survey measurements, benchmarks tied to the gage datum were located and surveyed for reference to the stage-discharge rating tables.

For ungauged streams included in the survey, bankfull discharge had to be estimated through the use of resistance equations. As described by Emmert (2004), bankfull discharge on those streams lacking USGS gaging stations was determined by estimating water velocity using a variation of the Darcy-Weisbach resistance coefficient (f). Simple linear regression was used to develop power function equations for bankfull hydraulic geometry of streams draining the Southwestern Appalachian ecoregion in Tennessee. The bankfull hydraulic geometry data and estimated bankfull discharge data for all 11 sites were regressed on drainage area at a log-log scale. For each bankfull regional curve, the dependent variable (bankfull discharge, width, mean depth and cross sectional area) was regressed on the independent variable of basin drainage area (DA). A least-squares power function equation was determined by fitting a best-fit line through each bankfull channel geometry relationship. Goodness-of-fit statistics for each regional curve included the regression coefficient (R^2), standard error of the estimate, the F -statistic, and the P -value. A significance level of $\alpha = 0.05$ was used for all statistical analyses.

RESULTS AND DISCUSSION

A comparison of the slopes of the regional curves from the data for the Southwestern Appalachians of Tennessee, against the North Carolina Piedmont and Blue Ridge and the Ridge and Valley of Virginia, West Virginia and Maryland was accomplished using analysis of covariance. The covariate was drainage area (DA), the independent variable was region and the dependent variables were bankfull discharge, cross-sectional area, width, and mean depth. Power function regression equations and the respective coefficients of determination, standard error of the estimate and the F -statistic are shown in Table 1. Bankfull discharge for streams draining the Southwestern Appalachians was significantly related to drainage area with a coefficient of determination $R^2 = 0.985$. Basin drainage area for the surveyed streams ranged from 0.08 to 272 square miles. Drainage area explained 98% of the variability in bankfull discharge. Of the four dependent variables (discharge, cross-sectional area, width and mean depth), bankfull cross section area had the highest $R^2 = 0.996$. Each bankfull regional curve (discharge, area, width and mean depth) had a $R^2 > 0.95$, which signified that each dependent variable was highly related to drainage area.

Bankfull discharge and hydraulic geometry relationships as a function of drainage area for stream channels draining the Southwestern Appalachians were compared to those determined by Harman *et al.* (1999 and 2000) and Keaton *et al.* (2005). Through analysis of covariance (ANCOVA), a statistically significant difference was found between the slopes of the regional curves for the Southwestern Appalachians and the other two regions except for curves of bankfull mean depth (Table 2). The Southwestern Appalachians had consistently higher values of bankfull discharge, cross-sectional area and width than the other two regions. The mean difference between bankfull mean depth for the Southwestern Appalachians and the North Carolina Piedmont and Blue Ridge was 0.02 feet, which was not significant ($P = 0.96$). As a result of this study, conclusive evidence exists in support of different bankfull discharge, bankfull cross-sectional area, and bankfull width for streams draining the Southwestern Appalachians of Tennessee.

Table 1. Power Function Equations and Statistics for the Southwestern Appalachian Ecoregion.

Equation	P-value	R ²	Std. Beta Coeff.	Std. Error	F-statistic ¹
Bkf Discharge (cfs) Q = 150.06(DA) ^{.75}	0.001	0.985	0.992	0.285	573
Bkf Cross-sectional Area (ft ²) Area = 32.48(DA) ^{.701}	0.001	0.995	0.998	0.144	1970
Bkf Width (ft) Width = 18.51(DA) ^{.444}	0.001	0.971	0.985	0.233	301
Bkf Mean Depth (ft) Depth = 1.76(DA) ^{.256}	0.001	0.966	0.983	0.147	253

¹For all models (n = 11), degrees of freedom (df)_{numerator} = 1 and df_{denominator} = 9
DA = Drainage Area

Table 2. Comparison of Mean Differences between the Three Regions.

Variable	Southwestern Appalachians		Ridge and Valley		Piedmont and Blue Ridge	
	Mean	SE	Mean	SE	Mean	SE
Bankfull Area (ft ²)	575 ^a	44	250 ^b	23	349 ^c	32
Bankfull Width (ft)	97.3 ^a	7.2	70.6 ^b	3.8	75.2 ^b	5.2
Bankfull Mean Depth (ft)	4.1 ^a	0.33	3.0 ^b	0.17	4.0 ^a	0.24
Bankfull Discharge (cfs)	3441 ^a	274	1221 ^b	144	1924 ^c	198

¹Means within rows followed by unlike letters are significantly different at P < 0.05

²Covariates appearing in the model are evaluated at Drainage Area = 74.7484 mi²

Due to the natural variability among processes acting on river basins, the reader should be advised that the regional curves developed in this study are preliminary and intended to be used as a tool for stream assessment and bankfull validation, and should not be relied on for precise bankfull calculations. The regional curves for the Southwestern Appalachians may be used to augment detailed fluvial geomorphic studies conducted on a particular stream reach within the ecoregion. Future investigations of streams in the Southwestern Appalachian ecoregion may be used to supplement the preliminary regional curves developed for this study. Results of this study have shown a need to develop regional bankfull discharge and hydraulic geometry relationships for Tennessee. Fluvial geomorphic investigations of streams throughout Tennessee will improve our understanding of regional morphological characteristics and aid in stream assessment. Future studies are needed to more accurately predict bankfull discharge and hydraulic geometry for other regions in Tennessee.

REFERENCES

- Andrews, E.D. (1980) Effective and Bankfull Discharges of Streams in the Yampa River Basin, Colorado and Wyoming. *Journal of Hydrology* 46: 311-300.
- Dunne, T. and Leopold, L.B. (1978) *Water in Environmental Planning*. San Francisco, W.H. Freeman & Company. 818 pp.

- Emmert, Brock A. (2004) Regional Curve Development for Kansas. *Proceedings of the ASAE September Conference: Self-Sustaining Solutions for Streams, Wetlands, and Watersheds*. September 12-15, 2004. St. Paul, Minnesota: 27-35.
- Emmett, William W. (1975) The Channels and Waters of the Upper Salmon River Area, Idaho. *U. S. Geological Survey Professional Paper* Washington, D.C.: WPO. 870-A.: 116 pp.
- Harman, W.H., Wise, D.E., Walker, M.A., Morris, R., Cantrell, M.A., Clemmons, M., Jennings, G.D., Clinton, D.R., and Patterson, J. (2000) Bankfull Regional Curves for North Carolina Mountain Streams. In: D.L. Kans ed. *Proceedings of the AWRA Conference Water Resources in Extreme Environments*. Anchorage, Alaska. 185-190.
- Harman, W.H., Jennings, G.D., Patterson, J., Clinton, D.R., Slate, L.O., Jessup, A.G., Everhart, J.R. and Smith, R.E. (1999) Bankfull Hydraulic Geometry Relationships for North Carolina Streams. In: D.S. Olson and J.P. Potyondy eds. *AWRA Wildland Hydrology Symposium Proceedings*. AWRA Summer Symposium, Bozeman, MT. 401-408.
- Harrelson, C.C., J.P. Potyondy, and C.L. Rawlins. (1994) Stream Channel Reference Sites: An Illustrated Guide to Field Technique. *General Technical Report. USDA, Forest Service, Fort Collins, Colorado*. RM-245: 61 pp.
- Keaton, J. N., T. Messinger, E. J. Doheny (2005) Development and Analysis of Regional Curves for Streams in the Non-Urban Valley and Ridge Physiographic Province, Maryland, Virginia, and West Virginia. *Scientific Investigations Report 2005-5076*. USGS. 116 pp.
- Kilpatrick, F.A. and Barnes, H.H., Jr. (1964) Channel Geometry of Piedmont Streams as Related to Frequency of Floods. *Geological Survey Professional Paper 422-E* Washington, D.C.: WPO. 10 pp.
- Knighton, David. (1998) *Fluvial Forms and Processes*. NY, New York: John Wiley & Sons, Inc. 383 pp.
- Leopold, Luna B. (1994) *A View of the River*. Harvard University Press, Cambridge, Massachusetts. 298 pp.
- Leopold, Luna B. (1994) *A View of the River*. Harvard University Press, Cambridge, Massachusetts. 298 pp.
- Leopold, L. B. and Maddock, T. Jr. (1953) The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. *Geological Survey Professional Paper*. Washington, D.C.: WPO. 252:57 pp.
- Leopold, L.B., M.G. Wolman, and J.P. Miller. (1964) *Fluvial Processes in Geomorphology*. NY, New York: Dover Publications, Inc. 522 pp.
- Montgomery, D. R. (1999) Process Domains and River Continuum. *Journal of the American Water Resources Association*. 35 (2):397-410.
- Rosgen, D. L. (1996) *Applied River Morphology*. Wildland Hydrology Books, Pagosa Springs, CO.
- Schumm, S.A. (1960) *The Shape of Alluvial Channels in Relation to Sediment Type*. U.S. Geologic Survey Professional Paper No. 352-B. 30 pp.
- Smith, D.P. and Turrini-Smith, L. (1999) Western Tennessee Fluvial Geomorphic Regional Curves. *U.S. EPA Region IV Water Management Division*, 14pp.
- Wolman, M.G. and Miller, J.P. (1960) Magnitude and frequency of forces in geomorphic processes. *Journal of Geology*, 68:54-74.

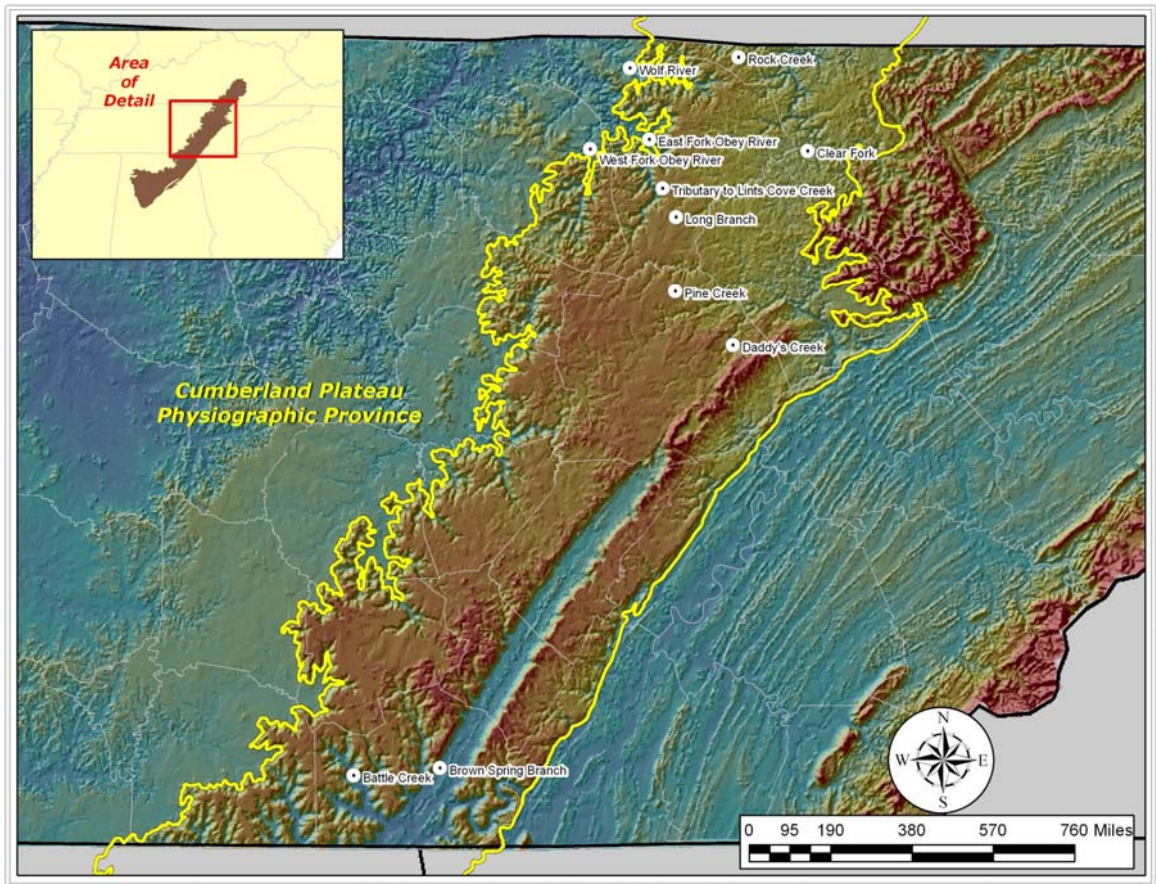


Figure 1. Location of Selected USGS Gaging Stations and Study Reaches in the Southwestern Appalachians 2005.

FALSE GAGES

William R. Barron, Jr.¹

ABSTRACT

Evaluation of data should always be the first item when conducting a study. All too often gaged data is considered the most accurate, best available data. This paper will describe four stream gages that have data that looks correct, but depending upon the intended use may not be correct. The four gages are the Roaring River above Gainesboro, TN (USGS DSN 03418070), the West Fork Stones River at Nices Mill near Smyrna, TN (USGS DSN 03428500), Caney Fork near Rock Island, TN (USGS DSN 03422500), and the Little Pigeon River at Sevierville, TN (USGS DSN 03470000).

Three of these sites (Roaring River, West Fork Stones River, and Caney Fork) record the data correctly, but a site visit reveals that physical characteristics of the area in the vicinity of the gage make the data highly questionable. The fourth site, the Little Pigeon River, has questionable high flows.

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SESSION 3A

SOURCE WATER

8:30 a.m. – 10:00 a.m.

Robertson County: Water for the Future
George C. Garden and William P. Hamilton

EPA Perspectives on the Future of Source Water Protection
E. Stallings Howell

Water-Demand Projections in the Upper Duck River, Tennessee River Watershed, Central Tennessee, 2000 to 2030
Susan S. Hutson

STREAM RESTORATION

10:30 a.m. – 12:00 p.m.

Overview of Construction of Three Large Stream Restoration Projects in Tennessee
Ken Barry and Michael Pannell

Bear Creek: Acid Mine Drainage Remediation Success Story
Carol C. Chandler

Stream Bank Stabilization Along Little Harpeth River is Eagle Scout Project
John McFadden

ROBERTSON COUNTY: WATER FOR THE FUTURE

George C. Garden¹ and William P. Hamilton²

INTRODUCTION

Robertson County, Tennessee is located immediately north of Davidson County (Nashville) along the Kentucky-Tennessee border. The county is ideally situated adjacent to some of the fastest growing regions of Tennessee. Its proximity to important transportation corridors and dynamic population centers make it a candidate for vigorous growth into the future.

Robertson County is unique among similar counties with large rural populations in that the entire county is served water from 3 primary suppliers. Both the Adams-Cedar Hill Water System (ACHWS) and the Springfield Water and Wastewater Department (SWWD) produce water from the Red River, while the White House Utility District (WHUD) draws its raw water from the Cumberland River. This arrangement is unique in that there are no utility districts supplying water to rural customers. This arrangement provides considerable potential for cooperation among the existing water suppliers; however, these suppliers will inevitably focus on the population centers that they serve. Thus, there is no entity advocating for the needs of rural residents of Robertson County.

Although each system faces its own challenges with respect to distribution, production capacities are currently adequate to meet the needs of the county. Because it draws its source water from the Cumberland River, the eastern part of the county is not resource-limited. The WHUD has a production capacity of 30 MGD, and can expand if demand warrants. The two systems in the western part of the county (ACHWS and SWWD) do not share that luxury. Since these two systems both draw water from Red River, a stream with much less capacity than the Cumberland River, they share a degree of interdependence, and additional growth in either community threatens the available water supply to the western part of the county. In addition, the distribution systems in the western part of the county have in large part reacted to growth and are not vehicles to promote growth. Both the ACHWS and SWWD systems are composed of primarily small diameter lines that limit the hydraulic capacity of each system. In addition, there is no interconnectivity between these two systems, so the limited water resources cannot currently be efficiently shared.

Realizing the strong degree of interdependence, the potential limits on growth, and the need for representation for the rural customers, the political leadership of Robertson County, in concert with the county industrial development board and the three regional water suppliers, commissioned a study to identify the future water needs of the county and the means available for county-wide planning. This study involved numerous meetings with stakeholders (political, environmental advocates, state regulatory, water producers, etc.) to determine future water needs and anticipated growth, and to identify solutions to regional water needs both now and into the future.

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POPULATION TRENDS

Based on US Census Bureau data, as well as state population projections, growth projections through 2025 were prepared and spatially distributed across the county. These projections indicated that the eastern and southern parts of the county would grow the fastest, while the western and northern parts of the county would grow relatively slowly. In all regions, however, forecasted growth (1.9%) was projected to exceed state average growth rates (approximately 1.3% per year). A closer look at projected growth along development corridors suggests that there was not adequate distribution infrastructure in place to accommodate future industrial development.

DEMAND PROJECTIONS

Using spatial population estimates and current pumping rates from monthly operating reports, demands were projected for each distribution system. Average per capita demands were estimated from average pumping rates and base (2000) populations for each distribution area. Table 1 summarizes the three per capita demands considered.

Table 1: Estimated *per capita* Demands for Each Water System

System	Average <i>per capita</i> Demand (gpcd) ^a	Maximum month <i>per capita</i> demand ^b factor	Maximum day <i>per capita</i> demand ^c factor
Adams-Cedar Hill	64	1.2	1.35
Springfield	173	1.2	1.75
White House	145	1.3	1.45

a average per capita demand = average monthly demand ÷ total population

b greatest monthly maximum demand ÷ total population

c greatest daily maximum demand ÷ total population

Figures 1 – 3 illustrate the projected demands for each water distribution system in Robertson County. As the Figures illustrate, no community is currently facing an immediate water quantity problem based on average per capita demands. Demand in the Adams-Cedar Hill system may exceed theoretical plant capacity within 20 years. Because Adams-Cedar Hill and Springfield jointly use the Red River as source water, withdrawal by Adams-Cedar Hill cannot be viewed as independent of Springfield’s activities. If Springfield realized its actual permitted withdrawal during critical low flow situations, Adams-Cedar Hill’s production could be restricted today. Springfield will likely experience maximum month demands in excess of 80% of its plant capacity in the next 20 years. As demands approach plant capacities, the need for cooperation and coordination between Adams-Cedar Hill and Springfield will increase. More connections between the Adams-Cedar Hill and Springfield systems will be necessary to optimize water usage from the Red River. In addition, as the region grows, wastewater and water quality issues will become increasingly important to communities along the Red River.

ALTERNATIVE SOURCE WATER OPTIONS

From stakeholder meetings, it became evident that relying on the Red River as the solution to the future water needs of Robertson County was unwise. Current permitted withdrawals at the SWWD plant are a significant fraction of the sustained low flow (7Q10), and state regulators indicated that a thorough investigation into the impact of additional withdrawals would be necessary before increased withdrawals would be permitted. In addition, as part of this study, a

modified stream tier assessment was conducted to establish the aquatic status of the Red River in the western part of Robertson County. This study concluded that the river is likely a Tier II stream, which would limit the degree of degradation, including withdrawal, allowed. Finally, due to nitrate concentrations that approach 60% of the drinking water limit, the stream is not currently meeting its designated use as a potable water source according to the Tennessee Department of Environment and Conservation. Should water quality continue to suffer, more costly treatment systems would be required when using the Red River as a drinking water source. Finally, environmental advocacy is strong in the watershed, and additional withdrawals would likely face strong opposition from stakeholders.

Through interviews with stakeholders, it became clear that the Cumberland River is the most abundant, long-term water source for Robertson County. In fact, a review of neighboring communities indicated that every county bordering Robertson County, including those in Kentucky, used the Cumberland as their source of raw water. Methods for bringing water to the western part of the county were investigated, including (1) expanding service from White House Utility District into the Springfield area, (2) making arrangements to purchase raw or finished water from the Logan-Todd Regional Water Commission in Kentucky, or (3) constructing and operating a new transmission line and water plant to serve the western and central part of the county. Of these options, an independent transmission line and plant may be the best alternative, although none of these options was inexpensive.

REGIONAL WATER AUTHORITY

A primary conclusion of this study is that addressing the future water needs of Robertson County, especially the needs of the communities in the central and western parts of the county, will require leadership and coordination. Because SWWD and ACHWS share the same source for drinking water many of the issues impacting these two systems are similar and linked, and therefore these two communities will need to cooperate and plan together as their communities and distribution systems grow. While these needs could be addressed through careful planning and cooperation, a regional water authority would provide a coordinated structure to planning and a vision for the future water needs of the region. In addition, because of the lack of rural utility districts in the county, a regional water authority would provide a voice for the rural residential, commercial, and economic water user who may have limited options for potable water, and whose water supply could be impacted by the effects of deteriorating groundwater quality, especially since source water quality may continue to degrade with increased urban growth. Thus, in addition to regional water planning and development, a regional water authority could provide leadership and county-wide vision for wastewater and water quality issues in the region.

A regional water authority can be codified in Tennessee using one of the following three legislative mechanisms: (a) a public act, (b) a private act, or (c) a resolution. A public act is a law or statute that is ratified by the Tennessee State Legislature, becomes amended to the Tennessee Code, and thus applies state-wide. A private act is a law or statute that applies only to a particular region, is ultimately ratified by a local governmental authority (such as a county commission or board of aldermen) and does not become part of the Tennessee Code Annotated (TCA). Establishing a regional water authority by resolution under the Water and Wastewater Treatment Authority Act (TCA §68-221-601) does not require any state-level legislation. After a properly advertised public hearing to discuss the merits of the authority, the local governmental authority adopts and approves a resolution or ordinance creating the authority. (See TCA §68-221-604.)

The functional differences in statutes codified through the different legislative mechanisms are trivial. In fact, the legislation establishing several existing regional water authorities in Tennessee

is nearly identical, regardless of legislative means. The primary difference in the different statutes is the composition of the board of directors. Most authorities populate the board with representatives from the participating utility agencies (1 member per agency) and political representatives from each participating municipality.

Ultimately, it was recommended that Robertson County form a regional water authority to provide leadership in water, wastewater, and water quality issues in the county. (The legislative mechanism used to form the Authority was left to the participants in the county.) The purpose of the Water Authority is to provide planning and coordination among the various interests in Robertson County in matters pertaining to water, wastewater (including stormwater), and water quality. It is not intended to take over county water and wastewater utilities or to exercise control over the day-to-day operations of these entities. Instead, the focus of the water authority should be on inter-system issues and issues which currently are not under the jurisdiction of any of the utilities in Robertson County.

A Regional Water Authority could:

- Utilize water and wastewater infrastructure to enhance economic opportunities and promote planned growth;
- Plan for future water supply needs in a cost-effective and timely manner;
- Work to preserve the critically important Red River as a drinking water source as well as an ecological and recreational resource.

Robertson County, Tennessee, faces significant opportunities and challenges with respect to interrelated water supply, water quality, and wastewater management in the next decade. A Regional Water Authority, focusing on solutions to regional water issues that affect one or more of its members (not on the day-to-day operation of existing utilities), can help the County exploit future opportunities and provide for long-term economic growth without sacrificing quality of life.

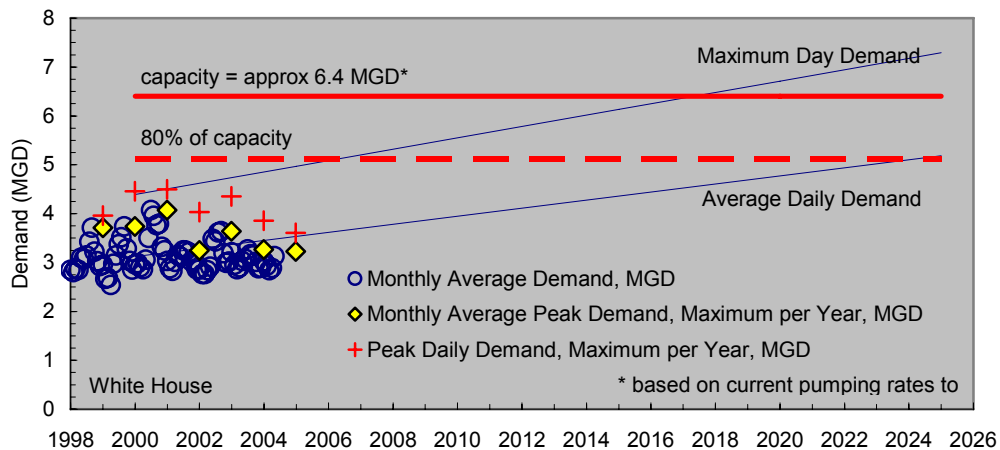
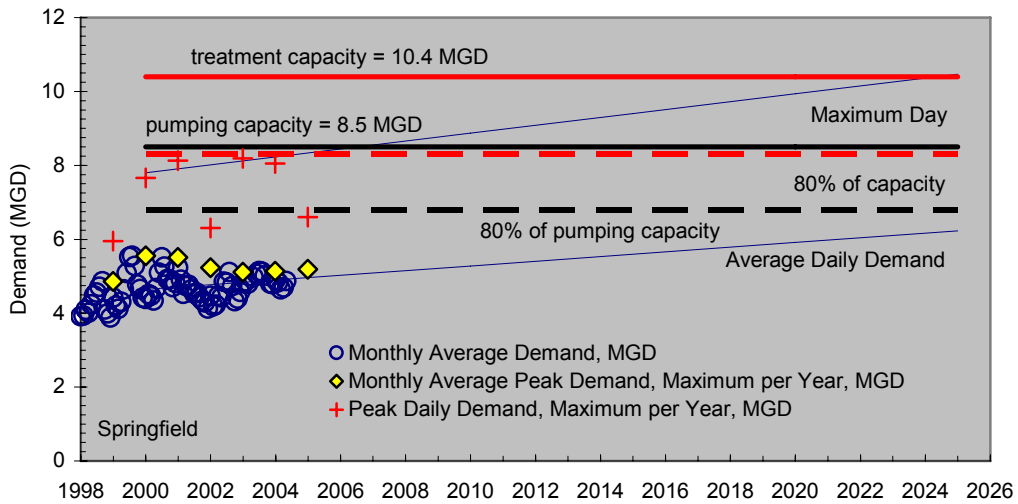
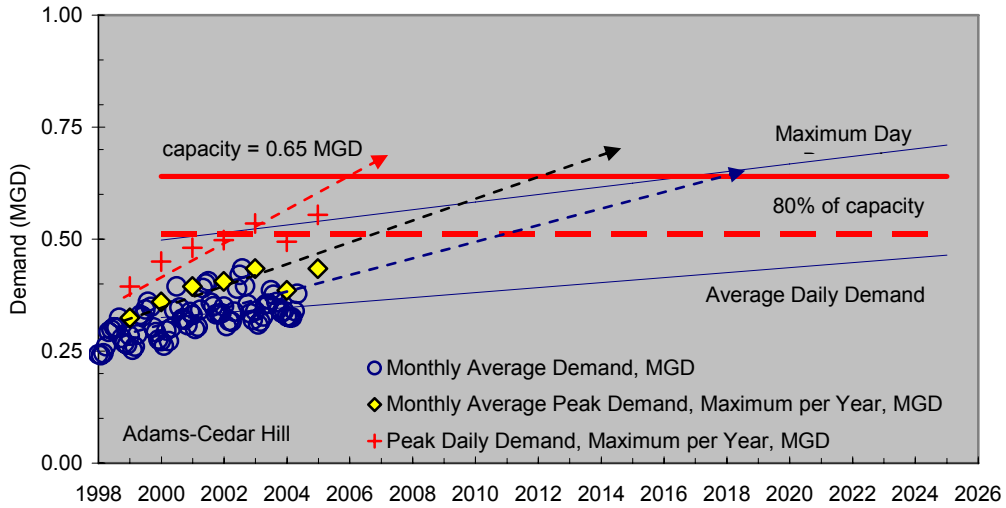


Figure 1 - 3: Treatment Capacity and Estimated Demand in the Systems Indicated. Solid lines indicate projections based on population. Dashed lines indicate trends in data points.

EPA PERSPECTIVES ON THE FUTURE OF SOURCE WATER PROTECTION

E. Stallings Howell¹

Source water is the raw, or untreated, water from streams, rivers, lakes, or aquifers which is used to supply private wells and public drinking water systems. Protecting source waters from contamination, protecting public health, and reducing the treatment cost for delivering safe drinking water to consumers is a national priority. The 1996 Amendments to the Safe Drinking Water Act established EPA's Source Water Assessment Program to promote clean and safe drinking water.

States, including Tennessee, have completed the source water assessment phase and are developing and implementing management strategies which include activities aimed at protecting water resources from activities that may be a potential threat. The challenge of protection requires stakeholders on all levels. EPA has initiated a network of dedicated federal, state, local and environmental organizations, along with public water system utilities, to take the necessary steps to ensure that safe drinking water is delivered everyday to all citizens. The future of our nations water quality depends on maintaining strong partnerships and collaborative efforts.

¹ Chief Ground Water / Drinking Water Branch Water Management Division, EPA Region 4, Atlanta, GA

WATER-DEMAND PROJECTIONS IN THE UPPER DUCK RIVER, TENNESSEE RIVER WATERSHED, CENTRAL TENNESSEE, 2000 TO 2030

Susan S. Hutson¹

Water-demand projections for the upper Duck River watershed for the period 2000 to 2050 were developed by the U.S. Geological Survey (USGS) in 1993 for Bedford, Marshall, Maury, and southern Williamson Counties and in 2001 for Coffee County. In 2002, the water-demand projections were used as input to the watershed model, Oasis, by HydroLogics, Inc.², as part of a water-need analysis of the upper Duck River watershed. The Duck River Agency (DRA), the Duck River Agency Technical Action Committee (DRATAC), and the Duck River Water Resources Council (DRWRC) recognized that population growth in the watershed increases water-supply demands on the Duck River. Under the planning process proposed by DRATAC and DRWRC and outlined in the Duck River Watershed Comprehensive Water Resources Plan: Part 1 Water Supply Plan—2003, water-demand projections were to be updated once every five years within a time horizon of at least 25 years. In accordance with the Water Supply Plan for the Duck River, the USGS in cooperation with the DRA conducted an investigation in 2004 to project water demand in the upper Duck River watershed encompassing Bedford, Coffee, Marshall, Maury, and southern Williamson Counties during the time period 2000 to 2030.

Water demand was estimated for normal- and high-growth scenarios by public-supply water-service area using The Institute for Water Resources-Municipal and Industrial Needs (IWR-MAIN) water-demand management software. IWR-MAIN software was used to manage the water use and climatological data inputs upon which the projections were based and to construct and execute the water-demand equations. The base year for the model is 2000, and the projections are for 2010, 2020, and 2030. For the upper Duck River, modeling scenarios were based on climatological conditions—as defined by long-term precipitation and temperature patterns—and the rate of expansion of the various customer billing accounts of the public-supply systems. Historical climatological data were acquired for the weather stations in Columbia (Maury County), Lewisburg (Marshall County), Shelbyville (Bedford County), and Tullahoma (Coffee County) for 1980 to 2003, which corresponds to the period of available billing account records for selected public-supply systems. The historical climatological data were compared to normal climatological conditions (1970 to 2000) as defined by the National Oceanic and Atmospheric Administration. Two climatological periods were identified—a normal and a drought period. The years 1980, 1981, 1985, 1986, 1987, 1988, 1999, and 2000 were identified as drought years based on below normal rainfall and higher than normal maximum temperatures.

Estimates of water demand also were based on projected growth of the 14 public-supply systems using water from the Duck River. Data included the number of customer billing accounts and the associated water use. Data were organized chiefly by residential, industrial, commercial, and other accounts including water processing, fire protection, line maintenance, and system losses. Although some variability exists in defining bill accounting sectors among the public-supply systems, all data were classified similarly for the model and results were aggregated and reported as residential, nonresidential (commercial and industrial combined), and other. Water-demand projections were not prepared for self-supplied domestic, self-supplied industry, or for self-

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² Any use of trade, firm, or product name is for descriptive purposes only and does not imply endorsement by the U.S. Government.

supplied golf courses. Under a normal-growth scenario, total water demand is projected to more than double (from 25 million gallons per day [Mgal/d] to 52 Mgal/d) from 2000 to 2030. Under a high-growth scenario and drought conditions, total water demand is projected to increase from 25 to 55 Mgal/d, or about 120 percent from 2000 to 2030.

OVERVIEW OF CONSTRUCTION OF THREE LARGE STREAM RESTORATION PROJECTS IN TENNESSEE

Ken Barry, P.E* , and Michael Pannell¹

Over the past three years the authors have been involved in several stream restoration or realignment projects in middle and east Tennessee. An overview of the construction of three of the larger projects is presented here. The three projects are:

- Realignment of 1300 feet of Love Creek in Knoxville,
- Restoration of 3200 feet of Paw Paw Creek and a tributary in Roane County, and
- Restoration of 4000 feet of Big Rock Creek in Lewisburg.

Specific discussion items will include storm water management approaches, in-stream structure installation successes and difficulties, bank stabilization technique results, construction phasing, contingency planning, feedback for future design activities, and lessons learned.

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BEAR CREEK: ACID MINE DRAINAGE REMEDIATION SUCCESS STORY

Carol C. Chandler¹

Bear Creek, originating in Scott County, TN, became devoid of life around 1900 when coal mines opened in the Bear Creek watershed. The runoff from these mines was acidic and contained dissolved heavy metals. Early written accounts state that all fish and macroinvertebrates died within a few years of the mines becoming active. As of 1990, little had changed in Bear Creek; biotic sampling at the mouth of Bear Creek indicated an almost sterile system. Landowners within the watershed reported that no fish had been seen in their life times.

In 1991 a determined group of local, state, and federal agencies, private landowners, and non-governmental groups banded together to find ways to restore Bear Creek's biotic integrity. By the late 1990s remediation construction was well underway. Today, as a result of this group's efforts, approximately 17 species of fish, and at least one species of crayfish, have been documented in Bear Creek.

This presentation highlights the group's cooperation, types of remediation used, results, and future management plans.

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STREAM BANK STABILIZATION ALONG LITTLE HARPETH RIVER IS EAGLE SCOUT PROJECT

John McFadden¹

The Harpeth River Watershed Association (HRWA) is a five year-old conservation organization with a history of, among other things, cooperative river restoration projects utilizing the Volunteer River Restoration Corps (VRCC). The VRCC utilizes youth and adult volunteers to carry out selected site-specific river restoration treatments in both the Harpeth And Duck River watershed. Collectively the VRCC has participated in fencing livestock out of 14,000 linear feet of stream, planted some 22,500 seedlings in riparian zones and stabilized close to 1500 linear feet of eroding creek bank.

In the fall of 2004, HRWA was approached by two Eagle Scout candidates who were interested in conducting Eagle Scout projects in cooperation with the HRWA. HRWA has a contract with Brentwood Parks and Recreation Department to implement stream bank stabilization treatments in the Little Harpeth River to 1) protect mature riparian trees and 2) to prevent downstream siltation. The requirements of the Eagle Scout Rank include the scout taking on and accomplishing some form of project that requires in up to 100 man-hours of work, in which the Eagle candidate does not necessarily carry out the work, but recruits other scouts to do the work, thus learning about project management as well as leadership.

The first project was accomplished in December of 2004 and included 12 scouts working for 8 hours in the frigid waters of the Little Harpeth for ½ day and then transplanting trees for the latter part of the day. The objective of this project was to surround a sycamore's root system with jute covered cedar revetments (as per Jen Hill Const. Materials) to protect the tree from dislodging from the stream bank. The cedar trees were selectively harvested from a Wilson County Farm, transported to the site. Once on site the trees were rolled in the jute. Scouts activities were managed and coordinated by two HRWA staff and the Eagle Candidate, who had been briefed prior to the day activities.

Initially, two scout were utilized to drive duckbill anchors into the lower margin of the streambed and three four feet above the streambed. Three to four scouts placed cedar trees rolled in jute and then cables were attached to the bottom anchors. Once the tree was in place and the cable attached, wire ratchets (Gripples) were used to tighten the trees against the bank. The initial treatment was along 35 linear feet of stream bank.

The second project was accomplished in August of 2005 and included almost 25 scouts, one father and one grandfather. The Eagle Candidate agreed to treat a section of stream that was 120 linear feet, and agreed as a part of this the scout would help harvest the 60 trees needed and roll the trees in jute prior to transport. This was accomplished in seven hours, included the same selective harvest method and included the scout taking responsibility for transport to the river site. Once on site the process was similar in that anchors were driven, cable attached and rolls lay in position for tightening to the bank. However, due to the inconsistency of the bank, it was not possible to fully tighten the cedar roll to the bank. Thus, scouts had to move five to seven cubic yards of gravel from an opposing gravel bed to backfill the cedar roll. This was done by hand. Following this effort geo netting was placed over the fill and planted with grass seed and

¹ Director of Science and Restoration Programs Harpeth River Watershed Association

buttonbush. All vegetation was doing well at the time of this and HRWA intends to plant cedar trees in the backfill area in winter 2006.

The Volunteer River Restoration Corps has been and continues to be, a successful way to cost-effectively carry out restoration projects. The City of Brentwood continues to utilize HRWA and the VRRC activities to meet their storm water permit requirements. Finally, and perhaps most importantly it gives our organization and the general public a concrete mechanism to interact with and impact the quality of the Harpeth River watershed.

SESSION 3B

STORM WATER

8:30 a.m. – 10:00 a.m.

Ten Days to a New You! (Easy Steps for NPDES Permit Compliance)

Tom Lawrence

Characterization of Storm and Non-Storm Discharge in a Storm-Sewer Channel in Memphis, Tennessee: In Search of Water and Contaminant Sources

Daniel Larsen, Delphia Harris, Kerry Clark, Alex Gamble, Chris Garner, Jason Morat, and Angela Owen

Outline of Metro Nashville Water Services Watershed Water Quality Management Plan

Steve Winesett

GROUND WATER MIGRATION AND CLASSIFICATION

10:30 a.m. – 12:00 p.m.

Altitudes of Ground Water Levels for 2005, and Historic Water Level Change in the Surficial and Memphis Aquifer, Memphis, Tennessee

Vamshi K. Konduru-Narsimha and Brian Waldron

The Mississippi, Arkansas, Tennessee Regional Aquifer Study (MATRAS)

John K. Carmichael

Groundwater Tracing in the Rock House Cave System, Carter County, Tennessee

Yongli Gao, Robert Benfield, Sid Jones, Taylor Burnham, and Nikki Gibson

10 DAYS TO A NEW YOU! (EASY STEPS FOR NPDES PERMIT COMPLIANCE)

Tom Lawrence¹

INTRODUCTION

Do you feel tired in the mornings? Do you get sleepy late at night while finishing up reports at work? Perhaps you feel hungry after skipping lunch to complete a letter or get dizzy from the blinking light indicating waiting unanswered voicemail. If so, you may be suffering from NIPS (NPDES Irritable Permit Syndrome). While the issues surrounding the NPDES Permit may be complex, simple actions may reduce your NIPS. There is currently no cure for NIPS, but the symptoms of NIPS can be controlled by making a few positive changes.

While you are following the 10-day program, be sure to keep a list of “action items” on the side for you to list items that you identify that need to be addressed and questions that need to be answered.

DAY 1: READ YOUR PERMIT

Make a copy of your permit on which you can write, including the Rationale and appendices. Copy the general permit if your permit is issued under a general permit. Get yellow, green and blue highlighters. Read the entire permit from the first word on the first page to the end of the last page. Highlight in yellow anything that sounds like a requirement. Include items that may have to be done if something else happens, such as “In the event that the primary contact changes, the permittee must notify the agency within 7 days.” Be sure to highlight requirements seen anywhere in the permit, since required actions may be located out of the identified “requirements” section. Using green, highlight important information, such as the permit number, who to contact for more information, and statements that pique your interest. Use the blue highlighter to indicate unusual terminology or words that you don’t know.

Copy and read in detail other documents that are important for permit compliance, such as a municipal ordinance or company compliance plan. Use the 3-color highlighter system to mark the documents.

As you read through these documents, you will identify areas that overlap or refer to each other. Write these references in the margins, so that you can find them again. Write in the definition of unusual terms and any sudden visions of clarity, such as restating a paragraph that is confusing as written.

DAY 2: MAKE A SAMPLE/DRAFT ANNUAL REPORT

Using what you learned in the permit review, prepare the Annual Report. The due date for the actual report may be months off, but by preparing the Annual Report now, you know what you need to gather in addition to having the template ready to go once the permit year ends. Even if you did the report last year, go ahead and prepare the draft for next year. Usually requirements in the permit evolve over time, thus the information needed for reporting will change. The permit

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will usually dictate how the Annual Report must be arranged. If not, it is recommended that you report on the tasks in the order they are listed in the permit.

DAY 3: ORGANIZE YOUR FILES

Go through your review of the permit and assign a number to each task you identified starting with one at the beginning of the permit. If you encounter a task which sounds like it is the same as or includes a previous task, write the number of the existing task; do not assign a new number. Be sure to reference the two tasks to each other. Several permit tasks may be one number, but be sure that it makes sense for them to be together, otherwise make separate files.

When you are done, type up the list with the task description next to the number. Make a file for each task. Go through your existing files and refile any information according to the new filing system. General information and non-permit compliance information (such as budget information) should be kept in a separate system of files in your usual manner of filing.

Make a list of specific deadlines for tasks as given in the permit, in particular for deadlines that fall before the end of the permit year.

DAY 4: MEET YOUR REGULATORS

Now that you have a thorough understanding of what is in your permit, set up a meeting with the regulators overseeing the permit implementation. If possible, meet with the State and Federal regulators, as well as the local regulators. Be sure to bring your list of action items to get clarity on any unusual terms or requirements that were not clear. Ask the regulators what they would like to see in the Annual Report. To make your report as good as possible, ask them if there is something that they liked in an Annual Report that you could include in yours. Also, meet with peer organizations to get their ideas and experience with permit compliance.

DAY 5: DEVELOP DATABASES

For permit tasks develop databases to track the information, so that you can extract the information needed to show compliance with the permit and to prepare the Annual Report. The databases may be computerized, such as to track sampling results, so that you can print out a compilation of the results for the Annual Report. The database may be as simple as instructing everyone to put a copy of each letter they send into a particular file.

DAY 6: MEET WITH “CO-PERMITTEES” AND CO-IMPLEMENTERS

Since there are many potential causes of storm water pollution, there will be several tasks within the permit that need to be completed by others within your organization. Also, NPDES permits may be written, such that you may be a “co-permittee” with other organizations for some of the permit tasks that have been identified. Determine where coordination is needed with others and meet with those people as soon as possible to discuss what needs to be completed and what sort of information you need to get for the Annual Report and when you need to receive the information. Clarify exactly what is expected of others and what you will provide. It is recommended that a reporting schedule be developed, such as monthly e-mails reporting on the percent completion of the task. If needed, offer to meet with the managers of your contacts to inform them about their employee’s participation and resource needs.

DAY 7: REVIEW YOUR BUDGET

Go through each of the task files to determine what needs to be accomplished by the end of the permit year. Develop a budget with each item listed and an estimated budget number next to it. Storm water tasks may need to be done by internal staff, some may need to be done by external contractors (due to the specialized nature of the task or need for independent review), while many tasks will have the option of being done either internally or externally, depending on staff and budget availability. Each task may have several budget items under it. It is recommended that the tasks be broken into as many items as is reasonable to enable a better analysis.

Since many items may be able to be contracted to outside firms, the budget should have at least four columns. The first column lists the task. The second and third columns are for identifying resources when doing the tasks internally. The second column is for the person-hours needed and the third column is for money needed to buy supplies for the task. The fourth column is a dollar amount for using an external source for completing the task. The basic four-column decision budget will provide adequate information to determine how to proceed with many of the tasks and to identify those tasks needing more in depth budget study. Using this table determine the number of person-hours and money needed, then determine which of the other tasks can be done internally and which can be contracted out.

If you do not know how much an item costs, now is the time to determine the cost in both person-hours and dollars. In addition to internet research, the costs can be estimated by contacting other organizations with similar permits and firms that provide the compliance services.

DAY 8: DELEGATE

Go through the tasks and let each person involved know what they need to do and when it needs to be done. It is important to let Co-permittees and Co-implementers know as soon as possible, so that they can incorporate the new tasks into their daily work flow. Contract out as many of the tasks as needed and get the contracting process started, since approval of contracts can sometimes be lengthy.

Take the list of tasks and write a name or names by each task to identify who is doing the task and when they were notified. It is recommended that each person be notified in writing and that a copy of their notification be kept in the "Delegate" file for future reference in case questions arise. Be sure to follow-up, particularly on tasks that you delegate to yourself.

DAY 9: DEVELOP TRAINING/INTERNAL INFORMATION/PUBLIC EDUCATION

NPDES permits require varying amounts of outreach. Develop a 10-20 minute general NPDES presentation that you can give to let others know why the organization has the permit, the basics of storm water pollution, and what is generally required. By this time you would have met with several groups, including regulators, co-permittees and people internal to your organization, and have a good idea of what people generally want to know and what is confusing about the NPDES permit.

In addition to tasks that are identified as public education and training, many of the tasks will have education components. It is important to develop the overall theme for the outreach method, so as to keep the message on focus and clear. For example, decide what will be the primary

contact for questions that will be emphasized in the outreach. Will it be to a specific phone number or a general phone number or an e-mail address, etc? What will be the consistent name of the program and will it have its own logo or use the organization's logo? Decide on as many of the theme elements as possible.

DAY 10: RESEARCH AND TRY SOMETHING NEW

In addition to the list of "Action Items" keep a list of "Ideas" that you add to as you read about programs done by other organizations or think of your own ideas about how to do things better. Often you will get suggestions about things to try, but for which the resources are unavailable. Add the ideas to the list. Add grant and partnership opportunities to the list as you become aware of availability. Over time the list will grow and as you hear about available resources or partners, you will have a ready list of projects to do to utilize the resources.

10 DAYS TO A NEW YOU! (EASY STEPS FOR NPDES PERMIT COMPLIANCE)

DAY 1: READ YOUR PERMIT

DAY 2: MAKE A SAMPLE/DRAFT ANNUAL REPORT

DAY 3: ORGANIZE YOUR FILES

DAY 4: MEET YOUR REGULATORS

DAY 5: DEVELOP DATABASES

DAY 6: MEET WITH "CO-PERMITEES" AND CO-IMPLEMENTERS

DAY 7: REVIEW YOUR BUDGET

DAY 8: DELEGATE

DAY 9: DEVELOP TRAINING/INTERNAL INFORMATION/PUBLIC EDUCATION

DAY 10: RESEARCH AND TRY SOMETHING NEW

CHARACTERIZATION OF STORM AND NON-STORM DISCHARGE IN A STORM-SEWER CHANNEL IN MEMPHIS, TENNESSEE: IN SEARCH OF WATER AND CONTAMINANT SOURCES

Daniel Larsen^{1*}, Delphia Harris², Kerry Clark³, Alex Gamble⁴, Chris Garner⁵, Jason Morat⁵, and
Angela Owen⁵

INTRODUCTION

Storm-water runoff is a well-known element of non-point source pollution to streams, lakes, and coastal regions (Berner and Berner, 1996; Smith et al., 2000; Lee and Schwartz, 2000). Many studies have characterized the chemistry of storm-water runoff for estimating total mass discharge loads to streams (e.g., Smith et al., 2000; Lee and Schwartz, 2000), but a cursory examination of the pertinent literature indicates that few have attempted to use chemical characteristics of storm-water runoff to locate major sources of runoff or non-storm discharges to the storm-sewer system. In this study, we investigated one storm-sewer channel in the city of Memphis, Black Bayou, to determine the main sources of runoff during storm and non-storm flows. The Black Bayou watershed (Fig. 1) is mainly residential and commercial land use with several schools and one golf course. Black Bayou is channelized along most of its extent; thus, opportunities for groundwater discharge and stream-bed infiltration should be limited. Black Bayou is of further interest in that water from the shallow aquifer beneath watershed is known to leak through the confining unit to the underlying Memphis aquifer (Larsen et al., 2003; Larsen et al., 2005), the municipal water source for the Memphis area.

The chemistry of runoff is closely related to land use, geology and soils, and hydrology (Berner and Berner, 1996; Drever, 1997). We use water chemistry from Black Bayou to try to ascribe chemical mass to various sources. Chemical and general water quality indicators indicate at any given location along a stream the source of much of the chemical loading. Chloride, a conservative chemical element, is used to determine chemical mass balance along the stream course, which assesses losses to or gains from groundwater. Fluoride, which is added to municipal water sources, is used as a tracer for municipal water contributions to storm-sewer flow.

This project involved the participation of high school, undergraduate, and graduate students working with faculty at the University of Memphis (Dr. Dan Larsen) and LeMoyne-Owen College (Dr. Delphia Harris). Students were involved with most aspects of sampling and analysis for the project.

APPROACH AND METHODS

Black Bayou was sampled during ambient flow conditions on July 9, 2004, and then again during storm flow on October 11, 2004. During the July event, Black Bayou was sampled at seven

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locations and ten tributaries were sampled where they entered the main channel. Because of time availability only 3 main channel stations were sampled during the October event.

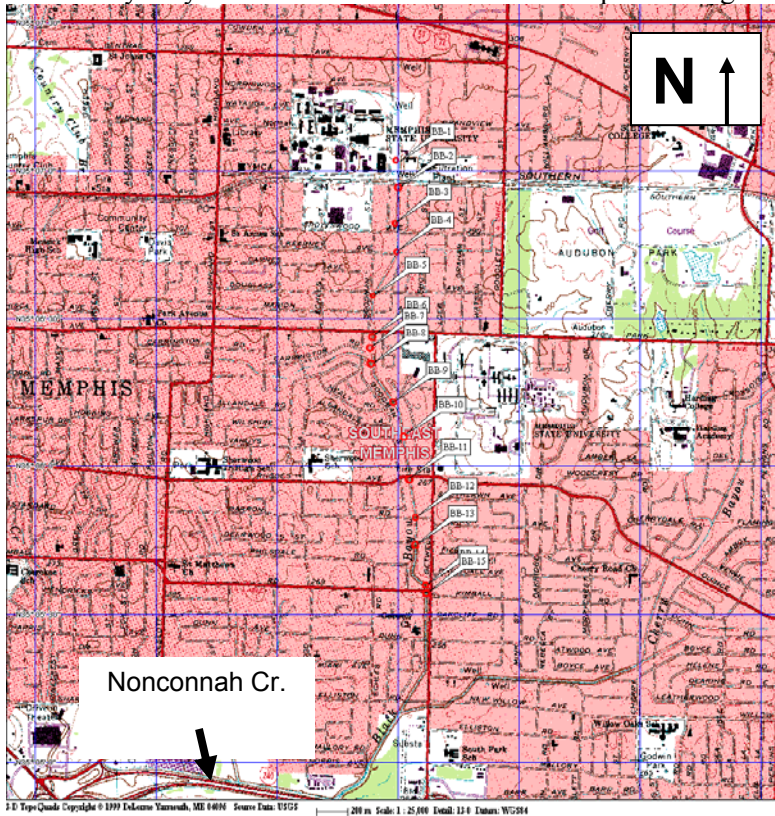


Figure 1. Topographic map illustrating Black Bayou watershed and sampling locations in central Memphis, Tennessee. Black Bayou discharges to Nonconnah Creek just to south of the shown map area.

Field measurements included pH, dissolved oxygen, nitrate, total iron, alkalinity, specific conductance, and temperature. Dissolved oxygen, pH, specific conductance, and temperature were measured using calibrated probes. Alkalinity was measured in duplicate with a Hach digital titration system. Total dissolved iron and nitrate were measured using Hach ampules and a Hach 2400 spectrophotometer. Discharge was estimated by measuring channel geometry, maximum water depth, and water surface velocity at most sample locations (estimated during storm sampling at BB-15). As many as three samples were taken at each location: 250 mL of raw water for anion analysis, 250 mL of filtered (0.45 micron) acidified (with 1 mL concentrated HNO₃) water for metal analysis, and 500 mL of raw water in glass bottles for organic analysis.

Anion analysis was determined by ion chromatography at the University of Memphis. Detection limits are generally 0.01 mg/L and one standard deviation errors are generally 10% or less for the concentrations observed in the Black Bayou samples. Metal analysis (major cations) was determined by flame atomic absorption spectrophotometry at both the University of Memphis and LeMoyne-Owen College. Detection limits are generally 0.01 mg/L or less and one standard deviation errors are generally 5 % for all metals except iron, which has an error of 8 %. Charge balance for the total sample analysis was generally within 10% of electrical neutrality.

The organic analysis was performed at LeMoyne-Owen College. EPA Method 3500c was used for liquid-liquid extraction using methylene chloride as the solvent. Acid Surrogate Standard and

Base Neutral Standard Mixture purchased from Ultra Scientific were added to the water sample before pH adjustment. The base/neutral and acid fractions were dried, concentrated and analyzed using GC/MS separately. Extracts were dried by passing them through anhydrous Na₂SO₄. Extracts were then concentrated and stored in a refrigerator. EPA Method 8270c was used for organic sample analysis. Compounds detected and estimates of order of magnitude concentration are reported based on comparison with surrogates of known concentration added to the sample.

RESULTS

Sampling for the July event occurred during base flow conditions. At the time of sampling, 0.3 inches of precipitation had accumulated sporadically at Memphis International Airport over a period of 4 days. Thus, flow in Black Bayou mainly came from groundwater discharge, interflow discharge (from the unsaturated zone), or anthropogenic sources (watering runoff, industrial runoff, waste runoff, etc.).

Sampling for the storm event occurred during an October rainstorm. The rainfall event produced 0.8 inches of rainfall over several hours at Memphis International Airport. Sampling occurred following the peak of the main storm at locations BB-1 and -3, but precipitation had started again and showed increased discharge that could not be measured (although a visual estimate was made) at location BB-15.

The results of the field measurements are shown in Figure 2. A comparison of the organic analyses for the base flow and storm sampling events is given in Table 1. Water temperature, specific conductance, alkalinity, and discharge for the July sampling event are plotted in Figure 2a. Water temperature at BB-1, which is in the non-channelized part of the stream, is lower (24°C) than that at the other locations, which are essentially all at 32°C. Specific conductance generally increases downstream. Alkalinity varies but does not increase or decrease substantially along the reach sampled. Most dissolved constituents vary in concentration downstream, but only pH, sodium, and chloride show a consistent increase. Concentrations in the tributaries are generally similar to those of the main channel suggesting that no major sources of poor water quality were discharging to the stream at that time.

Measured main channel discharge varies, but generally increases downstream (Fig. 2a). The cumulative discharge is calculated using the initial Black Bayou discharge and then summing the tributary discharges. The cumulative discharge follows the general trend of the measured main channel discharge, but deviates substantially at locations BB-2 and BB-12. The correspondence of the two discharge estimates suggests that our measurement of tributary flow inputs roughly balances with the measured main channel discharge of Black Bayou. Given that the deviations between the measured and cumulative discharges are much greater than the expected 25% errors, the difference may reflect stream bed infiltration losses along the respective reaches (BB-1 to BB-3 and BB-11 to BB-15). Additional support for loss of flow is variations in chloride mass balance with distance downstream (Table 1). Chloride mass does not change between locations BB-6 and BB-11, which suggests that either (1) no water is added along this reach (which is unreasonable because measured tributary discharges are observed) or water is added and subsequently lost along the reach.

Water temperature, specific conductance, and discharge for the storm sampling event are plotted in Figure 2b. Temperature, specific conductance, and alkalinity vary but do not substantially increase or decrease along the sampled reach of Black Bayou. Measured main channel discharge increases downstream, as would be expected for a gaining stream receiving runoff. Most

dissolved constituents are generally present in concentrations equal to or less than those of the July sampling

Table 1
Organic Analysis of Black Bayou
Comparison of Base Flow (July 9, 2004) and Storm Event (October 11, 2004)
Estimated Concentrations in ppm.

	BB-01		BB-03		BB-15	
	<i>Base</i>	<i>Storm</i>	<i>Base</i>	<i>Storm</i>	<i>Base</i>	<i>Storm</i>
pH	7.01	6.63	7.68	7.69	9.8	
temperature	24.1	21.2	24.1	20.7	31.6	
Anthracene	~0.1	nd	nd	nd	nd	nd
naphthalene	nd	~0.1	nd	nd	nd	nd
2-(2-butoxyethoxy)-ethanol	nd	nd	nd	nd	nd	nd
Benzene	nd	nd	nd	nd	nd	nd
Benzylbutyl phthalate	nd	nd	nd	nd	nd	nd
2-butanone	nd	~1	nd	nd	nd	<0.1
3-methyl-2-butanone	nd	nd	nd	nd	nd	<0.1
2,2,4,4-tetramethyl-3-pentanone	nd	~1	nd	nd	nd	nd
Cyclohexane	nd	>0.1	nd	nd	nd	nd
Chloroform	nd	nd	nd	nd	nd	nd
Diphenylethyne	<0.1	nd	nd	nd	nd	nd
heptadecane	nd	nd	~0.1	nd	nd	~0.1
Hexane	nd	nd	nd	nd	nd	nd
dodecane	nd	~1	nd	nd	nd	nd
Tridecane	nd	~1	nd	nd	nd	nd
Tetradecane	nd	~1	nd	nd	nd	nd
Undecane	nd	nd	nd	nd	nd	~0.1
3-methyl-Undecane	nd	~0.1	nd	nd	nd	nd
octadecanane	nd	nd	nd	nd	nd	~0.1
Methyl ester benzoic acid	nd	~0.1	nd	nd	nd	nd
Diethyl ester hexanedioic acid	nd	<0.1	nd	nd	nd	nd
Bis(2-ethylhexyl) ester Hexanedioic acid	nd	~1	nd	nd	nd	nd
2-ethoxyethyl acetate	nd	>0.1	nd	nd	nd	nd
1,3,5-trimethyl benzene	nd	~0.1	nd	nd	nd	nd
Toluene	nd	>0.1	nd	nd	nd	~0.1
Mono(2-ethylhexyl) ester 1,2-benzene dicarboxylic acid	nd	nd	nd	nd	nd	nd
Bis(2-ethylhexyl) phthalate	nd	nd	nd	nd	nd	nd
3-nitro-1,2-benzene dicarboxylic acid	~0.1	>0.1	>1	~0.1	nd	~0.1
Triphenylphosphine oxide	>0.1	nd	nd	nd	nd	>0.1
SiO compounds	*	nd	***	nd	**	nd
o-xylene or p-xylene	nd	>0.1	nd	nd	nd	<0.1

nd – not detected

A * indicates an unassigned peak on the chromatogram.

Base flow samples evaporated and were redissolved in 1 mL of methylene chloride. Volatile compounds may have been lost as a result.

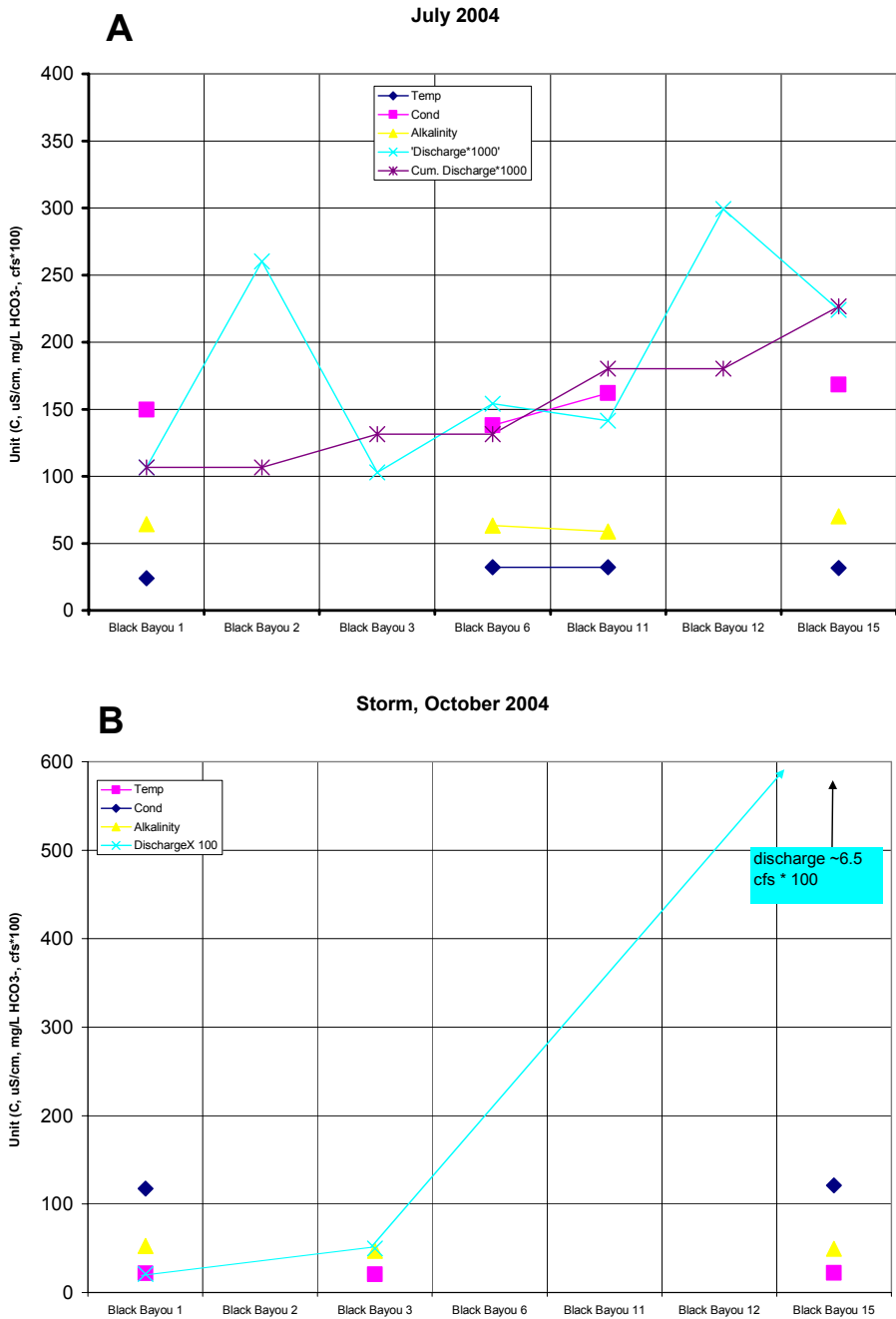


Figure 2. A. Results from July sampling event. Temperature (Temp, °C), Specific conductance (Cond., mS/cm), Alkalinity (mg/L CaCO₃), discharge (cubic feet per second *1000), and cumulative discharge (cubic feet per second *1000) at sampling stations along the channel (see Figure 1). B. Results from the October sampling event. Temperature (Temp, °C), Specific conductance (Cond., mS/cm), Alkalinity (mg/L CaCO₃), discharge (cubic feet per second *100), and cumulative discharge (cubic feet per second *100) at sampling stations along the channel (see Figure 1).

and do not consistently increase or decrease in concentration downstream. The main exception is dissolved oxygen; it shows higher concentrations than those of the July sampling event consistent with a greater degree of atmospheric equilibration.

From one to three organic compounds were identified in each sample under base-flow conditions. Most were approximately 0.1 ppm or less. Cyclohexane was found at higher relative concentration at two locations BB-02 and BB-11. Benzene was identified at BB-06 and 2-(2-butoxyethoxy)-ethanol at BB-05 in higher relative concentrations. Under storm conditions, BB-03 had no observed organic contamination, whereas BB-01 and BB-15 contained a number of additional organic compounds at ~0.1 and ~ 1 ppm relative to the non-storm sampling (Table 1). This may reflect storm-related flushing of urban surfaces such as parking lots that runoff directly into the storm-water channels. Due to equipment problems, the base-flow sample extracts were stored in the refrigerator before analysis. Many of the samples evaporated leaving only residue in the vials. The residue was re-dissolved in 1 mL of methylene chloride; however, volatile compounds were likely lost. The storm event samples were analyzed soon after extraction.

Fluoride concentrations provide information on the proportion of anthropogenic and natural runoff in the basin. Natural surface waters in the area have fluoride concentrations of less than 0.2 mg/L; some groundwaters have slightly higher concentrations, approaching 0.5 mg/L. Fluoride concentrations for the July sampling are almost all at or near 1 mg/L, which is the concentration set by Memphis Light Gas and Water at their water treatment facilities. The only exception is at BB-2, which is a runoff channel from the Sheahan pumping station, with a value of 0.47 mg/L. Thus, the water in Black Bayou sampled during the July sampling is ascribed to urban runoff of treated municipal water. The fluoride concentrations for the storm event are 0.25 to 0.33 mg/L, consistent with dilution by dilute rain water and surface runoff. Assuming that the fluoride content of rain water is below detection (0.01 mg/L), approximately 30% of the flow during this storm was municipal water runoff.

DISCUSSION AND CONCLUSIONS

The results of this study indicate the following in regard to the chemistry and hydrology of runoff in Black Bayou:

- The relatively dilute composition and limited quantity of chemical contaminants suggests that Black Bayou was not receiving extensive pollutant loads, either during base-flow or storm runoff conditions,
- The presence of more organic compounds in most of the storm samples relative to the base-flow samples at the same stations suggests that storm-related flushing of organic compounds from parking lots and streets occurs in parts of the watershed,
- The water in Black Bayou during base-flow conditions is largely derived from municipal runoff and little, if any, derives from groundwater or interflow discharge,
- The water in Black Bayou during storm conditions is a mixture of precipitation and municipal runoff; in the case of the sampled storm, the percentage of municipal runoff is estimated to be 30%.
- The discharge in Black Bayou increases downstream under both base-flow and storm conditions; however, the rate of increase in discharge with distance is greater for storm conditions. Some evidence for limited loss of flow beneath the base of the channel is suggested along at least two reaches.

The inorganic chemistry of the July runoff in Black Bayou appears to be affected mainly by addition of sodium and chloride from runoff and hydrolysis reactions with the concrete bed of

the channel. Sodium and chloride are common elements in urban runoff (Berner and Berner, 1996; Rose, 2002) and their increase in base flow discharge downstream is expected, especially where Black Bayou flows along strip mall and small industrial shops on Getwell Road. Crystalline solids in concrete will react with acid in water by undergoing hydrolysis. This reaction partially dissolves the concrete but also increases the pH by consuming hydrogen ions. This effect is particularly noticeable for the July samples, but seems to be less important for the storm samples obtained in October.

The types of organic compounds in Black Bayou waters are derived from petroleum, plastic, industrial solvent, and pesticide sources. Compounds such as anthracene, benzene, cyclohexane, heptadecane, and hexane are common constituents of gasoline and probably represent runoff from fuel-related sources. Other compounds, such as benzylbutyl phthalate and bis(2-ethylhexyl) phthalate, are emitted from plastics and maybe represent runoff from a variety of plastic sources. Cyclohexane, toluene, and xylene are commonly used as industrial solvents.

Water in Black Bayou under base-flow conditions derives almost exclusively from runoff of treated municipal water. Likely sources include runoff from watering lawns, washing cars, parking lots, and leaky pipes. The untreated water sources likely include overflow from the Sheahan pumping station as well as runoff from small ponds or lakes that are supported by rainfall.

Water in Black Bayou largely flows to Nonconnah Creek, but some may infiltrate into the soil beneath the channel. At several locations, part of the concrete bed of the channel is eroded or otherwise removed. This allows water to more readily seep beneath the channel bed. The shallow aquifer, which underlies the silty soil at the surface, is partially to completely unsaturated within the watershed of Black Bayou (Larsen et al., 2003). This creates potential for downward flow from the surface to recharge the shallow aquifer and to ultimately recharge the Memphis aquifer (Larsen et al., 2005).

REFERENCES

- Berner, E.K., and Berner, R.A., 1996, *Global Environment: Water, Air, and Geochemical Cycles*. Prentice-Hall, Upper Saddle River, New Jersey, 376 p.
- Drever, J.I., 1997, *The Geochemistry of Natural Waters*. Prentice-Hall, Upper Saddle River, New Jersey, 436 p.
- Larsen, D., Gentry, R.W., and Solomon, D.K., 2003, The geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA: *Applied Geochemistry*, vol. 18, p. 1043-1063.
- Larsen, D., Morat, J., Waldron, B., Ivey, S., Anderson, J., Owen, A., and Garner, C., 2005, Hydrologic assessment of leakage from Nonconnah Creek to the shallow aquifer in the vicinity of the Sheahan well field, Memphis, Tennessee: in *Proceedings of the Fifteenth Tennessee Water Resources Symposium*, April 13-15, 2005, Burns, Tennessee, p. 2B-15.
- Lee, S., and Schwartz, F.W., 2000, Transport and loading of organic carbon from a parking lot. *Geological Society of America, Abstracts with Programs - Geological Society of America*, v. 32, no. 7, p. 139

Rose, S., 2002, Comparative major ion geochemistry of Piedmont streams in the Atlanta, Georgia region: Possible effects of urbanization. *Environmental Geology*, v. 42, no.1, p. 102-113.

Smith, L.A., Shaver, L.A., Pugh, J.D., Andersen, C.B., Sargent, K.A., 2000, Impact of anthropogenic nutrient loading on the biogeochemistry of the Reedy River and Lake Greenwood, South Carolina. *Geological Society of America, Abstracts with Programs*, v. 32, no. 2, p. 74.

OUTLINE OF METRO NASHVILLE WATER SERVICES WATERSHED WATER QUALITY MANAGEMENT PLAN

Steve Winesett¹

As the largest municipality on the Cumberland River, Metro Water Service (MWS) is keenly aware of its responsibility and duty to protect this vital resource. Metro Water Services has implemented a number of programs aimed at preventing water contamination as well as providing quality services to its customers and insuring compliance with all federal state and local regulations. Although Metro has expended a considerable amount of resources to protect waters within its boundaries it becomes increasingly evident, with the number of segments on the 303(d) list and ever increasing number of TMDL's that more is needed.

Metro Water Services has an aggressive illicit discharge identification and corrective program. In order to insure a safe and healthy environment for future generations, a comprehensive preventative program must be developed. To accomplish this, Metro Water Service initiated a watershed water quality management program within its Stormwater Division's NPDES office in June 2005. The intent of this program is to examine all activities within each sub-watershed of Metro's jurisdiction and develop a plan that will instigate the removal of all segments from the 303(d) list and prevent additional segments from being listed in the future.

There are 27 sub-watersheds within the municipal boundaries of Metro with 71 segments listed as not meeting 1 or more of its use classifications (Figure 1). As a reference to developing a management plan that would address the corrective and protective needs of each, "The Practice of Watershed Protection" was reviewed (Schueler & Holland 2000). Although Metro Water Services Division of Stormwater NPDES office currently implements many of Schueler and Holland's (2000) suggestions, several were not within the realm of its statutory authority. Likewise, although most of the impaired segments are completely within Metro, several such as Manskers and Hurricane Creeks comprise the borders of Davidson and other counties. Therefore, the implementation of any plan to address water quality issues would have to rely not only on the services of the NPDES office, but also the services and resources of other departments and organizations. This required the forging of a strong multi-agency partnership of federal, state and local governments as well as local citizenry groups with the watershed management program enhancing communication, coordination, and cooperation among each. The watershed management program will work with these partners to gather additional information on sub-watersheds, gather data and analyze results to build additional partnerships and to formulate multi-entity plans to protect and enhance existing resources.

Internally, the watershed management program is working closely with NPDES staff to implement a sub-watershed information gathering/dissemination approach that will help lay the foundation on which efforts of the multi-agency partnerships can build. The key elements of this process involve: 1) public education, 2) data gathering, 3) monitoring, 4) communicating findings, 5) stream walks and 6) coordination of resources. Each element is briefly described below:

1) Public education and outreach is paramount in the development of any program aimed at correcting water quality issues. Although scare tactics and "gloom and doom" messages have

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Reference: T.R. Schueler & H.K. Holland editors (2000). *The Practice of Watershed Protection*. The Center for Watershed Protection, Ellicott City, MD.

been used to stress many environmental issues in the mainstream media, Metro Water Services, is adamant that its message be positive, scientifically accurate and directed in a way that will build an environmental awareness and feeling of stewardship among the citizens of Davidson County. The watershed management program is developing posters for field events that describe the 305(b) report and why streams are on the 303(d), what people can do in their homes, businesses and community to improve these streams, and why these improvements are needed. Likewise, brochures are being developed and will be mailed to residents and business whose property border 303(d) listed streams specifically outlining why that particular body of water is impaired and how they can help. Finally, short PSA radio spots and movies are in production that will put a real face to Stormwaters "Toxic Dude". Toxic Dude will initially be depicted as a typical citizen that is unaware his actions are having consequences in the watershed he lives. Over time Toxic Dude will gradually be depicted as becoming more aware and eventually a model citizen for water quality improvements.

2) Data gathering will examine what information we currently have, gathering additional data to fill in knowledge gaps, prioritizing 303(d) segments and updating our GIS software. This data once entered into GIS will be used to help isolate point source as well as speculate on potential non-point source discharges. It will also serve as a centralized database to efficiently disseminate information for land use planners, regulatory entities, partners and researchers.

3) Monitoring programs will be expanded beyond our NPDES permit requirements to assist in data gathering. Current monitoring programs include quarterly sampling of 303(d) listed streams, ambient monitoring of three larger watersheds, weekly river runs, and thermograph investigations for illicit discharges. Additionally, monitoring of pristine or least impacted waterways will be undertaken to develop a baseline of desired water quality conditions to use as attainment goals.

4) Communicating findings will involve yearly publications to the Director of Water Services reporting on the status of Davidson Counties waters, a comprehensive watershed management plan drafted from partnership input and presentations at scientific meetings, neighborhood associations, and public outreach events.

5) Stream walks, although time consuming, will be a vital component of the watershed management plan and will help determine potential and current sources of contamination not currently identifiable through thermograph studies or public communication. The process will involve having a field crew equipped with a GPS enabled palm pilot, running GIS software, to walk from the mouth to headwaters of an impacted segment. Along the way the crew will photograph, obtain data points, collect water samples and enter any field observations or data they find that may contribute to current or future water quality problems. During a recent pilot study of this process crews pinpointed several illegal dump sites, sanitary sewer maintenance issues, potential mitigation sites, stream bank stabilization issues, a couple of illicit discharges and were able to map all public and private outfalls. Since the data was stored on a palm pilot running our current GIS software, data transfer to our main GIS database was effortless and allowed for continual updates. Similarly, the findings were color coded into their respective categories enabling us to develop a database of problem areas and areas of potential mitigation sites that our partners could access when restoration funds become available.

6) Although Metro Water Services has the ability to provide many of the resources needed to protect water quality, coordination of all Metro and partnership resources is needed for its ultimate success. This can be achieved by promoting a synergistic mindset among all Metro Divisions, partners and surrounding counties when examining water quality issues and deciding on the utilization of resources for individual projects.

It is the responsibility of everyone living within the Cumberland River Watershed to protect and preserve this great resource. Metro Water Services is keenly aware of this responsibility and is aggressively pursuing programs that not only limits the level of degradation caused by water and sewer services but is fostering a multi-agency plan to address Non-Water Services issues. The overall goal is to improve existing stream conditions to a point that current 303(d) segments can be de-listed and insure future degradation within Metro is minimized. Although this is a very high goal, Metro Water Services is committed to reaching it, not only because this is where we live, work and play, but because it is right and needed for the Cumberland.

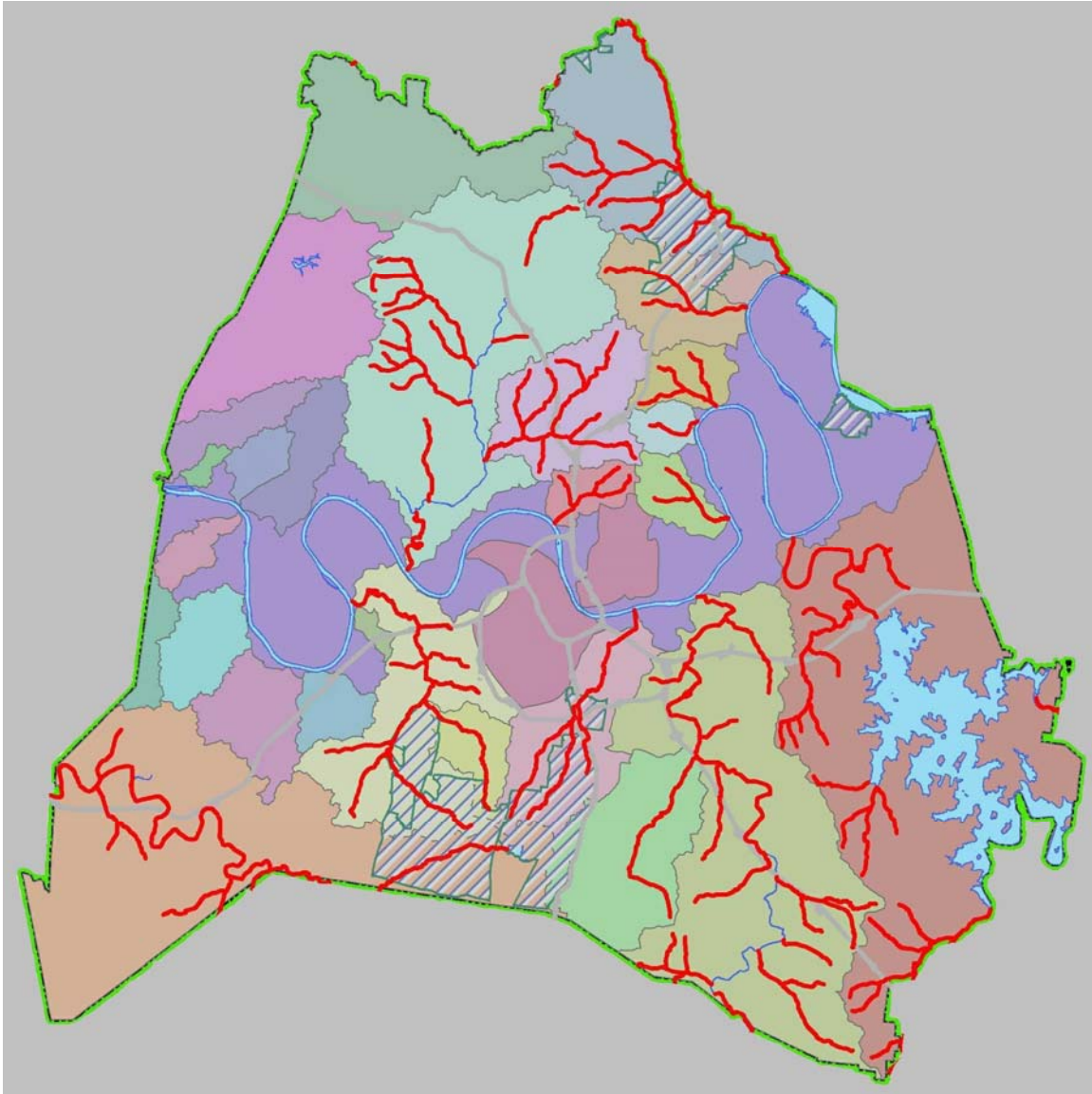


Figure 1. Davidson County sub-watersheds and impaired streams.

ALTITUDES OF AQUIFER WATER LEVELS 2005, AND HISTORIC WATER LEVEL CHANGE IN THE SURFICIAL AND MEMPHIS AQUIFER, MEMPHIS, TENNESSEE

Vamshi K. Konduru-Narsimha¹ and Brian Waldron²

The citizens of Memphis and Shelby County are fortunate to have an abundance of high quality ground water for public supply and other purposes. The primary source of municipal water for the Memphis area is the Memphis aquifer, which currently provides about 210 million gallons of water daily for drinking water and some industrial use. The high quality of the ground water in this aquifer in part results from the clean quartz sand composition of the Memphis aquifer and confinement provided by overlying protective clay beds of the confining unit. However, recent studies of the confining unit overlying the Memphis aquifer indicate breaches where the clay thins or becomes absent^{3,4,5,6}.

Pumping from the Memphis aquifer over the past 100 years has caused water levels in some parts of the aquifer to decline as much as 125 feet. As a result of this drop in the water level in the Memphis aquifer, the water level that is now present in the shallow aquifer is higher relative to the Memphis aquifer. The implication of this difference in water levels and the presence of the breaches is that water can potentially leak downward from the shallow system to the Memphis aquifer through breaches in the confining unit. The shallow aquifer contains water that is of a poorer quality than the Memphis aquifer and is prone to contamination from man-made sources (e.g., Williams Refinery, Hollywood landfill (closed), Velsicol Chemical Corp., Memphis Army Defense Depot). As long as withdrawals continue from the Memphis aquifer, the potential for downward leakage of water from the surficial aquifer to the Memphis aquifer will exist, as will a potential for future degradation of the high-quality drinking water in the Memphis aquifer.

Identification of these breaches commonly occurred when a well was drilled into the Memphis aquifer. Scientific interpretation of the driller's logs or geophysical logs of the geologic material within the borehole indicated an absence or thinning in the confining clay layer. Other forms of identification included mapping of the shallow aquifer water levels, where depressions or localized drops in the surficial water levels were indicative of leakage to the Memphis aquifer. The last water table map developed for the shallow aquifer was by the US Geological Survey in 1987⁵.

This research effort is being led by the University of Memphis with the support of the following financial partners: Tennessee Department of Environment and Conservation, Shelby County Government, US Geological Survey, and local industries such as Cargill. The intent of the research is to remap the water levels of the shallow aquifer, determine the interaction between the local rivers and the shallow ground-water system, possibly locate unidentified breaches in the confining unit, and update our understanding of the existing breaches. This effort will be

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⁴ Graham, D. and Parks, W., 1986. Potential for leakage among principal aquifers in the Memphis area, Tennessee, USGS Water Resources Investigations Report 85-4295.

⁵ Parks, W. S., 1990. Hydrogeology and preliminary assessment of the potential for contamination of the Memphis aquifer in the Memphis area, Tennessee, USGS Water Resources Investigation Report 90-4092, pp. 39.

⁶ Yates, R., 2002. Geologic setting and post-1940s evolution of the Wolf River flood plain, Shelby County, Tennessee, University of Memphis, Thesis, pp. 76.

accomplished through three main tasks: (1) develop an updated map of the shallow aquifer water table for all of Shelby County to identify water table depressions; (2) conduct water chemistry analyses at depression locations to assess mixing of shallow aquifer water with Memphis aquifer; and (3) perform subsurface geologic surveys using seismic reflection to further validate confining unit breaches. The latter information will also be useful for better understanding the conditions where breaches are more likely to exist. The project time period is 1½ years, to be completed in the Fall of 2006. Current status of the project will be presented at the Sixteenth Tennessee AWRA conference.

THE MISSISSIPPI, ARKANSAS, AND TENNESSEE REGIONAL AQUIFER STUDY (MATRAS)

John K. (Jack) Carmichael¹

Based on the importance of ground water as a resource in the northern part of the Mississippi embayment and recognition that insufficient information and understanding exist to adequately resolve known issues related to the resource, the U.S. Geological Survey (USGS) and the University of Memphis – Ground Water Institute (GWI) in conjunction with partner universities in the area, and the City of Memphis and Shelby County, Tennessee have resumed research on the geologic framework and ground-water flow in the Mississippi embayment and surficial aquifer systems in the Mississippi embayment. The Mississippi, Arkansas, Tennessee Regional Aquifer Study (MATRAS), initially began in 1999 with the objective of improving definition of the hydrogeology and ground-water flow in the Tertiary aquifer system in the Memphis area of northwest Mississippi, east-central Arkansas, and southwest Tennessee. Since the initial MATRAS began, interest in the concept by various agencies and stakeholders in the area has grown, leading to recognition that the scope of the initial MATRAS should expand beyond only the Memphis area and the Tertiary aquifer system as initially defined for the study.

In developing a general framework for a re-scoped MATRAS, the GWI and Shelby County, Tennessee have re-defined the overall objective as “...a much improved understanding of the water resources and availability in the Mississippi embayment to the degree that interested parties can develop the policies and programs necessary to ensure a sustainable regional ground water supply that will suffice for future municipal, industrial, agricultural, and environmental needs.” (GWI, White Paper to U.S. Congress, 2005, written comm.). Today, MATRAS has evolved into an overarching study of the ground-water resources in the Mississippi embayment and surficial aquifer systems in an approximately 170,000 square mile (mi²) area of the Mississippi embayment under which a set of specific initiatives will be carried out by the various projects. These initiatives consist of:

1) the Mississippi Embayment Regional Aquifer Study (MERAS), a 3-year initiative begun in FY2006 and lead by the USGS Arkansas Water Science Center (WSC), with assistance by the Tennessee, Mississippi, and Louisiana WSCs, and funded by the USGS Ground-Water Resources Program (GWRP). The primary objectives of MERAS are to 1) enhance understanding of regional ground-water flow and aquifer storage in the Mississippi embayment aquifer system, 2) estimate water budget components for the ground-water flow system in areas dominated by irrigated agriculture or public supply withdrawals, 3) evaluate the existing water-level monitoring and recommend improvements in monitoring network design and understanding of hydrologic factors crucial to the assessment of ground-water availability, and 4) assess the ground-water availability of the Mississippi embayment aquifer system..

2) the Mississippi Embayment Regional Ground Water Study (MERGWS), a proposed 5-year initiative begun in FY2006 and lead by the GWI, with participation by the University of Mississippi and Arkansas State University; local support by the City of Memphis, and Shelby County, Tennessee; and collaboration by the USGS Mississippi, Arkansas, and Tennessee WSCs. MERGWS currently is funded for one year under a federal earmark through the U.S.

Environmental Protection Agency (USEPA). The primary objectives of MERGWS are to assist in specific aspects of data compilation in support of MERAS; to work with partner universities, local agencies, and USGS WSCs in addressing data gaps and conducting research to improve understanding of the hydrology and geology of the Mississippi embayment; and to assist the

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USGS Tennessee WSC in development of a sub-regional ground-water flow model of the Memphis area.

3) the MATRAS Sub-Regional Model (SRM), similar in scope to the original 1999 MATRAS, this initiative consists of a proposed 5-year initiative on which work has resumed in FY2006 under the lead of the USGS Tennessee WSC, with assistance by the Mississippi and Arkansas WSCs, and the GWI and its partners. MATRAS-SRM currently is funded under a one-year federal earmark complimentary to MERGWS through the USGS. The primary objectives of MATRAS-SRM are to provide support to MERAS, MERGWS, to develop a sub-regional ground-water flow model of the Mississippi embayment and surficial aquifer systems for the Memphis area to better understand the ground-water resources of the area.

GROUNDWATER TRACING IN THE ROCK HOUSE CAVE SYSTEM, CARTER COUNTY, TENNESSEE

Yongli Gao¹, Robert Benfield², Sid Jones², Taylor Burnham^{1*}, and Nikki Gibson^{1*}

INTRODUCTION

The Rock House Cave is located in west Carter County Tennessee near the axis of the Stony Creek Syncline in between the Valley and Ridge and Blue Ridge provinces. The syncline at this location is younger rocks of the Knox Group (Ordovician age) before they plunge under the Buffalo Mountain klippe further to the west. The Rock House Cave stream served as a water supply for the community of Milligan until the system was taken over by the City of Elizabethton in the late 1960 or early 70's. In the late 1980's the city decided to stop using the cave stream and utilize the facility for a pump station only. The entrance of the cave is an impressive opening and water was drawn up to a filtering system over the cave's roof by wells penetrating the main passage in the cave. Several caves and creeks are founded to be connected to the Rock House cave groundwater system in this area. We conducted a preliminary study to investigate groundwater flow, surface and groundwater interactions around Rock House Cave.

METHODS

To establish groundwater flow velocity and direction, a quantitative test was designed based on a field inventory of springs, caves, wells, sinkholes and other features such as sinking streams found in the vicinity of Rock House Cave. Studies previously conducted were utilized to facilitate the design of this test. Based on our karst inventory in this area and previous dye tests conducted by Ogden et al. (1990) in Eastern Tennessee, a preliminary dye test was conducted in September 2005. Figure 1 shows the locations of the injection and ultimate output of this dye test. Three caves were found connecting Dry Creek and Buffalo Creek. From the east to the west, they are Rock House Cave, Salt Peter Cave, and Cave Spring Cave.

218 grams of Fluorescein powder was injected into the sinking stream where surface water from Dry Creek sinks into the Rock House Cave system. For this study water samples were collected from ISCO automated samplers and hand grabbed samples from three cave conduits in the area. Analyses for the tracing compound were preformed on a Turner Designs 10-AU Fluorometer. In-situ field measurements were conducted using Aquafluor™ Handheld Fluorometer.

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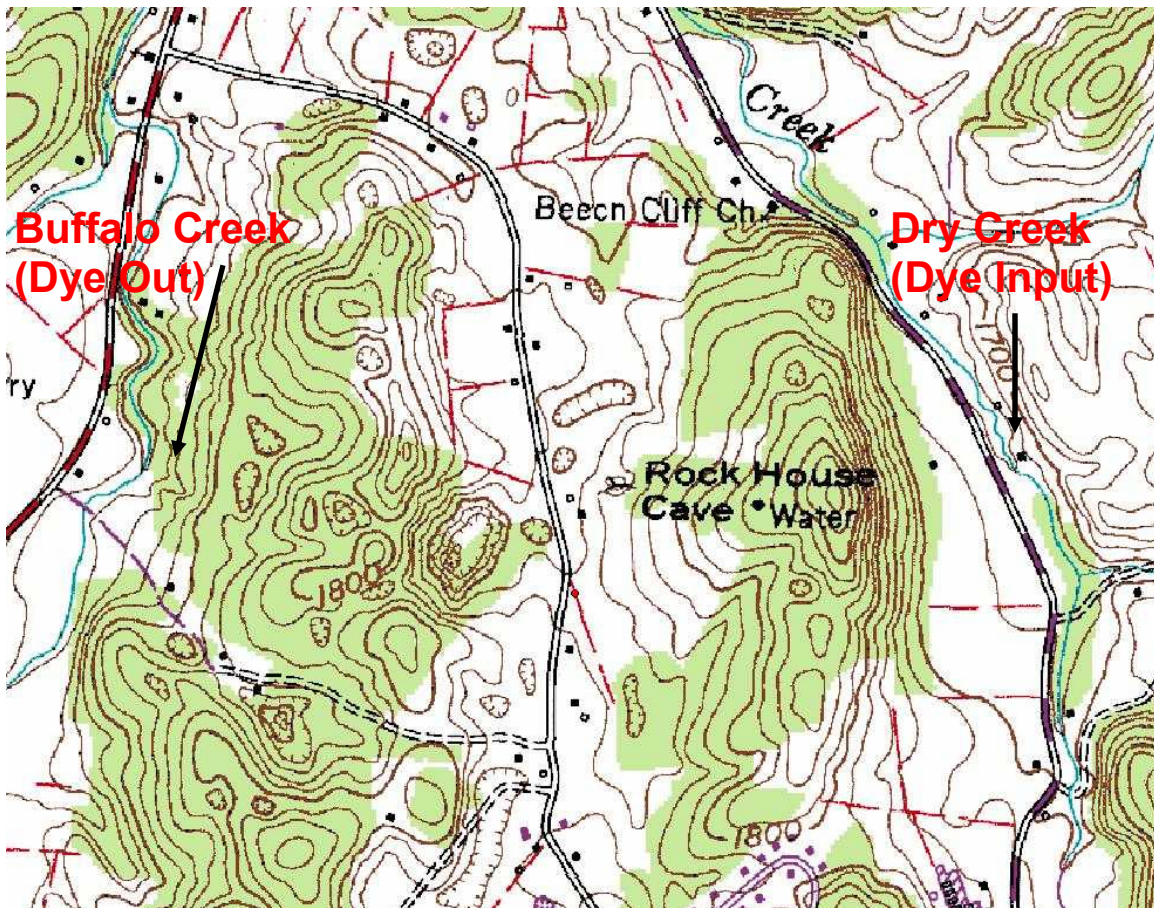


Figure 1. Locations of the dye tracing tests (notice that the Rock House cave system connects Dry Creek and Buffalo Creek, The map is from the Johnson City Quadrangle, Tennessee, 7.5 minute series topographic map, 1959 - photo revised 1968. The horizontal distance across this figure is approximately 2 kilometers.)

Onset HOBO Water level and Temp loggers were installed in the Rock House Cave groundwater reservoir and conduit system to measure water level and temperature changes in the cave. Field observation and salt tracing methods were used to estimate flow velocity and discharge in the creek and Rock House Cave groundwater conduits. Fisher brand AP85 Portable Conductivity/TDS Meter was calibrated and used to measure conductivity changes by salt tracing.

The basic relationship of the mass of a conservative tracer such as NaCl or Fluorescein and discharge is:

$$M = \int_0^{\infty} QCdt$$

where

- M – mass of recovered tracer
- Q – surface or groundwater discharge
- C – tracer concentration at time t

Mull et al. (1988) applied this equation for quantitative dye-tracing with different units under different circumstances. Our preliminary study used this equation to estimate surface water and groundwater discharge in this area and Fluorescein dye-recovery in the Rock House Cave conduit system.

RESULTS AND DISCUSSION

Figure 2 shows the breakthrough curve detected in the Rock House Cave. The shape of the curve is a typical asymmetric curve for dendritic karst conduit flow under low flow conditions. It took approximately two days for the dye to be transported from the sinking Dry Creek to the Rock House Cave. The peak of the Fluorescein concentration appeared after three and a half days after the dye injection. It took another week for the dye to pass through Rock House Cave. Figure 3 illustrates that water level was relatively stable during the dye-tracing test. Water level dropped slightly in the first 4 or 5 days and increased slightly from September 15 to September 17 2005. It then slowly dropped 2 cm from September 17 to September 22 2005. The water level fluctuation during the entire dye-tracing test is less than 2 cm. The water level drop for the last week of the dye-test explains the low flow condition and relative longer time for the dye to pass through. The distance between dye-injection location to Rock House Cave is approximately 500 meters. Therefore, groundwater flow velocity is estimated to be 200-300 m/day under low flow conditions. This flow velocity is at the lower end of previous dye-tracing tests in Eastern Tennessee karst area (Benfield et al. 2005; Oden et al. 1990).

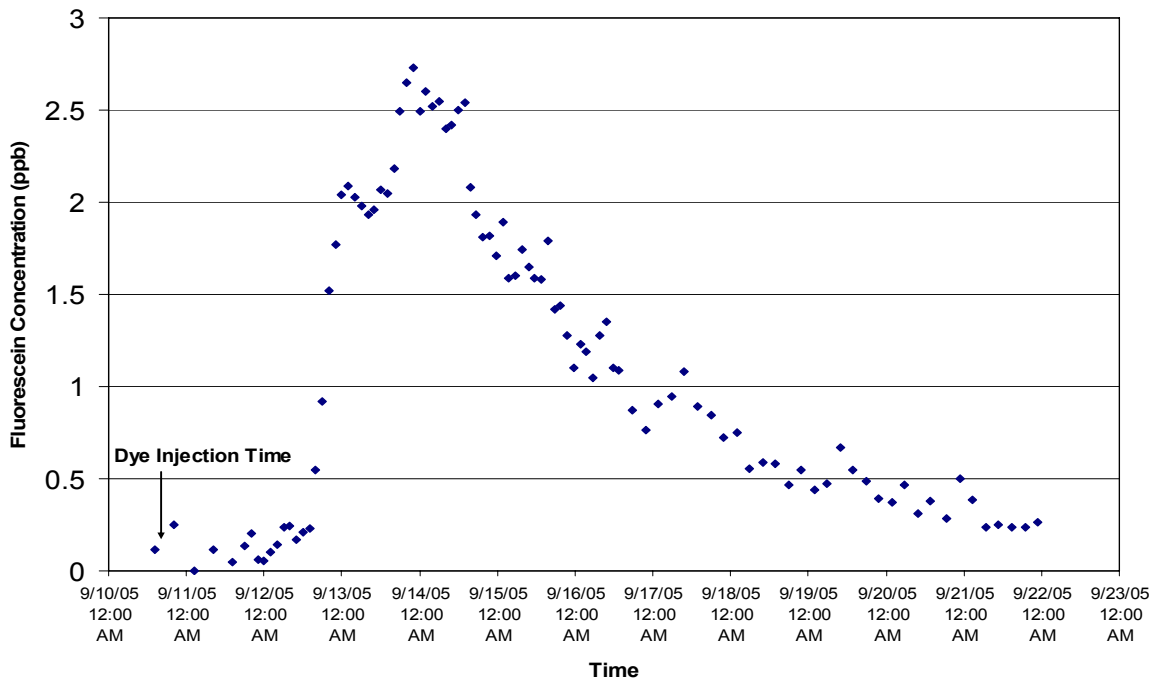


Figure 2. Tracer breakthrough curve in Rock House Cave (Fluorescein)

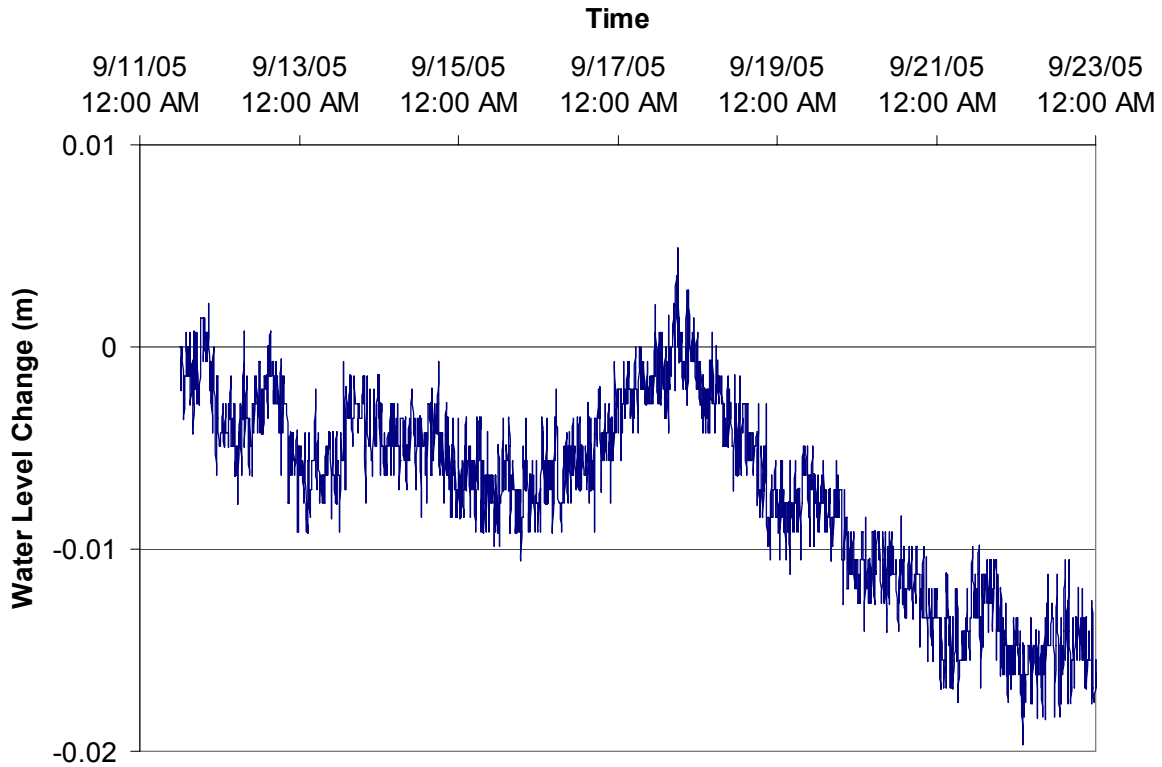


Figure 3. Water level change in Rock House Cave groundwater reservoir

Based on the salt tracing test in the Rock House Cave conduit system, the groundwater discharge is approximately 165 liter/s. The integration of the dye-recovery curve (Figure 2) is 0.77 g/liter. Therefore, $165 \times 0.77 = 127\text{g}$ dye has been recovered in the Rock House Cave. This corresponds to 58% of dye recovery. Fluorescein was also detected in large groundwater reservoirs in Rock House Cave and Salt Peter Cave. A significant amount of dye could have stayed in the groundwater reservoirs for a longer time period under low flow conditions.

SUMMARY

Our preliminary dye-tracing test shows that groundwater flow velocity is approximately 200-300 m/day during low-flow season in the Rock House Cave area. Fluorescent dyes were detected in Salt Peter Cave and Cave Spring Cave which are connected to the conduit system in Rock House Cave. These three caves are within one mile to a losing stream, Dry Creek. There are over a dozen caves within a 10 km² area around Rock House Cave. It is an ideal natural karst laboratory for future karst studies. Since this area has active flow during low-flow season and accessible aquifer test facilities, the long-term goal of this research is to test and develop hydrologic models in this unique karst aquifer system.

REFERENCES

Benfield R., Jones, S., and Davies, G., 2005, Elizabethton's Big Spring: a Case for Karst Aquifer Protection, *in* Waldron B (ed) The Fifteenth Tennessee Water Resources Symposium. Montgomery Bell State Park, Tennessee, April 13-15, AWRA, 2B24 – 2B29.

Mull, D.S., Liebermann, T.D., Smoot, J.L., and Woosley, L.H., Jr., 1988, Application of dye-tracing techniques for determining solute-transport characteristics of ground water in karst terranes. United States Environmental Protection Agency Region 4, Atlanta, Georgia, Publication EPA 904/6-88-001, 103 p.

Ogden, A. E., Brown, T.L., Hamilton, K.G., 1990, Delineation of "Wellhead Protection Areas" for Municipal Used Springs of Eastern Tennessee, Tennessee Water Resources Research Center Research Project Technical Report #124, 98 p.

SESSION 3C

DRUGS AND BUGS

8:30 a.m. – 10:00 a.m.

Twenty-four Month Pathogen Study of the Duck River Watershed Including Normandy Reservoir
Kimberly Childress

Bacteroides as an Alternative to E. coli as a Fecal Indicator
Alice Layton, Dan Williams, Randy Gentry, and Larry McKay

Exposure of Aquatic Organisms to Pharmaceutical Products in Surface Waters
Theodore B. Henry

PUBLIC EDUCATION AND AWARENESS

10:30 a.m. – 12:00 p.m.

Development of an Annotated Bibliography Characterizing the Duck River Basin (HUC TN06040002 and HUC TN06040003): Culture, History, and Science
Dennis B. George, Yvette R. Clark, Michael E. Birdwell, and Amy K. Knox

WaterWorks! In the Mainstream: Social Marketing
Karen Hargrove

The New Contractor EPSC Certification Program Developed by the City of Bowling Green Kentucky
Jeff Lashlee, Beth Chesson, and April Barker

24 MONTH PATHOGEN STUDY OF THE DUCK RIVER WATERSHED INCLUDING NORMANDY RESERVOIR

Kimberly Childress

In September of 2003 the Duck River Utility Commission with financial assistance from the Duck River Agency began a twenty-four month pathogen study of the Duck River watershed. The primary objective of the study was to create a water quality database of Normandy Reservoir and the Duck River. Due to the proposed Environmental Protection Agency's Long Term 2 Enhanced Surface Water Treatment Rule the results generated could also be used for the submission of grandfathered *cryptosporidium* data by each water treatment plant intake sample site.

Within the vast miles of shoreline between Manchester and Centerville, Tennessee, twenty-four sample sites were selected. Various tests were conducted at each site. The specific pathogens tested for at each site were based on the environmental impacts on that particular area. The results of the study demonstrated that during normal flow conditions the contamination levels of specific pathogens was minimal if not zero. However, after heavy rainfall, creating runoff and high flow conditions, pathogen levels at all sites increased exponentially.

Twenty-four sample locations were selected for testing. These sites included five water treatment plant intakes, five wastewater plant effluents, six tributary sites in Normandy Reservoir, one site above Normandy Reservoir, and seven sites down stream from Normandy Dam including the Normandy Dam release. The following lists the specific locations:

1. Water treatment plant intakes
 - a. Duck River Utility Commission
 - b. Shelbyville Water Plant
 - c. Bedford County Utility District
 - d. Lewisburg Water Treatment Plant
 - e. Columbia Water Treatment Plant
2. Wastewater treatment plant effluents
 - a. Manchester Wastewater Plant
 - b. Shelbyville Wastewater Plant
 - c. Tyson's Wastewater Plant
 - d. Lewisburg Wastewater Plant
 - e. Columbia Wastewater Plant
 - f. Major tributaries to Normandy Reservoir and the Duck River
3. Crumpton Creek
 - a. Ovoca/Bobo Creeks
 - b. Carroll Creek
 - c. Riley Creek
 - d. Fountain Creek
4. High recreational use areas
 - a. Anthony Bridge
 - b. Barton Springs Bridge
 - c. Mullins Mill Bridge

- d. Henry Horton State Park
- e. Carpenter Bridge
- f. Leftwich Bridge
- g. Hickman Bridge

5. Other sites

- a. Highway 41 North Bridge Manchester
- b. Normandy Dam release

The sample locations listed above were selected for several reasons. The water treatment plant intakes were selected to comply with the Long Term 2 Enhanced Surface Water Treatment Rule and also verify if any pathogens were present in the plants source water. The wastewater effluents were selected to determine if they were contributing to pathogen contamination in the watershed. The tributaries were chosen to investigate possible contamination contributions from farmland and new residential developments. Recreational areas were selected to identify if high use areas contribute to pathogen contamination. All sites were sampled in a forty-eight hour period, thus pathogen levels could be traced from site to site for increases or decreases.

All of the sample locations were tested for total coliform bacteria, *Escherichia coli*, *Enterococci*, and turbidity. These tests were conducted at the Duck River Utility Commission laboratory using Idexx colilert and enterolert quanti-tray methods. The turbidity was measured using a Hach 2100N turbidimeter.

Analytical Services, Inc. was contracted to perform several other tests. These included *Salmonella*, *Coliphage*, *Campylobacter*, *Giardia*, and *Cryptosporidium*. Methods used to perform these tests included, 9260D Quantitative *Salmonella* Procedures, method 1601 Somatic *Coliphage* in DW Enrichment Presence, method 1623 *Cryptosporidium* and *Giardia* by Filtration/IMS/FA, and Analytical Services, Inc. used a developing method for the *Campylobacter* testing.

Personnel from each participating water treatment plant collected water samples from designated locations. Ten to fifty liters of source water was filtered through a Gelman Envirochek HV Filter for the *Cryptosporidium/Giardia* testing method. Two half-gallon containers were collected for the *Salmonella*, *Coliphage*, and *Campylobacter* testing methods. Also collected were two 100ml sample bottles for *E. coli* and *Enterococci* and a container for turbidity testing. All samples were delivered to Duck River Utility Commission. Upon arrival all containers were sorted, checked for proper labeling and prepared for shipment to Analytical Services, Inc. These samples were all packed in ice and shipped by an overnight courier.

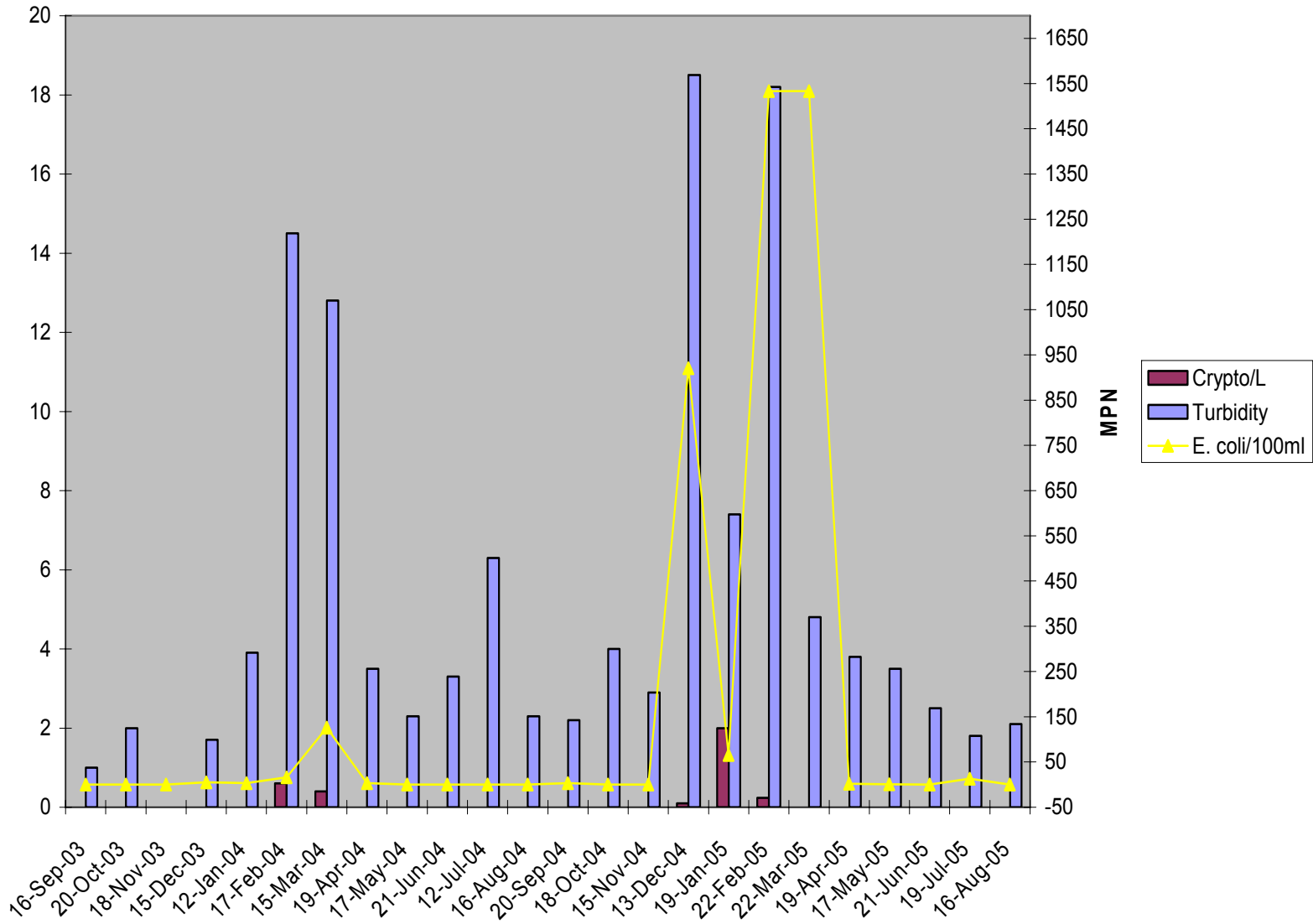
After approximately seven months from the beginning of the study testing for *Coliphage* and *Campylobacter* was stopped due to the minimal presence of these specific pathogens. Also site No. 7 Carroll Creek was deleted from the *Cryptosporidium/Giardia* testing due low detection levels. Existing sampling points that contained high levels of coliform bacteria were then added to the *Cryptosporidium/Giardia* testing list. These sample locations included sites No. 11 Mullins Mill Bridge, No. 16 Henry Horton State Park, No. 19 Carpenter Bridge, and No. 20 Leftwich Bridge.

In August of 2005 the study was concluded. There was no particular sample location that had a significant concentration of pathogens. Each location contained some amounts of contaminants. *Cryptosporidium* concentrations were the highest at site No. 14 Tyson's wastewater effluent. Site

No. 11 Mullins Mill Bridge contained the highest levels on a river location. And of the five water treatment plants, Lewisburg's water treatment plant intake contained the largest levels.

The Long Term 2 Enhanced Surface Water Treatment Rule uses the *Cryptosporidium*, *E. coli*, and turbidity data as a way of predicting if one pathogen influences the other. From the test data of this study there was not a correlation. The only predictions they can be made is that high flow conditions resulting from heavy rain create extremely high levels of pathogens in the Duck River Watershed. With the results of this study and others, the data could be used to help mitigation projects in the future to ensure better water quality in the Duck River Watershed.

DRUC LT2 Data



Duck River Watershed Pathogen Study								
Average Results - September 1, 2003 through March 31, 2004								
No.	Site Description	Collector	Crypto	Giardia	E. Coli	Enterococci	Salmonella	Coliphage
1	Highway 41 North Bridge Manchester above WWTP	Manchester	0.05	0.11	255.9	36.9	4.8	11
2	WWTP Effluent Manchester	Manchester	0.79	61.89	286.9	31.1	0.8	6
3	Anthony Bridge Manchester Normandy Reservoir	DRUC	NT	NT	107.7	19	NT	NT
4	Crumpton Creek tributary mouth Normandy Reservoir	DRUC	0.61	0.23	121.4	31	0.8	14
5	WTP Intake DRUC	DRUC	0.14	0.15	21.5	2.4	0.5	9
6	Ovoca/Bobo Creeks Normandy Reservoir	DRUC	NT	NT	12.9	2.3	NT	NT
7	Carroll Creek tributary mouth Normandy Reservoir	DRUC	0.09	0.63	17.2	1.6	2.7	7
8	Barton Springs Bridge Normandy Reservoir	DRUC	NT	NT	17.4	1.9	NT	NT
9	Riley Creek tributary mouth Normandy Reservoir	DRUC	NT	NT	15.9	2	NT	NT
10	Normandy Dam release	Manchester	0.24	0.03	24.9	14	2	1
11	Mullins Mill Bridge Boat Access Ramp	DRA	NT	NT	549.7	69	NT	NT
12	WTP Intake Shelbyville	Shelbyville	0.03	0.18	239.3	42.2	0.8	23
13	WWTP Effluent Shelbyville	Shelbyville	0.73	138.26	611.2	74.1	0.5	481
14	WWTP Effluent Tysons	Shelbyville	3.29	0	49	77.1	1	131
15	WTP Intake BCUD	BCUD	0	0.11	389.9	39.7	1.4	19
16	Henry Horton State Park	Lewisburg	NT	NT	144.6	3.2	NT	NT
17	WTP Intake Lewisburg	Lewisburg	0.06	0.01	116.4	25.7	2	17
18	WWTP Effluent Lewisburg	Lewisburg	0.51	95.31	691.6	62.4	2.4	840
19	Carpenter Bridge	DRA	NT	NT	222.2	27.4	NT	NT
20	Leftwich Bridge Boat Access Ramp	DRA	NT	NT	203.3	35.9	NT	NT
21	Fountain Creek Bridge Site	Columbia	0.4	1.14	433.3	52.2	4.5	220
22	WTP Intake Columbia	Columbia	0.21	0.13	253.5	48.1	4.8	29
23	WWTP Effluent Columbia	Columbia	NT	NT	79.3	10.7	NT	NT
24	Hickman Bridge Boat Access Ramp Centerville	DRA	NT	NT	135	16.9	NT	NT

All results = organisms per liter NT = Not Tested

BACTEROIDES AS AN ALTERNATIVE TO *E. COLI* AS A FECAL INDICATOR

Alice Layton^{1*}, Dan Williams, Randy Gentry, and Larry McKay

Bacteroides spp. are bacteria present in warm-blooded animal feces at concentrations several orders of magnitude higher than *E. coli*. In addition, they are host specific so that the *Bacteroides* found in human feces can be differentiated from the *Bacteroides* found in cattle feces. At the UT Center for Environmental Biotechnology we have developed molecular assays to quantify the amount of total feces (Allbac) in water and the amount of feces attributable to human (Hubac) and cattle (Bobac). This type of data may be useful for pathogen TMDLs, which require information on both the fecal load and the source of feces. However, in order for fecal data to be useful for pathogen TMDLs a relationship between the fecal data and *E. coli* concentrations must be established. Over the past two years we have collected *E. coli* data and *Bacteroides* data in several watersheds differing in size and land use patterns. Preliminary analysis indicates that *E. coli* concentrations and fecal concentrations are correlated ($r=0.4$ to 0.8 depending on the watershed). Application of the Hubac and Bobac assays to water samples from different watersheds indicate that sources of fecal contamination may be highly variable both spatially and temporally and may be influenced by flow and seasonality.

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EXPOSURE OF AQUATIC ORGANISMS TO PHARMACEUTICAL PRODUCTS IN SURFACE WATERS

Theodore B. Henry¹

Pharmaceutical products 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 target the neuroendocrine system, are biologically active at low concentrations, and have been detected in surface waters downstream of wastewater treatment plants (e.g., fluoxetine). SSRIs are among the most frequently prescribed drugs in human medicine and patients typically continue treatment over long periods of time.

In several experiments, the acute and chronic toxicity of five SSRIs was investigated in the Daphnid *Ceriodaphnia dubia*. The toxicity of fluoxetine was investigated in western mosquitofish *Gambusia affinis*. Concentrations of SSRIs lethal to 50% of *C. dubia* in 48 h (48-h LC₅₀) were several orders of magnitude higher than concentrations expected in the environment. Reproduction of *C. dubia* was inhibited by exposure to SSRIs in chronic tests but not at environmentally relevant concentrations. The toxicity of mixtures of SSRIs in *C. dubia* demonstrated that each SSRI component contributed additively to toxic effects. In western mosquitofish, chronic (100 d) exposure to fluoxetine (60 ppb) delayed development of adult sexual morphology suggesting potential for SSRIs to affect fish reproduction.

Results for individual SSRIs indicate that exposure at predicted environmental concentrations would not cause toxic effects in *C. dubia* or western mosquitofish. However, SSRIs are likely present in surface waters as complex mixtures and results indicate that concern over effects on aquatic organism should not focus on individual compounds but rather groups of compounds having similar modes of toxic action.

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DEVELOPMENT OF AN ANNOTATED BIBLIOGRAPHY CHARACTERIZING THE DUCK RIVER BASIN (HUC TN06040002 AND HUC TN06040003): CULTURE, HISTORY AND SCIENCE

Dennis B. George^{1*}, Yvette R. Clark², Michael E. Birdwell³, and Amy K. Knox⁴

INTRODUCTION

The Duck River basin (2,289 sq. mi. drainage area) is one of the nation's most ecologically diverse and biologically significant river systems. Portions of the Duck River are designated as a State Scenic River. The river and its tributaries also provide habitat for state-listed threatened or endangered species, including pink mucket pearly mussel (*Lampsilis orbiculata*), orange-footed pearly mussel (*Olethobasus cooperianus*) and Cumberland monkeyface pearly mussel (*Quadrula intermedia*) (<http://cookeville.fws.gov/docs/endanger.html>). Several river miles within the Duck River basin, however, are on the Tennessee Department of Environment and Conservation's (TDEC) 2004-303d List as impaired, resulting from storm-water runoff and chemical and nutrient loading from agriculture and sewage treatment discharges. Furthermore, the Duck River and its tributaries face significant impacts to habitat, hydrology and water quality as more land is converted to residential, commercial and industrial uses.

The culture that has emerged within the Duck River basin has been influenced by several historic events. Prior to the New Deal and the advent of the Tennessee Valley Authority (TVA), the Tennessee Electric Power Company (Tepco) operated a number of hydroelectric facilities along the Duck, some of which remain. Additionally, Grinder's Switch, near Centerville, was the childhood home of one of the Grand Ole Opry's favorite stars, Minnie Pearl Cannon. Shelbyville is home to the National Tennessee Walking Horse Competition. The prehistoric site Old Stone Fort, in Coffee County, is one of the most significant historic sites related to the Duck River. Gristmills proved necessary to the daily lives of citizens, and the remnants of some sites are still evident along the Duck. At New Johnsonville (on the Tennessee River), the discovery of the remains of four Ironclads the *Undine*, *Tawah*, *Key West* and *Elfin* generated a great deal of interest in the significant role rivers played in the Civil War in Tennessee. In Humphreys County, Confederates operated a significant operation to build vessels used on the Duck River. A great deal of Civil War activity occurred near the Duck between Manchester and Columbia. Sam Watkins, who wrote *Co. Aytch*, one of the most quoted personal accounts of the Civil War, hailed from Columbia and is buried there. This is just a small sample of the historically and culturally relevant events and sites endemic to the Duck River watershed.

SCOPE

The project integrated the cultural history with the wealth of existing environmental science data and information on the Duck River basin in an annotated bibliography. The bibliography was produced in a digital document-retrieval format on CD and is currently available on the Internet

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at www.tntech.edu/wrc/duckrivermanual/duckrivermanualbegin.htm and mt.duckriveragency.com/.

OBJECTIVES

The specific project objectives were to

- collect all historical and cultural information and documents of the communities in the Duck River basin;
- collect existing biological, water quality, geological, and hydrological data and information on the Duck River basin;
- analyze datasets for accuracy, completeness and trends;
- prepare an annotated bibliography of the cultural history of the Duck River basin;
- prepare an annotated bibliography of scientific data and information; and
- prepare information in a computerized format that can be easily queried and distributed.

APPROACH

The project was divided into three phases. **Phase 1** was devoted to data and document acquisition. In **Phase 2**, all data were analyzed for trends, documents were synthesized, and the annotated bibliography was prepared. The computerized format for the annotated bibliography was developed in **Phase 3**, and the information was archived according to this document-retrieval format on CD and for the Internet.

Phase 1. Data and Document Acquisition

Task 1.1. Cultural/Historical Information.

Objective: The objective of Task 1.1 was to collect cultural and historical records about events and the communities in the Duck River basin. Specific communities covered included Bell Buckle, Centerville, Chapel Hill, Columbia, Hurricane Mills, Lewisburg, Manchester, Shelbyville, Spring Hill, Tullahoma and Wartrace. The historical aspect of the project was broken into specific periods: Prehistory (prior to 1769); Colonial-Antebellum (1769-1861); Civil War and Reconstruction (1861-1877); Gilded Age (1877-1917); World War I, Depression and World War II (1917-1945); Cold War (1945-1989); and Common Era (1990-present).

Approach: Project personnel investigated records at the Tennessee State Library and Archives for written works, historic maps and manuscript collections relevant to the history and culture of the Duck River and its immediate environs. Information was also gathered from state agencies including TVA, The Nature Conservancy, individual counties in the watershed and other libraries. Maps, created using geographic information system (GIS) technology, delineated historical site and event locations.

Project personnel visited pertinent sites to photograph images, which were incorporated in the CD. The remnants of mills, roads, Tepco hydroelectric plants and other structures denoting a different time on the cultural landscape are fast disappearing. Some of the remains of these sites were also recorded and included on the CD.

Task 1.2. Biological, Water Quality, Geological, and Hydrological Data and Information.

Objective: The objective of Task 1.2 was to collect existing environmental scientific data and information pertaining to the Duck River basin.

Approach: Several state, federal and local agencies maintain historical environmental data and information on the Duck River basin. TDEC, alone, has more than 300 monitoring stations in the watershed with an estimated 69 additional stations maintained by other agencies. The TVA Guntersville-Tims Ford Watershed Team collects data and information on the Duck River basin. Recently, TVA, in cooperation with the Tennessee Duck River Development Agency, TDEC, U.S. Army Corps of Engineers (USACE), and the U.S. Fish and Wildlife Service (USFWS), completed an Environmental Impact Statement, titled “Future Water Supply Needs in the Upper Duck River Basin.” Also, the U.S. Geological Survey (USGS) has archived environmental data on the watershed and maintains multiple stream flow gauging stations within the watershed (Figure 1). The Tennessee Wildlife Resources Agency (TWRA) and USFWS maintain wildlife and habitat databases on species diversity in the watershed. Work by The Nature Conservancy was also included in the annotated bibliography. These data helped to identify historical sample locations, as well as provided benchmarks for identifying new sample locations, if necessary. Historical data and information were collected on the following categories:

- stream geomorphology and hydrodynamics,
- water quality,
- fish species,
- macroinvertebrate populations,
- mussel species,
- watershed land use,
- wildlife, and
- geology.

The quality of the data was assessed to determine its usefulness by considering such factors as sampling design and technique, analytical methods, and level of taxonomic resolution achieved.

Reports and graduate student theses and dissertations related to the Duck River basin were obtained and scanned using the Laser Fiche[®] software, which uses optical character recognition (OCR). Information obtained in the reports about the sampling stations, like the location by river mile, was represented on a GIS-created map. The stations were categorized based on their report numbers.

Upper & Lower Duck Watersheds

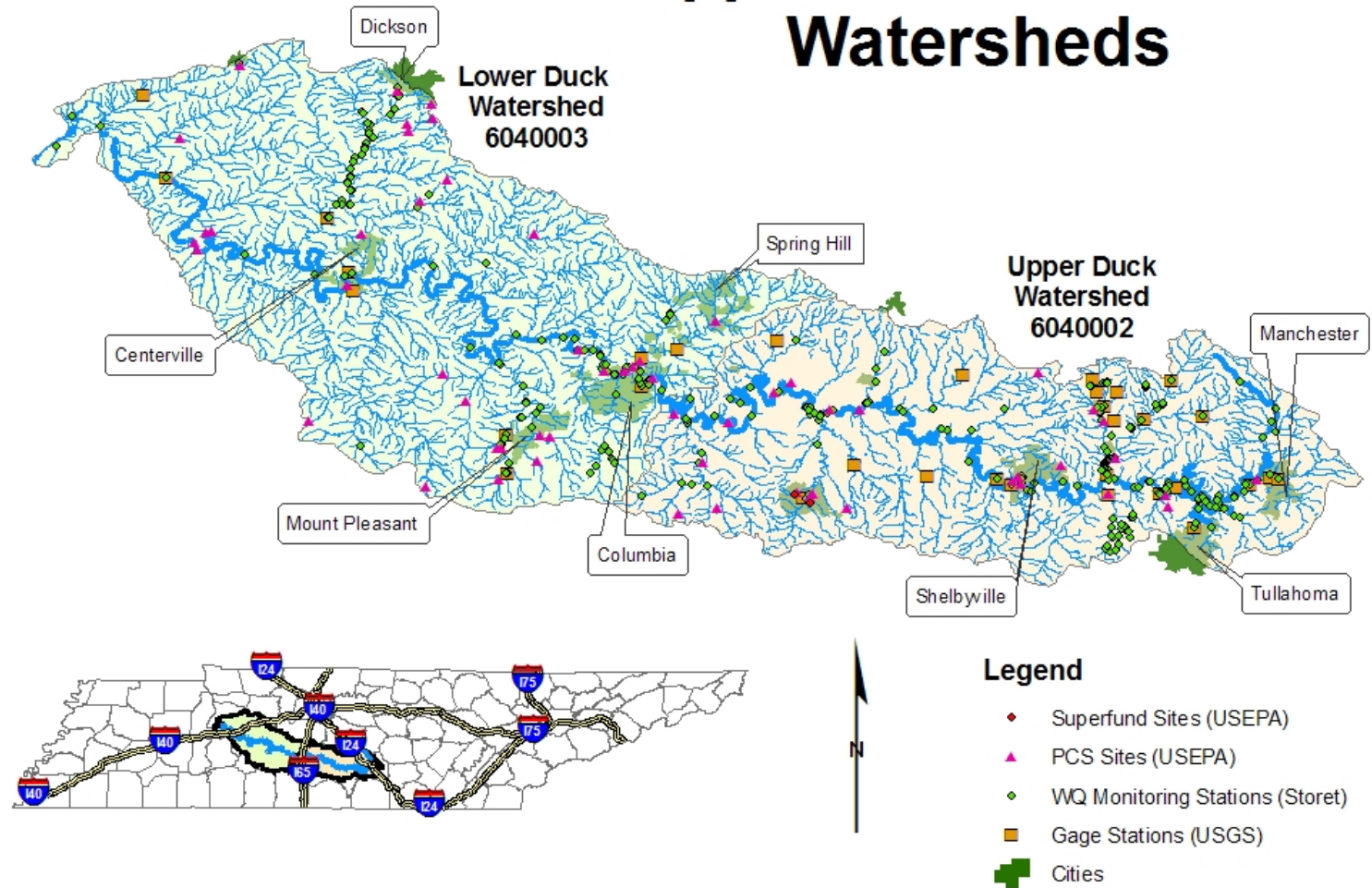


Figure 1. Stream Flow Gauging Stations within the Upper and Lower Duck Watersheds

Phase 2. Data Analysis

Objective: The objectives of Phase 2 were to assess the quality of data and information collected and determine data trends.

Approach:

Task 2.1. Cultural/Historical Information. All historical and cultural information collected was synthesized and placed in its proper chronological order. This included both historic and current images, historic maps, and information about key people, events, and the existing cultural landscape. Historic images and the rights to use them were acquired from the Tennessee State Library and Archives. The project also includes copies of primary documents pertinent to the history of the Duck River, which enhance the use of the disk as a research and educational tool for teachers and amateur historians. Data was cross-referenced and arranged both chronologically and topically to facilitate the ease of use.

Task 2.2. Biological, Water Quality, Geological, and Hydrological Data and Information.

Historical environmental samples, which were gathered by differing methods and represented various years and seasons, were obtained from several organizations. Differences in sample collection times, location, collection methods and analytical methods can cause a great deal of variation in values obtained and the contribution to understanding the ecological condition of the stream in the watershed. The data were evaluated to determine the value added to the historical ecological state of the streams.

After data quality assessment was completed, datasets were statistically analyzed to determine data trends. Data trends were presented graphically. Statistical information was georeferenced to sampling site location.

Phase 3. Annotated Bibliography Computerized Format

Objective: The objective of Phase 3 was to develop an interactive CD containing historic, cultural, scientific, archaeological and geographic information pertaining to the Duck River basin. The files created in this phase could also be used for the on-line version of the project.

Approach: The CD was created using the on-line help software and document-retrieval technologies available within the Macromedia RoboHelp® and Laser Fiche® suites. The CD allows end users to navigate compiled data in a user-friendly format.

The annotated bibliography allows the user to gain insight into the materials available, while in some cases pointing out the strengths and weaknesses of the material. Many of the annotations contain a précis of the work. The annotated bibliography also brings attention to areas where new or further improvements are needed. The bibliography is organized topically within the subcategories of river flow and quality, community, biology, culture, and history.

WATERWORKS! IN THE MAINSTREAM: SOCIAL MARKETING

Karen Hargrove¹

INTRODUCTION

Water education is ‘real life’ education. If Tennessee’s population continues to grow at the current rate, our citizens will soon be approaching a crisis situation regarding clean, potable water. Our economy, the health of our citizens, and wildlife habitat are dependent on plentiful and safe sources of clean water.

WaterWorks!---a new initiative in outreach education for the Center for Environmental Education at Middle Tennessee State University (MTSU), funded by the TN Department of Agriculture Nonpoint Source Program ---was launched in the fall of 2003, focused on improving water quality in Tennessee through a series of radio and television announcements.

WaterWorks! promotes social change through focused marketing to an audience of Tennessee households and homeowners, with specific components designed to promote and reinforce the message of individual responsibility.

NEED

At the same time that WaterWorks! was in the planning stage, the 85 Phase II stormwater communities (communities with municipal separate storm sewer systems, or MS4’s) in Tennessee were beginning to write and submit their NPDES permit applications for approval. In many communities, those officials in charge of stormwater programs were not prepared to plan educational or outreach campaigns, a required part of the plan; they were overwhelmed just by the daily workload. Through 319 funds from the Tennessee Department of Agriculture’s Nonpoint Source Program, the WaterWorks! Program is able to provide public education and outreach through public service announcements and other products and services to Phase I and Phase II stormwater communities in the state.

UNIQUE PARTNERSHIPS

WaterWorks! and the Tennessee Association of Broadcasters (TAB) proposed a unique partnership to the MS4 communities. With a membership of over 320 radio and television stations, TAB offered to air WaterWorks! announcements in a “noncommercial sustaining announcements” category, a classification which includes contributing funds from WaterWorks! and the MS4’s at much lower than commercial rates and which guarantees a minimum of four times the paid value in airtime. (The actual value is much higher, up to ten times the paid amount.)

Initially, WaterWorks! bought \$2,500 worth of airtime a quarter, and in the first two months of the campaign, the actual results showed that the advertising value was \$88,800. The television spots aired more than 460 times and radio announcements had 4519 airings. (Because not all

¹ WaterWorks! Program, Murfreesboro, TN

stations report the airing of these announcements, the true value of this program is actually much higher.)

Each of the MS4 communities may sign on to this statewide outreach campaign at \$500 per quarter, and are guaranteed a minimum of \$2000 of airtime value. TAB partners choose the time slots and also report airtime for the quarter. Even though some announcements are during the ‘wee’ hours (not really a problem since many Tennesseans work 2nd or 3rd shifts in hospitals and industry) many announcements have been heard or seen during sports events and “drive times” at the beginning and end of the average workday.

Because of the ability of the WaterWorks! program to provide needed outreach education about water quality to Tennesseans, the Tennessee Department of Environment and Conservation will match MS4 and WaterWorks! funds for additional airtime for ads that target oil and other automotive products that can pollute the state’s waterways.

BENEFITS

The benefits of the WaterWorks! and TAB partnership to the MS4’s are many, and include:

- professionally created messages
- statewide airtimes
- unified messages
- increased support for each other’s program
- local limited funds are leveraged
- partnering helps fulfill all or part of public education responsibilities

PROCEDURE

In thinking about solutions to environmental issues and problems, the focus is usually on a change in *behavior*, one brought about either through a revision of attitudes or a forced compliance to a rule or law. The WaterWorks! campaign is based on raising awareness, building knowledge, increasing skills, and reinforcing an “It’s easy for me to do it!” attitude through social marketing. An excellent source about the theory and application of social marketing techniques is Fostering Sustainable Behavior by Douglas McKenzie-Mohr, who advises those interested in social marketing techniques to study benefits of, and barriers to, the desired behavior².

Set GOALS:

- Raise awareness of the causes of water pollution in Tennessee
- Build awareness of the consequences of individual action
- Instill a sense of empowerment of Tennessee residents
- Change behavior that causes water pollution through motivation for responsible behavior
- Promote requests for more information

Examine BELIEFS:

- Only 37% of Tennesseans feel water quality in streams is good or excellent
- 63% rate drinking water quality as good or excellent
- Younger groups feel technology should solve pollution problem
- Over all, 82% believe human behavior can improve water quality

Determine MOTIVATIONAL FACTORS:

² McKenzie-Mohr, Douglas, *Fostering Sustainable Behavior*, published June 29, 1999 by New Society Publishers

Many citizens:

- Will respond to messages of personal responsibility
- Are influenced by children
- Link poor water quality to adverse health effects
- Link poor water quality to loss of recreational opportunities

Select AUDIENCE:

- Suburban and urban homeowners
- Do-it-yourselfers
- Parents
- Youth
- Educators
- Outdoor recreation enthusiasts
- Opinion leaders

Choose DESIRED RESPONSES:

- Rivers and streams are an asset to everyone in Tennessee.
- People who cause water pollution are driving up the costs of my water bill.
- People who cause water pollution are driving up costs for all of us (health care, taxes, government spending on cleanups.)
- What I do does indeed affect people, and all living things, downstream.
- My litter pollutes the water.
- I can make a difference by doing simple things to reduce water pollution.
- I need to be more responsible in the way I change my oil, use fertilizers and other chemicals.
- Now that I know I'm contributing to the problem, I will change my behavior.

Select POSITIONING STATEMENTS:

Organizational: "Protecting our water...for life!"

Motivational:

"Water pollution. It's NOT the other guy's problem." (2003-4)

"Water pollution. It's EVERYONE'S problem." (2005-6)

Select STRATEGY:

- Keep creative fresh while keeping quality high...produce a series of spots that can be released throughout the broadcast year.
- Appeal to pride in Tennessee's water resources. Use representative scenes and appeal to hunters, fishers, boaters and other outdoor recreationists.
- Appeal to desire to conserve our beautiful resources so that future generations can enjoy them and have clean, safe water.
- Show sources of water pollution and solutions to water pollution. Use messages that reinforce positive behavior.
- Appeal to urban and suburban audiences.
- Use localization for television and radio spots.

ADDITIONAL NOTES ON PROCEDURE

Select an agency with shared values that can understand your goals and work within your budget. It is beneficial to include funding agency personnel (or oversight committee members) in all stages of planning at appropriate intervals, especially on the sign-off of creative ideas. Use focus groups of similar demographics as your intended audience and listen to what they say.

WATERWORKS! PRODUCTS

- PSA's (or noncommercial sustaining announcements), both television and radio
- 1st creative phase—"in your face" attitude of main character, a catfish
- 2nd creative phase—softer approach, appeal to the future, Tennessee's beautiful rivers and streams, wildlife habitat
- Print media—FREE CD with print designs, which helped MS4's that use print materials as part of their education and outreach plan. The design for a homeowner's brochure can be localized for an MS4 or citizen group; the poster design with educator activity can be used in other ways; the black and white student page may 'outlast' the brochure as it will be brought home and posted on the home refrigerator
- Print Ad designs, as created, will be placed on the 'Print Media' page on the WaterWorks! website (www.tennesseewaterworks.com)
- Stream Savers Program---awards for youth groups that complete projects which improve water quality (stream cleanups, water monitoring, bank restoration, education, etc.) Groups, either classroom or clubs, scouts, can win money for their group, specially designed t-shirts and a certificate of recognition
- Watershed Map---a map of Tennessee which provides stormwater program information by county and watershed, with downloadable 'pullout' maps and contact information for MS4's, watershed groups, and water quality problems
- Stream Assessment information provided through the Tennessee Department of Environment and Conservation GIS format
- Statewide Surveys---Conducted in 2003 and 2005 which provide information about citizen attitudes and actions related to water quality
- Website---(www.tennesseewaterworks.com) showcases program components as well as some lovely Tennessee rivers, streams, lakes and waterfalls on the homepage, with a list of links and resources organized for use by K-12 educators, citizens, watershed groups, and municipal stormwater managers

ASSESSMENT

There are two aspects of assessment---the effectiveness of the WaterWorks! announcements on improving water quality in the state, and the increasing use of the announcements by the MS4 communities through partnership in the TAB program. Regarding the effectiveness of the program, the main question revolves around the ability to document behavior change directly related to the airing of the announcements. In the 2005 survey, respondents were asked if they had seen or heard the ads, and if they had changed any behavior because of it. Almost one-half, or 44%, of the respondents recalled seeing at least one ad about clean water quality on either commercial or public television...One-fourth of those who had seen the ad reported they had seen the ad on commercial TV or on local access channels.

The ads resonated with about one-fourth of the respondents by instigating self-reported changes in behavior. Ninety-three respondents were able to articulate specific changes in attitudes or behavior that they linked directly to seeing or hearing the ads. Impressively, 53% of those reporting a behavior change stated they had reduced littering and dumping and had increased recycling.

As far as the MS4 participation in the TAB partnership, more and more stormwater communities are joining in as funding becomes available to their programs. With the additional impetus that the TDEC match program gives WaterWorks! to help extend MS4 budgets, more and more stormwater communities will be able to share a statewide message.

It still remains to be seen if water quality improves significantly (based on past and future reports from the Tennessee Department of Environment and Conservation) and if improvement can be directly related to the WaterWorks! campaign. Very possibly, water quality improvement could be credited not only to this campaign but to the efforts of many active and effective watershed groups, to the MS4 program managers, and in the coming years, to an increased national focus on the importance of water quality.

LESSONS LEARNED

Year one---Use focus groups that represent the population of the desired audience. Make sure the people IN the announcements are representative of the desired audience. (Our first ads were aimed at a suburban audience, and the stormwater manager in a large urban area pointed out that as attractive as the ads were, they did not represent the diverse urban population he served.) Make sure appropriate contracts are in place for both recorded as well as print images, if you want to use both. (A limited budget and personalities prevented print use of photos of an actor.)

SUCCESSSES

Build and maintain a good team and good partnerships. Thank and give credit to everyone who helps. Cultivate patience. Be flexible; learn to juggle many ongoing tasks (managing website; creating new announcements, new products). Enjoy the process!

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"...and everything shall live where the river flows."

THE NEW CONTRACTOR EPSC CERTIFICATION PROGRAM DEVELOPED BY THE CITY OF BOWLING GREEN KENTUCKY

*Jeff Lashlee¹, *Beth Chesson², and April Barker³

EDUCATING AND INVOLVING CONTRACTORS IN NPDES PHASE II COMPLIANCE

The City of Bowling Green, Kentucky is a designated NPDES Phase II community and is therefore required to adopt and implement a construction site runoff control program. In December of 2004, the City adopted a stormwater ordinance that required “certified contractors” on development sites. The certified contractor requirement was included in the stormwater ordinance in an effort to educate contractors on the importance of Erosion Prevention and Sediment Control (EPSC) and to more actively involve site contractors with stormwater compliance initiatives. In the summer of 2005, the City contracted with AMEC Earth & Environmental and Civil & Environmental Consultants, Inc. to help them develop the Contractor EPSC Certification Program. This presentation will discuss the following:

- The City has involved homebuilders and contractors throughout the certification program development process to keep them informed about upcoming changes. Comments from the homebuilders and developers have been incorporated into the program where appropriate.
- The City has developed training modules for contractors, the first of which will be delivered in October and November. Attendees must pass a test on information presented in the training in order to obtain certification.
- Re-certification will be required every three years and will involve training by the City and attendance at one City-sponsored EPSC field day.
- The City will be requiring most new single family residential sites to have an EPSC plan for the site and to identify a Certified Contractor prior to issuing a building permit. This requirement reflects a movement away from holding a residential subdivision developer responsible for all land-disturbing activities and EPSC requirements within a subdivision when individual lots have been sold.
- In an effort to make certification program tracking simpler, a tracking system has been developed for the City to track certified contractor activities.

The City will begin requiring Certified Contractors for new developments and building permits beginning April 1, 2006.

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PROFESSIONAL POSTERS

Presenters will be available to answer questions from 5:30 to 6:00 p.m. on Thursday, April 20.

Evaluation of Plant Systems for Use in Protection of Water Resources from Synthetic Chemicals

E. Kudjo Dzantor, D.E. Long, and T.K. Amenyenu

Three Dimensional Data Analysis and Visualization for Ground Water Protection

Ke Liu

EVALUATION OF PLANT SYSTEMS FOR USE IN PROTECTION OF WATER RESOURCES FROM SYNTHETIC CHEMICALS

E. Kudjo Dzantor¹, D.E. Long, and T.K. Amenyenu

Soil is a conduit for chemical entry into surface and ground water resources. This underscores the urgent need to clean up contaminated soils. Concerted attempts to use plant systems to clean up soil contaminants are a relatively recent development; thus, there are aspects of the approach that need to be clarified before full development for deployment as a routine field practice. A major process that accounts for plants' abilities to destroy organic contaminants is *rhizodegradation*, which involves unique interactions between plants and microbes in which plant-supplied substrates (*exudates*) in the root zone (*rhizosphere*) stimulate microbial populations to enhance degradation of certain contaminants. We recently tested abilities of selected grasses and legumes to stimulate removal of the insecticides chlordane, dursban, talstar, and flagship from soil. After twelve weeks of growth in greenhouse microcosms, chlordane did not show any trend toward dissipation in planted or unplanted soil. Regardless of whether or not the soils were planted, from 70 to 80% of an initially added dose of dursban were lost from soil. About 50% and 40% of the initially added talstar had dissipated from planted soils and unplanted soils respectively. From 45 to 60 % of initially added flagship had dissipated from planted soils; there was no dissipation of the insecticide from unplanted soil. We are investigating rhizosphere interactions to increase our understanding of the processes involved in plant-facilitated removal of pesticide contaminants to enable their further improvement.

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THREE DIMENSIONAL DATA ANALYSIS AND VISUALIZATION FOR GROUND WATER PROTECTION

Ke Liu¹

Three dimensional (3D) data analysis and visualization has become an increasingly popular technology in today's environmental study. Most of the physical and chemical data in the ground water field are three dimensional in nature, but have been represented as two dimensional until recent years, when the development in computer processing made 3D visualization a feasible and fast evolving technology. Commercial software is now available to quickly build models to perform geostatistical analysis on spatial data and construct 3D objects for visualization. Shaw's GIS group has successfully employed the Environmental Visualization System (EVS) software, to generate cost-saving data analysis and comprehensible 3D display. Applying this technology to hydrogeological and chemical data, we have provided services to improve ground water monitoring and site characterization, remediation planning and operation, contamination litigation, and assist regulatory reporting. This poster demonstrates the capability of 3D technology by exhibiting EVS generated images of several key projects. The main contents include images from: expert-system guided 3D kriging, animated time-varying contaminant plumes, ground water contaminant volume and mass estimation, geology models with different structures, DNAPL and LNAPL remediation processes. This poster presentation is expected to educate and draw interest to new technology in data management and analysis in ground water resource protection.

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STUDENT POSTERS

Presenters will be available to answer questions from 5:30 to 6:00 p.m. on Thursday, April 20.

Assessment of Water Distribution System Vulnerability and Consequence Management Strategies
Terranna M. Baranowski and Eugene J. LeBoeuf

Development of a Protocol for Enhanced Bioremediation in Karst Using a Single Injection Well
Tarra M. Beach, Lashun K. King, Roger Painter, and Tom D. Byl

Survival and Transport of Bacteroides in Streams
Alyssa Bell, Larry McKay, and Alice Layton

Development and Testing of Methods for Dye Tracing in the Sub-visual Range
Terri Brown, Larry McKay, John McCarthy, and Randy Gentry

Development and Verification of a Computer Program That Predicts Fuel Biodegradation in Karst Aquifers
Ryan Fitzwater, Patricia Burton, Roger Painter, and Tom Byl

A Flux Term to Describe the Movement of Fecal Bacteria Between the Sediment and Water Column in a Riverine System
Tiffany Hines, James Davis, Lonnie Sharpe, and Tom Byl

A Geodatabase for Modeling Nutrient Loading in the Red River Watershed
Robert T. Hodges

A Comparison of Riparian Buffer Quality Using Visual Stream Assessment vs. Aerial Photography Interpretation
Jaelyn Overholser

Model Development Framework for the Groundwater/Surface Water Interface: Approaches, Concerns and Challenges
Ravi C. Palakodeti, Eugene J. LeBoeuf, James H. Clarke, Calvin C. Chien, Craig L. Bartlett, and Nancy R. Grosso

Ammonia Oxidation by Bacteria Collected from a Karst-bedrock Well
Kelly Ray and Tom Byl

Lactate Induction of Ammonia-Oxidizing Bacteria and TCE Cometabolism
Charner Rogers, Johnnie Williams, Kendra Head, Tarra Beach, Roger Painter, and Tom Byl

Calculating Dilution of Contaminants in Groundwater
William Spitzenburg, T.D. Byl, and R.D. Painter

Metal Ion Adsorption and Selectivity Studies in Water
Angela Stone and Nsoki Phambu

Binding of Multivalent Cations to Bovine Cartilage

Minh T. Tran, Rascheik D. Dixon, and Koen P. Vercruysse

Transport of Colloids by Transient Wetting Fronts

Ching Tu, Joe Zhuang, Nadine Goepfert, John McCarthy, and Larry McKay

Spill Management Information System Version 2.0 (SMIS 2.0): New Technology for Management of Our Inland Waterways

Janey V. Smith, Eugene J. LeBoeuf, James P. Dobbins, Edsel B. Daniel, Mark D. Abkowitz

ASSESSMENT OF WATER DISTRIBUTION SYSTEM VULNERABILITY AND CONSEQUENCE MANAGEMENT STRATEGIES

Terranna M. Baranowski¹ and Eugene J. LeBoeuf²

After the terrorist attacks of September 11th, the nation has become increasingly concerned with the vulnerability of water supply systems. Vulnerability assessments may be used to help identify water utility components that require strengthening against possible attacks. However, these assessments currently do not identify components of the water distribution network which can be susceptible to a variety of attacks, including physical destruction and/or biochemical contamination. Since vulnerability assessments that address attacks on the distribution network are lacking, further research is necessary to not only address system vulnerabilities, but to also evaluate possible consequences and corrective actions. Thus, the overarching goal of this research is the development of a comprehensive vulnerability assessment tool for water distribution networks which incorporates analysis of physical and chemical/biological threats while addressing societal and economical concerns. It will produce a set of strategies that effectively addresses protocols to best isolate an event and manage response measures, including an assessment of how these strategies can affect the rest of the system. One consequence management strategy is the isolation and containment of a contaminant. In this current effort, we utilize optimization techniques to determine the optimal demand to reduce contaminant concentration following sensor detection. This aids in consequence management of contamination events by supplying water utility operators with additional information to remediate contaminated sections. Application of these techniques to relatively simple networks demonstrates the usefulness of optimization methods in determining optimal demands in order to reduce contaminant concentration.

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DEVELOPMENT OF A PROTOCOL FOR ENHANCED BIOREMEDIATION IN KARST USING A SINGLE INJECTION WELL

Tarra M. Beach¹, Lashun K. King¹, Roger Painter¹, and Tom D. Byl^{1,2}

Approximately two-thirds of Tennessee and Kentucky are underlain by karst terrain. The groundwater aquifers in karst terrains are particularly susceptible to contamination. Once a contaminant has entered a karst-bedrock aquifer it is difficult to determine its precise flow-path through the bedrock. The contaminant may reside for long periods in stagnant areas of the aquifer or it may be rapidly transported through tortuous conduits. All the while, the contaminants are susceptible to biodegradation processes in the aquifer. Recently, the RTDB model was developed to calculate the contaminant biotransformation as a function of residence time in the aquifer. There have been two field tests successfully applying RTDB to contaminated karst sites with enhanced biodegradation. However, there is currently no standard protocol for the application of RTDB on karst sites. The objective of this research was to develop a general protocol for enhanced bioremediation of organic contaminants in karst terrains and the application of the RTDB model. Furthermore, since the discharge point is often off-site, unknown, or diffused, a single-well method was developed for the protocol. This protocol is based on data and reports from field studies done at Ft. Campbell. The protocol is divided into six steps. The first step is to gather historical data about the spill and develop background information about the site (geochemical, biological, and hydrological information). Second, based on the information collected in step one, an enhancement mixture is decided upon and calculations are done to determine how much enhancement-mixture should be injected. Third, the enhancement mixture mixed with a conservative tracer is injected at a depth equal to the conduit opening(s). Fourth, the tracer concentration is measured through time along with the chemical, hydrological and biological measurements. Fifth, the tracer data is used to calibrate the residence-time distribution portion of the RTDB model. Sixth, once calibrated, the RTDB model is used to quantify the amount and rate of contaminant biodegradation in the aquifer around the well. The protocol is intended to be flexible so it can be applied to a variety of contaminated karst sites.

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SURVIVAL AND TRANSPORT OF *BACTEROIDES* IN STREAMS

Alyssa Bell^{1*}, Larry McKay², and Alice Layton³

A series of lab and field experiments are being designed to test both physical and chemical factors which may affect the persistence of the fecal indicator *Bacteroides* in stream water. The lab experiments will involve batch tests of stream water spiked with fecal matter and subjected to different temperatures, turbidity, light, pH, and salinity to examine the influence of these factors on persistence of *Bacteroides* and other fecal indicators. It is hypothesized that persistence of *Bacteroides* will be greatest under conditions which inhibit grazing by microinvertebrates such as cold temperatures or high pH. This method will provide a quantitative analysis of *Bacteroides* persistence and rate of concentration decline, as opposed to previous studies which only measured presence or absence of the bacteria. After the laboratory testing is carried out the persistence of *Bacteroides* in natural streams will be evaluated by placing diffusion cells containing fecal material directly in a creek and monitoring concentration decline under natural physical and chemical conditions. Finally, if possible, we propose to carry out an actual stream tracer test using *Bacteroides*. In all of the lab and field studies, concentration of *Bacteroides* will be evaluated using quantitative real time PCR assays developed at the University of Tennessee.

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DEVELOPMENT AND TESTING OF METHODS FOR DYE TRACING IN THE SUB-VISUAL RANGE

Terri Brown^{1*}, Larry McKay², John McCarthy³, and Randy Gentry⁴

Artificial tracer techniques and technology as applied to karst aquifer studies have evolved towards the progressive reduction of both detection limits and dye concentrations. Modern spectrometric methods allow the detection of fluorescent dye at concentrations 10^3 to 10^6 times below the levels of dye needed to be visible in a given water sample. Sub-visual tracer tests are often necessary in groundwater investigations of public water supplies, threatened species habitats, for regulatory compliance purposes.

Successful dye traces in the sub-visual range are plagued by several complicating factors, including dilution along the flow path, retardation and degradation in the subsurface, interference due to natural and man-made background fluorescence, and occurrence of compounds that quench the fluorescent signal.

The goal of this research program is to develop methods and simplified protocols that not only improve the viability and defensibility of tracer testing in karst environments, but that facilitate the wider application of this important investigative tool.

In the laboratory, the authors aim to explore the advantages and disadvantages of synchronous scanning spectrophotometry for screening out background fluorescence, and will compare different methods of dye extraction. Batch and flow-through column studies may be conducted to examine sorption and persistence of dyes in soils and sediments. Field investigations will include traces in several different geologic settings, including sinking streams and residuum mantled karst, to test and compare various sampling and analytical methods.

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DEVELOPMENT AND VERIFICATION OF A COMPUTER PROGRAM THAT PREDICTS FUEL BIODEGRADATION IN KARST AQUIFERS

Ryan Fitzwater¹, Patricia Burton¹, Roger Painter¹, and Tom Byl^{1,2}

Approximately 40 percent of the United States east of the Mississippi River is underlain by karst aquifers. Karst ground-water systems are extremely vulnerable to contamination; however, the fate and transport of contaminants in karst areas are poorly understood because of the complex hydraulic characteristics of karst aquifers. Ground-water models developed using Darcy's Law coupled to rates of biodegradation are useful for predicting the fate of fuels in unconsolidated aquifers, but have little utility in karst conduits. Conceptual models developed for karst aquifers have a consistent theme of non-ideal flow, storage, and active flow components. This research used a residence-time distribution (RTD) model approach that integrated residence times of contaminants isolated in storage areas with the residence time of contaminants moving through conduits coupled to a pseudo-first order rate of biodegradation. This RTD-biodegradation model was adapted for large sites with a known source-to-discharge connection, and, for small, single-well, injection-monitoring systems. The first method assumes second points are measured (a release point & discharge point) and RTD is calculated using numerical integration. The second method assumes a single measuring point (as it leaves the release area) and uses differential integration to solve for RTD. These two approaches were tested in laboratory karst systems and fuel-contaminated field sites. The results found that the 2-point strategy worked well in the lab, but failed to account for dilution in the large-scale field study. Dilution must be factored into large scale site evaluations. The single-point strategy worked well in the lab and field studies. Both methods show great promise. These two numerical equations were converted to computer algorithms. Next a Microsoft Excel[®] 2002 and the Visual Basic[®] programming language were utilized to create a user friendly interface for the computer program. The RTD method that utilizes 2-monitoring points requires additional work on the dilution term before it is ready for use. The single point injection-monitoring method appears to be ready for use at contaminated karst sites.

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A FLUX TERM TO DESCRIBE THE MOVEMENT OF FECAL BACTERIA BETWEEN THE SEDIMENT AND WATER COLUMN IN A RIVERINE SYSTEM

Tiffany Hines¹, James Davis¹, Lonnie Sharpe¹, and Tom Byl^{1,2}

Fecal pollution in surface waters is a serious water-quality problem. As a result, scientists have developed a number of models in an attempt to predict the fate and transport of fecal pollution in riverine systems. Various models predict the rate of bacteria removal from the water column based on density, settling rates and water velocity. Such models, however, do not consider survival and reproduction of bacteria in sediments, or re-suspension. Flume and stream experiments were conducted to measure the survival, reproduction, and resuspension of fecal bacteria in sediments. These results can be used to modify a numerical model by incorporating survival of bacteria in bed sediments and re-suspension into the water column, in addition to other parameters such as water velocity, initial bacteria concentration, and settling rate. Fecal coliform bacteria were introduced into the circulating-water flume at known concentrations and monitored as they settled or remained suspended. Bacteria concentrations were measured in the water column and the sediment along the flume to determine bacterial fate and transport. The model accurately predicted bacteria settling from the water column. The sediment fecal bacteria population declined at an exponential rate over several weeks (experimental decay value = -0.2735). This decomposition rate was coupled to the numerical model, and additional tests were done in a small stream contaminated with fecal coliform. Comparison of the model and stream data were mixed due to irregular resuspension of bacteria-contaminated sediments. Additional work was done to incorporate resuspension as a function of water velocity, particle size and density into the formula.

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A GEODATABASE FOR MODELING NUTRIENT LOADING IN THE RED RIVER WATERSHED

Robert T. Hodges¹

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS

A geodatabase was constructed to facilitate three types of models for the Red River Watershed using EPA's BASINS-PLOAD software: 1) pollutant loading using standard land cover data retrieved from the BASINS website, 2) pollutant loading using more detailed land cover maps we developed from air photo interpretation, and 3) BMP evaluation for nutrient reduction in livestock areas.

Additional detail to the BASINS land cover map was digitized by utilizing normal color aerial photography from 2004 to differentiate agricultural areas (or to reclassify areas incorrectly identified as forests) into cow pastures, horse pastures, unspecified pastures (classified from low resolution aeriels), poultry, swine, row crops, tobacco, and grasslands. Photos for homeland security (acquired in December to limit deciduous canopy) with 6-inch resolution were used for urban areas in Montgomery County. Photos with 12-inch resolution were used for the remainder of the county, and 1-meter resolution for the remaining counties in Tennessee and all of the counties in Kentucky.

At the extremes of its frequency distribution, BASINS' land cover map included 14 polygons with areas less than 25 acres and 14 polygons with areas greater than 500 acres. Our more detailed land cover map included over 1800 polygons with areas less than 25 acres. Though approximately 100 of our polygons had areas greater than 500 acres, most of these were differentiated from the five largest BASINS polygons, whose areas ranged between 3,110 and 622,259 acres.

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A COMPARISON OF RIPARIAN BUFFER QUALITY USING VISUAL STREAM ASSESSMENT VS. AERIAL PHOTOGRAPHY INTERPRETATION

Jaclyn Overholser¹

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS

Normal color aerial photography was utilized to classify land cover adjacent to streams based on TVA's Riparian Buffer Classification Matrix, in which stream banks are characterized as *adequate*, *marginal*, or *inadequate* at removing pollutants based on vegetation type, width, and percent coverage. Photos for homeland security (acquired in December to limit deciduous canopy) with 6-inch resolution were used for urban areas in Montgomery County. Photos with 12-inch resolution were used for the remainder of the county, and 1-meter resolution for all other counties. This riparian buffer classification was compared with field data collected by the Red River Watershed Association, whose workers included APSU students who worked on both projects.

Statistical comparison of the two methods is difficult because the criteria for classification differ. Nevertheless, the advantages of onsite visual stream assessments are the ease of determination of width and adequacy of the riparian zone; its disadvantages are that field data collection requires more time, and the inaccessibility of many sites makes the collection of continuous riparian data difficult. Furthermore, determination of land use adjacent to the riparian zone is limited by obstacles blocking the view beyond the stream banks. The advantage of riparian buffer classification by aerial photo interpretation is the ability to continuously cover more stream distance in significantly less time; its disadvantages are reliance on photos taken during times of day or seasons that are not optimal for the interpretation of riparian buffer adequacy.

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MODEL DEVELOPMENT FRAMEWORK FOR THE GROUNDWATER/SURFACE WATER INTERFACE: APPROACHES, CONCERNS AND CHALLENGES

Ravi C. Palakodeti^{1*}, Eugene J. LeBoeuf^a, James H. Clarke^a, Calvin C. Chien², Craig L. Bartlett^b,
and Nancy R. Grosso^b

The need and ability to understand contaminant transport across the groundwater/surface water interface (GWSI) is an important part of overall human health and environmental risk assessment. Model development and enhancement for GWSI may best be approached from a systems-based development of a framework that assists in guiding regulatory agencies and interested parties in identifying existing tools, and needed capabilities for contaminated sites of concern that are close to a surface water body. In this context, modeling approaches for groundwater/surface water interactions in the stream/river, estuarine, and lacustrine environments are presented, systematically classified, and critiqued so as to understand the needs for future model development. Primary issues requiring resolution at present are identified as (i) incorporation of the accurate process descriptions in field-scale contaminant formulations; (ii) defining groundwater/surface-water interactions in a spatial and temporal framework; (iii) defining the GWSI; and (iv) techniques of scaling-up for process-level models. The objective of this work is to develop a roadmap to achieve modeling capabilities that will enable a scientifically-defensible and cost-effective evaluation of contaminant fate and transport across the GWSI. This roadmap will be applied to a specific site to assess its usefulness.

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AMMONIA OXIDATION BY BACTERIA COLLECTED FROM A KARST-BEDROCK WELL

Kelly Ray¹ and Tom Byl^{2,1}

Elevated ammonia concentrations can pose an environmental and health problem in groundwater. Animal and human wastes, fertilizers and decaying plant material all contribute to ammonia-nitrogen into the subsurface. Ammonia issues can be exacerbated in karst systems where it can enter directly through sinkholes or disappearing streams without any filtration. The rate of ammonia oxidation and optimum conditions for autotrophic nitrifying bacteria in a karst system are not known. The objective of this study was to characterize the rate of ammonia oxidation using bacteria indigenous to a karst aquifer in middle Tennessee. Liquid microcosms (300 mL, n=3) were established with an initial ammonia concentration of 20 mg/L. The pH in one-third of the microcosms was adjusted to either pH 3 with HCl, pH 10 with NaOH, or 7 (no addition). The growth in bacteria was monitored using a spectrophotometer. Ammonia concentrations were also measured through time. The microcosms with the greatest rate of ammonia-oxidation were pH 7, followed by pH 10 and pH 3, respectively. The growth pattern also confirmed that bacteria incubated at pH 7 had the greatest growth. Bacteria incubated at pH 3 or 10 did not demonstrate an appreciable increase in optical density, indicating they did not replicate to any significant degree. It is hypothesized that bacteria incubated at pH 3 were not able to take up ammonia as fast because the ammonia is ionized (NH₄⁺) at this pH. It is possible that ionized ammonia less able to transfer across the cell membrane than the un-ionized form. Further research is needed to answer this hypothesis.

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LACTATE INDUCTION OF AMMONIA-OXIDIZING BACTERIA AND TCE COMETABOLISM

Charner Rogers¹, Johnnie Williams¹, Kendra Head¹, Tarra Beach¹, Roger Painter¹,
and Tom Byl^{1,2}

Water containing bacteria was collected from a trichloroethylene (TCE) contaminated karst aquifer in north-central Tennessee to establish liquid, 300 ml microcosms. It was hypothesized that ammonia-oxidizing bacteria indigenous to the karst aquifer are capable of co-metabolizing TCE via the ammonia mono-oxygenase (AMO) pathway. To test this hypothesis, the microcosms were spiked with known concentrations of TCE and different formulations of ammonium-lactate, ammonium-chloride, and sodium lactate. TCE degradation was then monitored over time and the degradation rates for the different formulations compared. Reference controls for the study consisted of sterilized karst water and live microcosms without food injected with TCE. Microcosms treated with ammonia-lactate had the most rapid reduction of TCE and O₂, followed by the ammonium + sodium-lactate treatment. The control (sterile and live without food) microcosms did not experience a significant drop in TCE in the same time period. After 24 hours, the rapid TCE removal in all the ammonia-treated microcosms decreased due to the consumption of the oxygen. These preliminary results provide strong evidence that karst bacteria indigenous to this aquifer can co-metabolize TCE.

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CALCULATING DILUTION OF CONTAMINANTS IN GROUNDWATER

William Spitzenburg¹, T.D. Byl^{1,2}, and R.D. Painter¹

Contaminates in groundwater migrate due to advection and dispersion processes. In a karst system, the aquifer is often dominated by secondary porosity, also referred to as conduits. Conceptual models of conduit networks usually have them inter-connected and merging into larger conduits similar to the way small streams merge and become larger. If sufficient quantities of conduits merge, there is tremendous potential for dilution. This could be an important attenuation process in karst aquifers. The objective of this research is to develop a numerical approach to estimate dilution of contaminants in karst aquifers. This approach must be semi-quantitative and be suitable for coupling to the Residence-Time Distribution – Biodegradation (RTD-B) model used to quantify biodegradation of contaminants in karst aquifers. Since dilution in a karst aquifer is a function of recharge, discharge, flowpath and dispersion, one approach is to re-arrange the Water Budget Model (WBM) and solve for recharge. The WBM incorporates surface area, water-storage and runoff, ground-water recharge and discharge, precipitation and evapotranspiration. Solving the WBM for recharge provides a rough estimate of potential dilution but lacks consideration of flowpath and dispersion. Flowpath can possibly be addressed by potentiometric data that provides insight into the major conduit drains in a basin. Dispersion can be addressed using the RTD-B model, which calculates a Peclet value (an indicator of dispersion in the aquifer). Additional work is needed to determine if this approach provides a reasonable estimate of dilution and if it is adaptable to the RTD-B model.

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METAL ION ADSORPTION AND SELECTIVITY STUDIES IN WATER

Angela Stone¹ and Nsoki Phambu²

The fate of heavy metals dissolved in water is of concern because of their potential toxicity and threat to living systems. The sludge before it can be safely disposed in landfills must meet current waste disposal requirements. However, few studies have focused on this issue. The purpose of this research was to solve both metal ion removal from wastewater and subsequent metal ion activated carbon sludge disposal. Results are reported for experiments in which standard samples, artificially contaminated with cadmium, lead, mercury, and uranium salts, were decontaminated using activated carbon. The activated carbon showed the highest removal ability for mercury ions. Mixtures of each of the contaminants combined with uranium were used to test the selectivity of activated carbon. The activated carbon proved to be more selective to uranium than to the three other contaminants. Desorption of heavy metal ions were successfully performed with HCl/HNO₃ solutions.

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BINDING OF MULTIVALENT CATIONS TO BOVINE CARTILAGE

Minh T. Tran, Rascheik D. Dixon, and Koen P. Vercruysse¹

We have studied the binding characteristics of select multivalent cations (Cu^{2+} , Pb^{2+} , trivalent lanthanides) to bovine cartilage tissue. Cartilage tissue is a crude mixture of components rich in proteoglycans. Proteoglycans are proteins chemically modified with glycosaminoglycan polysaccharides like chondroitin sulfate A or C. These glycosaminoglycan polysaccharides are highly anionic making them ideal chelators for multivalent cations. We evaluated the effects of various parameters (amount of cartilage, cation concentration, time, pH, temperature, presence of Na^+ or Ca^{2+} cations) on the binding characteristics between cartilage tissue and the above mentioned multivalent cations. This study aims to evaluate cartilage tissue for potential applications in the removal of multivalent cation environmental contaminants.

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TRANSPORT OF COLLOIDS BY TRANSIENT WETTING FRONTS

Ching Tu¹, Joe Zhuang², Nadine Goeppert³, John McCarthy⁴, and Larry McKay⁵

Colloids are defined as particles ranging in size from submicron to a few micron; their transport in the subsurface is of concern to drinking water quality due to introduction of viruses, pathogenic bacteria and protozoans, as well as the potential for co-transport of toxic chemicals sorbed to mobile mineral colloids. More than 2000 published papers have addressed the topic of colloid transport, but the vast majority of these studies focused on water-saturated (groundwater) environments, even though most pathogens and toxicants enter groundwater via transport through the shallower soil which is only partially water-saturated. Further, almost all of studies of unsaturated systems are limited to steady state flow, while in nature, flow in partially saturated porous media is dominated by transient wetting events (e.g., storms, or flushing toilets). Early work attributed colloid retention under partial saturation to attachment to the air-water interface or “staining” in thin water films. More recent work, including collaborative studies between UT and Cornell University has called this prevailing paradigm into question. The work presented here uses a novel experimental approach to evaluate colloid transport under transient wetting fronts, and evaluates the relative importance of water content, colloid size and surface charge, and the role of electrostatic and capillary forces in colloid immobilization. We also compare transport in natural porous material (sand) and uniform model silica-sphere medium; the silica-sphere medium has a known pore structure, which will facilitate efforts to develop mechanistic transport models. Results are expected to improve predictions of pathogen transport in different geological settings and natural flow conditions, and may suggest novel strategies to mitigate human and environmental health risks in public water supplies.

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SPILL MANAGEMENT INFORMATION SYSTEM VERSION 2.0 (SMIS 2.0): NEW TECHNOLOGY FOR MANAGEMENT OF OUR INLAND WATERWAYS

Janey V. Smith, Eugene J. LeBoeuf¹, James P. Dobbins,
Edsel B. Daniel, Mark D. Abkowitz

The Spill Management information System (SMIS), developed by Vanderbilt University with support from the United States Army Corps of Engineers (USACE), provides a means to predict contaminant locations along inland water bodies to assist in either hazard planning or emergency management. The current version in use along the Cheatham Reach, Nashville, TN, includes the 2D water quality model, CE-QUAL-W2, from the USACE and the atmospheric dispersion modeling suite Computer-Aided Management of Emergency Operations (CAMEO) from the United States Environmental Protection Agency (USEPA) within a GIS coupled with a database management system (DBMS). SMIS 2.0 improves upon the previous version by integrating improved water quality modeling technology within a 3D spatial framework through the use of ArcView 9.1 and the 3D Analyst Extension (ESRI). Improvements in water quality modeling will allow for more precise determination of contaminant migration and location after a chemical incident. Three-dimensional hydrodynamic and water quality models with possibilities for use include: i. Surface-Water Modeling System (SMS) from Environmental Modeling Systems, Inc. (EMSI), ii. Environmental Fluid Dynamics Code (EFDC) from the USEPA, and iii. FLUENT, the computational fluid dynamics code software by Fluent, Inc. Use of GIS and 3D Analyst provides the capability to conduct virtual fly-over of the area and view rotations. SMIS 2.0 provides the next step in water security by providing a system that improves both hazard readiness and accident response that is applicable to any inland waterway.

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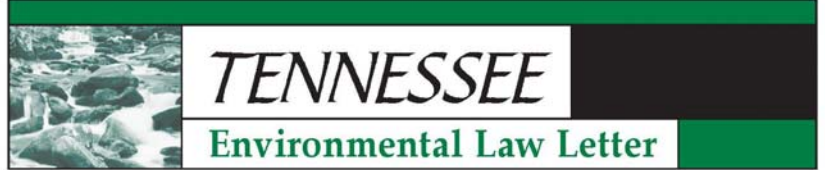
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