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Tennessee Section
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In
cooperation
with

Knox County Engineering and Public Works
Neel Schaffer, Inc.
Tennessee Department of Environment and Conservation
Tennessee Technological University
Tennessee Valley Authority
University of Tennessee, Knoxville
U.S. Army Corps of Engineers, Nashville District
U.S. Geological Survey, Water Resources Division

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PREFACE

These proceedings represent the ninth gathering of water resource professionals in Tennessee sponsored by the Tennessee Section of the American Water Resources Association. The purposes of this symposium are: (1) to promote communication on water resources research and management, and (2) to encourage cooperation among the diverse range of water professionals in the state. All of the previous symposia have been very successful, demonstrating the continued need for this opportunity to share information with our colleagues from across the state.

A special thanks goes out to the officers of the Tennessee Section AWRA including Tim Higgs of the Army Corps of Engineers, Barbara Hamilton of the Tennessee Department of Environment and Conservation, Mike Bradley of the U.S. Geological Survey, and Tim Gangaware of the University of Tennessee for the time and effort they put into running and organizing the section meetings. We would also like to thank the planning committee members Donna Flohr, Susan Barksdale, Chris Granju, Tom Allen, and Tom Moss for their assistance in organizing this year's symposium. A great deal of preparation is necessary to result in a successful symposium and no one knows this more than Lori Crabtree. She dedicated herself to making sure all of the details were taken care of and all the loose ends were tied. For all of her hard work and perseverance, Lori deserves an abundance of gratitude. We also acknowledge that without the willingness of speakers, and interest of attendees, there would be no purpose for these gatherings. Thank you all for your continued involvement and support in the Tennessee Section of the American Water Resources Association.

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Panel: David Feldman, University of Tennessee
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Larry Lewis, Tennessee Association of Utility Districts

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TENNESSEE'S
SOURCE WATER ASSESSMENT PROGRAM

Tom Moss[1]

The new Source Water Assessment provisions of the Federal Safe Drinking Water Act 1996 Amendments expanded the scope of protection beyond the existing Wellhead Protection Program for ground water systems to include protection of the waters supplying surface water systems.

Section 1453 of the 1996 SDWA Amendments requires that all states establish Source Water Assessment Programs (SWAP), and submit a plan to the Environmental Protection Agency (EPA) by February 6, 1999 detailing how they will:

- Delineate source water protection areas.
- Inventory significant contaminants in these areas.
- Determine the susceptibility of each public water supply to contamination.

Source Water Assessment Programs are not intended to replace existing programs addressing pollution sources. The assessments are intended to enhance the protection of drinking water supplies within existing programs at the federal, state and local levels. Tennessee's Source Water Assessment Program efforts are intended to be used to support and upgrade the existing Source Water Protection efforts, including Tennessee's Wellhead Protection Program and Watershed Management Program.

Source Water Protection will be incorporated into the Watershed Management Program goals, objectives and management strategies for the individual watershed plans. Tennessee's Watershed Management Program approach uses the 54 U. S. Geological Survey 8 digit Hydrologic Unit Code (HUC) watersheds (see figure below) that make up Tennessee. These 54 watersheds have been arranged into five groups across the state to be looked at in a five year cycle. Each watershed will have a plan issued at the wrapup phase of the five year cycle for that watershed. Source water assessments will be an integral part of the plan for both surface water and ground water.

The Division of Water Pollution Control began its watershed management cycles in 1996. In order for the Source Water assessments to become synchronized with this cycle, assessments will concentrate on the Group 1 and Group 2 watersheds to have them completed for the watershed plans due in the years 2000 and 2001, respectively.

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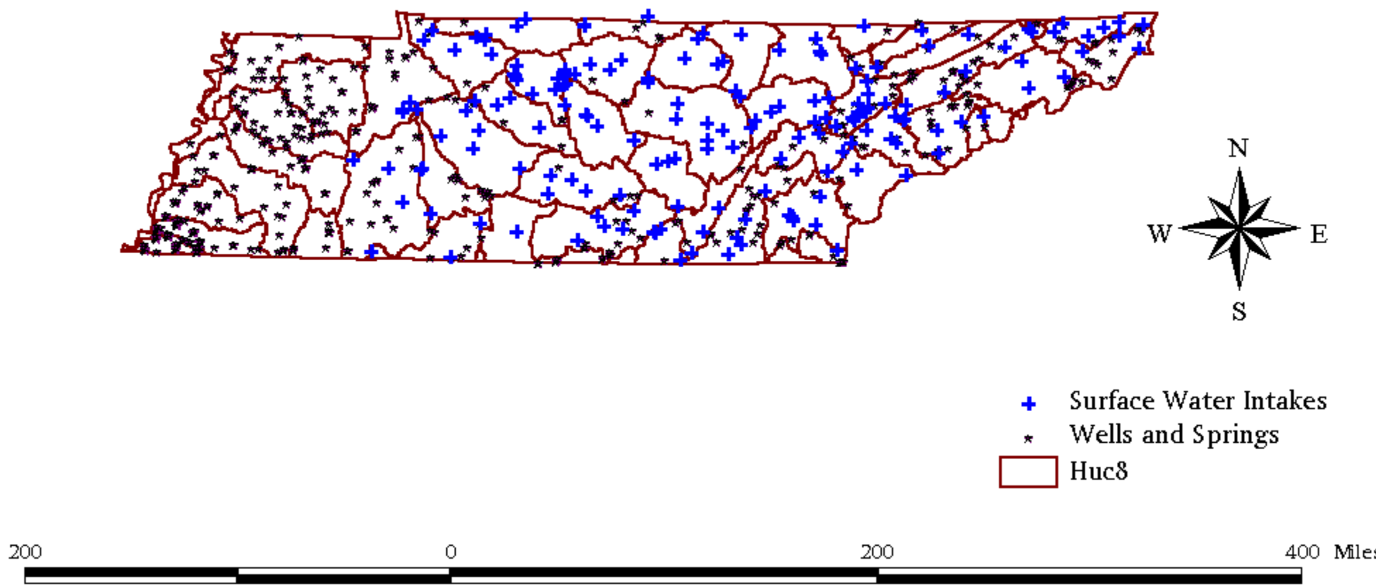
[1] Tennessee Department of Environment and Conservation, Water Supply, 9th Floor, L&C Tower, 401 Church Street, Nashville, TN 37243, email: tmoss@mail.state.tn.us

HUC8 WATERSHEDS WITH
PUBLIC SURFACE WATER INTAKES
AND COMMUNITY GROUND WATER SYSTEMS



Source Water Assessment Zones for Surface Water Systems

Tennessee is using a simplified time-of-travel for the designation of source water assessment/protection zones for surface water systems. It is based on using a flow velocity of 1 ft/sec, which is a high rate of flow just below or nearing flood conditions much higher than average. For eight hours time of travel, this roughly corresponds to 5 miles upstream. For 24 hours time of travel this roughly corresponds to 15 miles upstream. Water systems in Tennessee are already required to have 24 hour storage capacity or other alternative measures for water supply, which effectively gives 48 hours lead time.

This method of delineation is less complex than using modeling for individual rivers and lakes, but is actually more protective under most conditions. Normal flow conditions typically range from 0.2 to 0.4 ft/sec. At low flow conditions, where the waterbody is at its lowest levels and there is little benefit of dilution, fifteen miles actually translates into several days upstream (greater than 200 hours).

As a part of the individual assessments there will be a "survey corridor" of 1000 feet to either side of the stream within which potential contaminant sources will be inventoried. This corridor will more than encompass the 100 year flood zone, which is typically 200 - 500 feet off of the stream (TVA personal communication). Inventories will also include to within 1/2 mile downstream of the intake to account for the possibility of backflow conditions. All tributaries to the stream where the intake is located which are "blue line" streams {perennial streams which register as solid blue lines on USGS 7 ½ topographic maps} will also be included in the survey up to the appropriate distance from the intake.

For purposes of the assessments, there will be two zones of protection for each surface water intake (unless there is a consolidation of multiple intakes along a stream reach):

1) <u>Critical Source Water Protection Zone</u> - five miles upstream of the intake and along any major tributaries with a 1000 ft corridor.

2) <u>Source Water Management Zone (SWMZ)</u> - encompasses the remainder of the appropriate watershed within that HUC unit.

   <u>Zone A (Inner SWMZ)</u> 5 - 15 miles upstream of the intake and major tributaries with a 1000 foot corridor.

   <u>Zone B (Outer SWMZ)</u> from 15 miles to the upper end of the watershed

Susceptibility Analysis

Tennessee is blessed with an abundance of high quality ground water and surface water. Prevention of contamination is a critical element in the protection of these waters if Tennesseans are to continue to benefit from these high quality waters. There are certain natural and man-made factors which make certain water sources more susceptible to contamination. All water sources should be considered to have some susceptibility to contamination since no water source is completely immune. There are specific geologic and hydrologic settings that make the water source more vulnerable due to natural conditions. There are also certain man-made processes and activities that put the water sources more susceptible to contamination due to the proximity of these potential contaminant sources.

Determining the relative potential risk of contamination for each water system intake and well or spring allows EPA and the states to prioritize resources in the protection of water sources and also gives the water system information to better manage the water supply. Tennessee has developed a susceptibility analysis based on a series of yes/no potential contamination factors to keep the susceptibility evaluation as objective as possible. These factors are then incorporated into a pie chart, with each factor as a separate "slice." The size of the slice has been assigned a percentage according to concern (e.g., contamination detected at an intake is a high concern and a larger slice) will not change from evaluation to evaluation. The key to Tennessee's Susceptibility Analysis Method is whether the slice is a yes (shaded dark) or no (unshaded), with higher susceptibility indicated by the amount of the "pie" that is shaded.

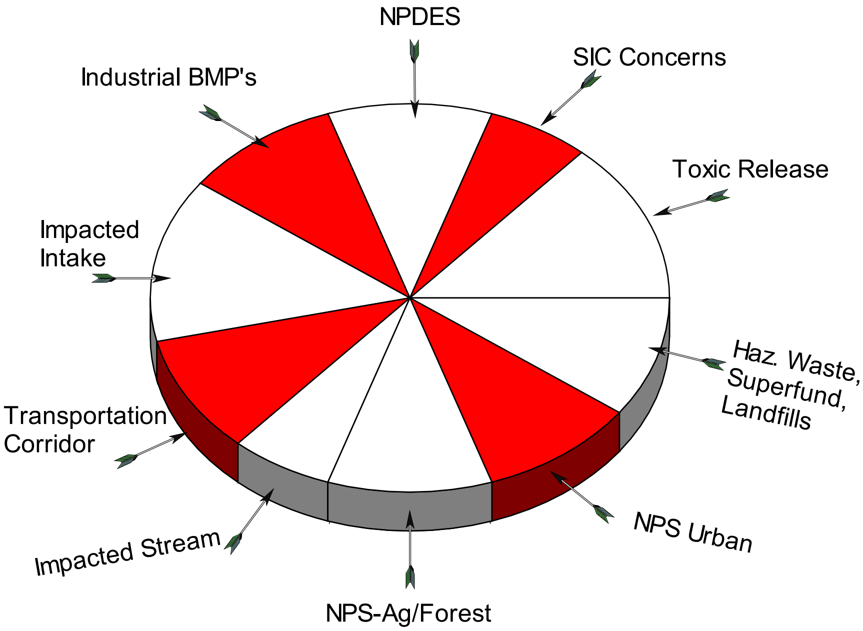
Intakes, wells/wellfields or springs that have more slices shaded in on their susceptibility diagram will be considered more susceptible to contamination. There are separate sets of factors for surface water and ground water. Example susceptibility diagrams for a hypothetical surface water intake and ground water withdrawal point are given below. Note that for ground water susceptibility determinations, there is a hybridization of vulnerability (geologic) and susceptibility (man-induced) factors.

Individual Source Water Assessments

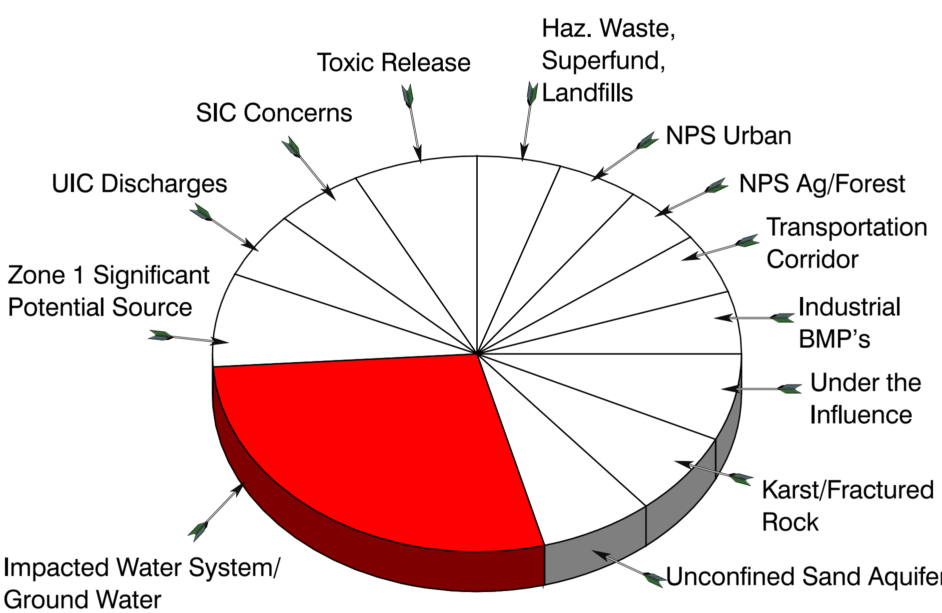
A source water assessment is required for each water system intake, well or spring. Tennessee will be relying predominantly on the existing information from the Wellhead Protection Program to develop the ground water source water assessments, with the addition of the susceptibility analyses. The assessments for surface water intakes will require considerable field work which is being contracted out. All of the assessments must be completed by May of 2003.

Congress required in the Safe Drinking Water Act Amendments that these assessments be made readily available to the public. Tennessee will be relying on the Consumer Confidence Reports required annually of each water system as an additional part of the Amendments to "get the word out." These reports are required to address the source of each system's water and the availability of the assessments. The assessments will be available via the Department of Environment and Conservation's webpage (www.state.tn.us/environment) and at local public libraries as well as being available in hard copy upon request.

Surface Water Intake Susceptibility Diagram



Ground Water Source Susceptibility Diagram



WATERSHED BASED INVESTIGATION OF THE ROME FORMATION AQUIFER IN CARTER COUNTY TENNESSEE USING GEOCHEMICAL AND CONTAMINANT DATA FROM LARGE SPRINGS

Robert Benfield[1]*

and

Michael Hughes[2]

ABSTRACT

Groundwater from the Rome Formation in Carter County Tennessee supplies most of the City of Elizabethton with a high quality water source. Prolific springs emerge from the Rome Formation "aquifer" in several locations throughout the county. Investigation of these springs in conjunction with springs from other bedrock aquifers in this area has provided discernable chemical and physical attributes between the Shady Dolomite, Rome Formation, and the Honaker dolomite aquifers. This investigation presents a new interpretation of the Rome Formation as a major aquifer and not an aquatard. Recognizing the Rome Formation as an aquifer is critical to the regulatory protection and evaluation of the vulnerable groundwater resource in this watershed. Due to their sinking nature, Dense Non Aqueous Phase Liquids (DNAPL) contaminant sources will have to be examined for the Tetrachlorlethelene (PCE) impacted and potential municipal drinking water source called Ball Park Spring. This investigation postulates that regional deep flows exist due to topographic high recharge of the Rome aquifer and that karst flow systems are present in this study area with rapid flow components that depart significantly from porous media concepts. To manage and protect these vulnerable aquifers, ideas of rivers as hydrologic boundaries will also have to be reconsidered and especially in any, regulatory mandated tracer studies. The people of Carter County currently enjoy groundwater as their sole source of drinking water and to ensure this continues, regional and or watershed based management strategies are essential.

PURPOSE

This study intends to document and record measurements of groundwater at select springs and use that data to draft a groundwater conceptual model for this watershed. In part, this study is to provide a framework upon which to aid new studies and evaluate older works. Environmental protection and wise use of the valuable groundwater resource is ever increasingly important, given the rapid land use changes in this watershed. It is the intent of this study to provide some new data and promote regional karst watershed investigations.

SYNTHESIS

The study of groundwater for this investigation focuses on several springs located along the Watauga and Doe Rivers in Carter County Tennessee. Resurgence of groundwater at these springs has facilitated the understanding of several physical characteristics associated with flow, recharge, and chemical variability within these karst aquifers. By studying the temperature and conductivity, three distinct responses to recharge have emerged. The springs associated with the Rome Formation exhibit extremely low variability in conductivity and temperature and show little or no change in response to recharge events (figure 1.). The Honaker dolomite springs exhibit an increase in conductivity while the Shady Dolomite springs decrease in overall conductivity and become more variable in response to recharge (figures 2 & 3.). Temperature measurements in the Honaker and Shady springs show a decrease as expected with relatively cool rain and snow recharge inputs (figures 4. & 5.). Flow increases were observed after major rain events, but not all the spring flows are directly observable.

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WATERSHED HYDROGEOLOGY

Located on the eastern margin of the Valley and Ridge Province along the Blue Ridge Mountains this study took in a small portion of the Watauga watershed. Found between Holston and Iron Mountains the Shady Thrust Sheet has been warped downward into a southwest plunging syncline named after Stony Creek. Bedrock in this area has undergone extensive fracturing and folding as a result of tectonic deformation. The rock structure is very complex and faulted. Generally, the carbonate rocks are limestones and dolomites that have undergone considerable dissolution to form caves and large sinkholes. In addition, the carbonate shale of the Rome Formation has undergone dissolution to form conduits. Dissolution features in the Shady Dolomite can be observed at depth in wells (>200 ft) and below the bottom elevation of the Watauga River. A notable feature in this watershed was the lack of surface water streams on Lynn Mountain and Bryant Ridge, which is composed of the Honaker dolomite. Precipitation falling on the Honaker is quickly lost, to sinkholes or dolines that are often several hundred feet across and often a hundred feet deep. The underlying Rome Formation is composed mostly of maroon colored (carbonate) shale. As an aquifer, the Rome Formation is often discounted due to a bias of low yield from shallow wells. However, two major carbonate beds within the Rome Formation combined with fractured carbonate shale give rise to significant flows of groundwater to important springs. Below the Rome Formation, the Shady Dolomite shares many of the same physical karst characteristics of the Honaker. The Shady Formation and the Honaker both have groundwater flow that is expected to be rapid. The Rome Formation flow is not known to be rapid or slow, but future tracer studies may shed light on this subject. The valleys are filled with alluvium mostly composed of sands, cobbles and boulders derived from the conglomerates, quartzites, and sandstones of the Chilhowee Group. Holston and Iron Mountains, are predominantly composed of the Chillhowee Group Flow in the alluvium is expected to be slow and approaching Darcy velocities.

The Doe River and Stony Creek form major tributaries to the Watauga River. Many of the smaller tributaries are dry except when periods of heavy precipitation occur. Tributaries that flow perennial often derive their flow from springs. It has been observed that some water flowing across the Shady Dolomite onto alluvium covered Rome Formation gains and losses in the same reach over time. Topographic relief is an important feature in that the valley floor is about 1500 feet in elevation and the bordering mountains tops approach 3000 feet. Recharge on the mountains allows the development of head pressures that can be seen released in artesian flows in the valleys. Much of the upland area is natural, steep and forested with the lowlands broad and in transition from farmland to residential or commercial use. The quantity of runoff is increasing with this transition and therefore increasing flooding potential. Due to, unknown groundwater recharge amounts, flows from leaking water lines, sewer lines, class V injections, and loosing reaches in the streams, may or may not be adversely affecting the flow from springs. Discharge values for this area are either lacking, or only estimates and very few people are working to obtain flows or quantify hydraulics in this region.

WATER SUPPLIES

The Elizabethton Water Department utilizes three springs to supply water to the City of Elizabethton. Two of these springs emerge from the Rome Formation and the third from the Knox Formation. The Rome springs are located in the small communities of Valley Forge and Hampton south of Elizabethton. These springs are of high quality and do not currently show impacts from typical pollutants. The Valley Forge Spring in recent years has tested positive for bacteria and turbidity (7 NTUs), however these anomalies may originate in a river contaminated spring box. The Knox Formation spring (Big Spring) was not evaluated in this study, but it is known to become very turbid in response to rain events. Turbidity has become the typical problem of the modern urban spring by virtue of land use changes. The Hampton and Valley Forge springs lacked visible turbidity during this study even though, land development is occurring in their immediate vicinity.

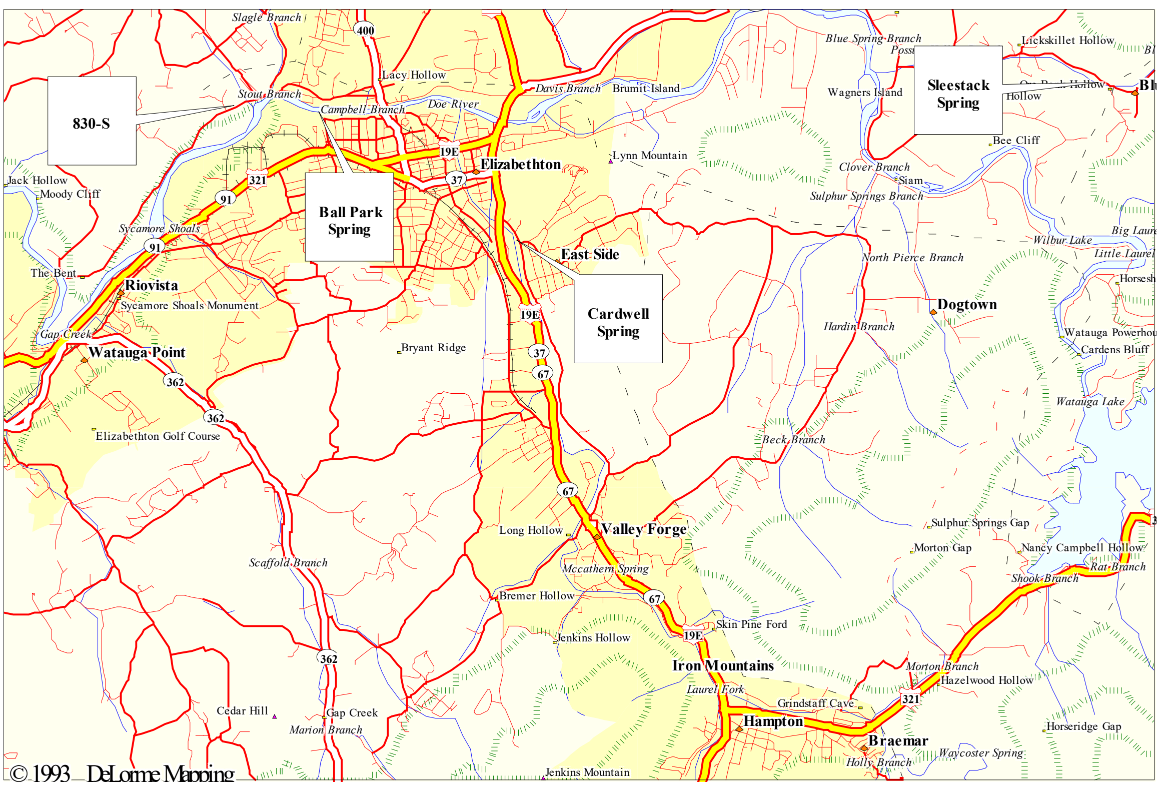
BALL PARK SPRING

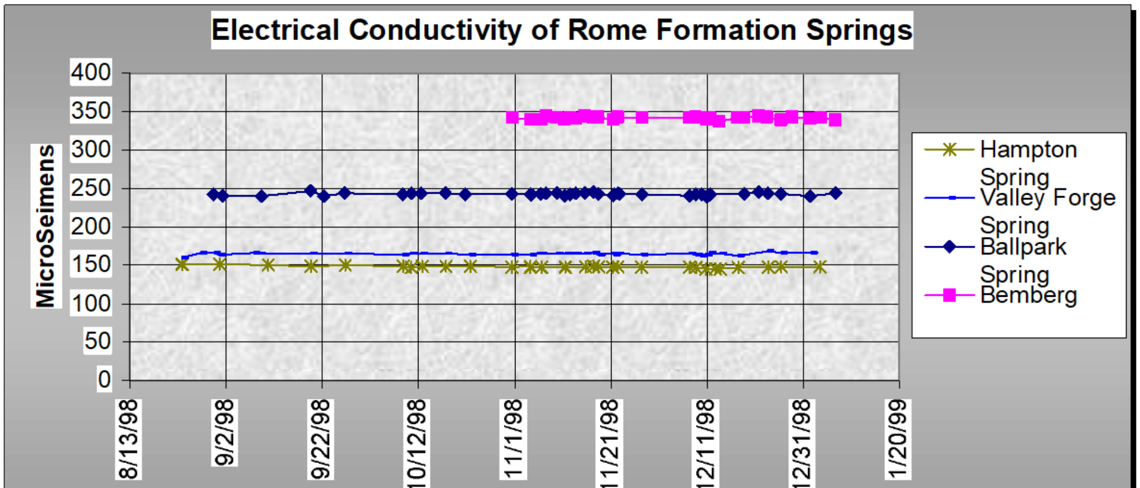
The Ball Park Spring, which is under consideration as a new water source for Elizabethton is located in the Watauga River in the city of Elizabethton. Ballpark Spring is currently impacted with the volatile organic compound PCE. Ball Park exhibits the same steady temperature and conductivity as the Hampton and Valley Forge springs. No visible turbidity has been observed at this spring during this study. This spring is called Ballpark Spring in this study, but also has been referred to as Bemberg Spring, and 882-S in older studies. Historically the spring was used as an industrial water supply for nearby defunct textile factories. Considerable amounts of water flow from this spring and considerable amounts were used by the textiles via a 24-inch pipeline.

The United States Geologic Survey conducted a pump test at this spring during this project. Based on chemical monitoring Ball Park Spring did not vary due to pumping or even respond to a two inch rain fall during the 7 day test. Estimating flow from the Ball Park Spring will be difficult due to the Watauga River flowing over the spring's discharge. An eyeball estimate puts this spring in the four to six million gallons per day range. In the past this spring was thought to emerge from the Honaker dolomite however, the spring occurs in the distinctive maroon beds of the Rome Formation. The characteristic steady temperature and conductivity also confirms its nature as a Rome Formation large spring. Chemical and microbiological analyses indicate no other obvious contaminants in the Ball Park Spring besides PCE. The low variability in these parameters indicates a long or deep flow path that and recharged is gained from a distant area. The source of PCE is not known, but it is reasonable to assume the DNAPL has went to depth under gravity flow and now dissolved phase PCE is being carried in the water. If typical road and petroleum contaminants were in this spring, a different conclusion about deep flow would be warranted. Ballpark Spring is an artesian spring that produces spectacular water and sand boils in the Watauga River. Gas bubbles can be seen from the spring as the water decompresses from depth. It is easily concluded the shale component of the Rome Formation is confining the water in this spring.

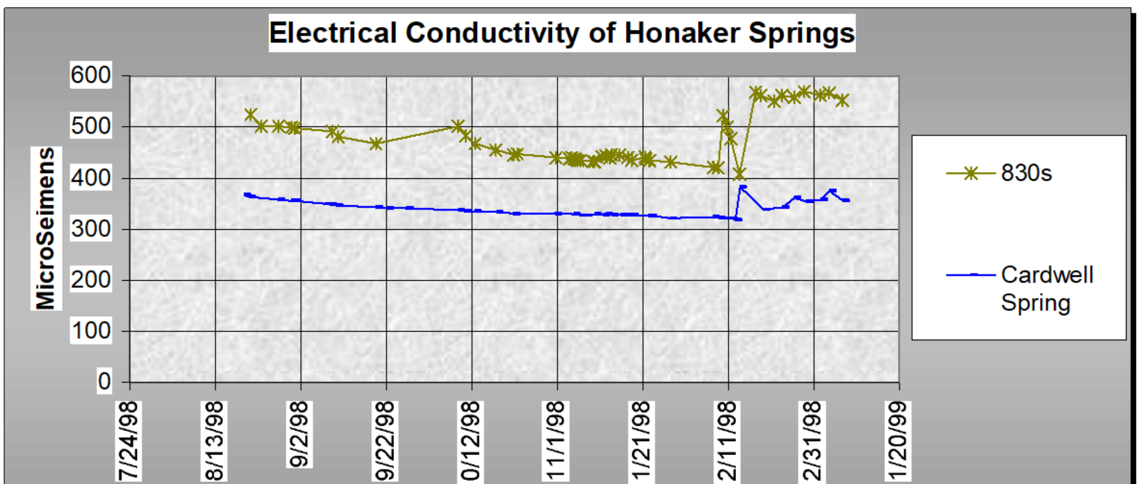
CONCLUSION

This project will go on to gather data for one complete year and hopefully after that time a more complete report will be generated, possibly with a broader scope. Identified has been a need to do some tracer studies as well as many flow measurements. The effort so far has been done to see if springs in this watershed could be differentiated on physical and geochemical characteristics. That being accomplished, there now exist a basis for a conceptual model to facilitate evaluation of the groundwater resources on the Shady Thrust Sheet.

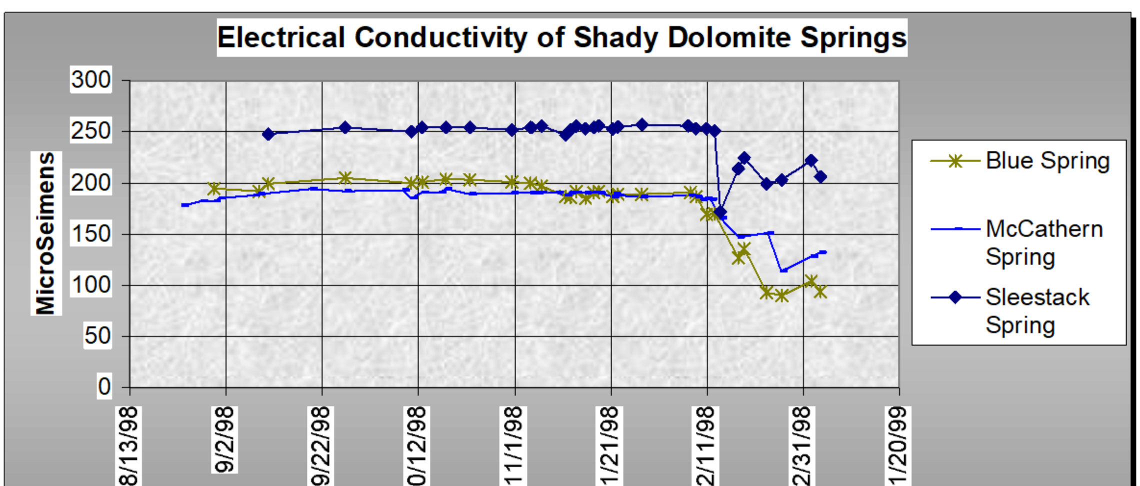




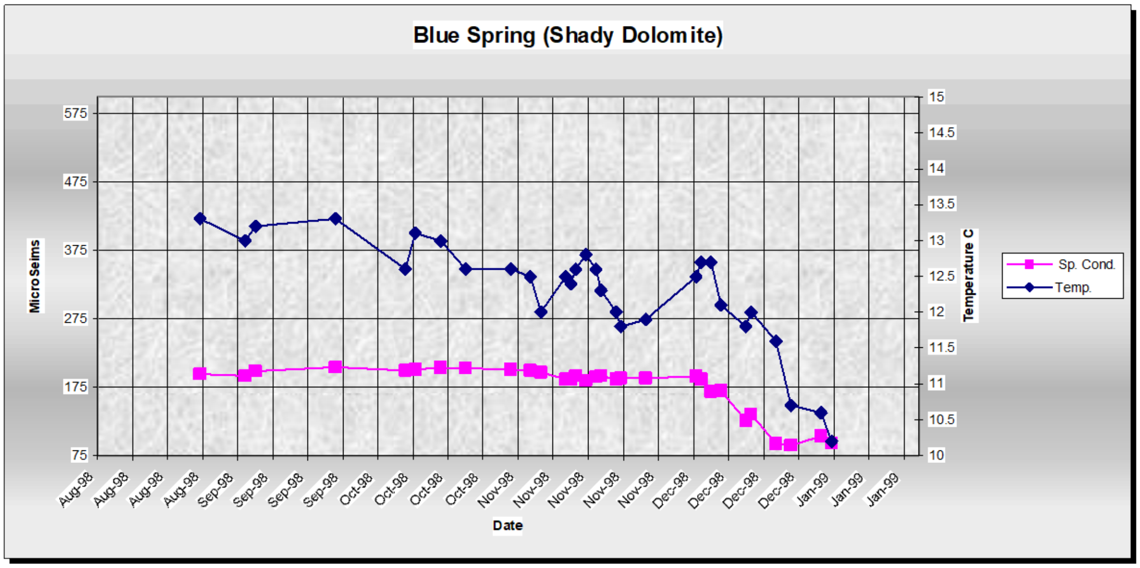
Drought ended when 2 inches of rain fell on 12/13/98
Figure 1.



Drought ended when 2 inches of rain fell on 12/13/98
Figure 2.



Drought ended when 2 inches of rain fell on 12/13/98
Figure 3.



Blue Spring (Shady Dolomite)
MicroSeims
Temperature C
Date
Sp. Cond.
Temp.
575
475
375
275
175
75
15
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
Aug-98
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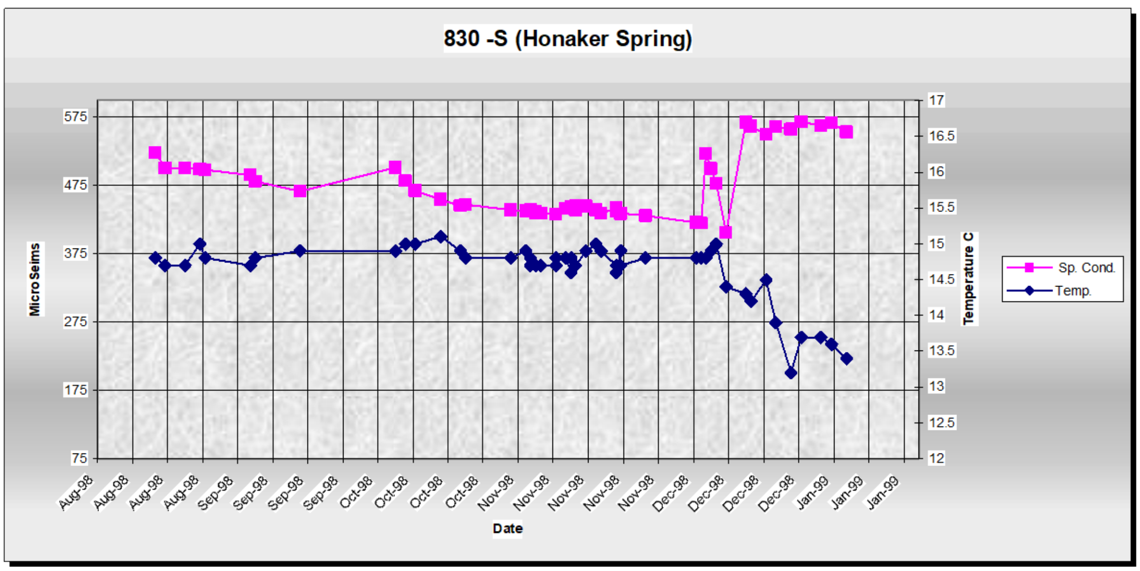
Nov-98
Dec-98
Jan-99



830 -S (Honaker Spring)
MicroSeims
Temperature C
Date
Sp. Cond.
Temp.
575
475
375
275
175
75
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
12
Aug-98
Sep-98
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Nov-98
Dec-98
Jan-99

Figures 4 & 5.

APPLICATIONS OF NEW SAFE DRINKING WATER RULES

Harry Little, P.E.[1]

and

William Dowbiggin, P.E.[2]

ABSTRACT

This presentation will overview recent developments of Safe Drinking Water Act Rules including:

Stage 1 and 2 Disinfection/Disinfection By-pass Rule (D/DBPR)
Interim and Long Term 1 and 2 Enhanced Surface Water Treatment Rule
Random and Other Radionuclides
Groundwater Rule
Future Limits on Specific Contaminants including Arsenic and Sulfate
Filter Backwash Rule

Ramifications of these regulations and actions taken by several Southeast utilities will be presented, including discussion of:

Actions taken for Stage 1 and 2 D/DBPR Compliance
The use of advanced technologies including chlorine dioxide, ozone, Granular Activated Carbon (GAC), membranes, and microfiltration
Ramifications of requirements within the Rules such as Enhanced Coagulation and Disinfection Benchmarking

The conclusion of the paper will forecast future regulatory developments based on the most current insight of persons involved in the rulemaking process.

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COMPETITIVE UTILITY OPERATIONS "SM" PROGRAM: AN ALTERNATIVE TO FULL PRIVATIZATION AT WATER TREATMENT FACILITIES

Stephen R. Kellogg, P.E.[1]

ABSTRACT

Privatization of water and wastewater treatment facilities in the United States is one of the fastest growing businesses in the environmental sector. Public Works Directors and municipal employees no longer have the option of continuing with business as usual. The efficiencies which can be gained by privatizing water and wastewater treatment facilities throughout the world have been well documented, and have led to substantial efficiency improvements and operational cost reductions.

The author's research indicates that by the Year 2000, more than 15% of water and wastewater treatment facilities throughout the United States above 1-mgd will be privatized at an annual revenue run rate of between $2 and $3 billion. Recent favorable tax law rulings, allowing for contract operations and maintenance of these facilities for up to 20 years without any requirement for repayment of bonds, has resulted in a marked increase in the number of municipalities pursuing privatization as an option. Over the last five, privatization has grown at a run rate of between 25 and 30% annually. This growth rate is expected to increase significantly over the next five to 10 years.

There are also disadvantages associated with giving up control of a utility asset to privatization. These include potential displacement of the community workforce, possible increased risk to the utility, and possibility of a change in the level of service to the utility's end users through a requirement by the private sector to operate profitably and in accordance with contract requirements. While performance by privatization firms historically has been quite good, arguably the priorities of a public utility may differ from a privatization company. No one, however, is arguing that the need for cost reductions and increased efficiency in utility operations is not desirable.

To offer public utilities an option to privatization and contract O&M, for the purposes of reducing costs and increasing efficiency, the author and CDM have developed a program called Competitive Utility Operations "SM" (CUO). The cornerstone of the CUO approach is to apply privatization efficiency techniques such as staff training, potential staff reductions, automation, optimization of chemical feed systems, performance of energy audits, implementation of formalized maintenance systems, functional outsourcing and other methods to achieve the same type of O&M efficiencies as privatization firms, without the requirement to give up control of the asset over the long term. One example of the extensive array of benchmarking parameters currently utilized in CUO is shown in Figure 1.

CUO utilizes a team of privatization efficiency experts trained within private sector contract operations and maintenance firms, working with engineers and operations staff, to partner with the utility for the purposes of cost reductions and efficiency gains. The full manuscript will describe in detail the privatization efficiency benchmarks that these experts have implemented on recent, successful projects.

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The first step in the CUO process is to benchmark the utility's operations against similar publicly and privately operated treatment facilities. CDM has assembled an extensive data base on number of treatment facilities over the past five decades. Personal relationships with individuals working at the facilities allows the team to get behind the numbers and ensure that the benchmarking is done on an "apples to apples" basis. Further, privatization experts redo the utility's budget from the perspective of a contract O&M firm to determine "where the bar is" and estimate the magnitude of potential efficiency gains.

The next stage in the process is to document areas for efficiency gains which will result in the greatest degree of improvement. The team then works with utility staff to implement these efficiency gains. The process may involve staff reductions through attrition, cross training, some work rule changes to reduce costs, and a collaboration effort with staff to ensure that all levels of the utility from field personnel through management have an opportunity to contribute to the process.

As the full manuscript will demonstrate, the results of the CUO process to date have been very promising. A number of utilities have taken control of their own destiny and identified and implemented cost reductions similar to those that could be achieved through privatization. As the process can take anywhere from three months to two years to implement, a screening technique is utilized to identify those areas of potential savings that should require the greatest degree of attention. The intent of CUO is not to perform a research project, but rather to achieve significant documentable improvements in a reasonable time period.

In summary, the author believes that privatization, as a driver towards efficiency, is significantly impacting utility management throughout the world. It is believed, however, that not all utilities have to give up control of their assets to privatization for a 20-year time period to achieve these efficiencies. In some instances, privatization may be the chosen path. It is important, however, for Public Works Directors, City Councils, Mayors, and utility employees to understand that CUO is an option for achieving cost reductions other than privatizing the utility asset.

Kellogg Figs.

TENNESSEE STRATEGIES FOR AVOIDING CONFLICT

Dodd Galbreath[1]

Traditionally, Tennessee has been a water rich state. However, diverse water uses in Tennessee are rapidly exceeding water availability, particularly during drought years. Large volumes of water needed for navigation, fisheries, recreation and pollution dilution in larger rivers are competing intensely with growing demands for public and industrial water withdrawals. These growing demands are creating demands for new water development which traditionally results in dams that alter free flowing streams and natural habitats on which rare or endangered species depend. Rural, water poor areas in the state, isolated from large reservoirs and rivers, seem the most vulnerable to growing water conflicts due to competing uses, limited sources and environmental protection. The state of Tennessee has embarked on an effort to promote regionalization (water sharing), long range planning, broader alternatives analysis and identification of new water development options and technology to avoid water conflicts, to protect rare streams and to provide water to growing areas. Cumberland County Tennessee has served as a pilot project for this effort. The pilot project has resulted in identification of new water options and initially, greater cooperation and planning among six independent utilities. Lessons learned can assist similar endeavors.

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PUBLIC-SUPPLY WATER USE IN TENNESSEE

Susan Hutson[1]

A need for current, accurate water-use data for public water-supply systems has been highlighted by droughts during the 1980's, wellhead-protection initiatives, changing water requirements for both instream and offstream uses, and concern about future water shortages. An inventory of public water-supply systems in Tennessee in 1995 was conducted by the Tennessee Division of Water Supply and the U.S. Geological Survey. The data revealed that 530 public water-supply systems supplied water to 4.42 million people, or 84 percent of the population. Public-supply water withdrawals totaled 779 million gallons per day (Mgal/d), 500 Mgal/d (64 percent) of which was from surface-water sources. All of the surface-water withdrawals took place within the Tennessee (279 Mgal/d or 56 percent) and the Ohio (221 Mgal/d or 44 percent) hydrologic regions. Ground water accounted for 279 Mgal/d (36 percent) of the total withdrawal for public-supply use, and was the sole source of public-supply water in the Lower Mississippi hydrologic region of western Tennessee. Of the 279 Mgal/d of ground water provided by public-supply systems statewide, 216 Mgal/d (77 percent) was used in western Tennessee.

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CUMBERLAND COUNTY REGIONAL WATER SUPPLY STUDY

by Todd Boatman[1]

Nashville District Corps of Engineers has recently completed a successful partnering effort with the State of Tennessee that produced the "Cumberland County Regional Water Supply Study." This preliminary engineering report, conducted under the Corps' Planning Assistance to States (Section 22) authority, provides Cumberland County residents with innovative alternatives for a water supply through the year 2050.

With several areas across the state of Tennessee growing at a rapid rate, water supply issues are becoming a top priority. We are facing difficult challenges in trying to provide utility districts with the water they need, while at the same time, protecting our natural resources.

This is the problem that has occurred in Cumberland County. The scenic and pristine rivers that are drawing new residents to the county, are the same resources that utility districts were trying to use to meet increasing water demands. Environmental pressures, however, made the permitting of impoundments extremely difficult, so the County turned to the State for answers.

The Corps of Engineers has long been the custodians of water resources throughout the Country, and the Nashville District is involved in permitting water intakes all across the State of Tennessee. So, it was at the first partnering meeting between the State of Tennessee and the Nashville District, when the idea for a regional approach to the problem was suggested. That idea turned into a six-month reconnaissance study that would be cost shared 50 / 50 between the State and the Nashville District.

Completed in December, 1998, the study is intended to aid the community in planning for the long-term water supply needs of the Cumberland County region. It serves the purpose of a reconnaissance or pre-feasibility study. The report includes a preliminary needs assessment of the county for a 50 year period along with the analysis of six water supply alternatives.

An assessment of the county water supply needs was followed by data collection and a minimum level of field work with respect to topographic surveys, and soil and geologic investigations. The local utility districts and environmental groups came together to create four possible growth scenarios which provide growth patterns based on (1) restricted growth, (2) historical growth, (3) a moderate increase to the historical trend, and (4) an unlimited increase to the historical trend. This estimated range of the future demand was used to provide a perspective of the feasibility of several different alternatives to supply additional water to the county. During a Feasibility Study / EIS process, a detailed Needs Assessment would be completed to define a single target water supply need. Table 1 provides a summary of the preliminary needs assessment.

Table 1
Results of Preliminary Needs Assessment

Growth Scenario	Preliminary Predicted Demand in 2050 (MGD)	Additional Water Supply Required in 2050 (MGD)
Limited	7.3	No Need
Historical	10.9	0.9
Median	13.1	3.1
Unlimited	68.3	58.3

[1] - Additional water supply required based on an estimated existing capacity of 10 MGD.

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After the needs assessment was complete, six different water supply alternatives were investigated:

- **Water Conservation**
- **Groundwater**
  - Five well sites located in Fentress and Overton Counties
- **Pipeline to large reservoir**
  - Watts Bar Lake
  - Center Hill Lake
  - Great Falls Lake
- **Storage Impoundments (New)**
  - Caney Fork
  - Meadow Creek (above Monterey Lake)
  - Meadow Creek (below Monterey Lake)
  - Meadow Park Lake (below existing dam)
  - Clear Creek

Storage Impoundments (Improvements to Existing)
  - Meadow Park Lake
  - Mayland Lake
  - Camp Ozone Lake
  - Tranquilechee Lake
- **Water Harvesting**
  - Traditional Method – Stream to constructed off-site impoundment
  - From Caney Fork to Meadow Park Lake
- **No Action**

Each alternative considered was sized to its maximum capacity for providing water supply. For those alternatives that require a target yield to be designed, such as a pipeline, 9 million gallons per day (MGD) was used as the target yield. While 9 MGD may or may not be the required yield for the County, using it for all alternatives that required a target yield provided an equitable comparison of each.

One of the unique things about this study is the way in which the data is presented. The alternatives were put into a matrix that shows which proposals warrant further evaluation in an environmental impact / feasibility study. The alternatives were categorized from both an engineering assessment and permitting points of view, and states whether or not that alternative should be evaluated in greater detail in the next phase. A summary of these preliminary alternatives is shown in Table 2.

This study is proof of what successful partnering can accomplish. It brought together a diverse group of interested parties that included representatives from regulatory agencies, the six county utility districts, local environmental interest groups, the Cumberland County Executive, and the State of Tennessee. The team developed the study so it could be used as a "model" for other local governments to effectively plan the use of their water resources.

Alternative	Safe Yield (MGD)	Contribution to Projected Need for Each Growth Scenario				Estimated Cost (Million Dollars)	Estimated Cost Per MGD	Feasibility Outlook	
		Limited	Historical	Median	Unlimited			Engineering	Regulatory
Water Conservation								Positive	Positive
Groundwater	9.0[1]	N/A[2]	2253%	184%	17%	$51.6	$5.7	Positive	Positive
Large Scale Pipeline									
to Center Hill Lake	9.0[1]	N/A[2]	2253%	184%	17%	$38.4	$4.3	Positive	Positive
to Great Falls	9.0[1]	N/A[2]	2253%	184%	17%	$33.5	$3.7	Positive	Positive
to Watts Bar Lake	9.0[1]	N/A[2]	2253%	184%	17%	$27.6	$3.1	Positive	Positive
Improvements to Existing Reservoirs									
Meadow Park Lake	4.0	N/A[2]	1000%	82%	7%	N/A[3]	N/A[3]	Negative	Neutral
Mayland Lake	2.0	N/A[2]	500%	41%	4%	N/A[3]	N/A[3]	Negative	Neutral
Camp Ozone Lake	1.0	N/A[2]	250%	20%	2%	N/A[3]	N/A[3]	Negative	Neutral
Tanquilichee Lake	N/A[4]	N/A[4]	N/A[4]	N/A[4]	N/A[4]	N/A[3,4]	N/A[3,4]	Negative	Neutral
New Impoundments									
Clear Creek	3.0	N/A[2]	750%	61%	6%	$28.4	$9.5	Positive	Negative
Meadow Creek (above Meadow Creek Lake)	N/A[5]	N/A[2]	N/A[5]	N/A[5]	N/A[5]	N/A[5]	N/A[5]	Negative	Negative
Meadow Creek (below Meadow Creek Lake)	7.0[6]	N/A[2]	1765%	144%	13%	$55.7	$7.9	Positive	Negative
Meadow Park Lake	N/A[7]	N/A[2]	N/A[7]	N/A[7]	N/A[7]	N/A[7]	N/A[7]	Negative	Negative
Caney Fork	12.0	N/A[2]	3000%	245%	22%	$63.5	$5.3	Positive	Negative
Water Harvesting									
Traditional Water Harvesting	0.8[8]	N/A[2]	220%	18%	2%	$18.6	$21.1	Positive	Positive
Caney Fork to Meadow Park Lake	11.0[9]	N/A[2]	2773%	226%	20%	$42.7	$3.9	Positive	Neutral

SUBSURFACE CORRELATION OF THE PIERCE LIMESTONE AND ADJACENT CONFINING UNITS OF MIDDLE TENNESSEE

by

James J. Farmer[1*] and E.F. Pat Hollyday[2]

ABSTRACT

Through the use of geophysical logs, the stratigraphic relations among aquifers and confining units in Middle Tennessee were determined. The logs were used to identify, subdivide, and correlate the Murfreesboro, Pierce, and Ridley Limestones of the Stones River Group. The published descriptions of type sections were compared to selected geophysical logs. These type logs were then correlated with other geophysical logs throughout the Central Basin. This correlation established that the Pierce Limestone is the lower of two thin-bedded, shaly limestone confining units that are present near the base of the Ridley Limestone. This identification of the Pierce Limestone resulted in an estimated range of thickness for the Ridley Limestone from 131 feet in the northeastern part of the Central Basin to 153 feet in the southwestern part. The Ridley Limestone is stated to be about 100 feet thick in the legend of most geologic quadrangle maps of the Central Basin, suggesting that a thin-bedded unit within the Ridley Limestone often has been mapped as the Pierce Limestone. The Pierce Limestone was determined to be consistently about 28 feet thick. The Murfreesboro Limestone is 428 feet thick near Murfreesboro and thins by less than 10 percent to the southwest and northeast. Detailed examination of the stratigraphy revealed specific examples of inconsistencies between published geologic maps and likely outcrops in Middle Tennessee. Correct interpretation of the stratigraphic position of geologic units is critical to understanding the dynamics of fluid movement in the rocks of Middle Tennessee.

INTRODUCTION

The U.S. Geological Survey (USGS) observed a core drilling operation at an industrial Superfund site in Lewisburg, Tennessee (fig. 1), in May 1997. These observations were part of a cooperative, statewide investigation of the movement and bioremediation of chlorinated solvents in karst performed by the USGS and the Tennessee Department of Environment and Conservation, Division of Superfund. Cores were examined by the site geologist to determine the lithology of the rock units and to relate the lithology to fluid-yielding openings. Prior to the coring operation, the permeability of the rock was tested using packers in 12 boreholes that were open from the lower part of the Lebanon Limestone into the lower part of the Ridley Limestone. The results of the packer tests indicated 23 fluid-yielding openings were present in the rock. These openings were restricted to a massive limestone unit that overlies a thin-bedded, shaly limestone unit. This shaly limestone is about 100 feet below the top of the Ridley Limestone. During inspection of the core, questions arose as to whether this thin-bedded, shaly limestone was the Pierce Limestone and as to the correct thickness of the Ridley Limestone. Evidence from well records (Newcome, 1958, p. 13) indicates that the Pierce Limestone is a significant confining unit. Whether or not the Pierce Limestone was breached by exploratory drilling during site investigation was a sensitive issue among the site investigators, the Tennessee Division of Superfund, and the U.S. Environmental Protection Agency.

In order to resolve the issue, the USGS undertook the task of examining published literature and unpublished geophysical logs to identify the Pierce Limestone and to establish accurate thicknesses for the adjacent formations within the Central Basin of Middle Tennessee.

The Pierce Limestone, the underlying Murfreesboro Limestone, and the overlying Ridley Limestone of Middle Ordovician age were identified, described, and named from outcrops of weathered rock in stream banks and hillsides in Rutherford County (Safford, 1851, 1869; Safford and Killebrew, 1909; Galloway, 1919; Bassler, 1932; Wilson, 1949). The thicker bedded, less shaly limestone lithology of the Murfreesboro and Ridley Limestones is easily distinguished in weathered outcrop from the thinner bedded, more shaly limestone lithology of the Pierce

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Limestone. In general, these two lithologic aspects alternate up and down the stratigraphic section and were used, in conjunction with fossil assemblages, to define the sequence of formations in Middle Tennessee. The thicker bedded units are similar to each other, and the thinner bedded units are similar to each other; therefore, discerning which formations are under observation is difficult when mapping geologic contacts at outcrops of low relief in the field. In addition, many folds of low amplitude on the surface cause difficulty in following the Pierce Limestone from outcrop to outcrop. This problem is compounded by the occurrence of several other thin-bedded, shaly limestone units within the upper two-thirds of the underlying Murfreesboro Limestone, as well as in the lower one-third of the Ridley Limestone. The authors hypothesize that thin-bedded units in the Ridley Limestone have been incorrectly identified as the Pierce Limestone. Crawford and Ulmer (1994) have also expressed this possibility.

The purpose of this article is to identify and correlate regionally the Murfreesboro, Pierce, and Ridley Limestones in the Central Basin of Middle Tennessee. This was achieved by relating lithology to typical signatures on geophysical logs. The scope of the article includes presentation of 7 of the 45 geophysical logs that were examined as part of the study and correlation of the geologic units. The study was targeted towards specifically identifying the Pierce Limestone among several thin-bedded limestones and determining the consequent thickness of the Ridley Limestone.

GEOPHYSICAL CORRELATION

Geophysical logs located in the Central Basin were used specifically to:

1. Differentiate thin-bedded, shaly limestone units in the Ridley Limestone from the Pierce Limestone
2. Divide the Murfreesboro, Pierce, and Ridley Limestones into smaller stratigraphic units for the purpose of subsurface correlation
3. Identify the presence and regional extent of thin-bedded, shaley limestone units in the Ridley Limestone
4. Establish the actual thickness of the Ridley Limestone
5. Correlate the Murfreesboro, Pierce, and Ridley Limestones regionally
6. Demonstrate how the geology shown on published geological maps could be reinterpreted using geophysical log data

DISCUSSION

Regional correlation away from the geophysical log at the type locality for the Pierce Limestone (well Ru:P-061, fig. 1) confirms that the Pierce Limestone, at the type locality, correlates with the lower of two moderately thick (about 20 to 30 feet), thin-bedded, shaly limestones that are present near the base of the Ridley Limestone (well Ms:N-001, fig. 2). This correlation establishes that the Ridley Limestone ranges from 131 feet thick in the northeastern part of the Central Basin in well Wi:L-001 to 153 feet thick in the southwestern part in well Ms:N-001 (fig. 2). The Ridley Limestone is described as “100 to 150 feet thick” in the legend of the Murfreesboro geologic quadrangle map but “about 100 feet thick” in the legends of the Dilton, Farmington, Fosterville, Gladeville, Lascassas, La Vergne, Rockville, Veronia, and Walterhill quadrangle maps. The confirmation of an average thickness closer to 150 feet rather than 100 feet for the Ridley Limestone suggests that a thin-bedded unit of the Ridley Limestone has been mapped repeatedly as the Pierce Limestone. This thin-bedded unit of the Ridley Limestone lies between 34 and 56 feet above the base in well Ms:N-001 (fig. 2). The regional correlation also confirmed a consistent thickness for the Pierce Limestone of about 28 feet. In addition, the correlation shows that the lower unit of the Murfreesboro Limestone is thickest in the Murfreesboro area in well Ru:J-001 (88 feet), thins to the northeast in well Ws:L-001 (54 feet), and has a constant thickness to the southwest in wells Ms:N-001 and Ms:F-001 (78 feet). The middle unit of the Murfreesboro Limestone is thickest in the Murfreesboro area in well Ru:J-001 (175 feet) and is approximately 160 feet in wells to the northeast and southwest. The upper unit of the Murfreesboro Limestone is thickest to the northeast in well Wi:F-001 (174 feet) and gradually thins to the southwest in well Ms:N-001 (147 feet)(fig. 2). The lower unit of the Murfreesboro Limestone herein is regarded as part of the upper white unit of the Wells Creek Formation by some geologists in the zinc-mining industry.

This study of regional stratigraphic thicknesses revealed specific examples of inconsistencies between geologic maps and likely outcrops interpreted from geophysical logs. By correlating geologic units up from the top of the lower unit of the Murfreesboro Limestone, the formation which occurs at the land surface at the well sites was identified. This identity was compared directly with the geologic map to determine if the map portrayed the correct formation. In addition, marker beds were correlated among several wells with geophysical logs to determine the structural altitude of the beds. The structure was then used to determine likely outcrop patterns. Several areas with inconsistencies were identified. For example the Murfreesboro geologic-quadrangle map shows continuous Ridley Limestone between wells Ru:J-057 and Ru:J-059, located approximately 3 miles west of Murfreesboro (USGS open-file well records. Correlation of units within the Murfreesboro Limestone among wells Ru:J-001,-057, and -059, however, shows that the Murfreesboro Limestone occurs at land surface at well Ru:J-059. This occurrence suggests a broad outcrop of this formation south and west of this well. Similar examples could be drawn from other geologic quadrangles in Middle Tennessee.

Correct interpretation of the stratigraphic position of geologic units at contamination sites is critical to understanding the geologic structure and the movement of water and water-borne contaminants in the subsurface of Middle Tennessee. Accurate interpretations can be made by collecting geophysical logs with readable amplitude at contamination sites, correlating these logs with logs that show the regional stratigraphic sequence, and determining the stratigraphic position of fluid-yielding openings at the site within the regional stratigraphic sequence. A library of logs that are annotated with the occurrence of fluid-yielding openings could support the development of conceptual stratigraphic models of fluid occurrence and lead to a predictive capability at new sites.

CONCLUSIONS

The Murfreesboro, Pierce, and Ridley Limestones, in the lower and middle parts of the Ordovician Stones River Group, can be divided into units that correlate regionally. These units aid in identification and correlation of each formation. Such correlation has identified the Pierce Limestone as the lower of two thin-bedded confining units that are associated with the Ridley Limestone. This identification reveals the Ridley Limestone to be between 131 and 153 feet thick, not "about 100 feet" as previously mapped. Comparison of geophysical logs with published geologic maps has revealed that the Murfreesboro quadrangle and 9 other geologic quadrangle maps in Middle Tennessee might benefit from the use of geophysical logs in the remapping and reinterpretation of the geology. Correct interpretation of the stratigraphic position of geologic units is critical to a thorough understanding of the dynamics of fluid movement in the rocks of Middle Tennessee. The stratigraphic position is important because fluid-yielding openings are concentrated in massive limestone units, frequently near the contact with thin-bedded shaly, limestone units, as at the Superfund site in Lewisburg, Tennessee.

REFERENCES CITED

Bassler, R.S., 1932, The stratigraphy of the Central Basin of Tennessee: Tennessee Division of Geology Bulletin 38, 268 p.

Crawford, N.C., and Ulmer, C.S., 1994, Hydrogeologic investigations of contaminant movement in karst aquifers in the vicinity of a train derailment near Lewisburg, Tennessee: Environmental Geology, v. 23, p. 41-52.

Newcome, Roy Jr., 1958, Ground water in the Central Basin of Tennessee, a progress report: Tennessee Division of Geology Report of Investigations No. 4, 81 p.

Galloway, J.J., 1919, Geology and natural resources of Rutherford County, Tennessee: Tennessee Division of Geology Bulletin 22, 81 p.

Safford, J.M., 1851, The Silurian basin of Middle Tennessee, with notices of the strata surrounding it: Journal of American Science and Arts, 2d ser., v. 12, p. 352-361.

_______1869, Geology of Tennessee: Nashville, Tenn., S.C. Mercer, 550 p.

Safford, J.M., and Killebrew, J.B., 1909, The elements of the geology of Tennessee: prepared for the use of the schools of Tennessee, and for all persons seeking a knowledge of the resources of the state: Ambrose Printing, Nashville, Tenn., 264 p.

Wilson, C.W., Jr., 1949, Pre-Chattanooga stratigraphy in Central Tennessee: Tennessee Division of Geology Bulletin 56, 407 p.

GROUND WATER SPRING BASIN DELINEATION IN RUTHERFORD COUNTY, TENNESSEE FOR INTERPRETING SINKHOLE FLOODING--YEAR TWO: RESULTS OF THE INVESTIGATION

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ABSTRACT

In the second year of funding from the Rutherford County Planning Commission six ground water traces were conducted enabling the partial delineation of four karst spring drainage basins. This work was performed to help determine how sinkholes, karst windows, and springs are interconnected for the purpose of understanding present sinkhole flooding problems and to help plan for future growth. Four of the dye traces were performed northwest of the confluence of Overall Creek and the West Fork of the Stones River between I-24 and the Old Nashville Highway. Three traces went to Spivey Spring #1 located along Stewart Creek in Smyrna. The dye injection points were located in: 1) Sunnyside Subdivision, 2) Belle Meade Subdivision, and 3) at the end of Justice Road in an area proposed for a new subdivision. One tracer traveled a distance of over three miles in approximately three days. A fourth trace was conducted from a sinkhole on Blackman Road next to I-24 to Highwire Spring, also located along Stewart Creek. This trace enabled separation of the Spivey Spring and Highwire Spring basins.

Two successful traces were conducted to springs located within the Murfreesboro City Limits, but that receive recharge waters from outside the City Limits. The first trace was to Murfree Spring from dye injected into a sinkhole at the outfall of Todd Lake. This trace shows that Murfree Spring is hydrologically connected to Black Fox spring which drains a significant area in the Lytle Creek drainage basin. The second trace was to the Oaklands Mansion Spring from a sinkhole located near the intersection of Mercury and Rutherford boulevards. This trace helped to better define the northwestern boundary of the Bushman Spring Karst Drainage Basin. In all of the spring basins, ground water moves through the Ridley Limestone perched above the Pierce Formation. Rapid movement of the tracing agents suggests that subsurface cavities have not been clogged by human activities but the thin Ridley Karst Aquifer essentially "fills up" during large storm events and cave waters backup behind natural constrictions associated with changes in cave passage size. Ground water moves through caves and solution-enlarged fractures in a north-northwest direction, first down the flanks of anticlines, and then along the troughs of synclines to emerge at stratigraphic and base level controlled springs.

Water injection tests were conducted at two wells on the MTSU campus to determine if storm floodwaters could be drained into the deeper Murfreesboro Limestone Aquifer. At an injection rate of 75 gpm, the water level rose close to the surface, but returned to the original 30 foot level within two minutes after injection ceased. This important test demonstrates that deeper storm drainage wells may work to alleviate sinkhole flooding problems in some areas of the County.

INTRODUCTION AND PURPOSE

The first year of funding from the Rutherford County Planning Commission enabled important discoveries to be made regarding ground water flow and sinkhole flooding. But Rutherford County is a large county, and development continues to occur on the limestone karst topography, which is characterized by numerous sinkholes, sinking and losing streams, karst windows, springs, and caves. As a result, many portions of the County need similar investigation. Year Two of the study focused on areas just south of Smyrna and large springs in the Murfreesboro City Limits that receive recharge waters from more distant places in the County.

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Since much of the area is relatively flat, shallow sinkholes are not easily discernible, particularly at the 10 or 20 foot contour intervals of the U.S.G.S. topographic maps. As a result, development has occurred in and around many sinkholes. With development comes more paved areas resulting in less ground percolation and larger, faster moving volumes of stormwater runoff that often is deliberately diverted to sinkholes. Rapid, natural and construction-related changes can occur that affect how well sinkholes and caves can drain stormwater. Caves, unlike storm sewers, naturally change in size. The increased runoff into sinkholes can thus back up behind natural constrictions. In addition, sediment-laden runoff waters from construction sites can clog sinkholes and segments of the cavernous subterranean drainage. Sinkholes are not solitary hydrologic entities, but are intricately tied together through a network of subterranean drainage pathways. Therefore, development around one sinkhole can have a pronounced impact on all others downgradient within the same ground water spring basin.

To interpret what causes sinkhole flooding in a karst terrane, it is vitally important to understand the permeability of the sedimentary rock layers beneath the ground. Even thin, clay rich shale beds can prevent the downward movement of percolating stormwaters. Such beds exist close to the surface in Rutherford County. Their effect on sinkhole flooding and a possible solution will be discussed in this paper. It is also essential to determine how the caves, springs, and sinkholes are interconnected and how fast the ground water moves to ascertain possible adverse effects from future growth in a particular spring drainage basin. This was done through ground water tracing using fluorescent dyes. The paper presents the results of six successful dye traces that were conducted.

STUDY AREAS

Dye tracing was conducted in four karst spring water basins. These are shown on Figure 1 and Figure 2. Spivey Spring #1 and Highwire Spring are located on the Smyrna Quadrangle on the south side of Stewart Creek between I-24 and the Old Nashville Highway. The discharge range of the springs is unknown, but appeared quite large throughout the study. Spivey Spring #1 and Spivey Spring #2 are in close proximity, but the dye tracing results show they have separate drainage basins. Successful traces were also conducted to Murfree Spring and the Oakland Mansion Spring located on the Murfreesboro Quadrangle.

HYDROGEOLOGIC SETTING

Rutherford County is located in the Central Basin physiographic province which is underlain by limestones of Ordovician age that have been gently upwarped to form the Nashville Dome. The oldest rocks exposed in the study area are those of the Murfreesboro Limestone which is approximately 400 feet thick. Above the Murfreesboro Limestone is the Pierce Formation, a shaly, thin-bedded limestone that confines water beneath it in the Murfreesboro Aquifer and perches water above it in the Ridley Limestone. All of the springs involved in the study emerge at the contact between the Pierce Formation and the overlying Ridley Limestone. The lower Ridley Confining Unit occurs approximately 30 feet above the Ridley/Pierce contact (Figure 3). All of the dye tracing for this study was conducted in the bottom 30 feet of the Ridley Limestone.

METHODS

Orientation Data

Ground water in karst areas flows primarily along solution-enlarged fractures (joints) and caves that have developed along the joint trends. Therefore, to help predict which direction ground water flows in the study area, joint orientations were made at outcrops using a Brunton compass. An indirect method of measuring fracture orientations is to map photo-interpreted fractures from aerial photographs. Photo-lineaments were delineated for this study from 1:20,000, black and white, stereo aerial photographs obtained from the Soil Conservation Service, and their orientations measured with a protractor. The orientations of the joints and photo-lineaments were then placed in 10 degree classes and plotted as rosette diagrams.

Ground Water Tracing

The ground water traces were conducted using the following fluorescent dyes: eosine (pink), rhodamine WT (red), and fluorescein (green). These tracing agents are non-toxic and routinely approved for use by various divisions of the Tennessee Department of Environment and Conservation. Prior to conducting the traces, the Tennessee Underground Injection Control Program was notified for their voluntary dye registration program. The injected tracing agents were detected by using activated charcoal packets that absorb and concentrate the levels in the water. The charcoal packets, called "traps", were suspended in the waters expected to receive the dyes on a stiff wires connected to concrete bases, referred to as "gumdrops". Prior to tracer injection, the traps were placed in the waters for approximately a week to test for background concentrations. The dyes are common coloring agents and frequently are found as "contaminants" in the ground water. Once background levels were determined, new packets were set out immediately prior to injection. After injection of the dyes, the packets were usually changed at three to seven day intervals and sent to the laboratory for analysis.

RESULTS

Orientation Data

Figures 4 shows the location of joint and photo-lineament measurement sites for this and other recent investigations (Ogden, 1997a and 19997b). Over 700 joint orientations are presented in Figure 5, and over 600 photo-lineament directions are shown on Figure 6. Although there is some scatter of the data, strong similarity exists around N50ºW and N40ºE. These are the orientations of the compressional joints formed when the rocks were uplifted and gently folded. Subtle synclines and anticlines occur "superimposed" on the Nashville Dome. Moore et. al., 1969, attempted to delineate some of these folds by constructing a structural contour map of the Upper Stones River Basin with the top of the Ridley Limestone as a datum. A predominant northern direction of the data is seen in some of the rosette diagrams. This is the general trend of the major fold axes and also the expected direction of extensional joints. The joint measurement site at Cripple Creek, for example, is located directly on a north-trending synclinal trough. The ground water tracing results from the last two years of investigation for the County and City show that ground water tends to first flow down the limbs of anticlines along the major northwest and northeast fracture trends and then moves along the strike (northern direction) of the synclinal troughs. This important discovery will help predict the direction of ground water flow in future studies and also will help to locate springs.

Ground Water Tracing

Six successful ground water traces were conducted in four spring drainage basins. Table 1 shows the locations and dates of dye injections and the springs testing positive for the dyes. The interconnections of injection points to the springs are shown on Figure 1 (Spivey Spring #1 and Highwire Spring) and Figure 2 (Oaklands Mansion Spring and Murfree Spring). Straight lines have been drawn between the points of dye injection and sites testing positive for dye, but it should not be assumed that the dyes flowed in a straight line between points.

TABLE 1. Summary of Dye Tracing Activities.

Dye Injection Dates	Injection Locations	Sites Testing Positive
2/3/98	Smith Farm Proposed Sub. (1 lb. Rhodamine WT)	Spivey Spring #1
2/4/98	Sinkhole at Todd Lake Outfall (1 lb. Rhodamine WT)	Murfree Spring
2/4/98	Sunnyside Subdivision Sink (1 lb. Fluorescein)	Spivey Spring #1

3/1/98	Slick Pig/Grog Shoppe Sink (1 lb. Fluorescein)	Oaklands Man. Spri.
4/3/98	Belle Meade Subdivision (1 lb. Fluorescein)	Spivey Spring #1
4/13/98	Blackman Road by I-24 (1 lb. Eosine)	Highwire Spring

Spivey Spring #1 Basin

Most of the dye tracing was conducted in the Spivey Spring #1 Basin. Spivey Spring #2 is located approximately 1000 feet down stream (Stewart Creek) from Spivey Spring #1. Initially, these two relatively large springs were believed to be hydrologically connected due to their close proximity. Three successful dye tracers were made to Spivey Spring #1, but no dye was ever detected at Spivey Spring #2 demonstrating that the two ground water basins are separate. One of the traces to Spivey Spring #1 traveled a distance in the subsurface of over three miles indicating a large recharge area for the spring. The similar discharge of the two springs suggests that Spivey Spring #2 also has a sizeable recharge area.

High Wire Spring Basin

One dye trace was successfully completed in the Highwire Spring Basin. Highwire Spring is located on Stewart Creek about one mile upstream from the Spivey Springs. The dye traveled from the injection point on Blackman Road a distance of nearly 1½ miles in three or less days indicating that the underground cavities are very open. The trace to Highwire Spring enables an approximate western boundary to be drawn between the recharge area for this spring and Spivey Spring #1.

Murfree Spring Basin

Only one dye trace was successfully completed in the Murfree Spring Basin, but the water inflow to the injection point is believed to represent most of the flow of the spring. Murfree Spring is quite large and was once used as the City water supply. Although the spring is located in the City Limits, it undoubtedly receives recharge from more distance points in the County. The dye that moved to Murfree Spring was injected into a sinkhole receiving the water that moves over the dam forming Todd Lake. The water that feeds Todd Lake comes from Blackfox Wetlands which begins at Black Fox (Fox Camp) Spring located along Red Mile Road. The source of Black Fox Spring is unknown at this time, but the authors believe it is derived primarily from leakage of upper Lytle Creek to the subsurface.

Oaklands Mansion Spring Basin

One dye trace was successful in defining a significant portion of the recharge area for the Oaklands Mansion Spring. Oaklands Mansion Spring is also located in the City Limits but receives some recharge water outside of town. Dye was injected into a shallow sinkhole behind the Slick Pig Barbecue Restaurant and the Grogg Shoppe. The dye traveled nearly two miles in three or less days indicating open subterranean drainage pathways. This is a very important trace in that it enables separation of the Murfree and Bushman springs drainage basins demonstrating that the Oaklands Mansion Spring basically occurs between the other two.

The Role of Impermeable Strata on Flooding Problems

Two layers of impermeable rock exist in the study area. The first is the Pierce Limestone at the base of the Ridley Limestone. The Pierce is a clay-rich, thin-bedded shaly limestone that perches ground water above it in the Ridley. As a result, most springs in central Rutherford County are found at this geologic contact. Whether sinkhole flooding occurs or not is largely related to the thickness of Ridley Limestone overlying the Pierce Limestone. In general, if less than 30 feet of Ridley Limestone occurs above the Pierce, there is a high risk of flooding. This is an important, though not exact, means to ascertain flooding potential in an enclosed depression area before approval of a new subdivision or commercial building site. In much of the Spivey Spring #1 Drainage Basin, for example, there is only about 30 feet of Ridley Limestone over the Pierce Limestone. Comparison of the elevations of the two Spivey Springs to the bottom of the sinkholes shows that the subterranean karst water table is quite flat and very close to the surface in many areas. Rapid movement of the tracing agents suggest that there are not artificial clogs in the subsurface, but that natural reduction in cave size or the amount of sediment fill causes water to back up during flooding, essentially filling all void spaces in the aquifer. The dye tracing results show that sinkholes near the springs are well connected to sinkholes many miles away. *Therefore, new development that increases runoff into sinkholes can cause flooding problems in sinkholes great distances away.*

The lower Ridley Confining Unit is another impermeable layer that restricts downward percolation in central Rutherford County. This unit has not been delineated on geology maps. The lower Ridley Confining Unit is a 25 foot thick sequence of thin-bedded limestones with few joints about 30 feet above the contact of the Ridley and Pierce limestones. The Black Fox Wetlands located between Black Fox (Fox Camp) Spring and Todd Lake exists due to the lower Ridley Confining Unit. Ground water in the upper Lytle Creek Basin moves through the upper Ridley Karstic Aquifer until the lower Ridley Confining Unit is intersected at Black Fox Spring. The ground water then emerges at the surface and flows forming the wetlands until the lower Ridley Karstic Aquifer is encountered at the base of Todd Lake. The water sinks at this point and then re-emerges at Murfree Spring at the contact of the lower Ridley and the Pierce Limestone. Rima et. al., 1977, noted that the East Fork of the Stones River gains and loses water between Woodbury and Lascasses as it travels over the Ridley Limestone. The authors made a similar canoe trip and recognized that the lose or gain of water is likely related to the river's location in regards to the lower Ridley Confining Unit. This scenario is the same as described for the Black Fox Spring-Todd Lake-Murfree Spring hydrologic system.

The Possibility of Using Injection Wells to Alleviate Flooding Problems

In many areas of central Rutherford County, there is only 20 to 30 feet of Ridley Limestone overlying the impermeable Pierce Limestone. Infiltrating stormwaters, particularly during the wet season, essentially "fill up" the Ridley Aquifer causing water in some cases to actually rise up from sinkhole bottoms. In these areas, shallow storm drainage injection wells (Class V-EPA) cannot help alleviate flooding problems. It may be possible, though, to drill deeper wells through the Pierce and into the underlying Murfreesboro Limestone Aquifer. Two wells were recently drilled for the Department of Geography and Geology next to Kirksey Old Main on the MTSU campus. These wells begin in the Ridley Limestone and were drilled approximately 225 feet into the Murfreesboro Aquifer. Ground water was encountered at approximately 175 feet and rose up the wells under artesian pressure to 30 feet from the surface. Nearly 80 feet of dry Murfreesboro Limestone was encountered before water was hit. On July 17th, 1998, injection tests were performed on these two wells with the help of the Murfreesboro Fire Department. Fifty gallons per minute (gpm) were injected into the most permeable well for approximately 30 minutes. At the end of the test, the water level had risen only 3 feet. The injection rate was then increased to 75 gpm. The water rose in the well to near the surface, but sustained that level for the next 20 minutes. Then after shutting the water off, the level in the well dropped back to 30 feet below the surface in just two minutes. This test has significant ramifications for possibly alleviating flooding within the County by using injection wells. It is important to note that the Murfreesboro Aquifer is not as karstic as the Ridley Limestone so drilling a successful injection well will depend on intersecting a fracture or cavity. This requires input from a karst hydrogeologist. In addition, the injection of stormwater into the subsurface requires a permit from the Tennessee Underground Injection Well Program to insure that drinking water supplies are not adversely impacted by the injected waters. In many areas of the County, and certainly within the City Limits, this should not be a problem since municipal water is supplied.

CONCLUSIONS

Ground water tracing in the second year of funding from the Rutherford County Planning Commission was successful in delineating portions of four spring watersheds in Rutherford County. The tracing activities show that ground water moves rapidly through the subsurface to springs across distances in excess of three miles. The rapid movement of the dye tracers suggest that the caves are not clogged by human activities. Therefore, two reasons exit to explain sinkhole flooding in the spring basins. First, the karst water table is very close to the surface perched upon one of two impermeable layers that exist in the study area. By studying the geology maps at a site planned for development, an estimate of aquifer thickness above an impermeable layer can be made and the potential for flooding ascertained. Second, natural constrictions in the subsurface cavities cause storm waters to backup behind the constrictions and fill the upgradient sinkholes. Understanding these two factors that affect flooding in the County can be used to plan for the future. Much is now known about many sinkhole interconnections within the studied spring basins. Therefore, when development in or around a given sinkhole occurs, there will be significant insight as to which areas down-gradient will likely be affected by the additional runoff to the subsurface. Perhaps the most important discovery of the second year of investigation is the possibility of using injection wells to help alleviate sinkhole flooding problems. Injection tests at the wells next to Kirksey Old Main on the MTSU campus strongly suggest that at least 50 gpm can be injected into to Murfreesboro Limestone. Stormwater injection wells drilled into fracture zones and cavities would likely accept much more water. The similarity of the joint, straight cave segment, photo-lineament, and sinkhole axes data shows that a variety of tools are available to help predict the direction of ground water movement within Rutherford County. In most cases, ground water moves down the limbs of anticlinal folds along fractures oriented around N50°W and N40°E and then along the strike of the synclinal troughs which are oriented close to due north. Therefore, the movement direction of any spilled or leaked contaminant can be predicted, as well as, the eventual emergence location.

REFERENCES

Burchett, C. R. and G.K. Moore, 1971, Water resources in the Upper Stones River Basin, central TN: Tenn. Dept. of Cons.-Div. of Water Res., Water Resources Series No. 8, 62 p.

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

Ogden, A.E., 1997a, Delineation of ground water spring basins in Rutherford Co., TN: a first step in understanding sinkhole flooding: Contract Rept. for the Rutherford Co. Planning Commission, 37 p., 3 plates.

Ogden, A.E., 1997b, Ground water tracing results at the Murfreesboro Old City Dump, Rutherford Co., TN: Contract Rept. for the City of Murfreesboro, 107 p.

Rima, D., M. Moran, and J. Woods, 1977, Ground water supplies in the Murfreesboro area, TN: U.S.G.S. Water-Resources Invest. 77-86, 76 p.

Ogden Fig. 1

Ogden Fig.2

Ogden Fig. 3

Ogden Fig. 4

Ogden Fig. 5

Ogden Fig. 6

GROUNDWATER BASIN DELINEATION AND SITE CONCEPTUAL HYDROGEOLOGIC MODEL FOR SADD – TROUSDALE SUPERFUND SITE, CSX RADNOR YARD SITE AND GENERAL ELECTRIC SERVICE FACILITY SITE IN NASHVILLE, TENNESSEE

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ABSTRACT

The Saad – Trousdale Superfund Site, the CSX Railroad Radnor Yard Site and the General Electric Service Facility Site were all possible sources of groundwater contamination of Croft Spring at Grassmere Wildlife Park in Nashville, Tennessee. A karst hydrogeologic investigation was performed that included the following: a) hydrogeologic inventory over a 20 square mile area, b) mapping of the potentiometric surface of the uppermost aquifer, c) dye traces of groundwater flow, d) delineation of groundwater basins, and e) preparation of a conceptual hydrogeologic model.

The following information was used in constructing the potentiometric surface map: a) water levels in monitoring wells, b) water levels at springs (surveyed from benchmarks), c) water levels along perennial streams estimated from a five-foot contour interval topographic map, d) water levels in the storm sewer system at Radnor Yard, measured at manholes, e) location size and elevation of springs and surface streams, and f) topography. A potentiometric surface map was prepared for both the wet season and the dry season in order to investigate changes in groundwater drainage divides.

Passive dye receptors were placed in springs, streams, wells, drain pipes, and storm sewers identified during the hydrogeologic inventory. ISCO Automatic Water Samplers were installed at Croft Spring and the Radnor Yard Storm Sewer Outfall (the two suspected discharge points for groundwater from the Saad and Radnor Yard sites). Six dyes were injected into existing monitor wells, pits and one drilled dye injection well. A map was prepared showing the dye flow routes for each particular dye, along with the potentiometric surface and the groundwater drainage divides.

A conceptual hydrogeologic model was prepared that included a hydrogeologic profile indicating that Croft Spring is located at the top of the Hermitage Formation along its contact with the Bigby – Cannon Limestone.

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GROUND WATER TRACING RESULTS AT THE ROSEBANK DUMP, RUTHERFORD COUNTY, TENNESSEE

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ABSTRACT

The Rosebank Dump was operated by the City of Murfreesboro from the early to mid 1950's to approximately 1964. To better understand ground water flow beneath the Site, three ground water traces were conducted using fluorescein, eosine, and sulphorhodamine B. The geology field work strongly suggest that the geology map by Wilson, Jr., (1965) is incorrect for the area around the Dump. His map shows that the Dump and much of the surrounding area is on the Pierce Limestone which is a shaly aquiclude. However, massive limestones characteristic of the Ridley Karst Aquifer were found throughout this area. Therefore, the ground water in the vicinity of the Dump is interpreted to move through the Ridley Karst Aquifer Limestone immediately below the lower Ridley Confining Unit to emerge at the Ridley's contact with the underlying Pierce Limestone. The injected dyes were detected only at the main spring at the toe of the Dump. Rapid movement of the tracing agents demonstrate that most of the ground water is moving through solution-enlarged joints and possibly conduits. The constructed geologic and topographic cross-section shows that injected dyes moved down the western flank of an anticline along fractures with average trends of N40°W and N45°E and then, along the strike of a synclinal trough. The three ground water traces demonstrate that the recharge area for the spring at the toe of the Dump is moderately large. The spring's recharge area is densely developed with numerous industries and several UST's. In addition, much of the stormwater runoff from streets and parking lots is diverted to sinkholes that are hydrologically connected to Rosebank Dump Main Spring. As a result, there are many potential sources for the Spring's contamination other than the Dump. The geologic interpretation of the Site has important ramifications regarding future water quality monitoring. The spring at the toe of the Dump is the best place to monitor. Monitoring wells would be of limited value for this site. If TDEC requires monitoring wells, they must be shallow so that the Pierce Limestone is not pierced to prevent contamination of the underlying Murfreesboro Aquifer.

INTRODUCTION AND PURPOSE

The Tennessee Department of Environment and Conservation-Division of Superfund met with the City of Murfreesboro on January 8, 1998 to discuss the State of Tennessee Inactive Hazardous Substance Site #75-528, known as the Rosebank Dump site. Subsequent to that meeting, the City chose to participate in the Tennessee Voluntary Cleanup, Oversight, and Assistance Program that involves a Site evaluation and risk assessment. As part of the Site evaluation, a ground water tracing study was conducted to determine the approximate recharge area of the spring that emerges at the toe of the Dump. This paper presents the results of three ground water traces that were performed, as well as, a geologic overview of the structural controls (folds and fractures) on ground water movement in the area. In addition, the paper discusses results of the ground water tracing for interpreting potential sources of contaminants in the spring water.

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SITE LOCATION AND BACKGROUND

The Rosebank Dump is located in Rutherford County on approximately 12 acres about one-eighth mile northwest of the intersection of U.S. Highway 41/70S and 96 within the City limits of Murfressboro, Tennessee (Figure 1). The Site is bordered to the southwest by the CSX railroad, to the south by West Lokey Street, to the southeast by Rosebank Drive, to the northwest by the West Fork of the Stones River, and to the north—northeast by West College Street. The exact extent of the landfill is not known at this time.

The Site is reported to have begun operation in the early to mid-1950's, and discontinued operation around 1964. Unauthorized dumping by residents is believed to have occurred throughout the 1960's, 1970's, and 1980's. The Site had a thick growth of trees and bushes during the field work, but this has recently been cleared.

HYDROGEOLOGIC SETTING

The Site is located in the Central Basin physiographic province and is underlain by limestones of Ordovician age that have on a regional scale been gently upwarped to form the Nashville Dome. The geologic map of the Murfreesboro Quadrangle (Wilson, Jr., 1965) shows that the Site is on the Pierce Limestone. This interpretation of the geology may be incorrect. The Pierce Formation is a shaly, thin-bedded limestone that confines water beneath it in the Murfreesboro Aquifer and perches water above it in the Ridley Limestone. The Ridley Limestone, which is the most karstic formation in Rutherford County, overlies the Pierce Formation. A zone of thin-bedded limestone with shale partings occurs 20 to 35 feet above the base of the Ridley Limestone and locally can perch water (Figure 2; Crawford, 1988). As a result, the Pierce Formation can easily be mis-identified as the Lower Ridley Confining Unit. This appears to be the case around the Site which has been mapped as the Pierce Formation although massive bedded limestones, indicative of the Ridley Limestone occur, as well as, sinkholes (one used as a dye injection point). Therefore, it appears that the Dump rests on the lower Ridley Limestone and that most, if not all of the springs monitored for the ground water tracing, emerge at the contact of the lower Ridley Limestone and the Pierce Formation.

Insight to ground water flow direction in the vicinity of the Rosebank Dump was provided by Moore et.al., 1969 who delineated synclinal troughs in the area based on a constructed structural contour map drawn over the Ridley Limestone. More recently, ground water tracing and fracture trend analysis by Ogden et. al., 1997 and Ogden, 1998 have provided important clues to ground water flow in areas near the Rosebank Dump.

METHODS

Well and Karst Inventory

The first task of conducting the well inventory was to obtain drillers' logs of wells in the study area from the Tennessee Division of Ground Water Protection. The Site is located on section 3 of the Murfreesboro Quadrangle, and 29 wells are listed for that section. None of the addresses in the well files are close to the Site. A door-to-door well inventory was conducted only along the roads adjacent to the Site including Riverside Drive, Rosebank Drive, and W. Lokey Ave. Industries served by City water that supplement their water supply with a well are required to have a check valve to prevent mixing of the waters. Therefore, the Murfreesboro Water and Sewer Department was contacted to see if any industries near the Dump have water wells.

A karst inventory was performed to search for springs, cave streams, and karst windows within the study area that could be used as dye injection points or dye monitoring locations. Observational canoe trips were made on the West Fork of the Stones River, and pertinent portions of Lytle Creek were waded to locate springs. Two foot contour maps of a one-mile radius around the Dump were obtained from the City to help search for sinkholes that could be used as dye injection points. Enclosed depressions within the one-mile radius were visited, of which many were man-made depressions rather than natural sinkholes. Finally, proprietary cave files of the Tennessee Cave Survey were checked to search for caves that might contain a stream within the one-mile radius.

Orientation Data

Ground water in karst areas flows primarily along solution-enlarged fractures (joints) and caves that have developed along the joint trends. Therefore, to help predict which way ground water flows in the study area, 118 joint measurements were made near the confluence of Lytle Creek and the West Fork of the Stones River using a Brunton Compass. An indirect method of measuring fracture orientations is to delineate photo-interpreted fractures from aerial photographs. One hundred and thirty-eight photo-lineaments were delineated from 1:20,000, black and white, stereo aerial photographs of 1958 vintage as part of the Old Murfreesboro City Dump Project (Ogden, 1997). Since the two dumps are only about one-half mile apart, the data is applicable to both sides.

Ground Water Tracing

The ground water traces were conducted using three fluorescent dyes: eosine (pink), fluorescein (green), and sulphorhodamine B (red). These dyes are non-toxic and routinely approved for use by various divisions of the Tennessee Department of Environment and Conservation. Prior to conducting the traces, the Tennessee Underground Injection Control Program was notified for their voluntary dye tracing registration program. Injected dyes are detected by using activated charcoal packets that absorb and concentrate the level of dyes in the water. Each charcoal packet, called a "trap", was suspended in the waters expected to receive the dyes on a stiff wire connected to a concrete base, referred to as a "gumdrop". Prior to dye injection, the traps were placed in the waters for approximately a week to test for background concentrations. Two measurements of background concentrations were made at most sites since the dyes are common coloring agents and frequently found as "contaminants" in the ground water. Once background levels were determined, new packets were set out immediately prior to injection. After injection of the dyes, the packets were changed at the approximate intervals: 1) 3rd day, 2) 7th day, 3)14th day, 4) 23rd day, and 5) 37th day. Sample name, number, time and date of collection were recorded on the sampling bag and on the chain-of-custody sheet at the time of collection. Disposable latex gloves were worn at all times during sample collection and handling. A new pair of gloves where used at each site to avoid cross-contamination of samples. The samples were then shipped overnight to the laboratory for analysis.

RESULTS

Well Inventory

Only two wells were located within the one-mile radius east of the West Fork of the Stones River. Both are on the south side of W. Lokey Avenue between the CSX railroad and the West Fork of the Stones River. The well closest to the River was not in use, covered, and inaccessible. The other well is being used only for cattle, and the house is connected to City water. Discussions with Murfreesboro Water and Sewer Department personnel indicate that no industries within a one-mile radius of the Dump are known to have a well.

Monitoring Locations

Figure 1 shows the locations of sites monitored for dye. Sites 1 and 2 are the upgradient and downgradient stations on Lytle Creek, respectively. Sites 3 and 10 are the upgradient and downgradient stations on the West Fork of the Stones River, respectively. Three springs emerge at the toe of the Rosebank Dump, depending on the amount of rainfall. These were designated: Main Spring (5A), Side Spring (5B), and Overflow Spring (5C). The Side Spring and Overflow Spring did not flow at all times during the monitoring period. A small stream channel combines with the flow of the springs at the toe of the Dump. This station was designated the Rosebank Dump Side Stream (4). The head of this stream is a large pipe that carries storm water runoff. The stream did not flow throughout the entire monitoring period. Three springs were monitored below the confluence of the Rosebank Dump Main Spring and the West Fork of the Stones River. These are shown on Figure 1 as station 6 (Taco Spring), station 7 (Ford Spring), and station 11 (Mulch Spring). Three other springs were also monitored
: Oaklands Mansion Spring (12) which forms the head of Sinking Creek; Sink Creek Spring (14) which enters Sinking Creek about 1½ miles downstream from Oakland Mansion Spring; and Murfree Spring (13) which forms a major tributary to Lytle Creek. Finally, Sinking Creek (15) was monitored at a point approximately 3½ miles downstream from the Oaklands Mansion Spring. Station 15 is located about 2 miles north from the upper end of Figure 1, and thus is not shown.

Ground Water Tracing

On May 18th, 1998, three dyes were injected near the Dump (Figure 1). All of the injection points appear to be geologically below the Ridley Confining Unit. The first dye injection was into a small sinkhole located approximately 50 feet west of the CSX railroad across from PROCON-Division of Roehlen Industries. Two pounds of fluorescein dye was pre-mixed with water and flushed with approximately 1250 gallons of water provided by the Murfreesboro City Fire Department. Then, two pounds of eosine dye, pre-mixed with water, were injected into a sinkhole on the Hardees Property near the intersection of Lokey Street and Broad Street. The dye was again flushed with approximately 1250 gallons of water. Then, two pounds of sulphorhodamine B were injected into a trash-filled sinkhole on the Chromalox Property located at the southwest corner of the intersection of Lokey Street and Memorial Boulevard. The dye was flushed with approximately 2500 gallons of water.

The relationship of injection points to the monitored springs, Lytle Creek, and the West Fork of the Stones River locations are shown on Figure 1. The hydrologic connection between the Rosebank Dump Main Spring and the Chromalox and Hardees sinkholes is presented as a *schematic* geologic cross-section on Figure 3.

Three days after injection (May 21st), the charcoal traps were retrieved. No rainfall had occurred. At that time, the dye detector at the Rosebank Dump toe spring tested positive for fluorescein and sulphorhodamine B. By the 7th day after in injection, larger quantities of these dyes were emerging from the Dump spring. Only trace amounts of rainfall occurred between the sampling events. Eosine began to emerge from the Rosebank Dump spring sometime between the 7th (May 25th) and 14th (June 1st) day after injection. About one inch of rainfall occurred during that period. All three dyes were still detected from the charcoal packets retrieved 23 days (June 10th) after injection. Nearly six inches of rainfall occurred between the 14th and 23rd days of sampling. Samples retrieved 37 days (June 25th) after dye injection still showed the presence of fluorescein, eosine, and sulphorhodamine B, but at lesser concentrations than on the 23rd day (June 10th). Approximately 1.5 inches of rain fell between the 23rd and 37th days of sampling. No other site showed increased levels of the dyes above background concentrations except possibly the Rosebank Dump Side Spring or the Rosebank Dump Overflow Spring. On the 4th (June 10th) and 5th (June 25th) sampling events after injection of the dyes, these two sites showed a greater than 100 fold increase in fluorescein concentration over background, but no significant increase in eosine or sulphorhodamine B above background levels. Since the Side Spring, Overflow Spring, and the Main Spring are only about 50 feet apart, all three of the dyes would be expected if the increase in fluorescein were a result of the dye injections. Of all the dyes used for ground water tracing, fluorescein is commonly found in the environment due to sources of contamination such as radiator fluid. No water at the monitoring locations showed coloration throughout the investigation.

Mulch Spring and the Old Murfreesboro Dump Dye Trace

Mulch Spring was monitored during the ground water tracing at the Old Murfreesboro City Dump. Mulch Spring is located along the West Fork of the Stones River next to the newly constructed City Greenbelt park on the opposite side of the River from the Rosebank Dump. A drainage pipe pours water onto the charcoal packets at Mulch Spring during storm events. The pipe appears to trend in a direction that drains several small industries and shops that could be sources of dyes. At the request of TDEC, Mulch Spring was monitored during the tracing activities at the Rosebank Dump, as well. Two sets of background results for dye, showed that the spring had higher levels of dye than peak levels found during the tracing at the Old Murfreesboro Dump. This demonstrates that the dyes found in Mulch Spring during the first tracing were a result of contamination from sources upgradient of the spring and not from dyes injected around the Old Murfreesboro Dump as was initially suspected. The levels of dye at Mulch Spring never exceeded background during tracing at the Rosebank Dump.

Orientation Data

Figures 4 and 5 present the orientation measurements for the photo-lineaments and joints, respectively. As mentioned previously, the photo-lineaments were delineated for the Old Murfreesboro City Dump project. The joint and photo-lineament orientations are very similar with the data being centered generally around N40°W and N45°E. These orientations are very close to the directions that the dyes moved from the injection points to the Rosebank Dump Main Spring. This demonstrates the control of solution-enlarged fractures on the movement of ground water.

Another important control is the location of synclinal troughs. Subtle synclines and anticlines occur "superimposed" on the Nashville Dome. Moore et. al., 1969, attempted to delineate some of these folds in the Upper Stones River Basin by constructing a structural contour map with the top of Ridley Limestone as a datum. They found that the anticlines are generally dome-shaped and located in the interstream areas. They also discovered that the synclines are elongated, and the troughs follow the trends of the streams and forks of the streams. Comparing the location of the synclinal troughs shown on Figure 6 to the results of the dye tracing demonstrates some control of ground water flow by the north/northwest oriented fold axes. Figure 6 has been modified from Moore et. al., 1969, original map to show the anticlinal axis that runs approximately through the Square of Murfreesboro. The ground water from the Chromalox and Hardees injection points appears to move down the western flank (down-dip) of the anticline flowing along the primary joint directions towards the synclinal trough. The ground water south of the Rosebank Dump Main Spring moves in a northwest direction primarily along the strike of the rocks and plunging synclinal trough.

Implications of Other Dye Traces for Delineating Recharge Areas

Other ground water traces have been conducted to springs in Murfreesboro by Ogden, 1998, that helped to delineate the recharge area of the Rosebank Dump Main Spring. The first was to Murfree Spring and the second was to the Oaklands Mansion Spring (Figure 1). This information, combined with topographic divides and surface water boundaries enabled the approximate recharge area for the Rosebank Dump Main Spring to be drawn.

Implications of Results for Interpreting Potential Sources of Contaminants

The ground water tracing results demonstrate that a large, densely developed portion of Murfreesboro contributes recharge waters to the Rosebank Dump Main Spring. This includes two State-listed Superfund Sites, many industries that use and store chemicals, street runoff, and numerous UST sites. One or more of the UST sites may be causing the occasional petroleum odor of the spring. Taco Spring commonly had a strong diesel or kerosene odor, as well. As a result, the contaminants found at the Rosebank Dump Main Spring cannot with certainty be attributed to the Dump. Therefore, without a thorough inventory of industries and the chemicals they use, followed by further dye tracing, it will be difficult to distinguish possible chemical degradation of the ground water by the Dump from other potential sites.

SUMMARY AND CONCLUSIONS

Three ground water tracers were injected into sinkholes on May 18th, 1998 in the vicinity of the Rosebank Dump. Within three days, the fluorescein and sulphorhodamine dyes were detected at the Rosebank Dump Main Spring. Within two weeks after injection, the eosine dye had also travel to the Spring. No other monitored site had dye concentrations above background except possibly two small springs located about 50 feet from the Rosebank Dump Main Spring. Observations of the rock outcrops near the Dump suggest that Wilson, Jr., (1965) mis-identified the lower Ridley Confining Unit, mapping it as the Pierce Formation. Therefore, much of the area around the Rosebank Dump is Ridley Limestone, not the Pierce Limestone as Wilson, Jr., (1965) shows. It is therefore believed that the ground water moves within the lower Ridley Karst Aquifer perched above the Pierce Limestone. Ground water from the injection points is believed to move down the western flank (down-dip) of an anticline and then generally along the strike of a plunging synclinal trough through solution-enlarged joints and possibly solution conduits.

The results of the investigation have important ramifications regarding monitoring water quality at the Rosebank Dump. The best place to monitor is the Main Spring that emerges from the toe of the Dump. Monitoring wells are not recommended, but if required, it is essential that they are shallow and not pierce the Pierce Limestone. Drilling through the Pierce could possibly lead to contamination of the underlying Murfreesboro Limestone Aquifer.

The ground water traces conducted for this investigation and others to nearby springs show that the recharge area is moderately large for the spring that emerges from the toe of the Rosebank Dump. Within that recharge area, there are numerous industries, two State-listed Superfund Sites, several UST's, and sinkholes receiving stormwater runoff from streets and parking lots. Therefore, a large number of potential sources could be responsible if contaminants are found in the Rosebank Dump Spring.

REFERENCES

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

Moore, G. K., C. R. Burchett, and R. H. Bingham, 1969, Limestone hydrology in the upper Stones River basin, central TN: Tenn. Dept. of Cons.-Div. of Water Res., 58 p.

Ogden, A. E., 1997, Ground water tracing results at the Murfreesboro Old City Dump, Rutherford Co., TN: Contract Rept. to the City of Murfreesboro, 107 p.

Ogden, A.E., 1998, Ground water tracing results in Rutherford County-Year 2: Contract Rept. to the Rutherford County Planning Commission, 83 p.

Wilson, Jr., C.W., 1965, Geologic map and mineral resources summary of the Murfreesboro Quadrangle, TN: Tenn. Div. of Geology, 5 p., 1 plate.

Ogden Fig. 1

Ogden Fig. 2

Ogden   Fig. 3

Ogden Fig. 4 & 5

Ogden Fig. 6

DNAPL ENTRY, DISSOLUTION AND DIFFUSION IN FRACTURED SHALE SAPROLITE

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ABSTRACT

Dense nonaqueous phase liquids (DNAPLs) have caused extensive groundwater contamination problems in many regions. When released into a fractured soil or rock, DNAPLs will enter fractures as an immiscible phase and these fractures can serve as rapid migration pathways resulting in very erratic distribution of contaminants. An initial entry pressure must be overcome for immiscible entry into saturated fractures or porous matrix and this is controlled by the fracture/pore aperture and the interfacial tension between the DNAPL and the water. Previous experiments performed with an undisturbed column of fractured saprolite from the Oak Ridge Reservation in east Tennessee, showed that DNAPLs can enter fractures at relatively low pressures. This suggests that even small DNAPL spills may penetrate to significant depths in fractured materials. Experiments are currently underway to further investigate physical and chemical factors influencing transport of a typical DNAPL, trichloroethylene (TCE), in saprolite. The experiments involve injecting immiscible phase TCE into undisturbed columns of fractured saprolite, then dismantling the column to measure the distribution of immiscible and dissolved TCE. Diffusion plays a particularly important role because as the DNAPL dissolves it diffuses into the fine-grained matrix. This can potentially lead to rapid disappearance of the immiscible phase and can help to localize contamination. However, this may greatly increase the difficulty and time required for remediation, as diffusion will also control the rate of contaminant transport back out of the matrix.

INTRODUCTION

Widespread industrial use of chlorinated solvents (DNAPLs) have led to an extensive groundwater contamination problem in North America. DNAPL's unique physical, chemical, and biological properties have combined to exacerbate this problem in fractured geologic material. At the Oak Ridge Reservation (ORR) in east Tennessee, a common disposal practice in the 1940s - 1960s was to bury waste, including DNAPLs, in shallow unlined trenches excavated into the shale saprolite (residual soil which retains the structure of the parent bedrock). These practices, in combination with the region's high precipitation and shallow water tables, have produced a complicated contamination problem. Dissolved DNAPL-contaminated ground water has been documented at depths of up to 83 m in Bear Creek Valley (Haase and King, 1990; Kueper et al., 1992) and a shallow plume of dissolved DNAPLs up to 50 m long exists at Waste rea Group 5 (WAG5) in Melton Valley (Jardine, personal communication). However, very few studies involving DNAPLs in the shale saprolite have been performed and none of these have focused on the role that dissolution and diffusion play in contaminant mass transfer.

The main objectives of this research are: (1) to investigate immiscible phase TCE entry into the fractures and porous matrix of weathered shale saprolite and, (2) to look for evidence of TCE dissolution and diffusion into the matrix.

DNAPL MIGRATION IN FRACTURED POROUS MATERIALS

DNAPL contamination in saturated fractured material can be an extremely complex problem that is distinctly different than in granular material. To date, there have been very few experimental investigations of DNAPL

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behavior in fractured clay-rich materials. In the conceptual model developed (Figure 1), a DNAPL spill can travel through the soil as a wholly separate liquid phase. When the DNAPL reaches an aquitard or a layer of low permeability, it may accumulate and form a pool. If the aquitard is fractured, the DNAPL may migrate through the fractures to an underlying aquifer given that the fracture entry pressure is overcome (Keuper and McWhorter, 1991). Typically, the DNAPL will enter the largest aperture fractures first because the required entry pressure will be the least. Theoretically, a continuously connected liquid phase will be able to penetrate smaller and smaller fractures as it travels downward because the height of the DNAPL column will grow, thus increasing capillary pressures at the advancing front (Keuper and McWhorter, 1991). If the capillary pressure exceeds the entry pressure at matrix pore throats, pure phase DNAPL can enter the matrix pore space (Slough et al. in press). Parker et al. (1994) proposed that dissolution of the DNAPL and its subsequent diffusion into the immobile pore water of the matrix adjacent to the fracture could cause disconnection of the immiscible phase, thereby reducing its ability to penetrate smaller fractures (Figure 2). The disconnected blobs of residual DNAPL will eventually dissolve completely and owing to chemical gradients diffuse into the matrix. These processes contribute to erratic distributions of spilled DNAPLs and a high degree of uncertainty in predicting the fate of a DNAPL spill or determining the performance of a remediation strategy.

Predicting DNAPL entry into fractures is problematic because there is a great deal of variability between different methods of estimating fracture aperture or matrix pore size (Hinsby et al., 1996; O'Hara, 1997; and Cropper, 1998). Studies in Danish and Canadian clay tills have noted that immiscible DNAPL transport is confined to fractures and biopores, bypassing the porous matrix (Hinsby et al., 1996; O'Hara, 1997; Jorgensen et al. 1998). O'Hara (1997) found evidence of matrix diffusion after dismantling and sampling a column of Canadian clay till. Using a column of saprolite from Oak Ridge, Cropper (1998) found that immiscible phase fracture entry occurred at very low capillary pressures (~10 cm of head), but matrix entry also occurred at relatively low capillary pressures (~140 cm of head), the kind that could easily be encountered with even a small spill. However, since Cropper used a clear, very low solubility DNAPL, he could not dismantle the sample and directly observe evidence of matrix entry. Also, it is not clear from Cropper's study whether the observed "matrix entry" represents actual matrix pore throat entry or entry of a smaller fracture set. These studies show that there is a great deal of variability in how a DNAPL (in both miscible and immiscible phases) is likely to be distributed in clay-rich fractured materials.

MATERIALS AND METHODS

The authors are currently preparing to carry out a series of experiments utilizing two large undisturbed saprolite columns collected from the Special Waste Storage Area 7 (SWSA7) area of Melton Valley on the ORR. The column material is very heterogeneous and consists of highly fractured and weathered shale saprolite derived from the Cambrian aged Dismal Gap Formation (formerly Maryville Limestone) (Hatcher et al., 1992). Despite intense weathering, the characteristic structures including bedding and three sets of orthogonal fractures are visibly intact. Methods for collecting undisturbed columns and making them solvent resistant have been developed by a previous researcher who has collected columns from the same site (Cropper, 1998). After collection, the columns are trimmed in preparation for fitting with end caps resulting in a length between 40 and 50 cm and a diameter of about 23 to 25 cm. The laboratory set up, which consists primarily of high precision injection system and pressure transducers, is illustrated in figure 3.

The first of two experiments will begin by injecting TCE to a column to measure the fracture entry pressure and calculating the resultant fracture aperture. This pressure will be stepped up until TCE exits the column after which the inflow will be stopped and the column will be allowed to sit for 2-3 weeks giving the TCE time to disslove and diffuse into the porous matrix. The column will be dismantled and sampled using a microcore technique developed by O'Hara (1997) to measure the concentration and extent of diffusional contaminant "haloes" adjacent to the fractures. The second experiment will be similar to the first, but a capillary barrier will be added to the column to prevent outflow of TCE, allowing capillary pressures to build as TCE is added. This will continue until matrix entry by immiscible phase is believed to have occurred. Again, the column will be dismantled and sampled and high concentrations within the matrix will be indicative of immiscible entry.

CONCLUSIONS

The research described above is expected to shed light on the processes that control the migration and fate of DNAPL spills in fractured clay-rich material which are common in east Tennessee and along the Appalachians. Previous studies have shown that even small DNAPL spills have the potential to contaminate large amounts of material. Both matrix entry of immiscible phase and matrix diffusion of dissolved phase have the ability to limit the extent of contamination and even cause the pure phase DNAPL to "disappear" from the fractures. While this may help localize the contamination, it can also be problematic for current remediation strategies as the rate of diffusion will also control how fast the contaminant can be removed from the matrix.

REFERENCES

Cropper, S.C. 1998. Experimental measurements of capillary pressure-saturation drainage of air and DNAPL in fractured shale saprolite. Masters thesis, University of Tennessee, Knoxville.

Haase, C.S., and H.L. King. 1990. Report and preliminary assessment of the occurrence of dense, non-aqueous phase liquids in the Bear Creek Burial Grounds, Hazardous Waste Disposal Unit at the Oak Ridge Y-12 Plant. U.S. Department of Energy, Report Y/TS629.

Hatcher, R. D., P. Lemiszki, R. Dreier, R. Ketelle, R. Lee, D. Lietzke, W. McMaster, J. Foreman, and S. Lee 1992. Status Report on the Geology of the Oak Ridge Reservation. U. S. Department of Energy, Report ORNL/TM-12074**.**

Hinsby, K., L.D. McKay, P. Jorgensen, M. Lenczewski, and C.P. Gerba. 1996. Fracture aperture measurements and migration of solutes, viruses, and immiscible creosote in a column of clay-rich till. Ground Water 34(6): 1065-1075.

Jardine, P.M. Oak Ridge National Laboratory, Environmental Sciences Division.

Jorgensen, P.R., K. Broholm, T.O. Sonnenborg, and E. Arvin. 1998. DNAPL transport through macroposour clayey till columns. Ground Water 36(4): 651-660.

Keuper, B.H., and D.B. McWhorter. 1991. The behavior of dense, nonaqueous phase liquids in fractured clay and rock. Ground Water 29(5): 716-728.

Keuper, B.H., C.S. Haase, and H.L. King. 1992. Leakage of dense, nonaqueous phase liquids from waste impoundments constructed in fractured rock and clay: theory and case history. Canadian Geotechnical Journal 29: 234-244.

O'Hara, S.K. 1997. Solvent DNAPL flow and matrix diffusion in natural fractured clay: a large column experiment. Masters Thesis, University of Waterloo, Canada.

Parker, B.L., R.W. Gillham, and J.A. Cherry. 1994. Diffusive disappearance of immiscible-phase organic liquids in fractured geologic media. Ground Water 32(5): 805-820.

Parker, B.L., J.A. Cherry, and R.W. Gillham. 1996. The effects of molecular diffusion on DNAPL behavior in fratured porous media. Chapter 12, pages 355-393 in J.F. Pankow and J.A. Cherry, Dense Chlorinated Solvents and other DNAPLs in Groundwater, Waterloo Press, Portland, OR. 522 pp.

Slough, K.J., E.A. Sudicky, and P.A. Forsyth. 1999. Importance of rock matrix entry pressure on DNAPL migration in fractured geologic materials. *In press*

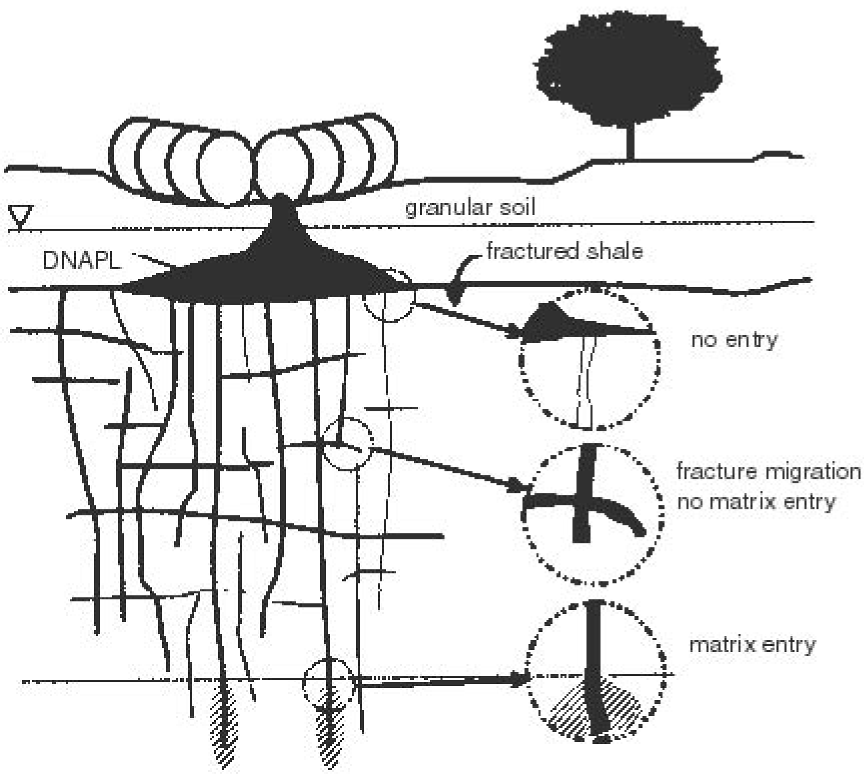

Figure 1. Immiscible DNAPL entry into fractures and matrix is illustrated. At the top inset, capillary pressure is insufficient for fracture entry. At the middle inset, capillary pressure is sufficient for fracture entry, but not matrix entry. At the bottom inset, capillary pressure exceeds matrix entry pressure and immiscible phase DNAPL can enter the porous matrix. (Adapted from Cropper, 1998).

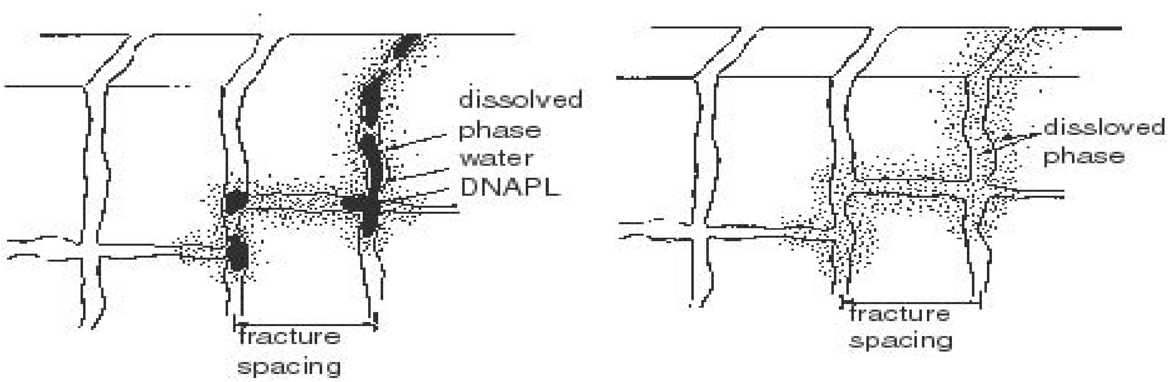

Figure 2. Effects of dissolution and matrix diffusion is illustrated. On the left, the processes contribute to disconnect columns of DNAPL. On the right, pure phase DNAPL has disapeared leaving "haloes" of dissolved phase in the matrix adjacent to the fracure. (Adapted from Parker et al., 1996).

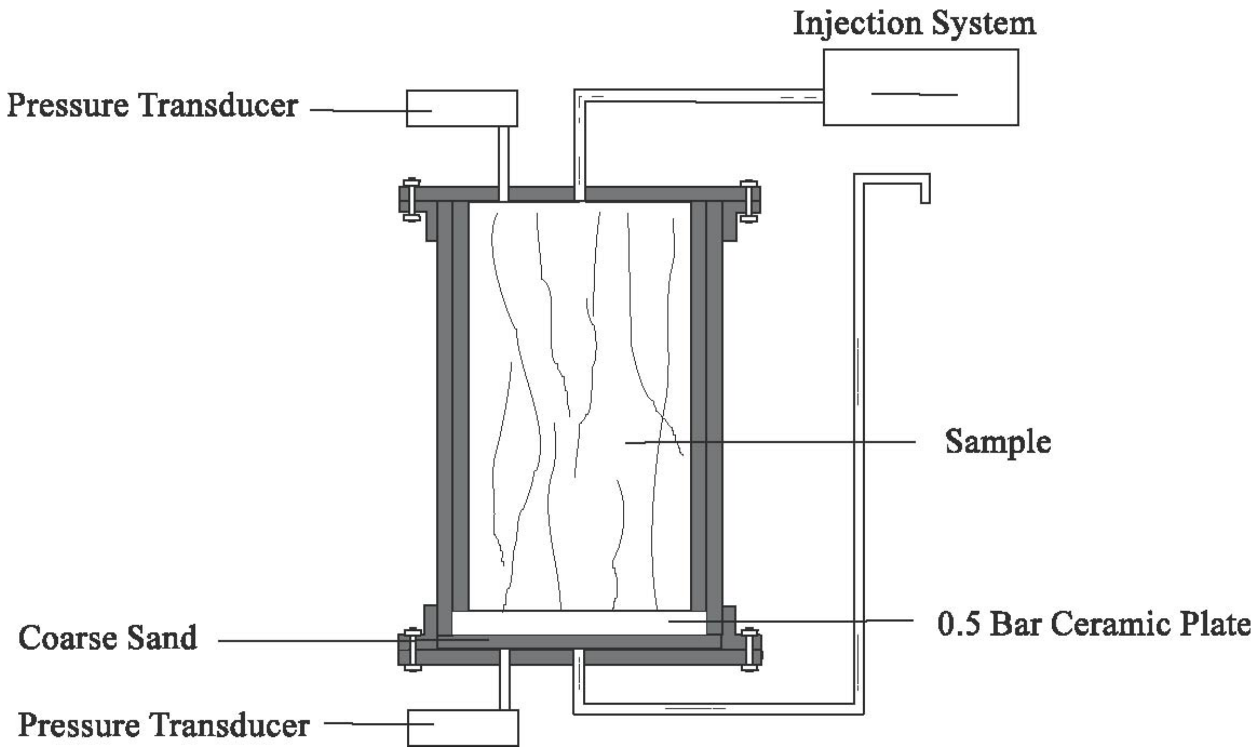

Figure 3. Illustration of the laboratory set-up.

BIODEGRADATION OF TRICHLOROETHYLENE IN FRACTURED SHALE SAPROLITE

Melissa Lenczewski[1*], Larry D. McKay[2], John Sanseverino[3], and A. Layton[4]

ABSTRACT

Research is currently underway to investigate factors influencing biodegradation of trichloroethylene (TCE) in fractured shale saprolite. The study is being performed using laboratory samples of fractured shale saprolite from an uncontaminated site (Solid Waste Storage Area #7, SWSA7) and a contaminated site (Waste Area Grouping #5, WAG5) at Oak Ridge Reservation (ORR), Oak Ridge, TN. Samples of the soil and water from the SWSA7 and WAG5 are assayed to examine microbial community structure and determine whether TCE degrading microorganisms are present. Microcosms were constructed to determine the rate of TCE biodegradation plus to observe changes in microbial community structure. This research will help develop a better understanding of the potential for TCE biodegradation in these widespread soils will assist regulators and operators in developing clean-up or containment strategies.

INTRODUCTION

Dense nonaqueous phase liquids (DNAPLs), especially chlorinated solvents such as TCE, have been widely used as industrial solvents since the 1960s and many of these solvents are commonly found in groundwater at industrial sites or landfills. To date, most of the research on DNAPL behavior in the subsurface has been carried out in granular aquifer materials or fractured, low porosity rock. Much less research has been carried out on DNAPLs in fractured, higher porosity clays or shales, which are common geologic materials in Eastern Tennessee.

Although TCE is biodegradable under some conditions (Fogel et al., 1986; Little et al., 1988; Chauhan et al., 1998; McCarty et al., 1998, and others), there are few *in situ* studies of biodegradation of dense chlorinated solvents in clay-rich geologic materials. As a result, the potential for biodegradation in these materials must be largely inferred from studies in granular aquifer materials or shallow soil horizons. The dissolved phase of many chlorinated solvents tends to be recalcitrant, that is it often does not readily degrade biotically in groundwater. The rate of biodegradation of these compounds is widely variable and depends on the properties of the contaminant, its distribution and the microbiological and geochemical environment. Many previous biodegradation studies have focused on TCE, which is one of the most common organic contaminants in groundwater, and an extensive literature base has developed on this subject. Although these studies are very useful, it is expected that there could be substantial differences in TCE biodegradation between fractured saprolite and granular materials because of the great differences in their physical and geochemical properties. Particularly, there is little known about the distribution of microbial communities in fractured clays, and whether degrading microorganisms and nutrients can enter or survive in the fine-grained matrix where most of the contaminant mass is expected to reside.

The only field example of suspected biodegradation of chlorinated solvents in a clay-rich material that we are aware of is at a former disposal site in WAG5 at ORR. A 50 m long contaminant plume containing TCE and its daughter products has been detected in the highly weathered and slightly weathered shales adjacent to buried waste pits (Jardine et al., in preparation). Little is known about the original contents of the trenches or about the history of waste disposal at the site. The monitoring site is located in the southeast portion of WAG5 and consists of a 35 m long transect of multilevel sampling wells along a discharge zone adjacent to existing waste trenches (Figure 1). In the waste trenches, volatile organic carbons (VOCs) including TCE are at their highest concentration with decreasing concentration away from the trench. Downgradient observation wells in the fracture zones and in the matrix indicate the presence of TCE, DCE, VC, ethylene, and methane which suggest anaerobic biodegradation.

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Preliminary microbiology data (Table 1) reveals the presence of anaerobic heterotrophs, methanotrophs, and sulfate-reducing bacteria. The methanotrophs are suggestive of aerobic biodegradation by cometabolism of TCE with methane. The methane may possibly be produced by methanogenic bacteria, but this has not yet been determined. Toluene-oxidizers and iron-reducers were not detected. These data suggest two possible mechanisms for natural attenuation of TCE: first, anaerobic biodegradation of the highly chlorinated compounds below the water table with production of methane; and second, aerobic biodegradation in oxygenated zones, at the seep or neat the water table resulting in nearly complete biodegradation of TCE. However given the diversity of microorganisms and pathways for TCE biodegradation the responsible microorganisms can not be predicted.

The main objectives of this research are: 1) identify potential TCE degrading microorganisms in samples of the groundwater and the fractured saprolite, 2) determine whether biodegradation of dissolved TCE in saprolite can be reproduced in the laboratory through use of microcosms.

MATERIAL AND METHODS

The experimental investigations will mainly be carried out using samples from two field sites, located about 1 km apart, and in the same geologic unit (the Cambrian age Dismal Gap Formation). Samples of uncontaminated weathered shale and groundwater will be collected from an existing research site in the proposed SWSA-7 while contaminated groundwater samples will be collected from WAG5. The physical and chemical properties of the weathered shales at this site have been extensively characterized (Hatcher et al., 1992; Solomon et al., 1991). The saprolite is expected to be representative of many areas in the southern Appalachians which are also underlain by highly weathered shale and other clay-rich fractured materials.

A clone library was used to identify the dominate species of microorganisms that are in a sample of water or soil and aid in determining the role they play in the groundwater ecology. The 16S rRNA that was obtained via PCR amplification with universal or domain specific primers will then be cloned into *E. coli* using the TOPO Cloning Kit (Invitrogen, Carlsbad, CA). The plasmid from individual colonies will be purified then sent to the Molecular Biology Sequencing Facility (MBSF) on the University of Tennessee campus. The MBSF returned the sequence of the 16S rRNA then were analyzed using GenBank or Ribosomal Database Project web pages to determine the identity of the organism and place it on the phylogenetic tree.

Microcosm studies are being conducted in a manner consistent with experiments done by Johnston et al. (1996). Uncontaminated groundwater, contaminated groundwater, and soil slurries are tested using known quantities of TCE (50-5 ppb). Additional substrates other than those found at the contaminated site were not be added to the microcosms. Molecular techniques developed above are being applied to different microcosm samples to determine differences in community structure and aid in identification of organisms responsible for biodegradation of TCE.

PRELIMINARY RESULTS AND CONCLUSIONS

A culture-independent phylogenetic approach was used to provide a preliminary analysis of the microbial communities in the groundwater at the SWSA7 and WAG 5 sites. In this approach the small subunit of the ribosomal RNA (16S rRNA) was amplified from DNA extracted from groundwater samples and cloned to create 16S rDNA libraries. 110 clone sequences were analyzed from the uncontaminated SWSA7 groundwater sample and 2 contaminated ground water samples from the WAG5 site. The majority of sequences at the SWSA7 site contained sequences which could be placed into known phylogenetic groups, whereas approximately 50% of the clone sequences from the WAG5 site could not be placed into known phylogenetic groups. Sequences with high similarity to known organisms or clones from other groundwater samples (Dojka et al, 1998) are shown in Table 2. The distribution of clone sequences into phylogenetic groups was similar for the libraries constructed from 2 different wells at WAG5 but was different for the SWSA7 library. It is unclear as to whether the differences in the clone sequences are due to the presence of contaminants or simply reflect differences in the geochemistry of the sites. This analysis also did not identify the microorganisms responsible for TCE degradation because a number of different microorganisms in different phylogenetic groups are capable of transforming TCE. These cloned sequences provide a background database for future experiments including the enrichment and isolation of organisms involved in TCE transformation and development of 16S rDNA oligonucleotide probes for monitoring specific populations.

ORR data suggests that anaerobic and some aerobic biodegradation of TCE is occurring at the contaminated site. It is anticipated that organisms with the potential to degrade TCE are present in the uncontaminated and the contaminated site and their activity will be induced by the presence of TCE. Microcosms studies are utilized to determine rates of biodegradation in controlled laboratory settings. Differences in microbial community structure with varies levels of TCE will aid in determining the types of microorganisms involved in biodegradation of TCE. Samples from the uncontaminated site will yield information about the potential degradation in these materials. The results from this study will also be used to determine the dissolved phase TCE level that will be injected into planned undisturbed column experiments.

REFERENCE

Chauhan, M. A., P. Barbieri, and T. K. Wood. 1998. Oxidation of trichloroethylene, 1,1-dichloroethylene, and chloroform by toluene/o-xylene monoxygenase form Psedomonas Stutzeri OX1. Appl. Environ. Microbiol. 64:3023-3024.

Dojka, M., P. Hugenholtz, S. Haack, and N. Pace. 1998. Microbial Diversity in a Hydrocarbon- and Chlorinated Solvent-Contaminated Aquifer Undergoing Intrinsic Bioremediation. Appl. Environ. Microbiol. 64:3869-3877.

Fogel, M. M., A. R. Taddeo, and S. Fogel. 1986. Biodegradation of Chlorinated Ethanes by Methane-Utilizing Mixed Culture. Appl. Environ. Microbiol. 51: 720-724.

Hatcher, R. D., P. Lemiszki, R. Dreier, R. Ketelle, R. Lee, D. Lietzke, W. McMaster, J. Foreman, and S. Lee 1992. Status Report on the Geology of the Oak Ridge Reservation. U. S. Department of Energy, Report ORNL/TM-12074.

Johnston, J. J., R. C. Borden, and M. A. Barlaz. 1996. Anaerobic Biodegradation of Alkylbenzenes and Trichloroethylene in Aquifer Sediment Down Gradient of a Sanitary Landfill. J. Cont. Hydrogeo. 23:263-283.

Little, C. D., A. V. Palumbo, S. E. Herbes, M. E. Libstrum, R. L. Tyndall, and P. J. Gilmer. 1988. Trichloroethylene Biodegradation by Methane-Oxidizing Bacterium. Appl. Environ. Microbiol. 54:951-956.

McCarty, P. L., M. N. Goltz, G. D. Hopkins, M. W. Dolan, J. P. Allan, B. T. Kawakami, and T. J. Carrothers. 1998. Full scale evaluation of in situ cometabolic degradation of trichloroethylene in groundwater through toluene injection. Environ. Science. Technol. 32: 105-110.

Solomon, D. K., G. K. Moore, L. E. Toran, R. B. Dreir, W. M. McMaster. 1991. Status Report: A Hydrologic Framework for the Oak Ridge Reservation. ORNL/TM-12026.

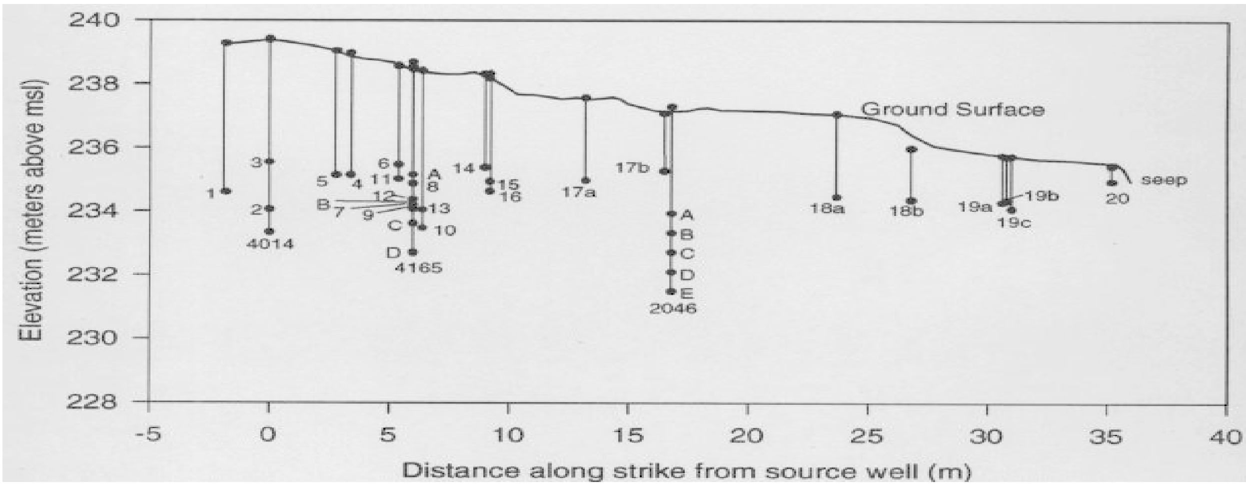

Figure 1: Cross-section of wells at the WAG-5 site showing the location and sampling depths of all groundwater monitoring wells (Jardine, 1997).

Table 1: Concentration of microorganisms from wells at the WAG5 site as determine by three tube MPN (Jardine, personal communication).

	Aerobic		Anaerobic		
Well Number	Methanotrophs	Tolene Oxiders	Heterotrophs	Iron Reducers	Sulfate Reducers
1	210	ND	2400	ND	4
2-4	39	ND	4600	ND	9
6	0.4	ND	2400	ND	ND
8	>2400	ND	4600	ND	ND
10	>2400	ND	2400	ND	15
15	4.3	ND	11000	ND	20
16	1100	ND	>24000	ND	4
17A	24000	ND	11000	ND	0.4
18A	240	ND	>24000	ND	0.4
19A	9.3	ND	>24000	ND	4

ND= Not Detected

Table 2. 16S rDNA clone sequences with matches to Genbank sequeinces with greater than 95% similarity.

SWA7 Site	WAG5 Site (DP10 and DP11)
Pseudomonas putida (97%)	Burkholderia picketti (99%)
Iron-Oxidizing Lithotroph (95%)	Geobacter arculus (96%)
Acinetobacter (98%)	Clostridium bifermentans (97%)
Ultramicrobacterium (97%)	Unidentified Archaeon clone WCHD3-30(97%)
Burkholderia picketti (97%)	Clone group s23 (96%)
Caulobacter vibroides (98%)	
Afipia genosp. 12 (97%)	
Clostridium bifermentans (98%)	

REDUCTIVE DECHLORINATION OF TETRACHLOROETHYLENE BY VITAMIN B12 AND ELECTROKINESIS

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ABSTRACT

The reductive dechlorination of aqueous tetrachloroethylene (PCE) by vitamin B12 and a small direct current (DC) was examined in saturated-soil columns and in water columns. A column (24 by 2 inches) filled with saturated soil and subjected to 200 millivolts (mV) DC and 1 micromolar (µM) vitamin B12 lost 10 µM (approximately 10 percent) of its initial PCE. There was a concurrent 16 µM increase in trichloroethylene (TCE). The other columns, lacking the vitamin B12, DC, or both, did not demonstrate a significant loss of PCE or gain of TCE over the 7-day study. In water columns (12 by 0.2 inches) there was a 38 percent decrease of PCE in control columns subjected to no DC or B12. The PCE decreased 55 percent in water columns subjected to DC (250 mV) without B12, and decreased 75 percent in columns subjected to B12 (1 □M) and DC. There was a lack of PCE degradation products in these columns indicating electrokinesis played a major role in removing PCE. In a 4-day experiment, water columns with 0.1 molar (M) sodium chloride, vitamin B12 and 600 mV DC demonstrated a 44 percent loss of PCE (44 µM) and a concurrent gain of 6 µM TCE. There was only a 20 percent loss of PCE in columns without vitamin B12 or DC and no TCE produced. The greater loss of PCE and the subsequent appearance of TCE support the hypothesis that vitamin B12 and a small DC can catalyze the reductive dechlorination of PCE.

INTRODUCTION

Transition-metal coenzymes such as vitamin B12 have been shown to catalyze reductive dechlorination of non-aqueous phase tetrachloroethylene (PCE) in the presence of strong reducing agents such as titanium citrate (Gantzer and Wackett, 1991; Burris and others, 1996; Lesage and others, 1996; Lesage and Brown, 1997). The dechlorination reaction occurs through an oxidation-reduction reaction, with titanium citrate providing the reducing power. Lesage and Brown (1997) suggest that a vitamin B12/titanium citrate mixture could be used to remove sources of PCE in soil or ground water. While the rates of reductive dechlorination for non-aqueous phase PCE appear promising (Burris and others, 1998), the issue of using a vitamin B12/titanium citrate mixture to dechlorinate PCE in the aqueous phase has not been thoroughly investigated. Delivering a mixture of vitamin B12/titanium citrate into a plume could pose a problem, because the titanium citrate could lose its reducing power and solubility before reaching the targeted PCE. Vitamin B12, however, is water soluble and somewhat resistant to rapid breakdown. A single vitamin B12 molecule can catalyze several oxidation-reduction reactions before losing its catalytic capabilities.

An alternative reducing agent to titanium citrate is needed if vitamin B12 is to be effectively used for reducing PCE in aqueous phase. This study examined a system where a direct current (DC), less than 1 volt, was used in place of the chemical reducing agent. The application of an electric current to facilitate transport of a contaminant in ground water has been termed electrokinesis (Cox and others, 1996). The electrokinesis process changes the oxidation-reduction potential of soil, thus, re-dissolving oxidized metals by reducing them, allowing them to be removed more efficiently. Because electrokinesis can provide reducing power for oxidized metals in saturated soils, perhaps electrokinesis could provide reducing power for the vitamin B12 in an aqueous system.

The primary goal of this research was to determine if aqueous PCE could be reductively dechlorinated in a soil or water column subjected to a small direct current and vitamin B12. The second goal was to do as little harm as possible to the soil microbial population during the process. Thus, the vitamin B12 catalyzed PCE-reduction could be used in conjunction with bioremediation. The third goal was to develop a preliminary conceptual model of the

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mechanism involved in the dechlorination of PCE by vitamin B12 and an electric current. This paper presents the results of the study.

MATERIALS AND METHODS

Two different column types were used to determine if vitamin B12 and a small DC could reductively dechlorinate PCE. Large plexiglass columns (24 by 2 inches) were used to test dechlorination of PCE in a soil/water matrix. These columns had 0.5-inch sampling portals every 3 inches along the length of the column to facilitate sampling. Additional experiments involved dissolved PCE without soil in smaller columns (12 by 0.2 inches) and were completely harvested at predetermined times (4 or 7 days). The electric potential was applied using a constant DC power supply, which supplied a current through platinum wires at the ends of the columns.

The soil used in the columns was collected from a West Tennessee aquifer, approximately 70 feet below land surface, using a direct-push roto-sonic drill (J.K. Carmichael, U.S.Geological Survey, oral commun., 1998). The soil was air-dried and stored at room temperature until used. The soil was saturated with distilled water in which the appropriate treatment had been dissolved (table 1). The columns were set up and incubated at room temperature [approximately 25 degrees Celsius (ºC)].

Table 1. Various treatments used in the evaluation of vitamin B12 and a direct current to dechlorinate PCE. Comparisons in the results section of this report are made only with treatments run simultaneously. (PCE=tetrachloroethylene, B12 = vitamin B12, DC = direct current, µM = micromolar, M = molar, na = not applicable)

Column number	Column type, replicates	Matrix	PCE added (µM)	B12 added (µM)	DC potential (mV)	Sodium chloride (M)	Incubation period (days)
L-1	Large, 1	Water/soil	100	1	200	na	7
L-2	Large, 1	Water/soil	100	1	0	na	7
L-3	Large, 1	Water/soil	100	0	200	na	7
L-4	Large, 1	Water/soil	100	0	0	na	7
S-1	Small, 3	Water	100	1	250	0	7
S-2	Small, 3	Water	100	0	250	0	7
S-3	Small, 3	Water	100	1	0	0	7
S-4	Small, 3	Water	100	0	0	0	7
S-5	Small, 3	Water	100	1	600	0.1	4
S-6	Small, 3	Water	100	1	0	0.1	4
S-7	Small, 3	Water	100	0	600	0.1	4
S-8	Small, 3	Water	100	0	0	0.1	4

The PCE and breakdown byproducts were extracted from the soil/water slurry or water by using a hexane extraction. The treated slurry or water was placed in a clean 12-milliliter (mL) screw-top test tube. The volume of water was brought up to 10 mL with distilled water. Then 2 mL of gas chromatography (GC) grade hexane was placed on top of the aqueous solution. A teflon-lined screw cap was carefully placed on the test tube to minimize bubble formation. The test tube was shaken vigorously for 30 seconds and placed in the refrigerator for several hours. The hexane fractions were transferred to 2-mL volatile organic compound (VOC) vials by using clean Pasteur pipettes. Aqueous solutions with standardized concentrations of PCE, trichloroethylene (TCE), cis-dichloroethylene (cDCE), and vinyl chloride (VC) were used to make calibration standards using the hexane extraction method.

The hexane-extracted samples were then analyzed using GC equipment with an automatic sampler. The GC was set up with 175 ºC split (25:1) injection chamber. The capillary-column temperature started at 40 ºC and rose 15 ºC per minute to a final temperature of 150 ºC. The carrier gas was ultra-pure nitrogen flowing at a rate of 2 milliliters per minute (mL/min). The electron capture detector maintained a constant temperature of 300 ºC. The make–up gas was ultra-pure nitrogen flowing at 26 mL/min. Each analytical run took 10.2 minutes. Calibration standards were run at the beginning and end of every experiment. Also, a known standard was run every sixth sample or less to be certain the baseline in the GC was not drifting.

Heterotrophic aerobic bacteria were counted in each of the soil columns by using tryptic soy agar. At harvest time, a 10-µL aliquot of slurry was suspended in a sterile buffer and placed on the agar by using the membrane filtration method (Eaton and others, 1995). The plates were incubated at 25 ^{o}C, and colonies counted at 24 and 48 hours.

RESULTS AND DISCUSSION

The reductive dechlorination of aqueous PCE by vitamin B12 and DC was examined in saturated columns with and without soil. The large columns filled with soil and subjected to 200 mV DC and 1 µM vitamin B12 lost approximately 10 µM of the initial PCE over a 7-day period. There was a concurrent 16 µM increase in TCE (fig. 1). The other columns, lacking either the vitamin B12, DC or both, did not demonstrate the same pattern of losing PCE and gaining TCE. Column 3, with PCE and 200 mV DC, does show a slight decrease in PCE, suggesting possible transport of PCE facilitated by DC.

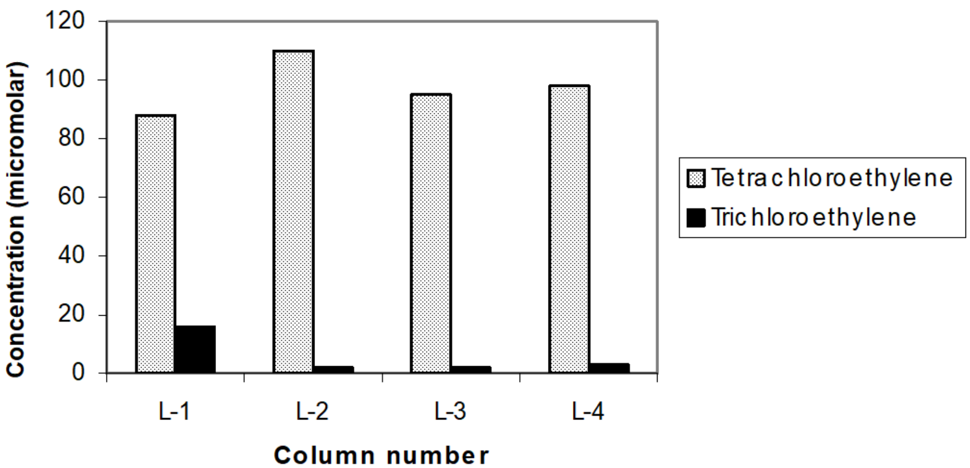

Figure 1. Remaining PCE and TCE extracted from the soil columns after 7 days of treatment. Column 1 had PCE, 200 mV DC, and B12. Column 2 had PCE and B12. Column 3 had PCE and 200 mV DC. Column 4 had PCE and no B12 or DC.

None of the treatments had significant trends in bacteria-colony-forming units. Numerous heterotrophic bacteria were present in all treatments, indicating that the PCE, vitamin B12, or DC did not harm the bacteria population; therefore, the potential exists for combining B12 reductive dechlorination and bioremediation.

Smaller columns containing 100 □M PCE dissolved in distilled water were subjected to vitamin B12, DC (250mV), or both. There was a 38 percent loss of PCE in control columns subjected to no DC or B12. This PCE loss could be due to sorption processes or volatilization through the silicone-sealed ends. The PCE decreased 55 percent in columns subjected to a DC without vitamin B12, and decreased 75 percent in columns subjected to a DC and vitamin B12. A lack of PCE degradation byproducts in these columns indicated electrokinesis may have played a greater role in reducing PCE concentrations than did chemical transformation (fig. 2). The lack of reductive dechlorination byproducts could have been the result of the water-column design and less current passing through the columns. For example, the water-columns with distilled water, no salt added, in very thin columns, in parallel circuits would increase the resistance of each column as compared to the saturated-soil columns and the current would decrease as predicted by Ohm's law (Current = Voltage/ Resistance).

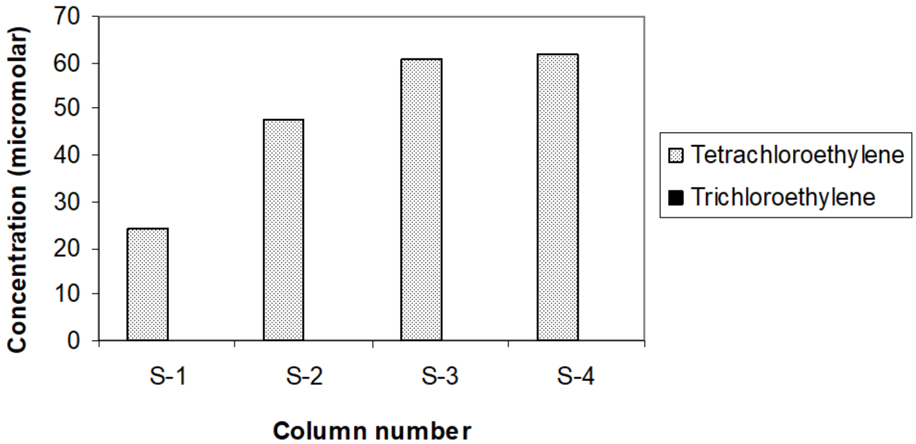

Figure 2. Tetrachloroethylene (PCE) extracted from small columns containing PCE dissolved in water. Trichloroethylene (TCE) was not detected in any treatment. Column 1 had PCE, Direct current (DC), and vitamin B12. Column 2 had PCE and a DC. Column 3 had PCE and vitamin B12. Column 4 had PCE and no vitamin B12 or DC. The coefficient of variation was 6, 10, 23 and 13 percent respectively.

Sodium chloride (0.1 M) was added to the next set of water columns as an electrolyte to reduce electrical resistance of the aqueous medium and the voltage was increased to 600 mV. Again the replicate columns were placed in parallel circuits because of limited DC power supplies. The columns with vitamin B12 and DC changed from pink to gray in 4 days (indicating the reduction of cobalt in the vitamin from a valence of 3+ to 1+). The columns were harvested after only 4 days to minimize the effect of volatilization on PCE loss. Columns treated with vitamin B12 and a DC demonstrated a 44 percent loss of PCE (44 μM) and a concurrent gain of 6 μM TCE. An approximate 20 percent loss of PCE with no TCE production occurred in the other treatments without vitamin B12 or DC.

The enhanced reduction of PCE and the subsequent increase in TCE support the hypothesis that vitamin B12 and a small DC can catalyze the reductive dechlorination of PCE. Furthermore, several new unidentified peaks were observed on the chromatograms of PCE columns treated with vitamin B12 and DC. These peaks could be breakdown products in addition to TCE. Chloroacetylenes, along with TCE, have been identified as primary byproducts of PCE transformation using vitamin B12 and reducing agents other than titanium citrate (Burris and others, 1998; Lesage and others, 1998). These primary byproducts were further transformed into cis 1,2-DCE, trans 1,2-DCE, 1,1-DCE, vinyl chloride, ethene, and ethane. Burris and others (1998) reported that trans 1,2-DCE was subject to a β-elimination process, forming chloroacetylene. In environments where two vitamin B12's catalyzed dechlorination of PCE in close proximity, Sagi and others (1990) reported the formation of two unstable chloroakyl radicals which subsequently dimerized to form chlorobutadiene. This dimerization process might explain the larger unidentified compounds found at the end of the chromatograph. Additional experiments are required to determine if the unidentified compounds are vitamin B12-induced PCE-degradation byproducts or an artifact of some other process.

The results of these studies indicate that dissolved-phase PCE treated with vitamin B12 and a sufficient DC will transform the PCE into TCE or other byproducts. A preliminary conceptual model of the mechanism involved in the dechlorination of PCE by vitamin B12 and a DC is proposed (fig. 3). Facilitated transport of PCE induced by the DC was observed in some of these experiments. The role this mechanism plays was not a part of this study, but could prove to be an additional removal process.

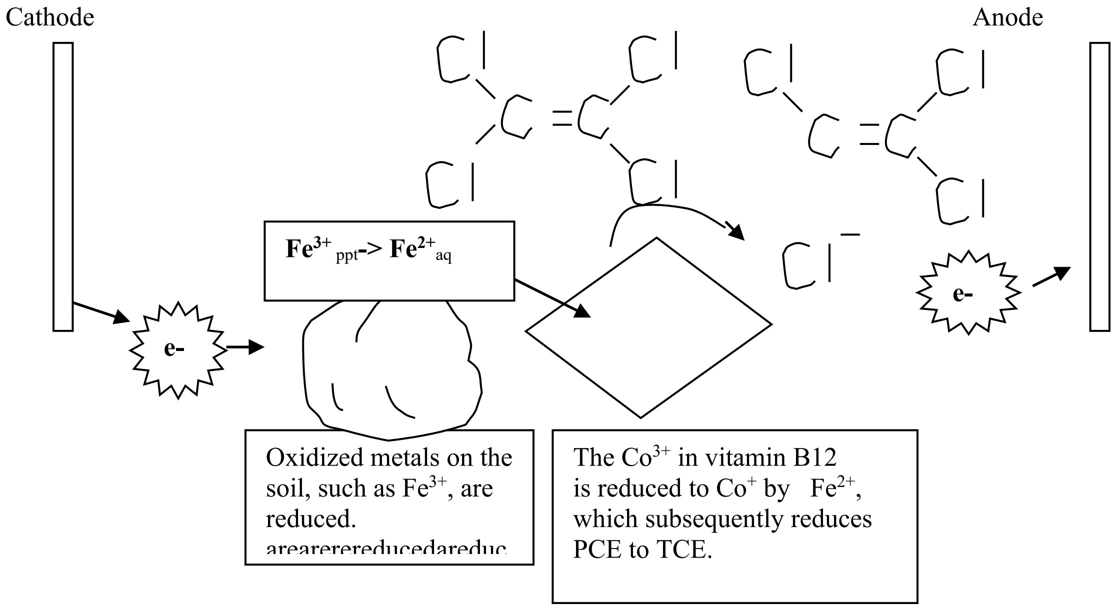

Figure 3. A preliminary conceptual model of the mechanism involved in the dechlorination of PCE by vitamin B12 using a direct current (DC) is proposed. The DC is unlikely to reduce the Co^{3+} in the vitamin B12 to Co^{1+} directly except at the anode. More likely, an intermediary reductant exists. For example, oxidized metals on the soil surface become reduced by the DC. The reduced metal becomes soluble and provides reducing power to the Co^{3+}, which subsequently passes the electron on to PCE, forming TCE and chloride.

REFERENCES

Burris, D.R., Delcomyn, C.A., Deng, B., Buck, L.E., and Hatfield, K., 1998, Kinetics of tetrachloroethylene-reductive dechlorination catalyzed by vitamin B12: Environmental Toxicology and Chemistry, v. 17, p.1681-1688.

Burris, D.R., Delcomyn, C.A., Smith, M.H., and Roberts, A.L., 1996, Reductive dechlorination of tetrachloroethylene and trichloroethylene catalyzed by vitamin B12 in homogenous and heterogenous systems: Environmental Science and Technology, v. 30, p. 3047-3052.

Cox, C.D., Shoesmith, M.A., and Gosh, M.M., 1996, Electrokinetic remediation of mercury-contaminated soils using iodine/iodine lixivant: Environmental Science and Technology, v. 30, p. 1933-1938.

Eaton, A.D., Clesceri, L.S., and GreenBerg, A.E., 1995, Standard methods for the examination of water and wastewater (19th ed.): Washington, D.C., American Public Health Association.

Gantzer, C.J., and Wackett, L.P., 1991, Reductive dechlorination catalyzed by bacterial transition-metal coenzymes: Environmental Science and Technology, v. 25, p. 715-722.

Lesage, S., and Brown, S., 1997, Biochemical degradation of tetrachloroethylene using generator columns containing residual DNAPL: Journal of Environmental Science and Health, v. A32, no. 1, p. 241-257.

Lesage, S., Brown, S., and Miller, K., 1996, Vitamin B12-catalyzed dechlorination of perchloroethylene present as residual DNAPL: Ground Water Monitoring and Remediation, v. 4, p. 76-85.

_______1998, A different mechanism for the reductive dechlorination of chlorinated ethenes: kinetic and spectroscopic evidence: Environmental Science and Technology, v. 32, p. 2264-2272.

Sagi, I., Wirt, M.D., Chen, E., Frisbie, S., and Chance, M.R., 1990, Dimerization of chloroalkyl radicals: Journal of American Chemical Society, v. 112, p. 8639-8644.

COMPARISON OF THREE SOIL-GAS SAMPLING METHODS AT SITES CONTAMINATED BY CHLORINATED SOLVENTS IN KARST AREAS OF TENNESSEE

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ABSTRACT

Three soil-gas sampling methods were compared at three karst sites contaminated with chlorinated solvents. The comparison evaluated the effectiveness of soil-gas sampling as a screening tool for chlorinated solvent contamination in karst settings. The three methods were (A) extraction of soil-gas samples from 0.7- to 1-meter borings and analysis in the field using a gas chromatograph equipped with a photo-ionization detector; (B) deployment of hydrophobic adsorbent material encased in a vapor-permeable membrane at depths of 0.5 to 0.8 meter below grade for at least 14 days and laboratory analysis using a gas chromatograph and mass spectrometer; and (C) deployment of metal strips coated with hydrophobic adsorbent material protected by an open-ended glass vial at depths of 0.09 to 0.15 meter below grade for at least 4 days and laboratory analysis using a gas chromatograph and mass spectrometer.

Previously studied sites were selected so that the results from the soil-gas surveys could be compared with existing water-quality data and conceptual models of contaminant distribution and movement. The three sites included an inactive landfill in a fluvially dissected area where thick (20-30 meters) regolith overlies nearly horizontal impure limestone, a train-derailment site in a sinkhole plain where thin (0-2 meters) regolith overlies nearly horizontal cavernous limestone, and a former nylon manufacturing plant in a structurally complex area where regolith of varying thickness (5-30 meters) overlies steeply dipping dolomites and siliceous carbonates with locally well-developed conduits.

Agreement among the three methods was strongest at the landfill site. All three methods detected trichloroethene (TCE) at three of 30 points at this site and 1,2-dichloroethene (cis) (cis-DCE) at one point. Two of the three methods detected chlorinated solvent at several additional points. The following table enumerates instances in which at least two methods detected one of the target chlorinated solvents.

Number of points with multiple-method hits of target compounds at landfill site [TCE, trichloroethene; cis-DCE, 1,2dichloroethene (cis); PCE, tetrachloroethene]

Methods	*TCE*	*Cis-DCE*	*PCE*
A,B,C	3	1	0
A,B	1	4	0
A,C	0	0	0
B,C	2	0	4

Agreement among the methods was weaker at the two other sites. At the train derailment site, only one of 33 points had multiple-method detections of any of chlorinated solvents. Methods B and C detected chloroform at this point. Three other points had single-method detections of chloroform, two by method B and one by method C. At the

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former nylon manufacturing plant, results from the three soil-gas methods show no agreement. Methods A and B detected no target compounds at this site, and method C detected tetrachloroethene (PCE) at 18 of 20 points.

All three methods yielded a similar picture of contaminant distribution at the landfill site, where much of the contamination occurs in and moves through the regolith. At the train derailment site, where contaminants have entered a bedrock conduit system that is well connected to the surface through numerous sinkholes, methods B and C provided imperfect pictures of known contaminant distribution and movement. Method A provided no information about contamination at this site, mainly because of the high detection limit of the field gas chromatograph for chloroform. At the former nylon manufacturing plant, where contamination is moving through a karst conduit system that is poorly connected to the surface, none of the methods detected previously documented contaminant distribution or movement.

Results of this study suggest that soil-gas sampling may be an effective screening tool for karst sites contaminated with chlorinated solvents, but only under limited conditions. These methods may be useful tools for sites where significant contaminant masses occur in and move through the regolith. Use of soil-gas sampling as a screening tool appears to be of limited value where the geologic setting favors contaminant movement into and through karst conduits.

MICROCOSM STUDY TO ASSESS THE POTENTIAL FOR INTRINSIC BIOREMEDIATION AT A KARST SITE

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ABSTRACT

The potential for bioremediation of trichloroethylene (TCE) is being examined at a karst site in Middle Tennessee where "pump and treat" wells are used to slow the movement of ground water away from the site and to remove some of the TCE. Ground-water samples were collected from nearby wells and analyzed to identify geochemical indicators of bioremediation (electron donors and acceptors), and to monitor trends in the concentrations of TCE and intermediate degradation products. Bacteria associated with the degradation of TCE were identified in water samples using the RNA oligonucleotide hybridization technique. Water-quality data indicate that both aerobic and anaerobic conditions occur in the contaminated karst aquifer. Sulfate-reducing and methanogenic bacteria, both associated with the reductive dechlorination of TCE (an anaerobic process), were present in samples from anaerobic wells. Methanotrophs and ammonia-oxidizing bacteria, both associated with co-metabolic degradation of TCE (an aerobic process), were present in samples from aerobic wells. Aerobic and anaerobic bacteria were identified in samples from wells that fluctuated in dissolved-oxygen concentration. Microcosm studies of ground water collected from the karst aquifer suggest that both biodegradation pathways are active. The rate of biodegradation was rapid in some samples, with a TCE half- life of 35 days. Degradation products indicative of the reductive dechlorination process were detected in other samples at 10 months. Additional water-quality and hydrologic monitoring of the karst aquifer are being conducted to determine temporal and spatial changes in water quality and to evaluate how these changes may affect the biodegradation processes at the site.

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LAKE MUNSON RESTORATION PROJECT
LEON COUNTY, FLORIDA

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and
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ABSTRACT

Once a viable wildlife habitat and recreational site, Lake Munson is now choked with aquatic vegetation, and sediments and trash are blocking the mouth of the lake creating a "delta". The Lake Henrietta basin, located upstream of Lake Munson, historically provided storm water treatment for the natural flow through the system, Channelization through the Lake Henrietta basin and increased storm water flows the result of increased development, have led to the creation of the "delta" and the degradation of Lake Munson.

Through more than ten years of investigations, studies, and master planning efforts, Leon County has identified five major objectives of the Lake Munson Restoration Program; to improve the water quality of storm water entering Lake Munson, to restore the natural storm water treatment ability of the Lake Henrietta basin, to improve the fishery quality and recreational value of Lake Munson, to improve the water quality of the discharge from Lake Munson to downstream waters, and to reduce flooding as much as possible in the Lake Munson system.

INTRODUCTION

The overall goal of the Lake Munson Restoration Program is to restore the Lake Munson system to a more natural state. Lake Munson will be improved with dredging, access improvements, habitat restoration, and sediment reduction. Restoration of Lake Munson will not be implemented until improvements upstream of Lake Munson have been implemented. The improvements upstream of Lake Munson include excavation of the "delta", improvements to Munson Slough, restoration of the Lake Henrietta basin, excavation of an attenuation pond and installation of trash racks (Figure 1). These improvements will be implemented in a manner that will enhance the function of the project area. The "delta" has formed at the confluence of Munson Slough and Lake Munson and has area of approximately 29 acres. The "delta" will be excavated and the surface water inflow to Lake Munson will be restored to a more natural state. Improvements to Munson Slough include realignment, regrading and stabilization of channel banks for erosion control. Restoration of the Lake Henrietta basin includes a storm water attenuation pond and trash racks, an increase in flood storage capacity, and wetland restoration. A diversion ditch has been included in the design for flow diversion during construction and for increased flushing in the north arm of Lake Munson, after construction is completed. The improvements, which are necessary for the restoration of Lake Munson, include significant construction activities and long-term maintenance.

Lake Munson and the area upstream of Lake Munson, where the improvements will be implemented, are located within the Lake Munson Sandhills Physiographic Region. The Sandhills region is an extensive area of dry hills and ridges composed of deep ads over limestone bedrock with a moderate amount of subsurface clay in between, Sinkholes and karst-formed lakes are present, but a review of published information and a comparison with site specific data indicates the probability of sinkhole formation in the project area is very low. Lake Munson receives surface water from most of the land area within the Lake Munson Drainage Basin. Lake Munson currently receives

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storm water runoff from more than 50% of the City of Tallahassee, Florida urban area. Due to the increase in storm water runoff from urban development, the floodplain has expanded.

The lake and slough were altered in the 1950's by the construction of a mosquito control ditch and maintenance berm, by active filling in the floodplain, and by sediment deposition and pollution from storm water runoff. The channelization of Munson Slough has altered and degraded the associated floodplain. Lake Henrietta has been converted from an open-water emergent marsh system to an emergent marsh-shrub swamp system, and Munson Slough, through erosion, has contributed significant sediment load which has formed the "delta". As indicated above, implementation of the improvements upstream of Lake Munson will improve existing conditions in terms of flood storage, storm water attenuation, and wetland restoration, and will provide greater opportunities for public use.

PROJECT DESIGN

A regional storm water model was developed and calibrated for the purpose of evaluating surface water quantities in the 72-square mile Lake Munson basin. An understanding of the rate and quantity of water flows helps determine the most effective methods for controlling flooding and protecting public safety. The model used for this study utilizes the RUNOFF and EXTRAN blocks of the USEPA Storm water Management Model (EPA-SWMM, Version 4-3). The Lake Munson Basin was subdivided into 245 hydrologic units for which land use, soil, and topographic characteristics were compiled. The calibrated model was used to predict flood stages (including wetland hydroperiods) and flows within the basin, and was subsequently used to develop an appropriate design for restoration of the Lake Henrietta basin, improvements to Munson Slough, and reconfiguration of the “delta” at the confluence of Munson Slough and Lake Munson.

The goal of the restoration of the Lake Henrietta basin, which includes a storm water attenuation pond and wetland restoration, is as follows. The stages and flows resulting from design storms (25-year and 100-year, 8-hour storm events) can not increase above existing levels and wetland hydrology must be improved. The project accomplishes flood attenuation with the proposed storm water attenuation pond. The proposed pond is designed with approximately 30 acres of wet area at a depth of 7 feet. The proposed pond will collect inflow from Munson Slough and from the East Drainage Ditch (Figure 1). Discharge from the proposed pond will be controlled by a spillway with a bleed down device and through equalization pipes into Munson Slough and the associated wetlands in the Lake Henrietta basin.

The size and configuration of the proposed pond was determined based on the location of existing development and minimization of wetland impacts in the Lake Henrietta basin, The degree, of flood attenuation for the design storms accomplished by the proposed pond approaches I foot for much of the project area north of the "delta". A benefit realized by the flood attenuation provided by the proposed pond is the ability to significantly reduce the sediment load that is currently carried downstream by storm water flow. Removal efficiency is estimated at up to 80% for most storms. The detention time achieved during most storms will result in the capture of sediment in forebay areas of the proposed pond. Maintenance to remove sediment from the forebay areas will be performed as necessary.

The storm water model was developed and calibrated to serve as the basis to compare existing, or pre-development, hydrologic conditions with post-development conditions. The post-development model incorporates the attenuation pond, structures, and the proposed changes to channel grades and inverts proposed by the project. The two primary objectives of the proposed system design includes lowering peak stages in the project area during design storm events without increasing flooding upstream or downstream, and restoring project wetland hydroperiods. Reductions in peak stages for the 25-year storm range from 0.0 to 1.0 feet as a result of the proposed improvements. Due to channelization, water levels in the project wetlands currently rise and fall in a short period of time. After implementation of the proposed improvements, the range of wetland hydroperiod fluctuation will not change significantly, but the wetland hydroperiod duration will increase.
Preliminary design of the structures to divert storm water flow from Munson Slough and the East Drainage Ditch into the proposed pond was sized for the 8-hour storm with return frequency of 2 years. Storm flows which exceed the 2-year peak flow, bypass the proposed pond and will be conveyed in Munson Slough and the associated floodplain. The bypass diversion structures are designed with a slide gate to convey baseflow during periods when maintenance for sediment removal from the proposed pond is implemented. Wetland restoration will be achieved by

improving wetland hydrology. Control structures with bleed down devices have been designed for this system to maintain ordinary high water levels (peak stages) within the wetlands during mean annual storms while at the same time increasing the duration of inundation over existing conditions.

Post-development storm water modeling results and project area topography have indicated appropriate locations, dimensions, and elevations of proposed project structures. The primary control structures that are proposed consist of four rectangular spillway weirs of varying lengths, each equipped with bleed down devices, The proposed locations of these control structures are as follows; at the outfall of the proposed pond (as described above), near the southern end of the Lake Henrietta basin, in Munson Slough (approximately 1200 feet north of the “delta” just upstream of the diversion ditch), and at the northern end of the existing "delta".

An integrated, flexible, ecosystem management approach was used to determine the appropriate design of the improvements upstream of Lake Munson. Wetland impacts were avoided or minimized, while wetland restoration was maximized in determining the design that provides the greatest benefits to the Lake Munson Basin, as follows.

Construction of the proposed attenuation pond will impact some wetlands west of Munson Slough within the Lake Henrietta basin. Channelization of Munson Slough has altered the hydrology of them wetlands. In addition, a portion of a wetland in this area has been filled. The design of the attenuation pond includes restoration of wetlands on the east side of Munson Slough and south of the attenuation pond within the Lake Henrietta basin. Channelization of Munson Slough has also altered the hydrology of these wetlands, but to a lesser extent. The wetlands west of Munson Slough within the Lake Henrietta basin, that will be impacted by construction of the proposed attenuation pond, have been significantly altered while the wetlands south of the proposed attenuation basin and east of Munson Slough within the Lake Henrietta basin have been altered to a lesser extent, and will be restored. These factors were considered in determining the location of the attenuation pond. Restoration of the Lake Henrietta basin will provide storm water attenuation and wetland restoration, and will restore the natural storm water treatment capabilities of the basin.

Excavation of the "delta" (which is entirely wetlands) is necessary for the restoration of Lake Munson. The "delta" acts as a source of accumulated storm water pollutants and limits circulation within the lake. The "delta" is not a natural feature of Lake Munson and excavation of the "delta" will return surface water flow to the lake, to a more natural state. Excavation of the "delta" and restoration of the natural storm water treatment capabilities of the Lake Henrietta basin will improve the water quality of Lake Munson.

The project is located in the 100-year floodplain. The proposed improvements are consistent with long-term floodplain management plans and will not reduce floodplain values as they will provide an improvement in the existing conditions in terms of flood storage (a net increase in floodplain storage), storm water attenuation, and wetland restoration. Failure to implement these improvements would result in the continued deterioration of Lake Munson and the Lake Henrietta basin.

PHYTOPLANKTON COMMUNITIES, ENVIRONMENTAL VARIABLES AND HABITAT CHARACTERISTICS IN WATTS BAR RESERVOIR, TENNESSEE

P. L. B. Inklebarger
and
C. C. Amundsen[1]*

Watts Bar Reservoir ecologically defines an area of aquatic, as well as the impoundment influenced terrestrial habitats , which together express appropriate biological communities. All ecological systems with integral identity include, at the least, functional communities capable of primary production (through the autotrophy of photosynthesis); as well as of heterotrophs which accomplish decomposition or mineralization (the catabolism of organic detritus to mineral nutrient status). Most ecosystems also include distinct consumers, heterotrophic organisms which depend either on the excess of primary produce available, or on detritus. Even small terrestrial areas support all three major system compartments, Producer, Consumer, Decomposer, with a degree of interdependence. As a general rule, however, only extensive aquatic habitats support a self-sufficient biological establishment which expresses sustaining, nutrient export-level activity from the premier Producer and Decomposer components, while at the same time many display a notable biomass of Consumers. Thus we can have a fishery in a body of water depauperate in both producers and decomposers, but perceptibly rich in composition of several trophic levels of consumers from insects and mollusks to fish to omnivorus and predatory birds.

The explanation is simple. Photosynthetic production on adjacent terrestrial substrates, often designated as riparian zones, is allochthonously supplied to the aquatic system to supplement the autochthonus primary production occurring within the waters. The allochthonous supply of organic nutrients subsidizes the secondary production, or growth, of the aquatic consumers well beyond the capability of the primary, autochthonous output. Many reservoirs in the Tennessee Valley exhibit these limitations; the aquatic primary production is low, the dependency of the system on adjacent (and available) terrestrial primary production is high.

In a somewhat similar comparison, aquatic habitat conditions in upper Tennessee Valley impoundments, such as the occurrence of non-mixing, anoxic strata at depths, limit the abundance and success of decomposer organisms. This often leads to accumulations of relatively unaltered, direct litter or detritus, in areas of restricted flow, or in bodies of water that do not regularly turn over from thermal responses. With a paucity of decomposers, organic material may sink or be transported away by the current, essentially unchanged and in unavailable form for many consumers.

Studies by the junior author and his students have described the reservoir riparian zone, mostly still forested, of the Watts Bar Reservoir (Amundsen, 1995; Amundsen et al. 1995; Hanahan, 1996) Hammons-Baxter and Amundsen, 1998) . Riparian zones are the source of, or the gateway for, those terrestrially generated particulate and dissolved organic materials which reach the aquatic system (Yeakley et al. 1995). Much of this material can reach the aquatic habitat after breakdown by terrestrial decomposers and subsequent percolation and transport in the subsurface flow zones, particularly in winter when the deciduous forest stands are inactive, and rainstorms are frequent.

These previous studies have not included details on two plant assemblages contributing autochthonously to the biological system of the reservoir, the aquatic, vascular plant stands and the communities of phytoplankton occurring within the reservoir confines. There are recurring stands of such emergent perennials as justicia, knotweed, cat-tail, cut grass, canary grass and a few less common taxa, but they are limited by the dynamics of the wave-washed shorelines and the engineered water level regime. They are more common in coves, particularly on the cove-head deltas of tributaries. Submersed plants are rarely found, perhaps due to the dynamics of wave and current shifted bottom sediments.

There is a well defined, albeit sparsely distributed, mudflat flora of some 20 vascular taxa that develops on silt surfaces exposed by the regular winter drawdown of the reservoir. Those taxa designated as mudflat plants have been restricted to the species that seasonally complete their life cycle between the lowering and subsequent spring raising of the reservoir pool levels. These plants are limited by the periodicity and endurance of the aerial exposure, and are less successful when the drawdown period is shortened. The biomass, and the autochthonous contribution of

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organic nutrient materials, from both the vascular aquatic plants and the seasonal mudflat plants to the heterotrophs of Watts Bar reservoir is, except for very local conditions, low.

This particular report summarizes a study which initiates an ecological characterization of the phytoplankton communities and habitats of the Watts Bar Reservoir in the upper Tennessee River Valley. We have set out to identify the genera of common algae of the reservoir, by designated habitat characteristics and season, and to speculate on major influences on the occurrence of these algal communities. The phytoplankton are predominant producers in this system.

Watts Bar Reservoir was constructed along the mainstream of the Tennessee River by the Tennessee Valley Authority (TVA) and was closed in 1942. It is the largest of fifteen TVA reservoirs upstream of Chattanooga, Tennessee and is approximately 34°30' North and 84°30' West. At normal or summer pool (elevation about 226 m, or 741' msl) , the reservoir has a surface area of some 15800 hectares (39000 acres) and a shoreline of about 1240 km (770 miles) with a channel (sail line) length of 154 km (95 miles). The now inundated areas above the original river course were mostly in managed field, unmanaged pasture and forested condition. Construction of the impoundment included forest clearing to the summer pool elevation (TVA, 1949). The reservoir pool is imposed upon once mesic terrain, which, where relatively undisturbed, supported a diverse forest classified by oak and hickory species. The establishment of a new growing season (spring through summer) shoreline has brought about the displacement, upwards, of the mesic habitat with a replacement by more hydric, reservoir riparian zone species in areas with gentle to moderate shoreward slopes (Hanahan, 1996). The mainstream reservoir receives the direct discharges of the Clinch and Piney Rivers and numerous smaller streams. Tributary riparian zones are sources for allochthonous material supplied to the main body of water. Most of the tributary confluences are now expressed as coves or embayments of various extent, depending on the preexisting relief of the tributary valley.

The autochthonous trophic state, or food web status, in the reservoir is dependent on the phytoplankton. The algal presence and abundance can be considered to provide a benchmark for on site, primary food resource availability. TVA measurements in Watts Bar have included sampling for carbon in the aquatic environment and determinations of the amounts, in samples, of chlorophyll a. These measures (Meinert, 1991) show more than a ten-fold reduction in surface area carbon detention when compared to pre-impoundment (terrestrial production) estimates of the same surface area parameter (Amundsen, 1995). The TVA reports did not include algal taxonomy.

We classified the algal habitats of the reservoir as embayment (navigable during winter drawdown); cove (essentially drained by winter drawdown -- a pool drop of some 1.8 m); channel (open and exposing the main shoreline); and other, such as winter mudflat pools, and algae on constructed surfaces. Almost all samples were collected with a Wisconsin plankton net of 80 micron mesh size. Trawls of two to three minutes in duration were made behind a slow jon boat when practical; or in the winter, mostly from shoreline casts from wading depth, with a minimum of 10 net casts and retrievals of about seven meters each. Sample areas ranged from Tennessee River Mile (TRM) 531 to TRM 582.3, and included a total of 56 collection events across embayments, coves, and along the channel. Seasonal collection periods included two month intervals during late fall, winter and early spring (drawdown conditions) and two week intervals during late spring, summer and early fall (normal pool conditions). All sampling was effected in the photic zone, a shallow stratum in this case. Samples were promptly identified with a light microscope, using general references , or preserved (2% glutaraldehyde in 0.1 M buffer with pH 7.2) and determined by Dr. P.L Walne, Department of Botany, UTK. Algae were identified to genera. Calculations of dominance, diversity and evenness values and the application of similarity indices followed the procedures outlined in Brower et al. (1990). The Mann-Whitney test was used to compare the distribution of algal genera of several algal (taxonomic) Divisions to selected southern (USA) reservoirs. At each collection site, segregated by season and habitat class, pH, conductivity, water temperature and water transparency (Secchi disc) were noted. Two instruments or two readings were used for each determination.

One hundred and ten phytoplankton genera representing five Divisions were collected during the 20-month study. The dominant Division was the Chlorophyta (the green algae) with 53 genera, followed by the Chrysophyta (the yellow-greens and diatoms) with 30, the Cyanophyta (blue-greens) with 17, and the Euglenophyta (euglenoids) and the Pyrrophyta (dinoflagellates) with five genera each. The chlorophytes were more likely to be found than any other divisional group, registering some 48% of the occurrences over the duration of the study. Forty-two phytoplankton genera showed a relative occurrence of ten percent or greater during the course of the 56 collections:

60-80%	*Pediastrum, Fragilaria, Melosira, Asterionella, Scenedesmus, Euglena*
40-59%	*Tabellaria, Anabaena, Bumilleria, Oscillatoria, Actinastrum, Microcystis, Merismopedia, Navicula, Cosmarium, Tribonema*
20-39%	*Spirogyra, Ceratium, Stephanodiscus, Oedogonium, Ankistrodesmus, Staurastrum Gymnodinium, Pandorina, Phacus, Dinobryon, Gomphosphaeria, Spirulina*
10-19%	*Gyrosigma, Trachelomonas , Asterococcus, Sphaerocystis, Synura, Golenkinia, Volvox, Eudorina, Rhizoclonium, Coelastrum, Kirchneriella, Cymbella, Arthrospira, Ulothrix.*

Considering all 110 genera (all listings and statistical calculations can be found in Inklebarger, 1997), the Simpson indices for dominance (l) and diversity (D_s) were applied, and evenness (E_s) was considered using the Simpson diversity index. The Simpson dominance index, based on occurrences of genera, showed $l = 0.0236$. The Simpson diversity $D_s = 0.976$. Evenness (E_s using D_s), $E_s = 0.984$. In these interpretations, the dominance of 0.0236 is considered low, indicating there are few, if any, genera characterizing the randomly sampled community by their repeated occurrence together. The diversity (0.976) is high, and is considered the probability of any intergeneric encounter, or the likelihood of a member of one genus being found with a member of another. The evenness value of 0.984, which is high, indicates the degree to which individuals were distributed as evenly as possible among the genera. Low dominance, low density for any particular genus, reflects high diversity. One evaluation of trophic status in TVA reservoirs (Placke, 1983) concludes that a mainstream reservoir should show high algal diversity, but low densities for any one genus. Our results agree with these statements, although Placke (1983) skipped Watts Bar.

Seasonal sampling designations were essentially the calendar periods, Summer (to 21 Sep.), Fall (to 20 Dec.), Winter (to 19 Mar.), and Spring (to 20 Jun.). Community similarity indices, developed by Sorenson and by Jaccard were used to compare total seasonal occurrences by taxonomic Division, as well as by genera. Chrysophytes (yellow green algae and diatoms) dominated in the winter, followed by the chlorophytes (green algae), the cyanophytes (blue-greens) and the euglenophytes. No pyrrhophytes (dinoflagellates) were found in winter samples. A study of the literature supports the reported tendency of the yellow greens and diatoms to prefer colder waters, while the dinoflagellates tend to be more often found in warm water communities. Conditions preferred by chlorophytes improved in the spring, and a general decline in the representation of chrysophytes was noted, although the diatom peak occurred only three days before the summer. By the time summer was well underway, the genera of chlorophytes were highest in occurrence. The dinoflagellate genera occurrences were more often recorded in late summer and early fall, the blue-greens were found most frequently in mid-summer. A comparison of seasonal phytoplankton dynamics with the less comprehensive reports of Placke (1983) indicates the patterns in Watts Bar more closely resembled the tributary reservoirs she reported as opposed to other mainstream impoundments in the valley. Tests of community similarity were also employed to examine the sameness of communities across seasons on the generic level. Six community assemblages were subjected to generic comparison and the indices calculated:

Seasonal Combination	Sorenson Value	Jaccard Value
Summer x Fall	.671	.505
Spring x Fall	.667	.500
Spring x Summer	.600	.429
Winter x Spring	.432	.276
Winter x Summer	.362	.221
Fall x Winter	.355	.216

There were no drastic changes in the environmental conditions between summer and fall, probably accounting for the highest similarity, above. Spring and Fall showed similar water temperatures at collection times. The summer raising of the pool, inundating (and flushing) the winter-spring mudflats, probably enhanced an increase in algal kind and number. Winter populations consisted of a preponderance of genera found in all seasons. These seasonal generalists are typified by the genera *Pediastrum, Merismopedia* and *Gyrosigma.* Inactive, small, propagules may have been present but not identified across several seasons for genera which appeared in mature forms only under more optimal conditions. It is clear that some algae are restricted to a narrower range of habitat conditions, and temperatures were the noted controlling factor determined in this study.

In terms of habitat classification and occurrence of genera, the embayments and coves supported a richer flora than the main channel. Placke (1983) reported that TVA experiences showed extensive algal growths (blooms) may occur in embayment areas while the richness and abundance of algae in the main channel is usually less. The inference is clear in this study that the conditions in the coves and embayments were such (higher pH, higher temperature, higher conductivity than the channel waters) that the conditions for algal growth and reproduction were more favorable than in open waters. This suggests a possible link to the greater concentrations of dissolved and particulate organic material allochthonously supplied to the tributary-fed coves through a more impacting interface with the tributary and reservoir (cove) riparian zones. Placke (1983) has concluded that light penetration (in the inorganically influenced turbid channel waters) is limited, and that the shallow photic zone reduces the success of algae in these offshore waters. It may also be that the continuous channel flow reduces the apparent numbers of algae, and reduces the residence time of necessary nutrients as well. We speculate that the channel configuration of the Watts Bar Reservoir is more riverine or lotic than lentic in regard to algal habitat.

In Watts Bar, temperature differences seemed to separate embayment/cove algal populations from season to season, and from channel populations, except in summer, when apparently most of the taxa collected were developing within their ranges of tolerance. No consistent relationship to pH or conductivity was apparent from this study, and, unlike some other reported analyses, the algal densities rarely appeared great enough (algal bloom) to affect water transparency of themselves, occurring only infrequently in summer-time cove habitat situations.

Mann-Whitney tests were applied to data on genera from several other "Southern" reservoirs. The null hypothesis that Watts Bar would show no difference was rejected. Placke reports (1983) that reservoirs tend to have about one-third of their species in common when compared, but no reservoirs she considered had more than one-half their species in common with any other. Watts Bar was not part of the TVA study, but we found richness beyond these limited taxonomic characterizations.

The presence, community composition and diversity of Watts Bar phytoplankton are influenced by seasonal phenomena and habitat morphometry and dynamics. Over one half of those genera found 50% of the time were found across all seasons. The floral distribution differed by over one-half from other regional impoundments able of comparison. The algal flora of Watts Bar is rather rich when compared to other temperate region reservoirs. The algae of Watts Bar need to be identified to species. It appears that the next appropriate research effort in this regard should be to integrate allochthonous inputs from the tributary and mainshore riparian zones with the presence and abundance of particular algae as further indicators of the ecological status of the reservoir. The importance of the consumer trophic levels (larval through adult) to the general public may require a better grasp of the consequences of continued "built" disruption of critical riparian zones; the innate value of a distinct, and supposedly independently autotrophic, algal, flora notwithstanding.

REFERENCES

Amundsen, C. C., 1995. Reservoir riparian zone characteristics in the upper Tennessee River Valley. In: C. C. Trettin, W. M. Aust, and J. Wisniewski (editors), Wetlands of the Interior Southeastern United States. Kluwer Academic Publishers. pp. 273 - 297.

Amundsen, C. C., R. Hanahan, S. Hammons, C. Loy and P. Inklebarger. 1995. Coincidental reservoir- riparian communities and the aquatic interface of the Watts Bar impoundment in East Tennessee. Proceedings of the 6th Annual SAMAB Conference, Knoxville, Tennessee.

Brower, J. E. , J. H. Zar and C. N. Von Ende. 1990. Field and Laboratory Methods for General Ecology. Wm. C. Brown Publishers.

Hammons - Baxter, S. L. and C. C. Amundsen, 1998. Reservoir riparian island habitats and representative arboreal species importance in Watts Bar, Tennessee. In: Proceedings of the 8th Annual Tennessee Water Resources Symposium. pp. 2C 15 - 18.

Hanahan, R. A. 1996. Comparison of forest stand edges in riparian and mesic habitats along Watts Bar Reservoir shoreline. M. S. thesis, University of Tennessee, Knoxville, Tennessee.

Inklebarger, P. L. B. 1997. Phytoplankton community composition in Watts Bar Reservoir, Tennessee, and some relationships to environmental variables. M. S. thesis, University of Tennessee, Knoxville, Tennessee.

Meinert, D. L. 1991. Reservoir vital signs monitoring. 1990. Tennessee Valley Authority TVA/WR/WQ - 91/10.

Placke, J. F. 1983. Trophic status evaluation of TVA reservoirs. Tennessee Valley Authority TVA/ONR/WR - 83/7.

Tennessee Valley Authority, 1949. The Watts Bar Project. U. S. Government Printing Office, Washington D. C. Technical Report No. 9.

Yeakley, J. L. , J. L. Meyer and W. T. Swank. Hillslope Nutrient Flux During Near-Stream Vegetation Removal. I. A Multi-Scaled Modeling Design. In: C. C. Trettin, W. M. Aust, and J. Wisniewski (editors). Wetlands of the Interior Southeastern United States. Kluwer Academic Publishers . pp. 33 - 50.

PREDICTING SEDIMENT AND CESIUM-137 TRANSPORTED TO OFFSITE DURING EXTREME FLOODS

Yixing (Steve) Bao[1]

ABSTRACT

This paper presents the methods and results of a research project for predicting contaminated sediment transport from Oak Ridge Reservation to offside under potential extreme flood conditions. A computer model, Hydrologic Simulation Program –FORTRANE (HSPF), was calibrated and validated for White Oak Creek watershed using a five-year data. The model was then used to quantify the effects of a potential 100-year flood event in terms of the sediment transport and ^{137}Cs movement. Results from computer simulation showed that during a 100-year flood event the watershed and channel bed became the major sources of the ^{137}Cs. A 100-year flood event may result in 3.2 Ci of the total annual release of ^{137}Cs which is six times of the averaged annual release observed during a five-year time period.

INTRODUCTION

Over a period of 50 years, the operation of and waste disposal activities at Oak Ridge National Laboratory* have resulted in an accumulation of cesium-137 (^{137}Cs) and other radionuclide contaminants that are bound to sediments distributed along the floodplain of the White Oak Creek (WOC) basin. The White Oak Creek basin area is about 16 km^2 with 80% forest, 10% riparian, and 10% developed area such as buildings, roads, and parking lots. Slope of the primary channels is in a range from 1/1000 to 4/1000. Prediction of the mobilization and transport of sediment-bound ^{137}Cs during extreme flood events is critical in order to assess the potential exposure risk to the public. The modeling task faces three challenges. First, the extreme flood event (100-year flood) needs to be simulated based on limited onsite observed data of precipitation and stream flow. Second, it is required to account for both nonpoint sources of ^{137}Cs from hill slopes including an old earthen dam site which is typically storm induced due to the surface soil erosion and point sources of ^{137}Cs influx from the Non-Rad Waste Water Treatment Facility discharges. Third, the upstream of weirs, the channel bed, and White Oak Lake in the system can serve as source or sink depending on the channel flow, sediment and ^{137}Cs concentrations.

METHODS

A comprehensive, continuous watershed model, Hydrologic Simulation Program-Fortran (HSPF), has been modified and applied to the WOC basin to simulate various hydrological processes, sediment transport, and movement of ^{137}Cs (Clapp et. al. 1996, Bicknell et. al. 1993). Four pervious land segments (subdivisions of the watershed) that are connected through seven channel reaches represent WOC basin in the HSPF model (Figure 1). Because a large number of parameters are required in HSPF modeling, a major effort in the modeling processes is the calibration by adjusting calibration parameters to make simulation results and measured values agree as closely as possible. A model was developed to automate the calibration processes by combining an expert system and a nonlinear optimization technique. The expert system component represents a collection of experiences of HSPF modeling and watershed characteristics. The nonlinear optimization component automates the process of determining values of calibration parameters by minimizing the absolute difference in streamflow between the observed and simulated values. This automated hydrologic calibration model dramatically reduced the time required for calibration process and improves the modeling results significantly. Over a five-year period, the simulated flow discharge closely matches with the observed values at the White Oak Dam. A goodness-of-fit test with zero intercept on the linear regression relates the simulated and observed flows over a period of five years with coefficient of determination of 0.955.

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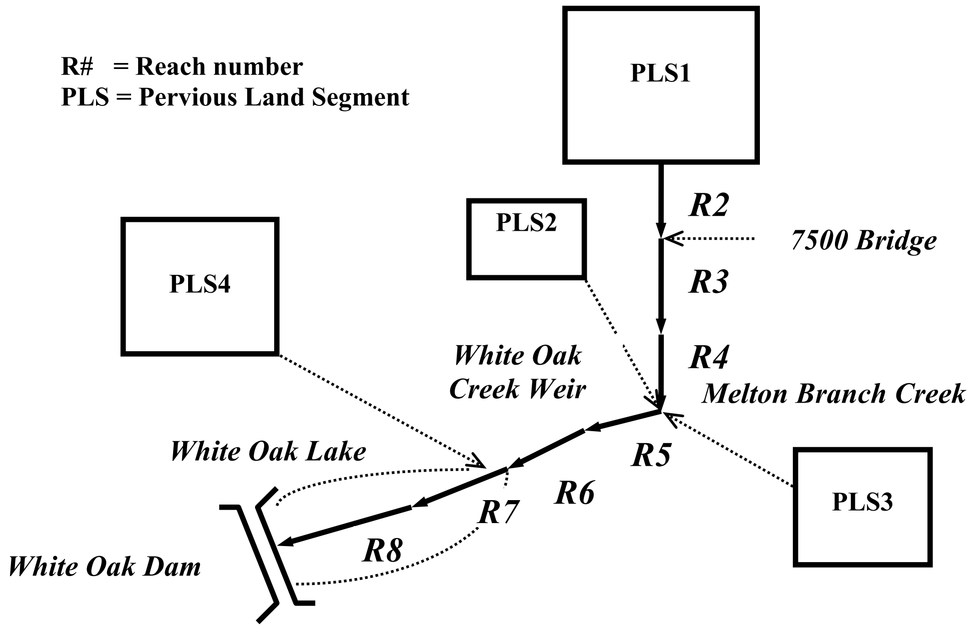
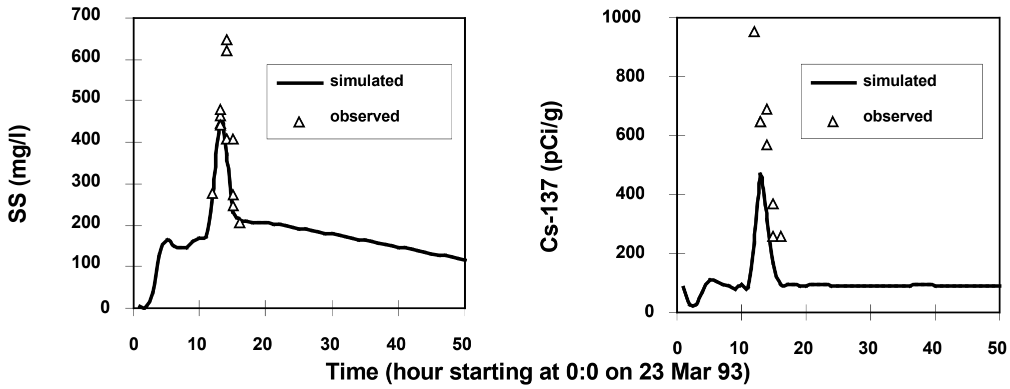


Figure 1. Schematic Sketch of the Model Elements Representing White Oak Creek Watershed

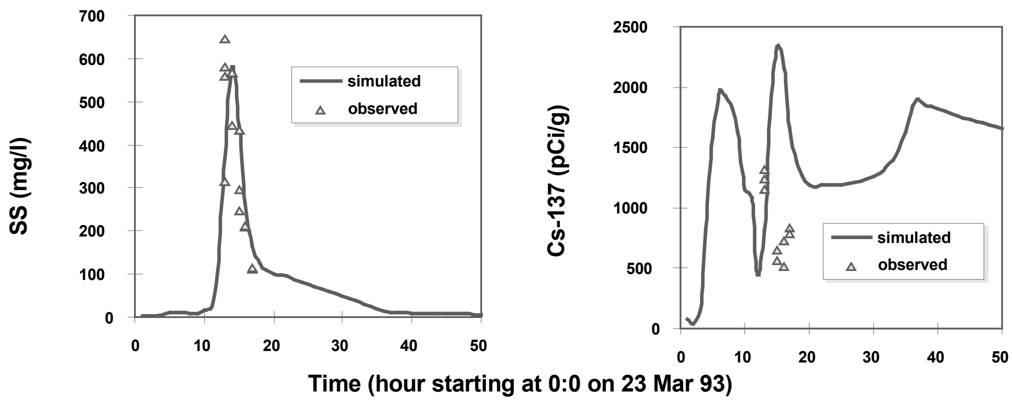
Two scenarios were analyzed in White Oak Creek watershed modeling. The first scenario was to simulate for a five-year period of 1990-94 using onsite real data such as precipitation and evaporation time series to understand system characteristics of White Oak Creek basin in terms of watershed hydrology, surface soil erosion, sediment transport, contaminant fate, and channel bed interactions. The second scenario was to quantify the effects of a potential 100-year flood event and the sediment transport and ^{137}Cs movement under the extreme flood condition. Three steps were needed for simulation under this scenario: 1) estimation of peak flow of extreme (100-year) flood, 2) selection and modification of storm event which resulted in 100 year flood, 3) simulation of flow, sediment and ^{137}Cs released to offsite under the extreme flood conditions.

RESULTS

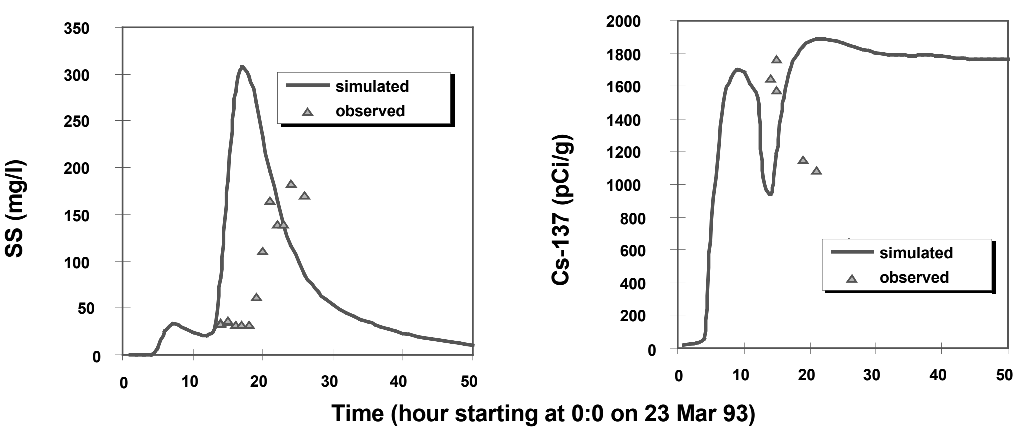
Figure 2 shows an example of results of simulated and observed suspended sediments and ^{137}Cs concentrations at upper White Oak Creek (7500 bridge, immediate below the lab complex), middle White Oak Creek (White Oak Creek Weir), and basin outlet (White Oak Dam) during March 23, 1993 storm. As shown in the figures, model under simulates the peak suspended sediment concentration by 30% and under simulates peak ^{137}Cs concentration by 100% at upper



(a) at 7500 Bridge Station



(b) at White Oak Creek Weir



(c) at White Oak Dam

Figure 2. Comparison of simulated and observed suspended sediments and Cs-137 during March 23, 1993 storm in White Oak Creek basin

WOC during the storm. The trend of both suspended sediment and ^{137}Cs concentrations at upper WOC closely match with the observed values. The simulated peak time for suspended sediment and ^{137}Cs concentrations also matches the observed peak time. At middle WOC, the simulated sediment concentration and ^{137}Cs concentration closely match the observed values. The observed suspended sediment concentration at WOD seems to be more attenuated and delayed in time.

Overall, the observed ^{137}Cs concentrations at all three locations during the storm are in a range comparable with simulated results. The baseline simulation results indicated that the bed sediment erosion occurred at upper WOC but not dramatically; sediment deposition occurred at White Oak Lake; and significant ^{137}Cs input was from upper WOC channel bed erosion during the storm. The simulated annual releases of ^{137}Cs to off-site locations matched data within a factor of 2 for 1990-94.

An adjusted November 27, 1973 hourly rainfall intensity data at NOAA Oak Ridge station was super imposed to replacing March 23, 1993 storm to simulate the potential 100-year flood. The simulated peak flow for the potential 100-year flood is 81.4 m^3/s (2,875 cfs).

The change of ^{137}Cs concentration during a storm depends on rate of changes in flow and suspended sediment concentration, and sources of sediments. ^{137}Cs concentration increases at the beginning of the 100-year storm because the stream flow starts to increase significantly to mobilize the sediment-bound ^{137}Cs mainly in the bed of channel and lake. In this stage both suspended sediment concentration and stream flow remain relatively low magnitude. As flow increases, the flow rate increase is greater than the increase of sediment concentration. Newly eroded non-contaminated sediments from Melton Branch Creek watershed enter the lake and mix with previous deposited contaminated sediments. Therefore, the ^{137}Cs concentrations decrease dramatically at the earlier rising limb of flood hydrograph. ^{137}Cs increase again as flood reaches to peak at the beginning of descending limb when significant sediment erosion occurs at channel/lake beds and hill slope contributed sediment concentration reach to its peak. Significant ^{137}Cs is released to the off-site during a short time.

The results from extreme-flood simulation showed that during a 100-year flood event the watershed and channel bed became the major sources of the ^{137}Cs. The total annual release of ^{137}Cs to offsite with 100-year flood event was 3.2 Ci v.s. 0.4 Ci for a normal year without 100-year flood. The peak concentration of ^{137}Cs was about 1960 pCi/g and maximum flux of ^{137}Cs was 0.99 Ci/hour during the extreme flood event.

REFERENCES

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., A.S. Donigian, Jr., and R.C. Johanson, 1993, Hydrological Simulation Program - FORTRAN User's Manual for Release 10. EPA/600/R-93/174. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, Georgia.

Clapp, R.B., Y. Bao, T.D. Moore, A.L. Brenkert, S.T. Purucker, D.K. Reece, B.B. Burgoa. 1996. *Waste Area Grouping 2 Phase I Remedial Investigation: Sediment and Cesium-137 Transport Modeling Report*, ORNL/ER-367, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

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DRY PONDS RETROFITTED OR CONVERTED TO BENEFIT STORM WATER QUALITY

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ABSTRACT

The Metropolitan Nashville-Davidson County (Metro) determined the feasibility and stormwater quality benefit of converting ten dry ponds to wet ponds. The conversion feasibility considered several issues including bedrock, utility rights-of-way, access, maintenance considerations, educational value, recreational benefits, public safety, cost, permit requirements, and flood control considerations. If it was determined that it was feasible to convert the pond, storm water quality benefits were considered. Storm water quality evaluations considered contributing land use, the optimal residence time of dry and wet ponds for the study area, existing dry detention pond residence times, and residence times of a wet pond given the site specific constraints. Preliminary evaluations indicate that two of the ten ponds had already been converted to wet ponds, and of the eight ponds that were not already converted, three could be retrofitted to wet ponds which will effectively benefit storm water quality.

INTRODUCTION

Metropolitan Nashville-Davidson County (Metro) was issued a National Pollution Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit in 1996 from the Tennessee Department of Environment and Conservation (TDEC). The Metro Department of Public Works (MDPW) has a series of work efforts planned and under way to address mandated conditions.

A key component of the NPDES MS4 permit implementation is runoff quality management from areas of new development or significant redevelopment. These areas are important to the NPDES MS4 program because post-development land contributes more stormwater runoff to the creeks and streams than pre-development land, through new paved and covered surfaces that do not allow water to infiltrate into the ground. Furthermore, these areas have more automobiles, people, and certain land use activities that contribute pollution by depositing oil, grease, antifreeze, trash, pet waste, dust from brake linings, metal fragments and dusts onto paved surfaces. Stormwater runoff flushes these pollutants into streams. Over time, the possible cumulative impact is degraded water quality, erosion, sedimentation, fish kills, and limited recreational access. Therefore, Metro is required by the NPDES MS4 to consider structural controls to reduce the runoff-related pollution.

Specifically, Metro was required to evaluate ten existing dry detention facilities for conversion to wet ponds. Converting existing dry ponds to wet ponds is desirable to many communities already experiencing stormwater quality problems in areas of redevelopment and built-out areas, or anticipating stormwater quality problems in areas of new development

A wet detention system includes a permanent pool of water, a shallow littoral zone with aquatic plants (or a larger permanent pool with no littoral zone), and the capacity to provide "live" detention (storage above the normal water level) to provide erosion control, flood control and treatment. The primary mechanism for the removal of particulate (suspended) forms of pollutants in wet detention ponds is sedimentation (CDM, 1998). Wet detention ponds can also achieve substantial reductions in soluble nutrients due to biological and physical/chemical processes within the permanent pool.

Converting dry ponds to wet ponds is desirable for the following reasons:

- There are existing dry ponds in place to control floodwaters. Additional water quality benefits can be achieved with relatively inexpensive modifications as compared to constructing entirely new facilities in urbanized areas.
- Using existing structures limits the expense of acquiring land and/or right-of-ways in heavy developed areas.
- Excess capacity of an existing structure may be used for permanent or live pools that improve water quality.
- In addition to the storm water quality benefit, the dry pond location may be converted into an aesthetically pleasing area used for public recreation or education.

This paper presents methodology applied to evaluate the ponds, stormwater quality benefit analyses results and preliminary recommendations.

POND EVALUATION

The following criteria were used to evaluate the conversion feasibility for each pond. The criteria are discussed to explain the importance of their consideration and how they should be incorporated into the conversion feasibility assessment and resulting design.

- **Bedrock -** Bedrock must be considered in the Nashville area because converting detention ponds from dry to wet often requires excavation and grading for a permanent pool. The permanent pool may be excavated into bedrock for a wet or dry detention pond, but the cost may be prohibitive. Furthermore, if there is highly fractured bedrock or karst topography, then the modification of a detention pond should be carefully considered because it may not hold water and the additional water flow and/or weight of water could intensify karst activity.

- **Utility Rights-of-Way -** The interaction with other utilities must be considered when converting from dry to wet ponds. It may not be practical to develop a permanent pool in an area that is needed by another utility. Furthermore, the cost of designing around utilities or utility relocation must be compared to the conversion benefit.

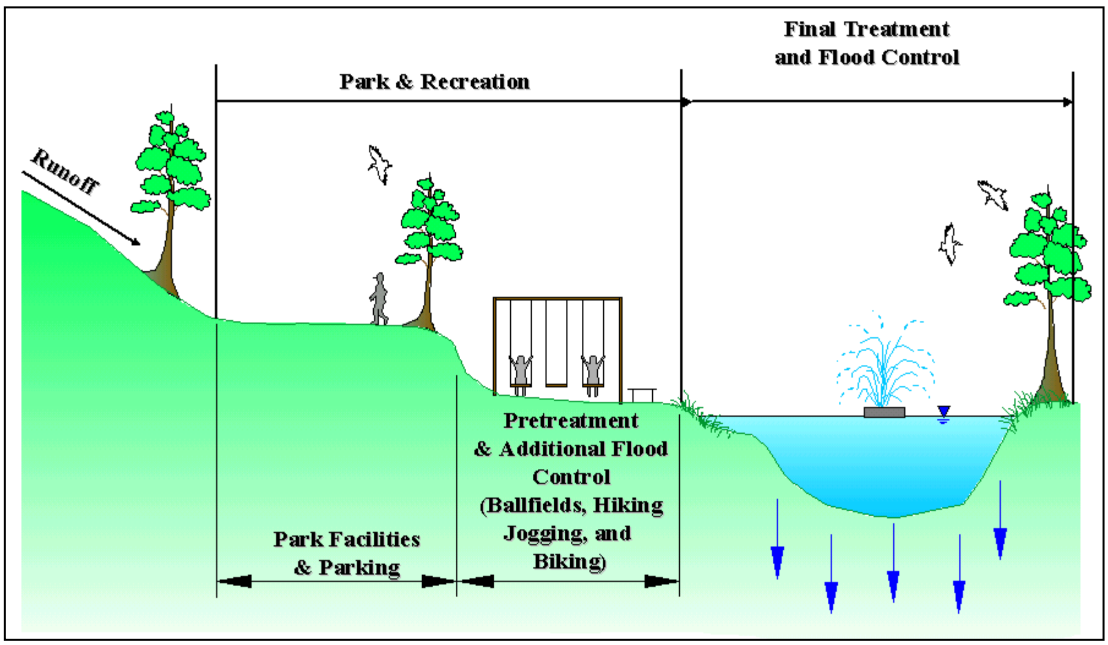
- **Access -** Access must be considered when converting ponds to account for maintenance crews and public interaction. Maintenance crews must have access to the site for proper maintenance. Ponds that are not designed with access for maintenance crews often become more of a nuisance than a beneficial part of a storm water management program. It may also be desirable to encourage or discourage access for the public. Public education and recreation may be facilitated by access to the pond, provided public safety is sufficiently addressed. In some cases, however, it may be desirable to restrict public access such as in especially sensitive or dangerous areas.

- **Maintenance Considerations -** The pond's success as a mechanism to benefit water quality is dependent on maintaining the permanent pool, skimmer devices, and inlet and outlet structures. This maintenance typically includes sediment, floatables, and debris removal from inlets, outlets and skimmers. Additionally, pond vegetation need to be trimmed or harvested as appropriate, grassy areas frequently mowed and repairs made to signage, walkways, picnic tables, or any other public recreation equipment. If both the operational and aesthetic characteristics of a wet pond are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly.

- **Educational Value -** Education of the public is understood to be critical to the success of any storm water management program. Some wet ponds can help educate the public on storm water issues and encourage stewardship of the natural resources. Signage or programs organized with local schools can be used to educate the public at the detention facilities. If a pond is to be designed for these types of activities, there must be enough room for the walkways and some measures taken to restrict access to sensitive or dangerous areas.

- **Recreational Benefits -** Ponds that serve smaller local site runoff do not offer as much recreational benefit as ponds serving larger regional runoff. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands or preservation zones, which allow a view of nature within the park schemes. **Figure 1** is an example of a multi-use regional facility.

Figure 1
Multi-Use Regional Facility



- **Public Safety -** The public's safety must be a foremost consideration. For the design of wet detention ponds, this usually takes place in the grading, fencing, landscaping, pipe cover, grating and signage. The most important design feature affecting public safety during a pond's operation is grading. The contours of the pond should be designed to eliminate "drop-offs". *Side Slopes* should be 6:1 or flatter to provide a littoral shelf and safety bench from the side of the facility out to a point 2 to 3 feet below the permanent pool elevation. Side slopes above the littoral zone should be no steeper than 4:1. Side slopes below the littoral zone can be 2:1 to maximize permanent pool volumes where needed. A short (0.5 foot) drop-off can be constructed at the edge of the pond to control the potential breeding of mosquitoes. When possible, terraces or benches are used to transition into the permanent pool. Within the permanent pool, it is desirable to have a wet terrace 12 to 18 inches below the normal pool level. In some cases there is not sufficient room for grading of this type and the pond may require a perimeter fence.

- For larger detention facilities, the structural integrity of the impounding embankment should also be considered. The embankment should be protected against catastrophic dam failure. (Roesner, et al, 1998).

- **Costs -** Capital costs must be weighed against the benefit of the expenditure. Nearly every dry detention pond can be converted to wet detention for a price. However, if the price to convert a pond is not warranted by the benefit to the storm water resources, then the pond should not be converted.

- **Permit Requirements -** The need for various permits, including potential USACOE dredge and fill and TDEC ARAP permits, should also be considered

- **Flood Control -** The control of flooding is important for public safety. Converting to a wet pond should not compromise the flood control benefits of an existing dry pond. The potential water quality benefits evaluated in this investigation were considered to augment flood control, such that the ponds can achieve an integration of flood control and storm water quality treatment.

STORM WATER QUALITY BENEFITS ANALYSES RESULTS

The storm water quality analyses were intended to determine if there was a benefit that justifies the estimated cost of construction, maintenance and operation. In general, a wet pond's pollutant removal efficiency is greater than that of a dry pond. In particular, removal efficiencies for total phosphorous and total nitrogen are on the order of 2 to 3 and 1.3 to 2 times greater in extended detention (wet) ponds than dry ponds (Hartigan J.P., 1988). The ability of a wet pond to remove more pollutants is a result of the residence time, or bleed down time of the "live pool" and the size of the permanent pool. If the permanent pool is not properly sized then its capacity to remove pollutants is limited. Therefore, storm water quality evaluations were performed and considered the contributing land use, optimal residence time of dry and wet ponds for the study area, existing dry detention pond residence times, and residence times for new wet ponds given the site specific constraints.

The site specific constraints principally included the availability of space. If there is ample space to expand a dry pond, given the slope restrictions and depth requirements discussed above, then an optimal wet pond may be constructed. If there is not enough space then a wet pond may still be built, but the residence time will be less than optimal, thereby reducing pollutant removal efficiency.

The USACOE Storage, Treatment, Overflow, and Runoff Model (STORM) was used to analyze a 48-year period of hourly rainfall (1948-1996) and evaluate the percent capture for dry and wet ponds. The percent capture is defined as the average annual runoff volume that flows through the detention device in the optimal range for residence times. The optimal residence times range for the bleed down or "live" pool for a dry detention basin is 12 to 24 hours and 24 to 60 hours for the "live" storage above the wet pond's permanent pool (CDM 1993). The STORM analyses indicate that "live" pool volumes between 0.5 and 1.0 inches per tributary acre area will capture 85 to 90 percent of the average annual runoff volume for treatment in the dry or wet pond. The optimal wet detention basin's permanent pool also has an overall residence time (permanent and live pools combined) of 2 to 4 weeks during the rainy season. STORM uses the rational method (Q=CiA) with hourly rainfall over a continuous period of hydrologic conditions to estimate flow rates, residence times and capture versus detention storage. The average annual rainfall for the period of record was 47.5 inches. The average detention time used for the dry detention analysis was 18 hours (based on a range of 12 to 24 hours). The average detention time used for the wet detention analysis was 42 hours (based on a 24 to 60 hour range).

PRELIMINARY RECOMMENDATIONS

It was determined that two of the ten ponds have already been converted to wet ponds, while three of the remaining ponds have potential for conversion. **Table 1** summarizes the investigations, storm water quality analyses and preliminary recommendations. At the time of this report, cost estimates were being prepared to support benefit to cost calculations. This evaluation will be used by Metro to determine any future actions that it may take with these facilities, given financial and political constraints.

The following is a summary of the design criteria being recommended for wet detention ponds:

- *Permanent Pool* - Wet detention permanent pond storage volume should provide for an average hydraulic residence time of at least 2 to 4 weeks. This volume may be determined by a calculation of the runoff volume during the wettest 2 week period during an average year.

- *"Live" Detention Volume* - A bleed-down, or live storage volume, should be provided for the first 0.5 to 1.0 inches of runoff, depending on the tributary impervious area and land use type. This bleed-down storage is to be provided in addition to the permanent pool storage. A triangular shape, or V-notch, weir is well suited to providing gradual release rates for erosion and flood control for larger events.

- *Sediment Forebay* at inlet points to provide pretreatment and reduce maintenance costs.

- *Live Detention Storage Recovery* - Wet detention pond outlets should be designed to drawdown, or recover, the bleed-down (or live) detention storage pool so runoff from the first 0.5 to 1.0 inch can be discharged in the first 24 to 60 hours following a storm event.

- *Length to Width Ratio* - By maximizing the distance between the inlet and outlet point of a detention pond, the greatest opportunity for suspended solids settling is obtained. Therefore, a minimum length to width ratio of 3:1 is recommended. (Wanielista, 1990).

- *Inlet Structures* should be designed to dissipate the energy of waters entering the facility and to help prevent short-circuiting.

- *Side Slopes* should be constructed to support public safety and promote/control vegetation and vectors.
- *Maximum Permanent Pool Depths* of 6 to 12 feet below the invert of the control structure are recommended to minimize the potential for thermal stratification and re-release of nutrients from bottom sediments due to potential anaerobic conditions. Fountains or aerators may be used for deeper ponds to circulate the water column and provide aesthetic benefits.

- *Skimmers* - Facilities that receive stormwater from contributing areas with greater than 70 percent impervious surface or that are a potential source of other floatable contamination.

- *Wetland Littoral Zones* are sometimes provided for biological removal or wetland habitat.

Table 1
Investigation and Analyses Summary

Evaluation Criteria	*SWC 5*	*SWC 7*	*SWC 8*	*SWC 11*	*SWC 12*	*SWC 13*	*SWC 14*	*SWC 15*
Bedrock	❶	❶	❶	✕	❸	--	❸	❷
Utility Rights-of-Way	❸	❸	❸	✕	❸	--	❸	❷
Access	❸	❸	❸	--	❷	❶	❷	❸
Maintenance Considerations	❸	❸	❸	--	❷	--	❷	❸
Educational Value	❸	❶	❶	--	❸	--	❸	❸
Recreational Benefits	❸	❶	❶	--	❸	--	❶	❸
Public Safety	❷	❶	❷	--	❷	✕	❷	❸
Evaluation Criteria Score	18	13	14	✕	18	✕	16	19
Potential Water Quality Benefits	Minimal	Minimal	Minimal	--	Medium	--	Low	High
Conversion Recommended	No	No	No	No	Yes	No	Yes	Yes

❶,❷,❸ *and* ✕ *indicate a low to high ranking for the individual evaluation criteria. An* ✕ *indicates that an evaluation for the specific criteria prohibits construction of a wet pond. A* ❸ *indicates that the specific evaluation criteria will not interfere with the construction of a wet pond.*

REFERENCES

Camp Dresser & McKee (CDM). Watershed Management Model Version 4.12 User's Manual. 1998.

Hartigan J.P., 1988 Basis for Design of Wet Detention Basin BMPs. Proceedings on an Engineering Foundation Conference on Current Practice and Design Criteria for Urban Quality Control. ASCE. 1988.

Roesner, L. A., et al. Urban Runoff Quality Management, WEF Manual of Practice No. 23 – ASCE Manual and Report on Engineering Practice No. 87. WEF/ASCE. 1998.

State of California Stormwater Best Management Practice Handbooks, Prepared by Camp Dresser & McKee, Inc (CDM). 1993.

Wanielista, Final Report on Efficiency Optimization of Wet Detention Ponds for Urban Stormwater Management. University of Central Florida. 1989.

A REVIEW OF SOIL TESTING FOR NUTRIENT MANAGEMENT

Hugh Savoy[1*]

ABSTRACT

Soil testing is successfully used for the purpose of more objectively making efficient lime and fertilizer rate recommendations in crop production systems. The development of a soil testing program involves soil test correlation, soil test calibration and soil test interpretation. Different soil test extractants give different numerical values for nutrients but may with proper calibration show similar soil test categories and interpretation. Altering soil test chemical extractant, laboratory procedure or soil sampling methodology can make the soil test results meaningless. Because soil tests used in crop production systems measure the highly available forms of nutrients, it follows that some relationship with nutrient levels in runoff water is expected. Recent research has shown this to be true. Soil tests, however, tell us nothing about total volumes of runoff water that might be generated for a given set of field conditions.

INTRODUCTION

In Tennessee, soil tests have been used to objectively evaluate the need for lime or fertilizer materials and the rates of those materials to apply. This is without a doubt the most economical approach to nutrient management for crop production purposes. “Don’t guess, soil test” became a popular slogan at producer meetings in Tennessee. The University of Tennessee, Soil Testing Laboratory in Nashville analyses some 30,000 or more soil samples annually for the purpose of making lime and fertilizer recommendations in the crop productions systems of Tennessee. The purpose of this paper is to briefly review the steps in development of a soil test. A better understanding of soil testing is needed in order to better understand its potential for use as an environmental tool and also its limitations for that purpose.

ASSESSING AVAILABLE NUTRIENTS VERSUS TOTAL SOIL NUTRIENTS

Early on, researchers recognized that total levels[1,2,3,4,5] of plant nutrients in a soil were not related to observed growth or quality response of crops grown on those soils. This is because most of these nutrients were tied up in some way by the soil components or as highly insoluble chemical compounds. The rate at which they became dissolved in the soil solution was to slow to have any appreciable effect on plant uptake.

Researchers began to focus on chemical extractants which would only take from the soil the chemical forms of nutrients that are accessible to plant roots or compounds likely to be convertible to such forms during the growing season (available soil nutrients). The procedures and process of selecting such a suitable soil test extractant is called soil test correlation[6] and involves research in the laboratory, greenhouse and field. From such research came our modern soil test extractants. The plant nutrients extracted by these certain very specific procedures (extractable soil nutrients) were found to be highly related to observed crop yield or quality response in the field. This is why soil tests are so useful in making recommendations on the need and amount of fertilizer materials to use. In the early years of soil testing, almost every state had their own particular soil test extractant. Over the last 20 years, significant progress has been made in standardization of soil test extractants and procedures within regions of the United States. Today, most state university operated laboratories in the south use the Mehlich I [7] or Mehlich III soil test extractants with standardized laboratory procedures and on soil samples collected by a very specific standardized method of sampling. Results obtained by altering the chemical extractant, laboratory procedure or soil sampling methodology often render the soil test results meanlingless.

In Tennessee the Mehlich I soil test is used by the University of Tennessee to assess available plant nutrients across the range of soil types found throughout the state. Soils tested by other procedures may show different numerical results, however when properly calibrated, the interpretation should be similar when the compared extractant is as well or better correlated with plant uptake as the Mehlich I extractant.

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WHAT DO SOIL TEST VALUES MEAN

Soil test calibration is that process of determining the meaning (in terms of potential for crop yield or quality response) of soil test values obtained by a specific soil test extractant. Calibration is used to establish soil test categories such as low, medium, high and very high. In Tennessee, research indicates that soils testing low means that in most cases, plants grown in those soil systems will respond to the application of that nutrient testing low. If the nutrient is not applied, deficiency symptoms may occcur and crops usually yield less than 75 percent of their full potential or exhibit some reduction in quality. Medium means that plants may or may not respond (yield or quality) to the application of that nutrient. Deficiency symptoms are not likely and crops grown on these soils can be expected to produce 75 percent or more of their full potential without the application of the nutrient. High means that the crops grown on these soils will produce at or near 100 percent of full yield without the addition of the nutrient. Amounts of the nutrient recommended are primarily to maintain present soil test levels and will closely approximate amounts expected to be removed in the harvested portion of the crop. Very high means that the supply of the nutrient in the soil is well in excess of the amount needed to produce 100 percent of the yield potential. Application of the nutrient is not recommended since further additions may create nutrient imbalances.

Diagnosing plant nutritional status is much more than just determining the amount of nutrient in the plant. It involves assessment of the soil's ability to supply that nutrient to the plant in a time period that will make a difference in the plant's growth and development. Often plant tissue analysis and soil tests are used together to provide the most complete picture of the soil/plant system. However, soil tests can be successfully used alone more often than plant analysis. Steps that can be used in diagnosing plant nutritional and soil chemical problems range from a simple visual diagnosis of plant nutrient deficiency symptoms to a more complex analysis of plant tissue and soil.

HOW MUCH FERTILIZER DO I NEED

Soil test interpretation is that process of developing fertilizer recommendations based upon soil test levels and other crop and climatic conditions. There are at least three different philosophies on how to do this.

The Crop Sufficiency approach focusses on potential for crop response to added nutrient. The expected response frequency and magnitude is what determines the recommended level of nutrient in each soil test category. This approach is based upon field research over many soils for several years. The research base must be sufficient for each crop on the existing soil types under the most prevailing weather conditions.

Soil cation balance focuses on the cation (Ca, K, Mg primarily) balance of the soil. The theory is that correct nutrient balance results in maximum crop response. This approach is often adopted when wide extremes in soil type or encountered, or the research base for the soil types encountered is not extensive.

The Maintenance approach to soil fertility results in the replacement of all nutrients removed at harvest. This is done even on high testing soils. This method is used in addition to the recommendation made by either the Soil Cation Balance or Crop Sufficiency approach. A yield response to this extra maintenance fertilizer is not expected, but the fertilizer is added in hopes of maintaining soil test levels over time.

Most University laboratories tend to primarily use the Crop Sufficiency approach to interpret soil test values.

SOIL TESTS TO ASSESS NUTRIENT RUNOFF IN WATER

Soil testing has been used very successfully to manage nutrient additions for the production of crops. Recent research[8,9] has shown that soil tests can also be related to the phosphorus levels in runoff water from land areas. The primary contaminant of surface waters is water soluble orthophosphate. This form of soil-P increases in concentration directly as soil test-P increases. Soil tests, however, tell us nothing about the amount (rate) of runoff water that might be generated for a given set of field conditions or what volumes would seriously impact a given water shed during a certain period of time. Such an assessment will obviously require additional facts about the site and will be very site specific.

SUMMARY

It is expected that soil testing will continue to play a major and important role in production agriculture. It's primary use is to assess the need for lime and fertilizer materials and the rates of those materials to apply. With the recent focus on water quality and the environment, soil testing may be further evaluated as a tool to assess potential for excessive nutrient loading of our water sheds. The complexity of the problem would appear to call for a multi-disciplinary approach in researching the potential use of soil testing as one tool in the chest needed to safeguard our water resources.

REFERENCES

Bray, R. H. 1929. A field test for available phosphorus in soils. Illinois Agric. Exp. Stn. Bull. 337.

Hester, J. B. 1934. Micro-chemical soil tests in connection with vegetable crop production. Virginia Truck Exp. Stn. Bull. 82.

Morgan, M. F. 1932. Microchemical soil tests. Conn. Agric. Exp. Stn. Bull. 333.

Spurway, C. H. 1933. Soil Testing: A practical system of soil diagnosis. Michigan Agric. Exp. Stn. Bull. 132

Truog, E. 1930. The determination of the readily available phosphorus in soils. J. Amer. Soc. Agron. 22: 874-882.

Corey, R. B. 1987. Soil test procedures: Correlation. P. 15-22. IN J. R. Brown (ed.) Soil testing: Sampling correlation, calibration and interpretation. SSSA Spec. Publ. 21. SSSA, Madison, WI

Reference Soil Test Methods for the Southern Region of the United States. 1983. Southern Cooperative Series Bulletin 289.

Johnson, G. V. et al. 1998. Animal Waste Management: Economics of Nutrient Recycling. p. 1-3. Proceedings of the 1998 Southern Soil Fertility Conference. Memphis, TN. Noble Foundation, Ardmore, OK.

Daniels, M. 1998. Soil phosphorus levels: Concerns and recommendations. University of Arkansas, Cooperative Extension Service Publication FSA1029. Fayetteville, AR.

CONTROLLING SOIL EROSION ON CONSTRUCTION SITES USING WOOD CHIPS

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ABSTRACT

Wood chips were studied for their efficacy in controlling soil erosion on construction sites with steep, disturbed soils. The purpose of this research was twofold: to develop a new management practice to reduce the off-site movement of soil during construction activities, and to find an environmentally sound alternative to the disposal of wood wastes generated in the urban forest. Twelve erodible plots were established on an embankment with a 55% slope and a change in elevation of nearly 12 m. Each plot has a width of 3 m and a slope length of 10 m. A series of flow dividers were installed at the toe of each plot to collect runoff and sediment. After each rain event, the total runoff and mass of sediment leaving the plot were determined. Four treatments were studied - large chips, a mixture of chip sizes, small chips, and bare plots. Three replicates of each treatment were installed. Chips were applied to give an initial coverage of 80%. Preliminary indications suggest that during rain events larger chips provide superior protection, and that chips do not float off the slope unless the soil is eroded out from beneath the chip.

INTRODUCTION

Off-site movement of soil disturbed by construction, mining, agriculture, and other land-disturbing activities is known to degrade the value and environmental sustainability of adjacent land and water. Soil erosion begins with the detachment of soil particles from the surface by raindrop impact. Unless detachment can be prevented or reduced, then sediment control methods must be employed to attempt to restrict off-site movement. Typical methods include sediment barriers consisting of silt fences or straw bales, and sediment detention basins - all of which are limited in their ability to capture eroded sediment and hold it on-site.

Generally, on steep slopes it takes very little runoff to transport detached soil particles, thus limiting particle detachment is the crucial component. It is well known that the most effective method of preventing detachment is to provide a permeable soil cover to adsorb raindrop energy, slow runoff, and increase infiltration (Benkobi et al., 1993; Jennings and Jarrett, 1985; Sarles and Emanuel, 1977; Stocking, 1994). These protection mechanisms can be provided by spreading processed organic material over the disturbed soil. Certainly this is not an original notion, but there is an absence of the quantitative information needed to design erosion control systems using organic cover on steep slopes.

The State of Tennessee enacted a comprehensive solid waste management system in the form of the Solid Waste Disposal Act of 1991 (TCA 68-211-861). This act mandated a 25% reduction of solid waste disposed of at municipal solid waste disposal facilities and incinerators (on a 1989 weight per capita basis) by the last day of 1995. Many municipalities have adopted a policy of refusing yard waste in order to meet the mandate. Wood chips comprise a significant portion of the yard waste generated in urban areas.

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One of the goals of this project was to find an alternative use for wood chips. Wheat straw is usually the organic cover of choice for protecting soils disturbed by construction. In East Tennessee, wheat is not a significant commodity and therefore the straw is expensive to import. However, wood chips are readily available in East Tennessee, and they are collected separately from household solid waste. Thus the primary objective of this research was to examine the effectiveness of wood chips as a cover to control the erosion of disturbed soils on construction sites with steep slopes.

METHODS AND MATERIALS

In order to determine if the size of the chip is a significant factor in providing soil protection, experimental treatments were established that included only large chips, only small chips and a mixture of sizes similar to the distribution generated by chippers. Additionally, a zero-cover treatment was established to determine the erodibility of the embankment. Samples of wood chips were taken from a local arboriculturist. The chips were graded into four size categories: 6.4 mm and under, 6.4 to 13 mm (small chips), 13 to 25 mm, 25 mm and over (large chips). Over 4 m^3 of chips were sorted with sieves and the resulting distribution of sizes is listed in Table 1.

Due to the differences in moisture content, it was decided to use volume rather than mass to quantify the distribution of sizes. The mixture of sizes treatment was proportioned (by volume) as 28% small chips, 51% medium chips, and 21% large chips. It was assumed that the material in the 6.4 mm and under category would rapidly degrade and thus this size fraction was not included in the study.

Table 1. Size distribution produced by chipper-style wood grinders*

Size	Description	Volume (m3)	% of Total Volume	% of Small, Medium, and Large
6.4 mm and under	mostly saw dust and ground leaves	1.46	33	0
6.4 to 13 mm	small chips	0.83	19	28
13 to 25 mm	medium chips	1.52	34	51
25 mm and over	large chips	0.61	14	21

*A total of 4.4 m3 of chips were collected during four separate sam pling events from Wolf Tree Experts in Knoxville, Tennessee.

An embankment was located in Knox County, Tennessee in the southern drainage of Brown's Mountain. The fill soil for this embankment was identified as a Tellico Clay Loam. This embankment was constructed with a consistent slope of 55% and an average elevation change of 12 m. Twelve plots were established on this embankment. Each plot had a 10 m slope length (measured horizontally), was 3 m wide, and was delineated by using 150-mm, plastic lawn-edging as a border. The volume of runoff and the mass of eroded soil was estimated by passing the discharge of each plot through a series of flow dividers (figure 1). These dividers are a modification of Geib (1933) and have been laboratory-tested for accuracy. The flow dividers were mounted on 21-L (5-gallon) buckets. All of the runoff flowed into the first bucket where the settleable solids were captured. Once the first bucket was full of water, overflow was divided across 24, 22.5° v-notch weirs. Overflow from one weir was directed to the second divider and likewise, the flow from one weir on the second divider was directed to the third bucket. The solids that settled in the first bucket were dried and weighed. After a thorough mixing, grab samples were taken of the water in buckets 2 and 3 in order to estimate the mass of suspended solids that was discharged with the excess water.

Three blocks of four plots each were segregated on the basis of the concavity of their profile. Block A had the most concave profile, block B was less concave, and block C was nearly linear from top to bottom. Within the blocks, the experimental treatments were randomly assigned. Chips were applied to the soil surface until approximately 80% of the surface was covered. A grid, with 100 nodes set on 10-cm square intervals, was employed to determine the percent cover. The grid was placed on the surface over the chips. Each node that had a chip beneath it was counted and the percentage of nodes over a wood chip was assumed to be the coverage.

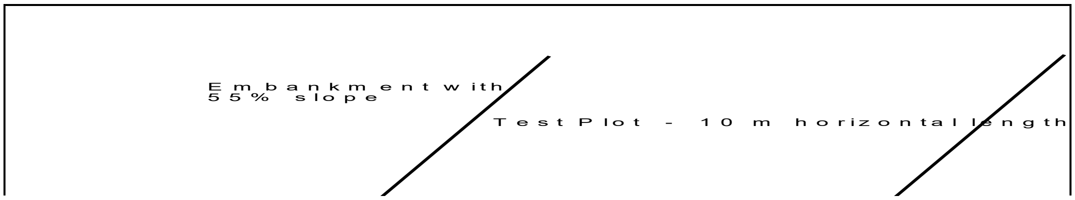
Erosion energy was supplied by natural rainfall events. Each event was recorded for duration, intensity, and depth using an Onset Computer Corporation Hobo Event Logger and Davis Rain Collector II tipping bucket raingage. The raingage had a tip resolution of 0.25 mm and the datalogger recorded each tip with time. Each significant storm was assigned an erosivity value using the procedure outlined by Renard et al. (1997). This value is referred to as the EI_{30} in the Revised Universal Soil Loss Equation and is an estimate of the erosive energy that the storm imparted to the soil surface.

Following Renard et al. (1997) significant rain events were defined as those exceeding 13 mm of precipitation. Events of less than 13 mm were considered insignificant unless 6.4 mm fell in 15 minutes or less. After each significant rain event, all the flow dividers were changed out to determine volume of runoff and mass of solids that had been discharged from the plots.

RESULTS AND DISCUSSION

Statistical comparisons were computed on the mass of solids that were discharged from each plot. The experimental design was a randomized complete block. A linear model of the results from each storm event was computed by using Proc GLM from SAS (SAS Institute, 1997). The experimental layout was based on three blocks of plots with similar concavity in their profile. Analysis of variance (ANOVA) among the blocks determined that there was no significant block effects. Therefore similar treatments were averaged across blocks to generate treatment means. The ANOVA F-test was used to determine if there was significant difference between means, and Fisher's least significant difference was employed to determine which treatments' means were different. Table 2 lists the treatment means for each storm event, the probability of the means not being significantly different, and how the means were separated. Generally speaking, the results were not considered significantly different unless the probability of making a Type I error was 10% or less.

For all storm events, the mixture of chip sizes and the large chips provided the best soil protection - albeit not always statistically superior. In most cases, the effect of the small chips was not different from having no cover on the soil surface. Using 10% as the threshold for significance, storm events 1, 2, 3, 5, and 6 produced results that suggest the mixture of chip sizes and large chips are statistically superior for erosion control. Storm 3 was the only event for which the small chips provided significant soil protection. The variability in the results from like treatments in storms 4 and 8 suggested that the results were not significant, although the results still followed the same trends as the other storm events.


Embankment with
55% slope
Test Plot - 10 m horizontal length

CONCLUSION

The consistent performance of the mixture of chip sizes is very encouraging, Suggesting that chips can provide protection to the slope without additional grinding or size segregation. Applying wood chips to disturbed soils at construction sites with steep slopes can provide an effective means of keeping the soil on site and utilize a waste material for the benefit of the environment. Future research in this area will need to focus on developing efficient methods to apply the chips, and determining if there are any agronomic problems created by the chips in the establishment of a permanent stand of grass.

Table 2. Means of total solids eroded during eight storm events.

Event	Storm1 Erosivity	Treatment Means (kg)				F-test2	LSD3	Storm Date
		Bare	Small	Mixed	Large			
1	612.4	8.40 a	8.27 a	1.00 b	3.05 ab	p=0.10	7.20	8/11/98
2	308.4	10.38 a	7.82 a	2.00 b	1.99 b	p=0.01	4.80	8/16/98
3	135.5	9.90 a	5.39 b	0.89 c	0.90 c	p<0.01	2.27	8/18/98
4	31.8	0.03 a	0.01 a	0.01 a	0.01 a	p=0.58	0.04	9/21/98
5	80.3	0.20 a	0.19 a	0.03 a	0.07 a	p=0.05	0.22	9/29/98
6	38.5	0.59 a	0.70 a	0.06 b	0.23 b	p=0.01	0.40	10/7/98
7	27.2	0.40 a	0.32 a	0.02 b	0.07 ab	p=0.09	0.35	11/11/98
8	104.8	1.19 a	1.53 a	0.21 b	0.55 ab	p=0.14	1.26	12/12/98

Means with the same letter are not different
1Storm Erosivity (MJ_mm/ha_h)
2F-test from ANOVA, probability that treatment means are not different
3Fisher's least significant difference

REFERENCES

Benkobi, L., M. J. Trlica, and J. L. Smith. 1993. Soil loss as affected by different combinations of surface litter and rock. J. Environ. Qual., 22(4):657-661.

Geib, H. V. 1933. A new type of installation for measuring soil and water losses from control plats. J. Am. Soc. Agronomy, 25(7):429-440.

Jennings, G. D. and A. R. Jarrett. 1985. Laboratory evaluation of mulches in reducing erosion. Trans. ASAE, 28(5):1466-1470.

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder, coordinators. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). USDA, Agricultural Handbook No. 703.

Sarles, R. L. and D. M. Emanuel. 1977. Hardwood bark mulch for re-vegetation and erosion control on drastically disturbed sites. J. Soil Water Conser., 32(5):209-214.

SAS Institute Inc. 1997. SAS/STAT Guide for Personal Computers. Cary, NC.

Stocking, M. A. 1994. Assessing Vegetative Cover and Management Effects. In: R. Lal (ed), Soil Erosion Research Methods, Second Edition. Soil and Water Conservation Society and St. Lucie Press, Delray Breach, FL.

EVALUATION OF THE USAGE OF PERSISTENT PESTICIDES IN THE ENVIRONMENT

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Regulatory agencies are continually faced with issues concerning the migration of organic and inorganic chemical constituents to and through multimedia systems (water, soil, air, etc.). Each of these issues requires that the potential risk to human health and various ecosystems be evaluated. Recently, much of this attention has been focused on exposure to persistent organic pollutants (POPs). Historically, these POP compounds have been associated with application in an agricultural crop setting. These POP chemicals are of concern due to their classification as "endocrine disruptors," which adversely impact the glandular system of the human body.

Several models are capable of simulating the transport and transformation of chemicals in the soil subsurface. None of these models, however, have been combined to provide a consistent set of linked unsaturated zone models that has the flexibility to handle a wide variety of hydrogeologic, soil, climatic, and source control scenarios. In addition, the formulation of the risk analysis problem requires more than a simple, deterministic evaluation of potential exposure concentrations. The inherent variability of force, capacitance and resistance in natural systems, combined with the inability to accurately describe these attributes of the system, suggest that exposure concentrations cannot be accurately predicted with certainty. Therefore, the uncertainty associated with concentration predictions must be quantified.

Nationwide, POPs are located in many diverse hydrogeologic environments (e.g., multiple aquifer systems, fractured and/or karst systems, and systems with wide variations in depth to the water table). In addition, recharge can vary widely because of irrigation practices and/or climate. Also, domestic and irrigation wells, which pump at different and varying rates, are commonly located throughout agricultural regions. Contamination scenarios in these regions must consider multiple point and non-point source loadings which vary both spatially and temporally.

The Pesticide Root Zone Model (PRZM-3) is a one-dimensional, dynamic, compartmental model that can be used to simulate chemical movement in unsaturated soil systems within and immediately below the plant root zone. It has two major components - hydrology (and hydraulics) and chemical transport. The hydrologic component for calculating runoff and erosion is based on the Soil Conservation Service (SCS) Curve Number (CN) technique and Modified Universal Soil Loss Equation (MUSLE). Evapotranspiration is divided among evaporation from crop interception, evaporation from soil, and transpiration by the crop. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content. The chemical transport component can simulate pesticide application on the soil or on the plant foliage. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar washoff, advection, dispersion, and retardation.

The primary objective of this project is to develop a methodology to investigate the relative and aggregate impact of meteorologic/site/hydrologic, chemical-specific properties, soil properties, and land use/management techniques on the occurrence of POPs in the upper soil zone of the terrestrial biosphere. This evaluation will be based on estimates of steady-state soil concentrations using the PRZM-3 model for each of the contaminants of concern (i.e., list of POPs).

This effort is currently ongoing. The methodology described above will be based primarily on detailed simulations of various POPs at locations distributed throughout the United States, sensitivity analyses to determine key parameters, and uncertainty analyses conducted using the PRZM-3 model's Monte Carlo simulation capabilities.

The results of this effort will be presented at the Symposium.

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SIMULATING SURFACE WATER FLOW AND CONTAMINANT TRANSPORT IN THE EAST FORK POPLAR CREEK AREA, OAK RIDGE, TENNESSEE

by

Shabbir Ahmed[1*], Warren Campbell[2], Alauddin Khan[3], and Judy Hardt[4]

ABSTRACT

A surface water flow and contaminant transport model was developed for the East Fork Poplar Creek (EFPC) site of the U. S. Department of Energy's (DOE's) Oak Ridge Reservation (ORR) as part of the removal action effort to control and treat mercury contamination in surface water. The hydrologic and physical characteristics were integrated to develop a conceptual model for the EFPC area. The data and information for the conceptual model of the EFPC area were organized to enter into a numerical model. The numerical model, SWMM (Storm Water Management Model), was used to represent the conceptual model for the EFPC area. The model simulated different scenarios based on separate mercury loadings at Station 17 located downstream of the Oak Ridge Y-12 Plant in EFPC. The model simulations were performed for a wide range of rainfall conditions. The rainfall conditions included single storm event, average rainfall year, peak rainfall year, and continuous long-term rainfall for a period of ten years. The model was calibrated based on isolated storm event data. The calibrated SWMM model was used to simulate the transport of mercury along EFPC segments. The simulations indicated that the mercury concentration along EFPC varies in both space and time. The average predicted mercury concentration at Station 17 varies from 990 ppt to 2,085 ppt corresponding to average and peak rainfall years. Changes in loading from Y-12 Plant at Station 17 impacts the concentration of mercury at the U.S. Geological Survey gaging station.

INTRODUCTION

Over the past four decades, large quantities of mercury were lost to the environment from the Oak Ridge Y-12 Plant, owned by the U. S. Department of Energy (DOE). Exact estimates of the total mercury discharged to the environment are unknown. Approximate estimates indicated that the maximum amount of mercury discharged to the environment could have been about 2.4 million pounds (UT, 1996). A significant portion of mercury was lost to the environment through the surface water system. Surface water transport of mercury occurred through Upper EFPC, adjacent to the Y-12 Plant. Significant soil concentrations have been measured at several sites (SAIC, 1994 and SAIC, 1998).

University of Tennessee (UT, 1996) developed a model to investigate flow and transport of mercury in the Upper EFPC area. The model was calibrated and validated for simulating transport mechanism from Y-12 area into Upper EFPC (Fig. 1). The model can be used to simulate flow and mercury concentration in the Y-12 area leading toward Station 17. The modeling study did not include flow and mercury transport mechanism downstream of Station 17 in the lower EFPC area.

Because the discharge from upper EFPC at monitoring Station 17 becomes the headwaters of Lower EFPC, any remedial decision about the surface water quality of Upper EFPC will ultimately impact the water quality of Lower EFPC. Therefore, any alternative to meet the remedial action objective for surface water in Upper EFPC must also consider the overall effect downstream. The present modeling study is a part of the removal action effort intended to evaluate both current conditions and the removal efficiency of future cleanup options.

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MODEL CONSTRUCTION

The site conceptual model for surface water system was developed and understood to select the appropriate numerical model for a realistic representation of the physical system. The model requirements included the ability to simulate time-varying hydrologic conditions, rainfall excess for runoff, infiltration, and flows with constant inflows of flow management water and groundwater in the system. The EPA Storm Water Management Model (SWMM; Huber and Dickinson, 1988) was selected because it meets these criteria and because it has proven to be an efficient and robust numerical model.

Of all the SWMM data, surface roughness, slope, width of flow, depression storage, imperviousness, washoff, and runoff coefficients bear special significance in terms of calibration and validation. These parameters were evaluated based on site-specific conditions. Surface features such as buildings, grass areas, parking lot, etc. were taken into consideration for evaluating these parameters.
The flow and contaminant routing scheme in a hydrologic model is organized by discretizing the overall catchment into subctachments or smaller drainage areas. The discretization is done on the basis of individual properties of subcatchments. In SWMM, the subcatchments are evaluated as spatially lumped, nonlinear reservoirs with outflows routed through the channel or pipe network.

The EFPC that routes flow and contaminant is also discretized into different segments for appropriate distribution of properties and flows. A schematic representation of the contributing subcatchments and the corresponding channel segments receiving flows and contaminant loadings is shown in Fig. 1.

CALIBRATION

The February 13, 1991 storm produced 1.41 inches of rainfall over 34 hours. This storm was used for calibration of the model. The observed (223 cfs) and computed (234) peak flows were very close at USGS gaging station. The average flows at Station 17 and at USGS gaging station was simulated at 9.8 cfs and 21.2 cfs respectively, based on average rainfall year data. These simulation results are consistent with the average conditions along EFPC. A close match between simulated (2.5 µg/L) and observed (2 µg/L) peak concentrations of mercury at USGS gaging is obtained. A reasonable agreement between observed (6.8 µg/L) and simulated (7.7 µg/L) peak mercury concentrations at Station 17 is also obtained.

SIMULATION RESULTS

The simulated concentrations of contaminants largely depend on the available loadings from contaminated drainage areas. The model simulation results for an average rainfall year are shown in Fig. 2. An average mercury concentration of 0.99 µg/L is observed at Station 17 which is consistent with the observed data. Evaluation of different scenarios was primarily based on the simulated flows and mercury concentration at Station 17 and USGS gaging station. The loading rates from Y-12 area were determined and used in the model for different target concentrations at Station 17. The flows and mercury concentrations along EFPC are simulated for different mercury loading concentration at Station 17. The concentrations and fluxes of mercury in the EFPC are summarized for the simulated scenarios as shown in Table 1.

DISCUSSION CONCLUSION

In the present modeling study for the East Fork Poplar Creek area, the hydrologic and contaminant transport variables were integrated into SWMM for simulating short term (storm event conditions), average, peak, and long term rainfall conditions. Emphasis was placed on calibration and validation of the model so that the site hydrologic and transport conditions were realistically represented for the site.

The mercury concentration at Station 17 and USGS gaging station were compared. It was observed that the mercury concentration decreases at USGS gaging station due to increased dilution as the flow increases downstream for both average and peak rainfall years. The long term simulation also indicates similar variation in mercury concentration along EFPC.

For peak rainfall conditions, the mercury concentration and flux increase compared to average rainfall condition. Long term simulations using ten year rainfall data indicate decrease in mercury concentration and flux at USGS gaging station. Mercury concentration and flux also decrease at Station 17 due to long term washoff and transport of mercury from drainage areas.

All the simulations for different loading scenarios show consistent variations of mercury concentration along EFPC segments. The reduction of loading in the primary source area (Y-12 Plant) impacts mercury concentration along downstream. Washoff occurs from secondary source areas (downstream of Station 17) and distribute in space and time over the reaches of the lower EFPC.

REFERENCES

Huber, W. C. and Dickinson R. E., 1988. Storm Water Management Model Version 4: User's Manual. Environmental Research Laboratory. Office of Research and Development. U. S. EPA, Athens, GA.

SAIC, 1994. EFPC - Sewer Line Beltway Remedial Investigation Report. Volume I. Prepared for: U. S. DOE under contract DE-AC05-91OR21950; ESC.

SAIC, 1998. Report on the Remedial Investigation of the Upper EFPC Characterization Area at the Oak Ridge Y-12 Plant, Oak Ridge, TN. Prepared for U.S. DOE under contract DE-AC05- 98OR 22700.

UT, 1996. Modeling of the Hydrologic Transport of Mercury in the Upper EFPC Watershed. Prepared for: Lockheed Martin Energy Systems, Inc. Under PAI Contract No. 90K-VE450C. Oak Ridge, TN.

ACKNOWLEDGEMENT

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T a b l e 1 .

S	D c e e	S		t	a U	t	i S o
		F s n	C d a	F o r	F r wi l	C piu b	F t x o (i
1	A v e	9	9r .	a71 9	g58	0 3 e1	1 9 5
2	P e	a1	2 kl	4 0	r 25	8 a 8 8	54 i 0 0 n
3	L o n	9	g6 .	61 8	t 63	e5 3 0	r 1 0 4 m
4	L o a	9	d7 .	81 i 3	n 24	0 2g 1	1 0 9
5	L o a	9	d5 .	89 i 0	n 2	0 6 2g 1	1 3 5
6	L o a	9	d3 .	86 i 6	n 2	0 9 2g 1	9 3 2
7	L o a	9	d 5 .	80 i 1	n 2	9 1g 1	6 8 6
8	L o a	9	d 1 .	80 i 2	n 2	2 1g 1	6 3 6
9	N o	9	l 5 o	80 1 a	2	d9 1 1	0 i 8 0 n

c f s : c u b i c
p p - 3 m t : i p c a o r tg s r
l b s : p o u n

Ahmed Fig. 1

Ahmed   Fig 2

THE DEVELOPMENT OF A GENETIC ALGORITHM TECHNIQUE TO DETERMINE HIGHLY PROBABLE AREAS OF ACCRETION TO A SEMI-CONFINED AQUIFER

Randy Gentry, Ph.D, P.E.[1], Charles V. Camp, Ph.D.[2], Jerry L. Anderson, Ph.D., P.E.[3]

ABSTRACT

The goal of any ground water inverse problem is to identify the distribution of an input function or certain other variables describing the unique flow dynamics of an aquifer. A genetic algorithm combined with a numerical modeling technique is useful in determining both the spatial distribution and the flux represented by the accretion component of the ground water flow equation. The square root of the sum of the squared error between modeled head and actual or observed head was utilized as the fitness function. The technique tracked the patterns or schema that developed in the binary string representations of the domain to determine probability regions. The technique was tested utilizing synthetic test cases and existing field data. The technique was capable of locating the accretion area and tended to converge to a flux most representative of the flux entering the aquifer. However, the technique was susceptible to typical problems affecting the inverse problem, such as non-uniqueness.

INTRODUCTION

The focus of current environmental and water resources directives, such as wellhead protection or source water protection, is to minimize the possibility of catastrophic contamination of natural resources that constitute drinking water sources. In part, the planning necessary to prevent such contamination requires an understanding of the hydraulic dynamics of the aquifer system. A detailed knowledge of the sources and sinks to the system are necessary in order to better understand the hydraulics of the system. Accretion to a semi-confined aquifer has a spatial component that may be arduous to define with any certainty. The goal of this research was to develop a tool to determine the most probable location of accretion to a semi-confined aquifer given a limited set of observation data. The inverse problem seeks to determine the magnitude and spatial distribution of the variables that define the solution of a given problem. The technique developed in the context of this research utilized a genetic algorithm search technique coupled with a finite difference modeling technique to locate highly probable regions of accretion within a given problem domain.

Genetic Algorithms

The concept of genetic algorithms and adaptive systems was brought to the forefront of optimization techniques by the work of John Holland and colleagues at the University of Michigan. The primary monograph defining the subject was Holland's (1975) *Adaptation in Natural and Artificial Systems*. Genetic Algorithms (GAs) represent a powerful search tool for the investigation of complex search spaces (Goldberg 1989). The primary concept behind the use of GAs was the representation of solutions to a problem in an encoded format, such as binary and hexadecimal schemes. These encoded parameters (alleles) are joined to build strings referred to as genes. The random interaction of the genes in populations under different GA operators constitutes the GA technique. The underlying strength of the GA approach was the building of patterns in the genes after repeated GA operations. As the solutions become more fit (based upon a fitness function), certain patterns become prevalent, or schema develop.

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Optimization studies have incorporated the use of GAs over a broad area of disciplines. In the area of civil engineering, the GA approach has been utilized to research areas from water network rehabilitation to ground water management (Ahlfeld and Sawyer 1990; Halhal et al. 1991; Mckinney and Lin 1994; Ritzel and Eheart 1994; Wang and Ahlfeld 1994; Huang and Mayer 1997). The use of the GA technique for solving the inverse ground water problem is missing in the literature.

RESULTS AND DISCUSSION

Case One

The boundary conditions for the case one scenario are shown in ***Figure 1***. The test case represents a 1 mile by 1 mile domain with a symmetric accretion function centered in the domain. A total of eleven known points were selected throughout the domain as observation points for the technique. The testing performed on the Case one domain was intended to reflect the amount and type of data that may be available to the ground water investigator. Utilizing all eleven of the known points the technique was capable of locating the accretion window, see ***Figure 2***. Varying the number of known points altered the development of the probability regions. ***Figure 3*** shows the affects of utilizing only nine of the known points. The probability regions are not only affected by the number of knowns in the domain but the location of the knowns in the domain. Further testing showed that by utilizing eight known points on the boundary of the domain probability regions were not developed. The case one analysis converged to a flux of 351,204 ft^3/day to 359,362 ft^3/day. The known flux for the case one domain was 329,415 ft^3/day.

Case Two

The boundary conditions for the case two scenario are shown in ***Figure 4***. The test case represents the same physical dimensions and aquifer properties as case one but, the accretion function is non-symmetric with respect to the domain. Analysis of the test case revealed that the technique was capable of locating the accretion sites in the domain. The results also indicated that the location of the known points were important in determining the extents of the accretion sites. ***Figure 5*** shows the results of the case two domain with all of the known points utilized in the test. The results presented in ***Figure 6*** also show the results of the analysis with only nine known points but, the location of the nine points were somewhat altered.

Case Three

The boundary conditions for the case three domain are shown in ***Figure 7***. The model parameters were taken from Ng's (1993) model of the Shelby County Landfill. Studies of the site have been extensive and the accretion site has been located during field activities (Bradley 1988, 1991; Kingsbury and Parks 1993; Parks and Mirecki 1992). Previous studies had estimated the flux from the shallow aquifer to the Memphis Sand aquifer to be 18,000 ft^3/day to 350,000 ft^3/day (Bradley, 1991). The GA technique converged to an average flux of 442,875 ft^3/day with a standard deviation of 30,776 ft^3/day.

CONCLUSIONS

The conclusions of the study, based upon the data from the analyses of synthetic test case data and existing field data from the Shelby County Landfill in Memphis, Tennessee are as follows:

1. The GA technique is capable of locating an area of accretion to a semi-confined aquifer;
2. The average probability regions developed from a single GA run or multiple runs can effectively describe the extent of an accretion area;
3. The location and number of knowns utilized for the GA analysis has a direct impact on the non-uniqueness of the problem; and
4. The GA technique converges to a flux entering the aquifer.

RECOMMENDATIONS FOR FUTURE RESEARCH

The following recommendations are based upon the conclusions of the study and observations noted during the study:

1. A new algorithm should be developed that investigates a step wise approach by evaluating multiple variables;

2. The GA technique should be further investigated by utilizing additional information for the fitness function, such as, tracer concentrations; and
3. Further research should be performed on the determination of more efficient domain mappings that could increase the amount of data stored while decreasing the overall string length.

REFERENCES

Ahlfeld, D.P. and C.S. Sawyer. 1990, Well Location in Capture Zone Design Using Simulation and Optimization Techniques. *Groundwater* 28(4):507-512.

Bradley, M.W., 1988, Construction, Geology, and Ground-water Data for Observation Wells near the Shelby County Landfill, Memphis, Tennessee: U.S. Geological Survey Water Resources Investigation Report 88-186, 32p.

Bradley, M.W., 1991, Ground-Water Hydrology and The Effects of Vertical Leakage and Leachate Migration on Ground-Water Quality near the Shelby County Landfill, Memphis, Tennessee: U.S. Geological Survey Water Resources Investigation Report 90-4075, 42p.

Goldberg, D.E. 1989, *Genetic Algorithms in Search, Optimization, and Machine Learning*. Reading:Addison-Wesley.

Halhal, D., G.A. Walters, D.Ouazar, and D.A. Savic. 1997, Water Network Rehabilitation with Structured Messy Genetic Algorithm. *Journal of Water Resources Planning and Management*. 123(3):137-146.

Holland, J.H. 1975, *Adaptation in Natural and Artificial Systems*. Ann Arbor: The University of Michigan Press.

Huang, C., and A.S. Mayer. 1997, Pump-and-Treat Optimization Using Well Locations and Pumping Rates as Decision Variables. *Water Resources Research*. 33(5):1001-1012.

McKinney, D.C., and L. Min-Der. 1994, Genetic Algorithm Solution of Groundwater Management Models. *Water Resources Research*. 30(6):1897-1906.

Kingsbury, J.A., and W.S. Parks, 1993, Hydrogeology of the Principal Aquifers and Relation of Faults to Interaquifer Leakage in the Memphis Area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4075, 18p.

Ng, Y. G., 1993, Ground Water Modeling at the Shelby County Landfill, Memphis, Tennessee:unpubl. Master's Thesis, Memphis, University of Memphis, 101p.

Parks, W.S. and J.E. Mirecki, 1992, Hydrogeology, Ground-water Quality, and Potential for Water-Supply Contamination near the Shelby County Landfill in Memphis, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 91-4173, 79p.

Ritzel, B. J., J. W. Eheart, and S. Ranjithan. 1994, Using Genetic Algorithms to Solve a Multiple Objective Groundwater Pollution Containment Problem. *Water Resources Research* 30(5):1589-1603.

Wang, W., and D. P. Ahlfed. 1986, Optimal Groundwater Remediation with Well Location as a Decision Variable: Model Development. *Water Resources Research*. 30(5):1605-1618.

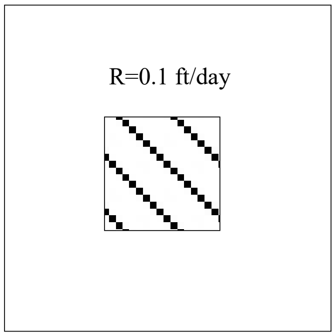

Figure 1. Case One Domain with accretion window. Constant head boundary on all sides with h= 100 ft.

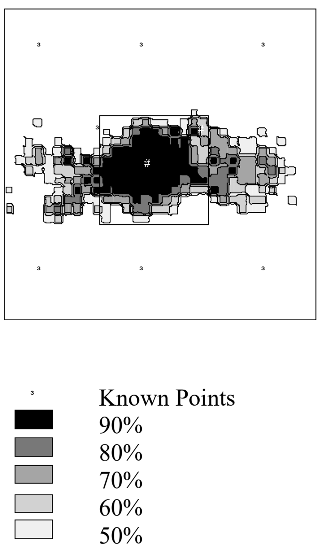

Figure 3. Case one with only nine of the available eleven known points.

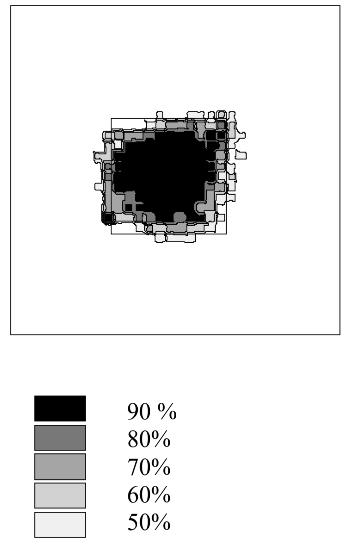

Figure 2. Case One analysis with all eleven known points.

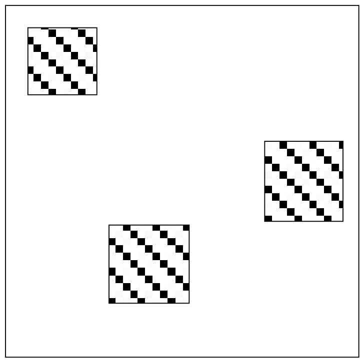

Figure 4. Case two domain with multiple accretion sites. Constant head boundaries on each side with h=100 ft.

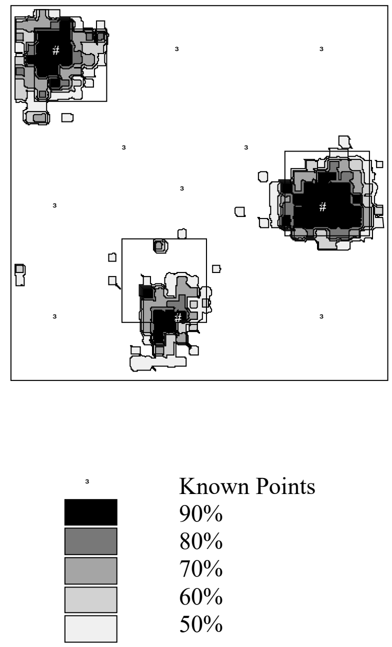

Figure 5. Case two analysis utilizing all eleven known points.

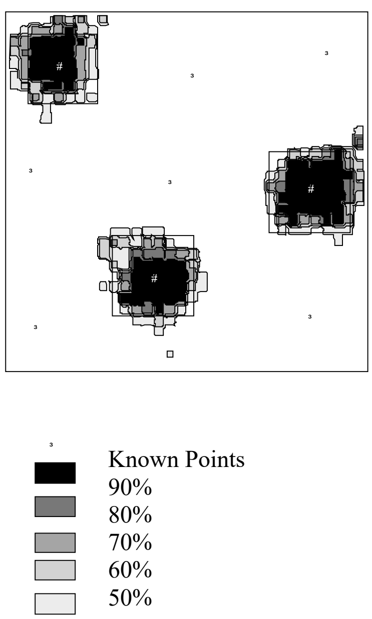

Figure 6. Case two analysis utilizing nine known points in modified locations.

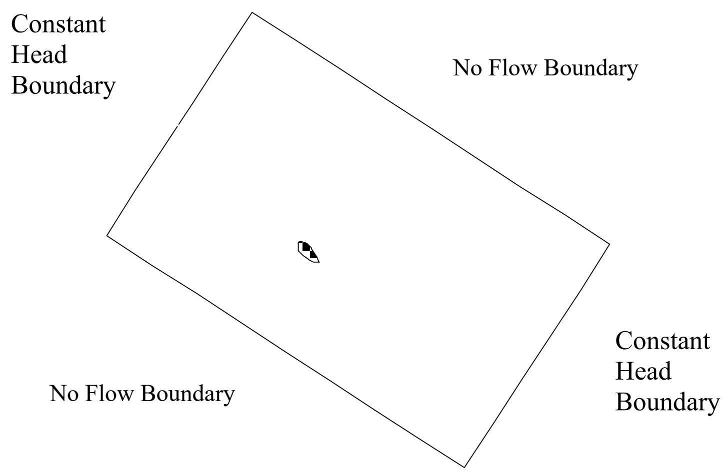

Figure 7. Case three domain with suspected accretion site.

FLOATING DEBRIS ON LAKES AND RIVERS: EFFECTS ON OPERATION, USE, AND SAFETY OF LAKES AND DAMS

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Susan R. Jacks,[2]

and

Dr. Bruce Tschantz[3]

INTRODUCTION

Floating debris on reservoirs can cause a variety of potential hazards to dam and lake safety. Debris-caused hazards affect navigation, recreation, flood control, and safe operation of lakes and dams. The concerns associated with floating debris are often neglected because the dam safety community does not view floating debris as an 'imminent danger.' The potential hazards associated with floating debris are: trash lodged in gate mechanisms; damaged gates; damaged rip-rap protection; dam battered by debris; bent spillway supports and trashracks; blocked spillways; blocked intakes. For the purposes of this paper, floating debris refers to material such as logs, branches, trash, ice, plant life, and various other buoyant materials. Sources of floating debris may also include docks loosened from their moorings, loose barges, building debris of beavers, loose branches from ice and snow storms, excess organic material resulting from fires, and the waste form clear cutting operations.

This paper shows that floating debris represents a national concern to dam safety by demonstrating that legislation, hydraulic scenarios, previous dam incidents, dam maintenance, and the attitudes of state and federal agencies towards dam safety reinforce the negative effects of current policy and practice relating to floating debris. The paper also includes responses to a recent survey of federal and state dam safety representatives and an analysis of the collected information, addressing federal and state requirements for maintenance and disposal of reservoir debris.

BACKGROUND OF DAM SAFETY AND LAKE MANAGEMENT

Due to the evolution of legislation concerning dam safety and lake management developed in the United States, rules governing floating debris vary from dam to dam, owner to owner, state to state, and agency to agency. Although dam safety issues are garnering more attention among legislators, agencies, and owners, no set safety standards exist for debris maintenance. The number of autonomous agencies involved in dam safety necessarily produces a variety of regulatory inconsistencies, creating many different responses to debris hazards within the various parts of the dam safety community.

United States legislative attempts to organize nationwide dam safety policies have failed to create a comprehensive debris management program. Regional agencies have been able to implement more effective and inclusive debris management strategies within a larger, watershed-management agenda. For instance, TVA's watershed-management programs have dealt with floating debris issues as an inherent aspect of their guidelines of general resource management. The same efficiency, resources, and care, however, have not been available or properly handled at a national level. A nationally regulated management protocol of this sort would create consistency in laws and regulations governing dam safety. Additionally, it would develop a clearly defined hierarchy, delineating the responsibilities of various governing agencies. While a program of this magnitude may not be immediately practical, the lack of a comprehensive approach to watershed management has resulted in the establishment of inconsistent regional, state, or agency specific policies relating to dam safety issues. These endeavors have created dissimilarities in policies throughout the nation, policies generated by the unnecessarily large number of organizations involved in the management of watershed programs. Moreover, the dam safety objectives of a specific controlling agency are frequently secondary to its primary mission and objective (Adler, 1995). Due to the way dam safety in the United States emerged, a complicated and fragmented political and institutional system developed for protecting and managing water resources (FEMA, 1998). In order to combat some of the problems associated with dam safety, the dam safety community and the government have begun sharing information among various dam safety organizations.

Within this cooperative framework, agencies share knowledge and information that help improve dam and reservoir safety efforts. Although efforts to refine dam and reservoir safety have been moderately successful, industry intercommunication focuses on the structural integrity, flood capability, and management practices of dams, often overlooking the issue of floating debris above dams. Floating debris is not always an apparent hazard, nor does it always produce an imminent danger. However, floating debris has the potential to represent a great hazard to life and property under certain circumstances. In addition to the cost associated with the loss of life and property caused by a dam incident, floating debris constitutes additional hazards to navigation and recreation.

Federal and state policies generally place accountability for the safety, operation, and maintenance of each individual dam on the owner. Nevertheless, the responsibility for what flows into and through the reservoir is not always relegated to a single agency. The nature of debris contamination in reservoirs predicates a comprehensive watershed-management system that integrates land and water resource policy into a coherent and symbiotic legislative structure. Normally, other agencies besides the dam safety office are responsible for reservoir management. However, these issues must be considered in relation to their effect on dam safety, specifically with regard to floating debris.

HAZARDS CAUSED BY FLOATING DEBRIS

Existing records of previous debris-caused dam incidents confirms the tangible threat these concerns present. The National Performance of Dams Program (NPDP) compiled a list of seventy-six (76) dam incidents involving debris (NPDP, 1998).

The first relationship developed from this data relates dam incidents involving floating debris and the affected dam's hazard category ranking. This analysis demonstrates that almost one-half of the relevant dam incidents are in the high hazard category. The second relationship shown is between floating debris and the dam type, where over sixty-five percent (65%) of the dams involved are some type of earthen dam, which are more prone to fail when overtopped.

A major benefit of many dams stems from the lakes created by the dam's impounded waters. Communities frequently use lakes for recreational activities. These activities include boating, skiing, fishing, and swimming. Floating debris hazards can jeopardize these activities if it accumulates within these recreational waterways. Large rainfall events are capable of washing debris into the reservoir. Other sources of debris in lakes are trees left in reservoirs before it is filled.

Boaters can experience severe problems while navigating through debris-infested waters. These obstacles also present a real threat in the damage that might occur to their boats. The severity of the problem these kinds of accidents represent is hard to quantify because "many accidents [are] never reported" (USDOT, 1997). In addition to property damage in boating accidents, the graver consequence is not monetary, but the potential for fatalities. Of the over 800 boating related deaths in 1997, 13 are directly contributed to collisions with floating objects (Schmidt, 1998). According to the U.S. Coast Guard's Recreational Boating Accident Statistics (Schmidt, 1998) the number of accidents caused by collisions with floating objects is rising, from 194 in 1995 to 204 in 1997.

MAINTENANCE ISSUES

Safe operation and use of reservoirs and dams is of paramount importance. In addition to the legislative complexities and hazard scenarios encountered when considering the issue of floating debris as it affects dam and reservoir safety, careful attention must be paid to debris maintenance, both its collection and disposal. Operational agencies are painfully aware of the cost and time associated with the collection and disposal of debris, but they do not view floating debris as an 'imminent danger'. Many regulatory agencies view floating debris as a non-safety issue, regarding it as a simple maintenance matter. Since floating debris is considered a maintenance issue, operational agencies do not address the potential for debris-caused dam failure. Most state agencies consider legislation stating that 'dams must be operated in a safe manner' as adequate policy for maintaining debris. Also, they rely heavily upon dam inspections to address problems on a site-specific basis. Unfortunately, "almost half of the most potentially dangerous [dams] have not been inspected in the last five years" (DeSena, May 1998). This inevitably leads to the conclusion that debris could accumulate and build-up around trashracks and spillways for more than five years, which inhibits their hydraulic capacity. During a rainfall event, this decrease in hydraulic capacity could cause overtopping of the dam.

Concerns also include deficient budgets for dam safety maintenance. Many agencies, both federal and non-federal, provide insufficient funding and manpower for effective and adequate dam safety programs (DeSena, May 1998 and FEMA, 1992). Additionally, many organizations consider dam safety a secondary priority to their main function, i.e. irrigation, mining, hydropower, etc. As stated in FEMA's National Dam Safety Program: 1990 & 1991 A Progress Report, for most federal agencies, "dam safety is peripheral to the main thrust of their activities" (FEMA, 1992).

ELIMINATION AND/OR COLLECTION OF DEBRIS

Ideally, elimination of debris would reduce the risk to dam safety. All debris eradication options should be weighed against their possible negative environmental repercussions. Maintenance organizations use pesticides to reduce aquatic plant life that historically collects in dangerous quantities on dam structures. While this reduces the amount of debris that could be potentially harmful to a dam, this procedure releases dangerous toxins into the water supply. Another method of reducing the amount of debris accumulation is to 'clear cut' the reservoir before it is filled. Unfortunately, 'clear cutting' can radically decrease the number of habitats available to fish and wildlife. An additional procedure to eliminate debris from entering the reservoirs involves current legislation prohibiting dumping trash into lakes and reservoirs. Sadly, these laws are either too difficult to enforce or not enforced at all.

If debris is not eliminated before it reaches the dam, it may accumulate in the spillway, if it does not pass through it completely. Collection of debris can take place at dam sites, banks along reservoirs, or within the reservoirs themselves. Debris collection and disposal methods vary by agency and location. For instance, some larger dam operators, such as TVA, use volunteer community groups to gather trash and debris on their lands. This type of cooperation benefits both the community and TVA: the community receives a safer, more aesthetically pleasing recreational environment, while TVA gets the cost benefit of free labor. Debris can also be towed or pushed by boat towards the banks of the lake or reservoir in order to clear waterways or facilitate removal of the debris.

The primary mechanisms utilized to prevent debris from entering inappropriate sections of dam facilities are trashracks. Trashracks also have to be cleaned and maintained to properly eliminate debris. Trashrakes are often used to scrap the debris from trashracks. Another variety of elimination tool are booms, which are "designed to retain floating debris before it reaches the trashracks or screens" and "may also be used in the active collection of debris from lakes and reservoirs" (USBR, 1992). Cranes and clamshells are also employed in lifting debris out of reservoirs.

In the past, the most convenient and often used method of destroying debris after collection was burning. Current air pollution and public fire hazards concerns, though, have sparked legislation to require burn permits. Not all forms of debris, however, can be burned. Tires and other non-organic trash must be disposed of in a landfill. More volatile and hazardous debris must first go through costly tests to determine whether or not it is hazardous waste, and if it is, it must then be disposed of properly. Many agencies also allow the flushing of debris through spillways, which does not dispose of the excess, but merely makes the debris someone else's problem

There are many costs associated with the collection of debris. Any equipment will require substantial capitol cost. Even after the initial outlay of capitol, maintenance, upkeep and repairs on the equipment require further expense. Additionally, sorting the debris entails extensive manual labor cost, especially during dangerous flood events when Workers' Compensation may exacerbate labor costs. There is an inherent danger when workers have to clear debris from spillways during high flood events. Some other costs associated with collection, elimination, and disposal of debris include:

- Landfill cost charge by pound for trash and by the tire
- Testing for hazardous waste
- Labor cost associated with sorting, carrying, and disposing
- Damage to dam structures by allowing it to flow through spillways

One reported debris-caused incident resulted from beaver debris plugging the principle outlet which contributed to the emergency spillway washing out. In this particular case, the cost associated with debris removal and dam repair at the site was $80,000, with an additional $20,000 in repair costs to downstream roadway (NPDP, 1998).

FEDERAL AND NON-FEDERAL ATTITUDES TOWARDS FLOATING DEBRIS

The concerns associated with floating debris are made more pressing by the lack of emphasis placed on the problems by federal and non-federal agencies. There are many legislative and economic indicators, such as budgeting, evolving legislation and various agencies' stated goals, regulations, policies, and procedures, which signify these attitudes.

According to the National Inventory of Dams, there are 74,187 dams in the United States, of which ninety-five percent (95%) are state regulated (FEMA, 1995-1996). Therefore, dam safety at the state level in the U.S. involves fifty (50) different sets of legislative policies, various budgeting, and differing priorities, precluding central and consistent management of the various facilities. "The degree to which states focus manpower and resources toward dam safety varies greatly from state-to-state" (FEMA, October 1998). Often the citizens and governmental agencies which own dams consider floating debris more of a nuisance than a serious safety issue. Floating debris is more than just a nuisance; it is a demonstrated safety hazard. This type of negligent attitude of the dam safety community is further reinforced by the lack of resources allocated for dam safety. "The lack of resources is evidenced by small budgets, low numbers of staff, support for continued staff training, and owner education and public relations program" (FEMA, October 1998). As mentioned previously, dam owners focus manpower and resources on their primary objectives, often neglecting their dam safety responsibilities. For most federal agencies, "dam safety is peripheral to the main thrust of their activities" (FEMA, 1992). For example, the Mine Safety and Health Administration (MSHA), while deficient in some of the Federal Guidelines for Dam Safety, selects "other high priority items to place on its Regulatory Agenda" (FEMA, 1992). This lack of attention to dam safety issues can only magnify the problems faced in this area.

In order to have a clearer understanding of federal and non-federal attitudes, a survey addressing common regulations, practices, and problems was recently sent to all federal and state agencies. Responses to the primary survey questions are found in Table 1. The survey revealed that only eight (8) agencies, or fourteen percent (14%), claim to have regulations or procedures for floating debris management. Some agencies consider the use of trashracks or logbooms their debris management regulation, while other agencies, which answered 'No' to this question, also use these mechanisms, but do not view their use as stated debris regulations. Many state agencies consider their inspection process as a primary method for controlling debris. They notify the owner when debris needs to be removed. As stated previous, this could result in debris accumulating for five year intervals which can reduce the hydraulic capacity of the outlets and spillways potentially causing dam overtopping. Another finding of this survey is that almost sixty (60%) of agencies allow or do not specifically prohibit flushing of debris through spillways. Furthermore, 69.5% have experienced interference from floating debris in the operation and maintenance of dams.

CONCLUSION AND RECOMMENDATION

While many of the measures currently in place, both mechanical and legislative, adequately control floating debris at most dams, there are a variety of debris-caused incidents which have proved these methods insufficient and resulted in the loss of life and property. These past incidents prove that floating debris is a national concern to dam safety, and the problem is complicated further by dam agencies' attitudes towards floating debris and the lack of consistent various legislation specific to debris regulation. While many dam designers often address debris concerns by installing auxiliary apparatuses on intakes and spillways, this is not always a sufficient method for dealing with debris. Many of the primary national concerns associated with debris are linked to the way dam safety is regulated and the attitudes of controlling dam agencies.

These legislative and regulatory bodies must take the hazards presented by floating debris more seriously and recognize the necessity of facing these problems with consistent, adequate debris management policies. Dam design and maintenance protocols should reflect the real concern the evidence presents. The responsibility for dam safety rests in the owners hands but remains a complicated issue; while the threat of floating debris may not appear as urgent as others dam safety issues, it must be addressed and remedied effectively, both in design and regulation, within the existing structure of the dam safety community.

LIST OF REFERENCES

Adler, R.W., “Addressing Barriers to Watershed Protection,” *Environmental Law*, Vol. 25, No. 4, Pp. 973-1106, Fall 1995.

DeSena, M., “Aging US Dams Pose Serious Risk,” *US Water News*, Wichita, KS, May 1998.

Federal Emergency Management Agency (FEMA), “1997 Update Report on Review of State Non-Federal Dam Safety Programs,” FEMA 335, Washington, DC, October 1998.

Federal Emergency Management Agency (FEMA), “Model State Dam Safety Program,” FEMA 316, Washington, DC, 1998.

Federal Emergency Management Agency (FEMA), “National Dam Safety Program: 1990 & 1991, A Progress Report,” Washington, DC, 1992.

Federal Emergency Management Agency (FEMA) and US Army Corps of Engineers (USACOE), *National Inventory of Dams*, Washington, DC, 1995-1996..

National Performance of Dams Program (NPDP), *Dam Incidents Involving Debris*, November 1998..

Schmidt, B., telephone conversation (202) 267-0955 and e-mail from bschmidt@comdt.uscg.mil, US Coast Guard, Office of Boating Safety, 5 October, 1998.

Tschantz, B.A., “Review and Responsibility of State Dam Safety Programs,” Engineering Foundation Conference Responsibility and Liability of Public and Private Interests on Dams, Pacific Grove, CA, Pp. 51-62, 28 September – 3 October 1975.

US Bureau of Reclamation (USBR), “Investigation of Debris and Safety Boom Alternatives for Bureau of Reclamation Use.” R-92-04, Denver, CO, 1992.

Table 1. Survey Responses

STATE OR FEDERAL ENTITY	HAS REGULATION OR PROCEDURES FOR DEBRIS	ALLOWANCE OF FLUSHING DEBRIS THROUGH SPILLWAY	INTERFERENCE WITH DAM O&M
AK	No	Yes	Yes
AL	No	N/A	N/A
AR	No	Yes	Yes
AZ	No	Yes	No
CA	No	Yes, Not Prohibited	No
CO	No	No	Yes
CT	No	No formal regulations	Yes
DE	No	N/A	N/A
FL	Yes	Yes	Yes
GA	No	Yes	Yes
HI	No	Yes	****
IA	No	Yes, Not Prohibited	Yes
ID	No	Yes	Yes
IL	No	Yes	Yes
IN	No	Yes, Not Prohibited	Yes
KS	No	N/A	No
KY	No	Not Known	Yes
LA	Yes	No	****
MA	No	No	Yes
MD	No	Yes	Yes
ME	No	No	No
MI	No	Not Known	Yes
MN	No	Yes	Yes
MO	No	Yes – Small; No – Large	Yes
MS	No	Not Allowed or Disallowed	No
MT	No	Yes	Yes
NC	No	No	Yes
ND	No	Yes	Yes
NE	Yes	Yes	Yes
NH	No	Yes	Yes
NJ	No	Not Known	No
NM	No	No	Yes
NV	No	Yes	No
NY	No	Yes, Not Prohibited	Yes
OH	No	Yes	Yes
OK	****	****	****
OR	No	No	Yes
PA	****	****	****
RI	No	No	Not aware of any
SC	No	Yes	Yes
SD	No	****	****
TN	No	Not an Issue	Yes
TX	No	Yes	Yes
UT	No	Yes	Yes
VA	No	Yes, Not Prohibited	Yes
VT	No	Yes, Not Prohibited	Yes
WA	No	Not Known, Outside Jurisdiction	Yes
WI	No	Yes, Not Prohibited	Yes
WV	Yes	Yes, Not Prohibited	Yes
WY	No	Yes	Yes
USBR	No	****	Yes
USDA	Yes	No	Yes
FERC	No	Yes	Yes
USACOE	Yes	Yes	Yes
DOE	No	****	No
NRC	No	No	No
MSHA	No	N/A	No
TVA	Yes	Yes	Yes
IBWC	Yes	Yes	Yes

Note:

1) ‘ ****’ indicates no response or question was not directly answered.

2) USBR= US Bureau of Reclamation, USDA= US Department of Agriculture, FERC= Federal Energy Regulatory Commission, USACOE= US Army Corps of Engineers, DOE= Department of Energy, NRC= Nuclear Regulatory Commission, MSHA= Mine Safety and Health Administration, TVA= Tennessee Valley Authority, and IBWC= International Boundary and Water Commission.

CONCRETE GROWTH MITIGATION AT TVA DAMS

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and

Charles D. Wagner[2]

ABSTRACT

Concrete expansion due to Alkali-Aggregate Reaction (AAR) commonly known as concrete growth has caused operational and structural problems in Hydro structures worldwide. Three of The Tennessee Valley Authority (TVA) major hydroelectric projects are experiencing this phenomenon. My talk will review TVA practice in the long-term management of existing AAR-affected dams.

I will focuses on progress made particularly in relation to long-term management. The key elements, such as instrumentation, modeling and repair, that makes the management of this problem more achievable.

I will discuss the problems, concerns and mitigation at our Chickamauga Lock and Dam.

Stress relief slot cutting is becoming common place in dealing with AAR problems. Is it being used to much? I will address the pros and cons of slot cutting. When should slot cutting be a part of the management plan. When should slot cutting not be used. I will review how TVA is using the finite element analyses, instrumentation, and experience to help make the decision on slot cutting.

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CORPS OF ENGINEERS/TENNESSEE VALLEY AUTHORITY COOPERATIVE DAM SAFETY EMERGENCY EXERCISE

Kathy Grimes[1]* and R. Cris Hughes, P.E.[2]*

INTRODUCTION

Federal agencies such as the U.S. Army Corps of Engineers (USACE) and the Tennessee Valley Authority (TVA) that are responsible for large hydro projects must follow standard guidelines for developing and maintaining a comprehensive dam safety program. These guidelines are provided in the Federal Guidelines for Dam Safety manual. Included in the guidelines are requirements for developing and maintaining emergency action plans for all federal dams that pose the threat of potential hazard to life and/or property should a failure occur. In addition, the guidelines require agencies to periodically prepare emergency scenarios and conduct exercises to test the readiness capabilities of project staff.

The USACE requires each of its Districts to develop and execute an emergency exercise each year. TVA normally develops and executes 1 to 2 functional level exercises each year.

ASSOCIATED PROJECTS

The Nashville District and TVA have hydro projects at two locations that are associated with each other. These are the Barkley and Kentucky Dams, located in southwestern Kentucky, and Center Hill and Great Falls Dams located in middle Tennessee.

Barkley Dam is located on the Cumberland River and Kentucky Dam is located on the Tennessee River. The dams are within a few miles of each other and their lakes are joined by an uncontrolled canal. This configuration requires a cooperative effort between the two agencies to operate the two projects as one unit.

Both Center Hill Dam and Great Falls Dam are located on the Caney Fork River. Just over 60 river miles separate the two projects, with Center Hill being the larger, downstream project. The proximity of these projects and the common goal of meeting Federal Guidelines requirements seemed to justify them for an interagency joint exercise.

TVA and Nashville District staff held a meeting to discuss interagency exercise possibilities, select projects for an exercise, and identify key objectives. Center Hill and Great Falls dams were selected as exercise projects, and August 13, 1997, was selected as the date for both agencies to participate together in a real-time tabletop emergency exercise. The following objectives were developed for the exercise.

1. Provide an opportunity for personnel from both agencies to get to know each other, build working relationships, and do some team building.

2. Provide a training opportunity that would involve several agencies.

3. Provide an opportunity to have some exposure to each other’s procedures and reference material.

4. Promote cooperation and coordination between agencies.

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5. Provide an opportunity for each agency to identify weak links in their emergency response procedures and make improvements.

Fifty-two people committed to participate in the cooperative exercise. Twenty seven people represented the Corps of Engineers. This included the Division Office Dam Safety Program Manager from Cincinnati, the Nashville District Dam Safety Committee, Emergency Operations, Public Affairs, Information Management, and key project personnel. Additional Corps support came from both the Engineering and Operations Divisions. TVA brought twenty four people from several different organizations including Dam Safety, Emergency Preparedness, River System Operations, Police, and Media Relations. In addition to federal agency representation, the Tennessee Emergency Management Agency participated by providing a representative for the exercise.

PROJECT INFORMATION

The Nashville Districts' Center Hill project is a combination concrete gravity and rolled earth embankment dam. The dam is 226 feet high and has concrete gravity section 1382 feet in length and 778 feet of earthen embankment for a total top length of 2160 feet. The spillway consists of 8 bays, each with a 37 by 50 foot tainter gate. The design discharge is 454,000 cfs at the design surcharge stage of 44.2 feet. A fuse plug is located on the right bank. The storage capacity of Center Hill Lake is relatively large compared to Great Falls Lake, having a total storage capacity of 2,092,000 acre-feet. If Great Falls failed catastrophically, even during a high flow period, the entire volume could be contained in the Center Hill pool. If Great Falls failed during an extreme flood and Center Hill was within two feet of the top of the flood pool, a decision would be made about increasing releases to prevent exceeding the top of the flood pool. Factors considered would be:

1. Magnitude of flooding on the Cumberland and lower Caney Fork Rivers

2. Magnitude of flooding that would have occurred naturally

3. How high Center Hill would rise above flood pool if releases were not increased.

About 1500 feet east of Center Hill's main dam is an earthfill saddle dam constructed to close a V-shaped notch in the reservoir rim. A portion of this saddle dam was removed and replaced with an erodible emergency spillway. The fuse plug crest is about 3-1/2 feet below the dam crest, which will ensure rupture, increasing spilling capacity to prevent failure of the main embankment in the event of a probable maximum flood. Estimated failure time is 30 minutes. The fuse plug has an 8-foot wide inclined clay core that serves as an impervious barrier when reservoir levels are below the crest of the plug. A sand filter was placed on either side of the clay core to serve as a transition zone and coarse sand and gravel was used for the upstream and downstream shells. A one-foot thick filter blanket and 1-1/2 foot thick layer of riprap protects the upstream face of the sand and gravel shell. The downstream slope is protected with a 2-1/2 foot thick layer of 2-inch stone. The entire structure rests on a concrete slab faced with a sheet pile cut-off wall. A sheet pile breakwater was installed near the upstream crest to prevent wave action from causing premature failure. The breakwater sheet piling interlock is not continuous and will allow erosion to occur, inducing failure when the reservoir exceeds the crest of the fuse plug.

TVA's Great Falls Dam is a 92 foot high, 800 foot long concrete gravity dam. The structure consists of an ogee spillway section flanked by two nonoverflow sections. The 535 foot spillway section contains 18 radial gates, each 25 feet wide and 14 feet high. It has a discharge capacity of 150,000 cfs at maximum design headwater elevation. A public roadway is located on top of the dam and a state highway passes very close to the south end of the dam. The Great Falls reservoir extends approximately 22 miles upstream and has a total volume of 50,200 acre-feet.

Great Falls has a 2 unit powerhouse located on the bank of the Caney Fork River approximately 3500 feet downstream from the dam. Water for power production enters through two intake structures in the reservoir and flows through two concrete-lined tunnels and steel plate penstocks to the powerhouse. Two surge tanks are located in the immediate vicinity of the transition from the concrete tunnels to the penstocks. The control building for Great Falls is located on a hill behind the powerhouse, well above any possible flood level.

EXERCISE DESCRIPTION

The exercise scenario began on the morning of 10 March. The Tennessee and Cumberland River Valleys had experienced higher than normal rainfall for the past few weeks and were now 72 hours into a stalled frontal system. Moderate to heavy rainfall, embedded with strong thunderstorms continued throughout the region. TVA and the Corps were both operating their river systems in major flood control modes. TVA was passing the maximum amount of water through Great Falls and had both turbines generating while the Corps was holding water to lessen flooding downstream. Existing seeps around Center Hill had increased and new seeps had appeared.

The exercise began with Center Hill pool at Elev. 681.5; three and 1/2 feet below spillway crest. This put 23.5 feet of water on the fuse plug for the first time. Headwater at Great Falls was 811.1, about 20' above the spillway crest. The top of the concrete non-overflow section is 812.16.

During the course of the exercise, three hours of events took place.

At Center Hill, a seep appears at the bottom of the fuse plug. Lightening strikes the station service, shutting down the turbines and a tornado rips the roof off the Resource Manager's Office.

At Great Falls, water is standing a few inches deep around the powerhouse and is splashing over the retaining wall. The Senior Operator hears a loud explosion. Power is interrupted so he goes outside to see a big plume of dust and smoke coming from the direction of the dam.

Back at Center Hill, silt and clay are flowing from a downstream spring weir and a new seep appears just above it. PZ and uplift cell readings are at, or near, historically high levels.

Meanwhile, Great Falls plant foreman and a State Park ranger discover a large crater in the south end of the dam. Material is washing away and the roadway across the dam is destroyed. The state highway that is located adjacent to the south end of the dam is in danger of being washed out. Due to the added outflow from the breech, water is now rushing over the retaining wall at the powerhouse and water is 1 1/2 feet deep and rising.

The seep at Center Hill's fuse plug has doubled and now contains some fines and appears to be migrating and enlarging. Just downstream, a railroad car sized block of rock falls from a new seep in the right abutment, destroying the weir beneath it. There is a noticeable increase in seepage.

At Great Falls, the breach in the dam has stabilized over the dam itself, but the abutment material continues to erode. The depth of this portion of the hole is now about 15 feet and the opening has progressed about 3 feet closer to the State road.

Efforts to stem seepage at the Center Hill fuse plug are unsuccessful. It is now a cloudy discharge with visible materials.

While all this is going on, players are getting phone calls from headquarters, the local news media, the South Eastern Power Administration, a Senator, and CNN. A very persistent local news reporter finds his way into the powerhouse and it takes about 20 minutes to physically remove him. When chaos reaches a peak, all the phones are purposely disconnected to simulate communications breakdown. This really heightened the level of urgency.

The fuse plug at Center Hill eventually fails from the bottom, ending the exercise - to the great relief of all the players!

CONCLUSIONS

Everybody reassembled at the Center Hill Maintenance Shop to discuss the exercise. They all completed an evaluation form. In general, comments on the exercise and the overall interagency cooperation were very positive. The following issues and suggestions were generated:

a. Resource sharing could use some improvement.

b. Lines of responsibility should be worked out between the two agencies to improve response.

c. Official contact for each agency should be spelled out.

d. We should participate in each other's in-house exercises.

e. We should continue to develop and hold cooperative exercises in the future.

As a result of this exercise, we felt we had accomplished 3 things:

1. We had a closer working relationship and could now put names with faces.

2. We had a better understanding of what each agency needed during this type of emergency.

3. We set the stage for an even larger interagency exercise in the future involving the Barkley and Kentucky projects.

Overall, the exercise was considered a success.

TALKING TRASH II: A RETURN TO DEBRIS REMOVAL

J. F. Sadler, Jr.[1]

INTRODUCTION

The accumulation of floating drift and debris is a universal problem. This paper investigates three specific problem sites, identifies the problem and cause, and discusses remedial measures and their effectiveness. The three sites are:

- The Cheatham Project is a combined lock/dam/powerhouse located downstream of Nashville, Tennessee on the Cumberland River. Water flow passes through the powerhouse with approach velocities sufficient to draw waterlogged trash and floating debris onto the intake trash racks. Consequently, trash accumulates on the racks and floor of the forebay. This clogging reduces efficiency of the turbines resulting in lost revenues from lower power generation capability.

- Huntsville Spring Branch is a tributary of the Tennessee River that receives the watershed of Huntsville, Alabama. During periods of high rainfall and/or elevated flows, trash and debris wash into the stream and are carried through metropolitan Huntsville into Redstone Arsenal and Wheeler Wildlife Refuge. The backwaters of the Tennessee River catch and deposit floating debris all through this once pristine environmental habitat.

- Lake Cumberland is the water reservoir impounded by Wolf Creek Dam near Somerset, Kentucky. Similar to Huntsville Spring Branch, during periods of high rainfall and/or elevated flows, trash and debris wash into the stream and are carried through rural Kentucky. Woody debris as well as cultural waste deposit along the river banks, at Cumberland Falls, and ultimately Lake Cumberland. In addition, large floating wood rafts present a hazard to navigation on the lake.

CHEATHAM POWERHOUSE

Cheatham Powerhouse was built in 1958. It contains three Kaplan-type turbines rated at 21,400 hp capable of generating 12,000 kw each. The turbines have a design head of 22 feet and an operating speed of 60 rpm. Due to the accumulation of debris and subsequent head loss, a trash boom was provided in front of the powerhouse in 1963. The boom was successful in preventing floating trash from reaching the power intake, but ineffective in catching the waterlogged material that washed under the boom. Floating debris was periodically flushed through spillway gates to reduce safety and operating problems at the project. Debris that was too large or waterlogged was dredged out biannually using floating plant. The debris was loaded onto a barge, floated upstream then unloaded and secured on the river bank. Due to the manpower and floating plant expense, alternative methods of cleaning and disposal were investigated. Nashville District personnel visited self-cleaning trashrack installations and were favorably impressed.

The system was designed to lift a diversified collection of debris ranging from refuse, bottles and other small items to entire trees. Several trash removal systems were evaluated and deemed too limited in their applicability. The system chosen for removing trash from the turbine intake areas utilized water velocity to move the debris toward the trashrack and then teeth or pins on motor driven chains would lift the trash (both submerged and floating) to the conveyors and subsequently to a collection area. The continuous operation enhanced the system effectiveness. Debris bound on lifting pins would be released from that pin and lifted by a subsequent pin. The racks had to be large enough to cover all three intakes, approximately 60 feet high by 25 feet wide. Conceptual layouts of the system and preliminary computations assured that self-cleaning trashracks could be constructed large enough for this project.

After installation, the Self-Cleaning Trash Racks performed with mixed success. The specifications required the trash racks to remove a broad range of debris with vastly different sizes. This caused operational difficulties in some small debris passing through the trash screens and binding the lifting chains. Modifying the chain guards

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alleviated this binding. The conveyor system also had jamming problems due to the sharp elevation angle. Conveying the debris riverward instead of landward removed the sharp angle. Disposal of stockpiled debris became major expense. Due to excessive maintenance costs, the system was removed in January 1996.

HUNTSVILLE SPRING BRANCH

Huntsville Spring Branch watershed drains about 86 square miles of municipal Huntsville, Alabama and the surrounding Madison County. The drainage deposits debris into Redstone Arsenal, Wheeler Wildlife Refuge, and ultimately Wheeler Reservoir.

The deposits detract from the natural aesthetics, adversely affect river hydraulics, increasing flooding, and destroy wildlife. The Energy and Water Development Appropriations Act of 1995 (Public Law 103-316) provides the legal authority for this project.

This problem was first documented in 1971 at a meeting between Redstone Arsenal personnel and City of Huntsville employees. In September 1994, a General Investigation study of the Huntsville area identified a potential federal interest in the environmental restoration of Huntsville Spring Branch. In assessing typical site conditions for potential remediation, a typical 20-foot by 20-foot section was selected for debris composition analysis within Redstone Arsenal. This count established trash at 10% or less of the total debris volume; wood comprises the balance.

The system is required to remove 90% of debris in a cost effective, environmentally acceptable manner. This will achieve flood control and hazard reduction on Huntsville Spring Branch as well as wildlife habitat restoration and quality of life protection on Redstone Arsenal. In November 1997, The City of Huntsville considered five removal options and selected a passive screen across the channel that will direct debris to a self-cleaning trashrake. Debris will be deposited on the stream bank for removal by city maintenance personnel.

A floating boom will be constructed in the stream to collect debris. The buoyant boom will be connected to vertical pipe supports with low friction attachments to allow capture of debris at various flood events. The boom is sufficiently angled to the current allowing the flowing water of the stream to force the captured debris to the self-cleaning debris rake.

The rake removes the debris from the water and deposits it into a sluiceway leading to a debris collection area. Maintenance personnel sort the removed material for disposition. A weir is designed for the other side of the stream to allow overflow in case of damming of the boom and trash rake. Construction is tentatively scheduled for FY 1999.

Based on the Corps' experience at the Cheatham Project, the trashrake is considered appropriate for the anticipated debris at this site. Additionally, a flume to transport the raked debris to a staging area will reduce binding that was exhibited at Cheatham.

LAKE CUMBERLAND

The Cumberland River watershed drains about 1,653 square miles of rural eastern Kentucky including Whitley, Knox, Bell, and Harlan Counties. This drainage accounts for approximately 25% of the total Lake Cumberland watershed. The deposits detract from the natural aesthetics, adversely affect river hydraulics, increasing flooding, and destroy wildlife much like Huntsville Spring Branch. Floating debris endangers navigation of Lake Cumberland by commercial and recreational boat traffic. The Energy and Water Appropriations Act of 1998 (House Resolution 2203) provides authority and funding for this project.

The upper Cumberland River has long been a rustic wilderness area fraught with pollution. Rural Appalachia historically disposed its waste in areas common to living habitat. The river would take farm developed waste downstream, away from living areas. Natural attenuation would reduce this degradable waste to an unnoticeable volume. As these rural communities grew and developed, larger numbers of inhabitants disposed of not only degradable waste but also nondegradable waste such as glass, plastics, and metals. This, added to woody debris from eroding shorelines during flood events, results in environmentally damaging pollution and endangers river and lake navigation.

In June of 1997, a team of Corps professionals and special consultants spent several days evaluating the problem and researching potential debris removal locations on Lake Cumberland and the upper Cumberland River. Consistent with the previous paragraph, the team found debris blockades on bridge piers, inaccessible boat landings due to trash buildups, and illegal dumps. As the goal of trash interception is to capture trash before it enters Lake Cumberland, and noting that the Cumberland River winds through a gorge and is a protected Wild and Scenic River immediately upstream of the lake, the best site was deemed downstream of the Highway 204 bridge. Ample land is available as well as favorable river hydraulics.

The system is designed to remove debris in a cost effective, environmentally acceptable manner. This will achieve flood control and waste reduction on the Cumberland River as well as floating hazard reduction on Lake Cumberland. Conceptual layouts of the system and preliminary computations assured that the “trash gate” would be effective at this location.

The system consists of a fixed glance rack extending approximately 100 feet into the Cumberland River at a thirty degree angle to the flow.

The rack extends an additional 130 feet up the bank to collect to about the 10-year flood event. Above that flood event, the flood plain is quite expansive and debris tends to spread out. After flood events, a removal device, such as a trackhoe, will remove the collected debris and deposit it into a staging area. The debris will then be sorted and dispositioned. Some of the woody debris will be either mulched for volume reduction or cut into firewood. Garbage and recycling bins will be provided for the cultural waste. A management plan for potential hazardous waste is being developed. An optional floating glance boom could enhance the capture effectiveness, dependent on model results.

Construction was completed December 1998. The first removal event is scheduled for Mar 1999.

Based on the Corps experience at the Cheatham Project, the glance rack is considered appropriate for the anticipated debris at this site. The staging area will allow efficient cleaning and disposition of the collected debris.

SAFE DAMS PROGRAM:
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
APRIL 1999

Lyle Bentley[1]

The Tennessee Safe Dams Program (SDP) started when the Safe Dams Act of 1973 was passed. This occurred in the wake of the failures in 1972 of a coal tailings dam on Buffalo Creek in West Virginia which killed 125 people and Canyon Lake Dam in Rapid City, South Dakota, which contributed significantly to the 236 deaths during heavy flooding there. Renewed interest occurred after the failures of Teton Dam (Idaho-1976), Laurel Run Dam (Pennsylvania-1977), and Toccoa Falls Dam (Georgia-1977), all of which killed people. Since 1983, when the SDP was moved to the Health Dept., over 100 dams have undergone major repairs to achieve current safety standards. Over 250 more have had minor repairs performed to achieve compliance.

WHAT IS THE GOAL OF THE SAFE DAMS PROGRAM?

The primary goal of the Safe Dams program is to protect the public from dam failures.

WHAT DOES THE SAFE DAMS PROGRAM DO?

We inspect dams for safety and require that they meet stability and spillway standards in order to get an operating permit. Dams are inspected every 1, 2, or 3 years depending on whether they are high hazard, significant hazard, or low hazard, respectively. Unregulated dams are reviewed every five years for changes in ownership and hazard category.

We review plans for repairing existing dams and issue alteration permits for such repairs.

We also review plans for new dams and require that they meet strict standards in order to get a construction permit.

WHAT IS A DAM?

Any structure which can impound at least 30 acre-feet of water or is least 20 feet high. An acre-foot is an acre of water one foot deep, a 1/2 acre two feet deep, etc., or 43,560 ft^3. Height is the difference between the elevation of the downstream toe and the elevation of the low point of the dam crest.

EXEMPTIONS
1. Any dam owned or operated by the federal government, such as TVA and the Corps of Engineers.
2. Any dam licensed by the Federal Energy Regulatory Commission (FERC).
3. "Diversion weirs", "roadbeds", "water tanks", and "wastewater impoundment barriers" as defined in the Act.

THE BIGGIE-> 4. "FARM POND": any dam which is used for conservation, recreation, or agriculture only by the owner and which is closed to the general public. USE OF THE LAKE DETERMINES "FARM POND" STATUS. Farm Ponds can be any size or hazard category.

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WHAT KINDS OF DAMS ARE THERE?

Most dams in the state are earth dams, 50 feet or less in height.
About 30 dams are concrete, the tallest being 50' high.
There are eight dams larger than 100', the tallest being a coal tailings dam in Marion County which is 315' high.

TOTAL DAMS IN STATE: ~1100.

REGULATED: ~600. FARM POND: ~500.

Currently, 97% of high hazard dams and 94% of all dams in Tennessee are in compliance.

CLASSIFICATION OF DAMS

Dams are classified by size and Hazard Potential Category (HPC).

The size classification is based on dam height OR storage volume, whichever is greater.

Category	Storage (Ac-ft)	Height(ft)
Small	30 to 999	20 to 40
Intermediate	1,000 to 50,000	41 to 100
Large	greater than 50,000	greater than 100

The HPC is determined by the damage which could result downstream if a dam failed.

High hazard (HPC-1) dams would probably cause loss of life in the event of failure.

Significant hazard (HPC-2) dams would cause property damage or temporary loss of roads or utilities with a remote chance of loss of life.

Low hazard (HPC-3) dams would have little or no effect downstream if they failed.

NOTE: The size of a dam is fixed by its physical dimensions and can change only if physical changes are made to the structure or its impoundment. On the other hand, the hazard category can and does change when new houses or businesses are built or old ones are torn down in the flood plain.

HAVE DAM FAILURES EVER HAPPENED IN TENNESSEE?

50 known dam failures which caused release of water have occurred in Tennessee this century. An additional 21 dams have had partial failures which could have resulted in release of flood waters had remedial action not been taken.

The most disastrous failure in the state occurred in 1916 when the John Thompson dam failed and killed 24 people**.** The dam was located on the Barren Fork River in Claiborne County, and its failure caused the failures of five smaller dams downstream. The dam overtopped during a rainfall of 12-15 inches in five hours. (This is approximately a 1/2 Probable Maximum Precipitation (PMP), which small, high hazard dams and intermediate, significant hazard dams now have to pass without failing.)

Since 1973, 33 dams in Tennessee have failed, of which 29 were unregulated. In the past three years 9 dams have failed, of which 6 were farm ponds and 3 were regulated. In two of these three cases, the dams were low hazard structures that overtopped when a large rain occurred that exceeded their spillway capacity. In the other case, the dam is still intact. Its grassed emergency spillway eroded out and drained the lake. There have also been 3 partial failures.

Most dams fail when excessive rain causes the lake to rise and overtop the dam, washing it out. A smaller number fail due to excessive seepage of water through the dam leading to the dam caving in and failing.

DO EMERGENCIES EVER HAPPEN WITH DAMS?

YES! Dams can develop a number of problems which are listed in the attached generic Emergency Action Plan (EAP).
An EAP is required for every high hazard dam. A breach analysis to determine the actual floodplain is also required for all NEW significant and high hazard dams.

EMERGENCY RESPONSE: THEORY VS. PRACTICE

1st Rule of Dam Emergencies (in theory & practice): The primary responsibility for doing any repairs or taking any emergency action at a dam lies with the dam owner**.**

THEORY (Regulated Dams): If an owner refuses to take appropriate action, the Safe Dams Act calls for the Commissioner of Environment and Conservation (TDEC) to seek an Emergency Declaration from the Governor. If the Declaration is made, TDEC can take control of the dam, take whatever appropriate remedial actions are necessary, and then use liens or other means to get reimbursed from the dam owner for all expenses incurred.

THEORY (Farm Ponds): The SDP has no legal authority to do anything with unregulated dams.

PRACTICE (Regulated & unregulated): SDP staff will respond to any emergency with a dam. Our primary function is to provide technical expertise on evaluating the extent and mechanism of the problem(s) and determining what is the safest and most practical means of alleviating the problem(s).

Our first step is to work with TEMA and/or county emergency personnel to get the owner to take appropriate action.

If this fails, the next step would be for SDP and county emergency personnel to contact the county executive or judge and request that he authorize emergency action by the county or other party, such as a local contractor.

If such requests are ignored, TEMA regional or state headquarters would be contacted to make the request of the county executive or judge.

If that request is ignored, and conditions warrant, TDEC would ask TEMA to seek an emergency declaration from the Governor to allow TEMA to take whatever measures are necessary.

There are several reasons for having TEMA instead of TDEC request an emergency declaration:

1. A request from TEMA would carry a lot more weight with the Governor than a request from TDEC. You are his emergency experts.

2. TEMA can ask for an emergency declaration for any dam, regulated or unregulated.

3. TEMA is set up to mobilize resources and equipment in an emergency, whereas TDEC is not. Again, our forte is technical assistance.

To date, TEMA and TDEC have been able to bring every dam emergency to a successful conclusion working through the owner (despite initial resistance of some owners to spend any money).

We are aware of some dams, regulated and unregulated, which have problems. Over the past couple of years, my staff has contacted some of you about dams in your county. These dams have problems which might lead to failure. We want you to be aware of them because you are nearby and can keep an eye on them.

If you ever see something about a dam that concerns you, call us! We look forward to working closely with you to make Tennessee a safer place to live!

<u>Explanation of fields and codes on inventory.</u>

ID	Identification number of dam assigned by Safe Dams Program.
D_Name	Dam name.
CO	County.
O_Name	Owner name.
Quad	Topographic map on which dam is located.
Lat/Long	Latitude/Longitude.
DPC	Damage (or Hazard) Potential Category

DPC Codes

Hazard	Regulated	Farm Pond
High	1	H
Significant	2	S
Low	3	L

O	Too small to regulate
B	Breached (no longer holds water)
F	Federal
X	Diversion weir, roadbed, water tank, wastewater impoundment barrier

Bentley Fig

DAM SAFETY IN THE CORPS OF ENGINEERS

Timothy McCleskey[1]*

ABSTRACT

Dam Safety is a very important mission of the Corps of Engineers. It is a particularly important mission of The Nashville District. That mission is to assure the structural integrity, operational adequacy, safe operations and appropriate emergency response for all dams in the district. This mission is accomplished through a formalized dam safety program that had its beginning over thirty years ago. The program has expanded over the years in keeping with the latest technology and now encompasses pertinent features of a comprehensive dam safety program. As a federal agency, one objective of the Corps of Engineers is to comply with the spirit and intent of the "Federal Guidelines for Dam Safety." These guidelines are intended to outline management procedures that will continually stimulate technical methods in all aspects of dam engineering.

INTRODUCTION

The Corps of Engineers is a federal agency under the Department of Defense with offices located throughout the United States and several foreign countries. Its primary mission is to provide engineering and construction management services, as directed by the United States Congress, for the Army, the Air Force, and the rest of the nation. The Corps of Engineers has thirty-five district offices, eight division offices, five research and development offices, and an office of the Chief of Engineers in Washington, D.C. Each division office is composed of several district offices located generally in major cities of a particular region. The Nashville District is one of seven district offices in the Lakes and Rivers Division, with a division office in Cincinnati, Ohio. Major river basins, the Great Lakes, and coastal regions generally define district boundaries. The Cumberland and Tennessee River basins are the primarily boundaries of the Nashville District.

Historically the mission of the Nashville District has been the development of water resources projects primarily within the Cumberland River basin. The district operates and maintains ten multi-purpose projects on the Cumberland River and its tributaries. The major features of these projects are dams, locks, and powerplants. Project purposes include flood control, navigation, power, water quality, and recreation. Table 1 provides basic information regarding the location, purpose, and major features of these ten projects.

The district's concerned for dam safety dates back to the initial design and construction of several dams during the first half of the century. Although no formal dam safety program existed then, standards used in developing those projects were state-of-the-art for that time period. Particular emphasis on dam safety began with implementation of the Periodic Inspection and Continuing Evaluation Program during the-mid 1960s. It was a forerunner for our current dam safety program and indeed is a major component of it today. The near failure of Wolf Creek Dam in 1968 was an awakening for the district to a higher emphasis on dam safety. Dam failures in the 1970s renewed emphasis on dam safety in the Corps and awakened the dam engineering community throughout the nation. In June 1976 the Teton Dam, a Bureau of Reclamation dam failed during the initial reservoir filling. This event was the catalyst for development and eventual publication of the Federal Guidelines for Dam Safety. These guidelines were developed from recommendations of an *ad hoc* interagency committee and a panel of recognized experts in dam engineering following failure of Teton Dam. The current district dam safety program incorporates principles and notions contained in the Federal Guidelines for Dam Safety.

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I'LL SEE YOU TOMORROW IF THE CREEK DON'T RISE
VIRTUAL-WATERSHED: ENVIRONMENTAL EDUCATION AND THE INTERNET

Susan Kuner, Ed.D.[1]

ABSTRACT

Virtual-Watershed is a hands-on science workshop for teachers sponsored by Vanderbilt University with funding from Eisenhower Math/Science grants. For the past 5 summers, Tennessee teachers grades 1 – 8 have participated in this professional development opportunity. The teachers learn how to bring watershed lessons into science units as well as other disciplines. Students learn about their watersheds by monitoring streams, observing local land use, participating in classroom activities, doing research and communicating over the Internet. Over 230 teachers have participated in this project. This paper describes the Virtual-Watershed program and the importance of collaboration between universities, scientists and water resource agencies with teachers and students.

INTRODUCTION

"I'll see you tomorrow, if the creek don't rise" took on a new meaning during last summer's Virtual-Watershed workshop, held July 13 – 15, 1998, at Vanderbilt University in Nashville for 35 Tennessee teachers, grades 1 – 8. Three days of intense rainfall caused serious flooding in several counties. We heard the tragic news of lost lives and property as water poured off the roof of our classroom building and the surfaces of the parking lots. Watershed issues took on critical importance. Teaching our children about their watersheds is an excellent example of science that meets the new education standards: systems rather than isolated concepts, inquiry into the natural world, and meaningful connection to others.

VIRTUAL WATERSHED WORKSHOP

<u>Objectives of Virtual Watershed</u>
Virtual Watershed is a teacher professional development workshop and classroom curriculum for Tennessee teachers grades 1 – 8. Supported by Eisenhower Math/Science grants, this environmental education workshop has been held every summer for the past 5 years. At the workshop teachers learn how to use lessons about their watershed as content for teaching hands-on science as well as other disciplines. The main objectives of Virtual Watershed are that teachers and students learn to:

1. Monitor water quality of local streams through observation, simple measurements, and collecting macroinvertebrates.
2. Know their watersheds and local conditions that impact the watershed such as land use and rainfall.
3. Research and communicate over the Internet
4. Partner with water resource agencies, scientists, and universities.

<u>The Need for Teacher Professional Development</u>
In this age of change and information, one of the most profound problems for school systems is to develop ways to support lifelong learning for teachers. How can a classroom teacher keep up with the latest developments in science and teaching methodologies? How can we be sure that these developments in knowledge and technology are finding their way into our classrooms?

Vanderbilt's Virtual School addresses this need. One goal of the Virtual School is to explore how true partnerships between universities and schools can improve K-12 education. The Internet has created an opportunity for a new partnership model. In the old ivory tower scenario, research and knowledge belonged to the realm of the university and flowed downward to the K-12 schools. With the Internet comes an exciting opportunity for genuine two-way collaboration between universities and schools. Input from both sides is needed to make this partnership successful. Virtual Watershed is an example of this new type of partnership.

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The History of Virtual Watershed

Since 1991, over 9,000 teachers have come to Vanderbilt to participate in Virtual School classes where they learn how to use e-mail and the World Wide Web. How can this technology be used to improve student learning? Virtual Watershed is one of many innovative programs answering this question. Supported by Eisenhower Math/Science grants given to universities to support K-12 education, Virtual Watershed was first funded for the summer of 1994 and has been funded every summer since. Virtual Watershed was designed to take advantage of bountiful Tennessee resources: our natural resources as a state criss-crossed with rivers and streams and our technology resources as the #1 state in the nation with Internet connectivity to our schools.

Tennessee has a great tradition of environmental education. Virtual Watershed was built on work already done by people like Ray Norris of the Izaak Walton League, Judy Butler with the Harpeth River Project in Williamson County, Mary Ball with the Watchable Wildlife program, Project Learning Tree, Project WET, and many other programs from federal, state and local agencies.

Two Strategies Make Virtual Watershed Unique

Two strategies make Virtual Watershed unique. The first is the incorporation of the Internet into environmental education. Although Internet technology remains frustratingly difficult to use at times, teachers will endure this frustration when the reward is better learning for their students. The opportunities to do research, have access to real data, and communicate with students and scientists from near and far, bring freshness and immediacy to learning.. Other excellent examples of Internet in environmental education include GREEN and the Jason Project. Virtual Watershed familiarizes teachers and students with other environmental Internet learning opportunities.

The second strategy is a model of teachers teaching other teachers. The design and teaching of the Virtual Watershed workshop and curriculum is done by classroom teachers. Experts from the university and other resource agencies serve as advisors. This ensures that the content is realistic for a classroom teacher to use, instead of another pie-in-the-sky scheme dreamed up by someone out of touch with school reality. The teachers become role models for other teachers and spark an important interchange of adaptations and ideas. Most of all, the opportunity for teachers to present to other adults is almost entirely missing from a teacher's professional life. The teachers who are part of Virtual Watershed's Development Team learn valuable lessons in leadership as well as science.

VIRTUAL WATERSHED WORKSHOP FOR 1999

This summer's workshop is called *Virtual Watershed: The Science of Water.* Twenty Virtual Watershed teachers from past years will come to Vanderbilt in July 1999 for a four day Institute to learn about water chemistry. They will translate what they have learned into Internet lessons which will in turn be delivered in school districts around the state. As in past summers, the workshop activities are designed to simulate a three part teaching sequence:

1. Prepare students in the classroom prior to a stream visit using hands-on science activities and the Internet.
2. Monitor the water quality of a local stream.
3. Return to the classsroom and integrate what has been learned.

The length of time spent on this sequence is up to individual teachers. Some teachers may do these activities over the course of a few days. Others may turn them into a unit. that may last a week, a six-week report card period, a semester, or even an entire school year. Still others may incorporate these activities into a school wide interdisciplinary study and celebration.

This summer's "intensive" is a response to teachers' wishes to learn more science. At last summer's workshop, teachers began to ask questions as they performed simple tests and measurements of the stream. "What is pH?" "If the rain tests acid, how can the stream be neutral?" "Why is sediment a stream pollutant even though it is not poisonous?" "Why do macroinvertebrates tell so much about a stream?" Their questions demonstrate the pressing need for teacher professional development in science. By learning more about the science of water, teachers will be able to answer these questions for themselves and their students. Teachers are ready and eager for this endeavor.

Following the Science of Water Institute , 40 more teachers around the state will attend 1-½ day in-service sessions in their counties. These local sessions, led Virtual-Watershed teacher/trainers, will use the new Internet lessons developed at the Virtual-Watershed Institute, existing hands-on science activities, and science materials supplied through the program. All activities are related to the National Science Education Standards and the Tennessee Science Education Framework. Over 230 teachers have participated, and 32 are now certified as trainers. The teachers represent a cross section of the state's racial, economic, rural, suburban, and urban diversity.

Legacy, an Internet Teaching Tool
Teachers at the Science of Water Institute will develop Internet lessons using the Legacy instructional model developed by Vanderbilt's Learning Technology Center through a National Science Foundation grant In the model, challenging questions are posted on the Internet. Working with others in class and on the Internet, students proceed through a cycle of teacher-guided inquiry, based on cognitive research and science education standards. As the students develop multiple ways to answer the challenges, their solutions are gathered as a "legacy" for other students and teachers to read. Virtual-Watershed teachers will use this model to create units to use with their students.

CONCLUSION

How does Virtual Watershed benefit teachers, students, and the community?
Hands-on science is as much fun for teachers as it is for students. Teachers give the Virtual Watershed workshops high ratings. They learn science, Internet technology, and meet other teachers who are using environmental education in the classroom. The workshops are attended by science and curriculum administrators as well as teachers, supporting systemic improvement for science education.

And the students? Malissa Johnson, a 3rd grade Virtual Watershed teacher at University School of Nashville describes a class excursion to monitor a stream: "The students were so completely engaged, and parents went right into the creek to participate. It was a great opportunity to bring us all together for an important learning experience."

Virtual Watershed makes teachers and students aware of the many wonderful people and resources of local environmental agencies. Enabling teachers to meet agency representatives and the information they provide builds the necessary awareness and support for the issues that will protect and sustain Tennessee's precious drinking water.

Collaboration
Virtual Watershed is a model of the best kind of partnership. Educators, parents, along with federal and state governments investing millions of dollars in the Internet, can ensure that this technology enhances student learning. Water resource agencies can provide science expertise to teachers and students along with their environmental educational messages. Today's school children are tomorrow's citizens. Universities can open channels of communication to infuse schools with the latest knowledge and prepare students for future education and careers. Tennessee, with its bounty of rivers and streams and the ConnecTEN Internet initiative linking all schools, is the ideal setting for this collaboration.

VIRTUAL WATERSHED: SAMPLE LIST OF WORLD WIDE WEB RESOURCES

Virtual Watershed Web Site
http://www.vanderbilt.edu/VirtualSchool/vwmain.htm

Virtual Watershed Interactive Web Resource Links
http://relax.ltc.vanderbilt.edu/vw/links/
Please join us on this line site and add your favorite links.

Surf Your Watershed:EPA's Surf Your Watershed
http://www.epa.gov/surf/

Tennessee Water Data:USGS - Tennessee Water Resources
http://wwwdtnnsh.er.usgs.gov/

Environmental Education Sites
Jason Project
http://www.jason.org

GREEN
http://www.igc.apc.org/green/mainpage.html
Global Rivers Environmental Education Network

Harpeth River Project
http://www.wcs.edu/river/river.htm
Harpeth River Project in the Williamson County Schools

Adopt a Watershed
http://www.adopt-a-watershed.org/
California's Adopt a Watershed program

Science Education Standards
National Science Education Standards
http://www.nap.edu/readingroom/books/nses/html/

Tennessee Science and Mathmatics Frameworks with Hot Links
http://cesme.utm.edu/resources/framewks/hotlinked.html

Integrating the Internet into curriculum
WebQuest Design:Learning How to Design your own WebQuest
http://www.memphis-schools.k12.tn.us/admin/tlapages/WQ-WRITE.HTM

For more information about Virtual Watershed email: susan.kuner@vanderbilt.edu or phone (615) 343-8848

GETTING THE WORD OUT:
SAY IT THROUGH THE NEWSPAPER OR A PLACEMAT

Debbie Hubbs[1]

ABSTRACT

If you are like 99% of every conservation/environmental program, group, or agency in the country, you are short on time, money, and other resources. Creating and carrying out effective educational programs to educate the general public about nonpoint source pollution is not easy or cheap.

Coming up with non-traditional ways to reach watershed residents in the 80,000-square-mile area of the Tennessee Valley is a continual challenge to TVA's Clean Water Initiative Teams. A newspaper insert and a restaurant placemat project are two approaches that have proven to be successful. The publication works well in capturing the public's attention about a river's past, present, and hoped-for future, while the placemats are eye-catching tools for delivering your message to restaurant patrons.

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DAM SAFETY OFFICER AND COMMITTEE

Ronald J. Riberich[1]

The chief of the Engineering/Planning Division is the district Dam Safety Officer. A dam safety committee assists the Dam Safety Officer on dam safety issues. Overall responsibility for execution of the dam safety program is assigned to the District Dam Safety Officer and the dam safety committee. They are responsible for ensuring that the district, as a matter of policy and in actual practice, makes every reasonable and prudent effort to enhance the safety of dams in the district. The Dam Safety Officer is responsible for directing the district toward full compliance with the letter and spirit of the Federal Guidelines for Dam Safety. The committee meets at least semiannually with the Dam Safety Officer to review the dam safety program and make recommendations for improvement.

PERIODIC INSPECTIONS

A periodic inspection program was implemented in the-mid 1960s and continues today. This program involves inspection of all dams in the district at recommended intervals. Guidance for these inspections is provided in the Corps' Engineering Regulations and in the Federal Guidelines for Dam Safety.

The inspection program consists of four types of inspections. Major inspections consist of a thorough visual inspection of all vital project features, operation of vital machinery and equipment, evaluation of all instrumentation data, review of project files for historical documents, and a detail inspection report covering inspection findings and the inspection team's recommendations. Intermediate and quarterly inspections involve thorough visual inspections of all vital project features and a documentation of the inspection results in a report. Special inspections are performed when unusual events such as pool of record, seismic activity, observation of abnormal condition, or unwatering of a major project feature occurs. These inspections are also documented with a report.

Major inspections are performed at every dam in the district on scheduled intervals. The inspection interval depends on the age, type, and the condition of the dam. New earth and rock-fill dams are inspected immediately after topping out and prior to impoundment of the pool. The second inspection is performed at a reasonable stage of the normal operating pool but not later than one year after impoundment is initiated. Subsequent inspections are performed at one-year intervals for two years and at two-year intervals for two years, after which, it is extended to five-year intervals if warranted by results of the last inspections. Initial inspections of concrete dams are performed immediately prior to impoundment of the reservoir. The second inspection is performed at normal operating pool but not later than one year after impoundment is initiated. Subsequent inspection intervals are performed on the same intervals as for earth and rock-fill dams. All dams in the district are currently on a five-year interval inspection schedule. Intermediate and quarterly inspections are performed on an annual and quarterly basis respectively. Special inspections are not performed on any scheduled interval. They are conducted during or following a unique event, activity, or observation of an abnormal condition.

Inspection teams for major inspections consist of team members having expertise in appropriate disciplines to assess the structural integrity, operational adequacy, and the emergency readiness of a project. The inspection team will generally include the following disciplines:

Inspection Coordinator	Geotechnical Engineer	Structural Engineer
Instrumentation Engineer	Hydraulic Engineer	Electrical Engineer
Mechanical Engineer	Geologist	Powerplant Manager
Con-Ops Representative	Division Office Manager	

An invitation to participate in major inspections is generally extended to the State Dam Safety Office and to local emergency managers of counties immediately downstream of the dam. Members of the Dam Safety Committee, interns, and others may augment the inspection team. The project geotechnical engineer and/or structural engineer,

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geologist, and the inspection coordinator perform intermediate inspections. Quarterly inspections are performed by the powerplant manager or the resource manager.

INSTRUMENTATION SYSTEM

Numerous instruments have been installed in district projects to monitor performance and detect anomalies that may indicate a threat to the safety of the dam. The instrumentation system in each dam represents a line of defense against dam failure. They are used to monitor displacements, settlements, pore water pressure, seepage and leakage, seismic activity, temperature, uplift pressure, joint and crack movement, headwater and tailwater elevations, and rainfall. Instruments include alignment plugs, surface movement monuments, piezometers, weirs, seismic instruments, thermometers, uplift cells, joint movement gages, inclinometers, rainfall gages, and pressure transducers. Data are collected on a regular schedule from all instruments, in a prescribed manner, by project personnel or by contract. Procedures are implemented during data collection to determine if threshold values have been exceeded. Data exceeding threshold values are reported to the district office immediately for evaluation. Once the data are collected and transmitted to the district office, it is processed for evaluation. All project data are evaluated at least annually; however, any abnormal date is evaluated immediately after it is reported.

EMERGENCY ACTION PLANNING

Emergency action plans have been developed for all district projects. These plans provide vital information for making appropriate responses to abnormal conditions that may threaten the integrity of the dam. Each plan is updated annually and when known changes occur. A typical plan will include emergency notification procedures; a list of abnormal conditions that could threaten the integrity of the dam and ways of dealing with them should they occur; type, quantity and location of emergency repair materials; contractors within the project vicinity who could be called on to make emergency repairs; maps delineating downstream areas that would be flooded in event of a dam failure; emergency procedures for dewatering the reservoir; and responsibility for emergency repairs.

Dam safety training is mandatory for all project personnel and is conducted on a four-year cycle at each project by personnel familiar with details and history of the project. The training is site specific oriented so that the project staff is fully informed of the pertinent features of the dam where they work. It covers design features of the dam and foundation, any weaknesses in the dam-foundation system, indications of potential problems that could threaten the safety of the dam and how to deal with them, procedures for reporting instrumentation data exceeding threshold values, and emergency and non emergency reporting procedures.

Dam safety exercises are conducted annually to evaluate and improve our response to potential emergency situations. These exercises could involve any project personnel and anybody in the district office assigned to the project or who has responsibility for dam safety. The district conducted a joint exercise with TVA and others in 1997.

DAM SAFETY ASSURANCE

Dam safety assurance is a program that provides a way to modify existing dams that do not meet present day design standards, (e.g., inadequate spillway capacity and seismic deficiencies.). All dams in the district have been evaluated under this program and one dam (Center Hill Dam) was modified because of a spillway inadequacy. The fix for Center Hill Dam involved construction of an erodible fuse plug in a saddle dam located in the right reservoir rim.

CONCLUSION

Failure of one of our dams would be catastrophic; therefore, we can ill afford to take dam safety lightly. It is a very serious business in the Nashville District and will continue to be a high priority mission of the Corps of Engineers.

This paper presents a frank discussion of the safety issues concerning the interaction of recreational boating and commercial navigation as they compete for the use of the same body of water, principally the Tennessee River Waterway. The recent tremendous growth and popularity of recreational boating has brought with it many new problems in accident prevention and the increased need for safety education. The Tennessee Valley has not been spared from these new problems and concerns brought about by the explosion in recreational boating. As part of its responsibility of managing water resources throughout the Tennessee River Valley, the Tennessee Valley Authority initiated a Marine Safety and Recreational Boating Safety Partnership for commercial and recreational users on the Tennessee River, its tributaries and lakes. Partnering with the U.S. Coast Guard, TVA is attempting to provide a forum to address the impacts associated with navigation on the waterway. Several initiatives have been developed and will be discussed, such as; (1) establishment of a Steering Committee made up of members from the commercial towing and barge industry, federal, state and local agencies and private sector and how it has identified problems and recommended actions; (2) Boating population for a geographical area, number of boats, people, sales, their economic impacts and associated safety issues; (3) Accidents/fatality statistics, commercial and recreational; (4) Boater operator education, and; (5) High density - mixed traffic areas of critical concern, commercial and recreational use.

PROCEDURE FOR REDUCING ERRORS IN RADAR AND RAIN-GAGE DATA

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ABSTRACT

A study is presented that evaluates a procedure developed to reduce errors in radar and rain gage data. The study catchment is the Dale Hollow Reservoir drainage located within the Cumberland River Basin. The study employs the models PRECIP and ViewRain to calculate basin average rainfall. PRECIP, developed by the US Army Corps of Engineers Hydrologic Engineering Center, calculates basin averages using data recorded by rain gages. ViewRain, developed by the Tulsa District Corps of Engineers, calculates basin averages using radar data calibrated with rain gages. The procedure developed herein identifies and corrects for missing and outlying radar and rain gage data prior to calculating the basin average rainfall using PRECIP or ViewRain. The calculated basin average rainfall values then serve as data input to predict runoff, stream flow and reservoir stage using the HEC-1/API model developed for the study catchment. The study compares measured and predicted reservoir stage using basin average rainfall derived by the following methods: (1) PRECIP (hourly gage data); (2) hourly PRECIP values adjusted by 24-hour values from VIEWRAIN (calibrated Stage III data); (3) method 2 with use of the corrected radar and rain-gage data. Rainfall-runoff for a total of three storm events between 1997 and 1998 was simulated. The results showed a progressive improvement in the predicted pattern of reservoir stage going from method (1) to (3).

INTRODUCTION

Rainfall-runoff predictions are required for the proper design and operation of multi-purpose reservoirs that provide flood damage reduction, hydropower, and recreation. Accuracy of these predictions necessarily depends upon the accuracy of rainfall measurements and the calculation of a representative spatial average rainfall. In particular, it is often important that these measurements account for the spatial variation of rainfall observed under certain conditions, such as highly convective storms common in mountainous terrain. The NEXRAD Stage III rainfall data product, now available through the National Weather Service, may significantly improve the accuracy of rainfall-runoff prediction by providing greater spatial resolution of rainfall pattern. Radar data include rainfall on an hourly basis for grid cells that are nominally 4 km square (Peters et al. 1996). In comparison, rain gage networks record rainfall at various times, but only provide for a sparse spatial resolution. The average density of rain gages in the United States is about one per 700 km^2 (Linsley et al. 1992). Rain gages, however provide more accurate measurements at the point-of-measurement compared to radar and are used to calibrate the Stage III radar product. This study, in collaboration with the Nashville District of the US Army Corps of Engineers, compares a number of methods for calculating basin average rainfall based on radar and/or rain gage data. For the use of both data sources, this study has developed a procedure for reducing error by identifying and correcting missing and outlying data.

STUDY AREA

The study catchment is the Dale Hollow Reservoir drainage (936 mi^2) located within the Cumberland River Basin. The reservoir is located in North-central Tennessee and South-central Kentucky and the pool is a combination of the Obey and Wolf River systems. The reservoir was originally intended for flood control and hydropower, but more recently has been managed for water quality, water supply, fish and wildlife habitat, and recreation.

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The Obey River basin receives an average of 53.7 inches and an average snowfall of 14 inches. There is a range of elevations in the basin from 505 feet (at the dam), to 2040 feet. These steep, mountainous slopes and rugged topography cause the Obey River basin to have a very rapid runoff. In the past, floods have been caused by short, intense and highly convective (spatially varying) storm patterns moving through the area. These convective storms produce a sharp hydrograph response. The study catchment has been divided into five sub-basins: East Fork Obey River, West Fork Obey River, rain on the pool, Dale Hollow Local, and Byrdstown Basin. There are three rain gages located inside the basin at Byrdstown, Jamestown, and at the dam.

PRECIP

The program PRECIP calculates area-average hyetographs from a rain gage network using a least distance square calculation. The program may also be used to calculate moisture indices, spatial averaging of snow depth data, and air temperature (maximum and minimum) data although these processes were not considered in this study. This program is used in conjunction with other HEC programs for stream flow forecasting. Recording, non-recording gages or a "bucket" survey may acquire the data needed for the program. The PRECIP program is capable of handling up to 200 gages for a network, which is adequate for this research project.

One of the limitations of employing PRECIP to calculate spatial average rainfall is that the rain gages are sparsely distributed. In the past, convective storm patterns have moved through the Dale Hollow Basin but there was no record of rainfall at the gages. Another problem with the program is the redistribution of rainfall over a period of time. For example, if a rainfall event occurred in one hour and the gage reported every six hours, PRECIP would redistribute the rainfall over six hours. This can diminish the effect of a high intensity and low duration rainfall event. Another problem with PRECIP is that only five gages may be used to calculate the basin average at a point. The program sets up a quadrant at the calculation point and only allows one gage from each quadrant to be used.

VIEWRAIN

The ViewRain program incorporates the use of both radar and rain gage data. The program can be used to graphically edit, display, or manipulate rainfall/radar data sets. The program uses various utilities to read gage/radar data sets along with geographical information (GIS) coverage in order to produce a final basin average rainfall output.

ViewRain receives the data of the radar and rain gage files in order to calculate the basin averages. Figure 1 shows an example of the radar data as seen by ViewRain. This figure shows the Dale Hollow Basin and the Stage III data for the storm in June of 1997. This storm event was the cause of the highest flow for that year in the Dale Hollow Reservoir. The contours on the picture represent different amounts of rainfall. The ViewRain program uses the CAL_RAD utility to calibrate the radar data to available gage values. This may be performed on a time interval specified by the user. The program does this by adjusting the radar values to the observed gage values. If a gage reading has a value of one inch and the radar reads two inches at that same location, the radar will be adjusted to one inch at that point. The contours that define the radar coverage are then recalculated. The program uses the Z values of the triangular gage network to adjust all the radar grid cells that lie within. Therefore the radar data will match the gage at the points of the triangular network while preserving the relative images where no gages exist.

The ViewRain program puts 100% trust in the observed gage values rather than the radar value at the location of the gage. This resembles the same process that the National Weather Service uses in creating Stage II data for they calibrate the radar images to the gages that are operated by their affiliation. The advantage of ViewRain is the use of additional gages to further adjust the radar values to correct for errors in the data.

HEC-1/API

The basin averages that PRECIP/ViewRain calculates are transformed into runoff through the use of the HEC-1/API model developed by the Nashville District. The antecedent precipitation index, API, is an empirically derived value that relates runoff to the initial level of soil moisture (Ponce 1989). This model simulates the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. This runoff model allows the comparison of the runoff hydrographs to flow data observed at the gages. In addition, observed stage data at the dam is used to compare the routed hydrographs through the reservoir so that observed versus calculated volumes can be compared.

STORM EVENTS

Three storm events were simulated in the study: February 25 – March 10,1997; May 24 – June 24,1997; and March 01- March 24, 1998. Only results from the May 24-Jun 24, 1997 storm are presented here. The event of May 24-Jun 24, 1997 was a frontal storm pattern as opposed to the March, 1997 and March, 1998 event which both showed a convective pattern of rainfall. The two storm events in 1997 were chosen for they were the cause of the largest flows in magnitude for that year. The storm event of 1998 was chosen due to the availability of the radar data at the beginning of the study. Radar data is available from earlier time periods but is not recommended because the manner in which the National Weather Service has processed the data has changed considerably.

ERROR REDUCTION PROCEDURE

Figure 2 illustrates the procedure to identify and correct radar and gage values. The procedure begins by identifying missing data in both sets. If gage data is missing, a new value is calculated with the radar data. If the radar data is missing, a new file is created using the gage network. If data is missing for more than 25% of a day for a gage, it is not used in the calculations. If radar data is missing for more than 25% of a day, PRECIP is used. A statistical analysis compares the radar data to the gage data at the gage location for a 24-hour period. The difference between the data sets for each radar-gage pair is calculated, an 80% confidence interval is established, and outliers are detected. The data is then checked for any outliers on an hourly basis. If an outlier is detected, the radar pixel is compared to the surrounding pixels on an 80% confidence interval. If the radar is ok, the gage is compared to the surrounding radar pixels on an 80% confidence interval.

RESULTS

The results shown in Figure 3, 4 and 5 are from the May 24- Jun 24, 1997 storm event. Figure 3 shows the results of using PRECIP to calculate the basin average rainfall. The figure shows the observed stage of the reservoir versus the calculated stage. The underestimates (June 2-8) of PRECIP counter-effect the overestimates (June 8 – 14) of PRECIP and, therefore, the result of the calculated reservoir stage closely matches the observed stage.

Figure 4 shows the results of using the daily values of ViewRain to adjust the hourly values of PRECIP for basin average rainfall. This represents the time increment of rainfall recorded by the gages while reflecting the daily values of ViewRain. In comparison to Figure 3, there is an improvement upon the pattern of the calculated stage. It is recognized that the underestimation of the calculated curve could be adjusted with the re-calibration of the HEC parameters.

Figure 5 shows the results of applying the error reduction procedure to the radar and rain gage data before the calculation of basin average rainfall. The basin average rainfall was calculated with the hourly values of PRECIP adjusted by the daily values of ViewRain. In comparison to Figures 3 and 4, there is an improvement upon the pattern of the calculated stage.

SUMMARY & CONCLUSION

This study compares measured and predicted reservoir stage using basin average rainfall derived by the following methods: (1) PRECIP (hourly gage data); (2) hourly PRECIP values adjusted by 24-hour values from VIEWRAIN (calibrated Stage III data); (3) method 2 with corrected radar and rain-gage data. Rainfall-runoff for a total of three storm events between 1997 and 1998 was simulated. The results showed a progressive improvement in the predicted pattern of reservoir stage going from method (1) to (3). The error reduction procedure developed as part of this study shows promise as a method to improve basin average estimates.

REFERENCES

Linsley, R.K., Frazini, J.B., Freyberg, D.L., and G. Tchobanoglous (1992). Water Resources Engineering. McGraw-Hill, Inc., New York, N.Y.

Peters, J.C., and Easton, D.J. (1996). "Runoff Simulation Using Radar Rainfall Data." Water Resources Bulletin. 32(4), 753-760.

Ponce, V.M. (1989) Engineering Hydrology, Principles and Practices.

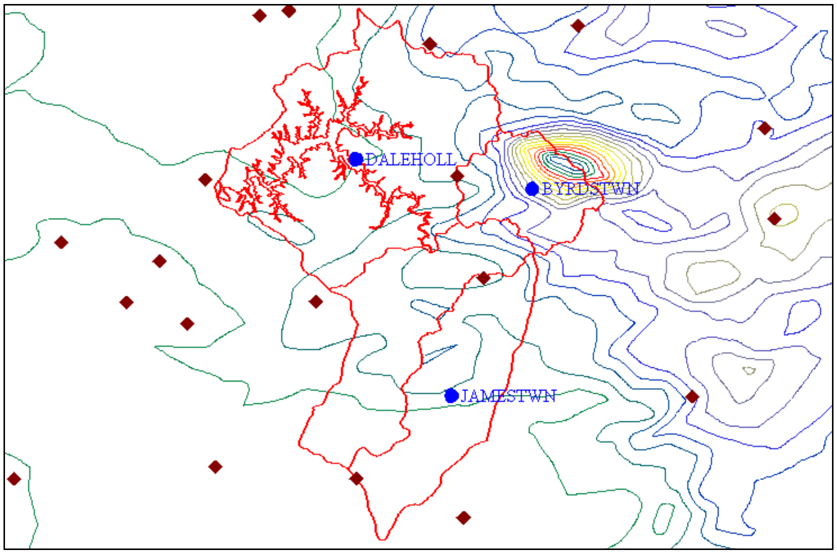

Figure 1 – ViewRain image of Dale Hollow Basin with radar data from May 24 – June 24,1997 storm event.

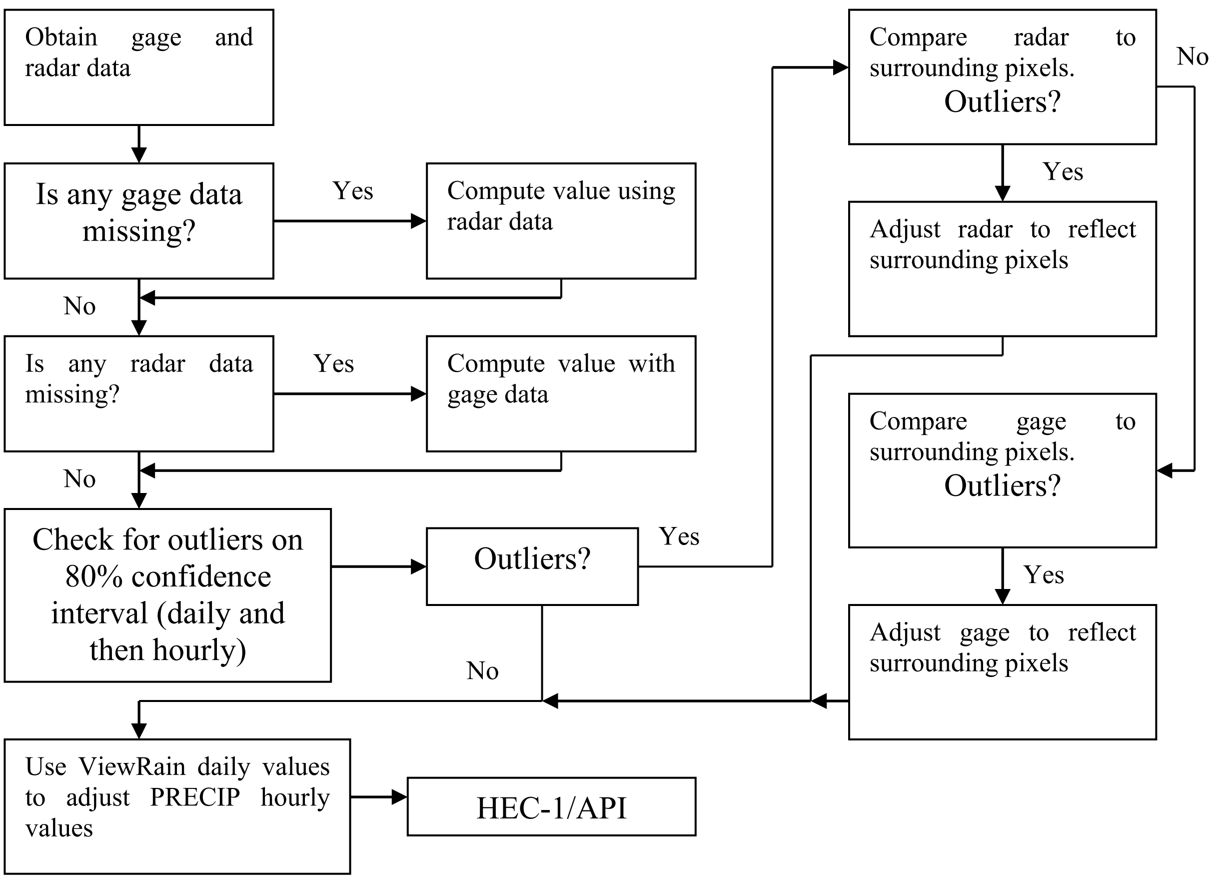

Figure 2 – Flow chart for error reduction procedure

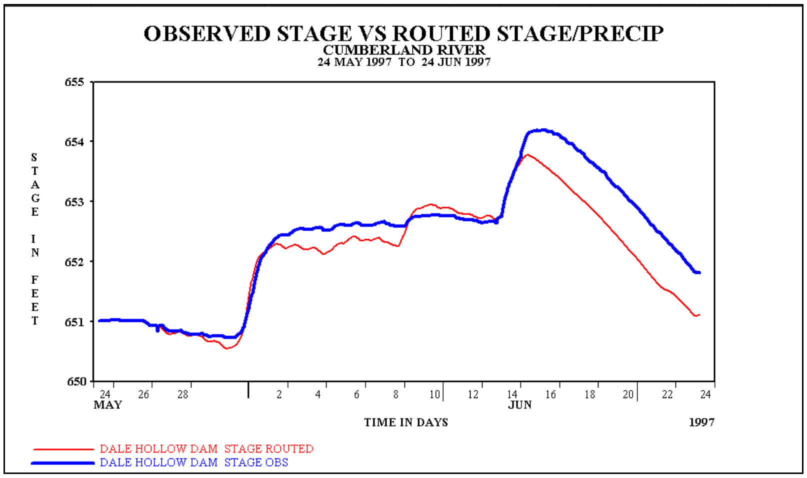

Figure 3 – Results of PRECIP

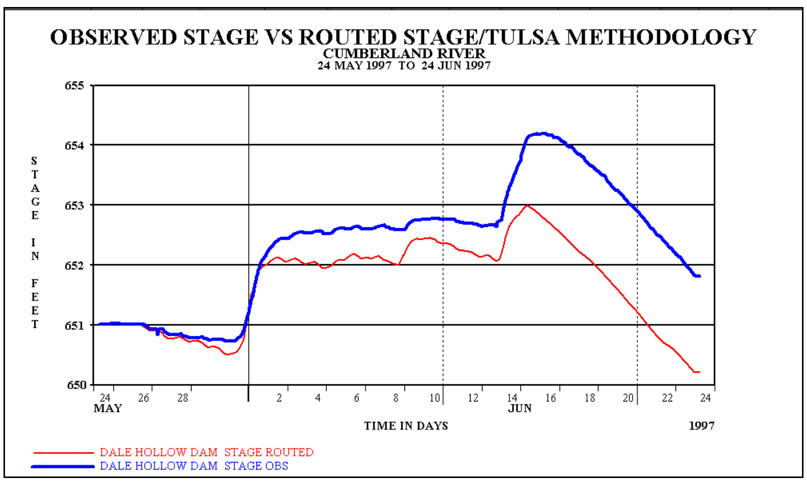

Figure 4 – Results using ViewRain

Figure 5 – Results using error reduction procedure

INCORPORATING THE CONCEPTS OF SOIL HYDROLOGY INTO THE HSPF WATERSHED MODEL

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and

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ABSTRACT

In the HSPF watershed model, a mainstay in hydrologic analysis and watershed planning, the subsurface component is simulated using conceptual relationships that are mostly empirical and not related to current soil-water theory. We are currently adding a physics-based submodel of soil-water processes as an alternative to the conventional HSPF relationships. Our presentation relates our ongoing work and the concepts, pitfalls, and possible benefits of incorporating more soil physics in the HSPF modeling system.

PROJECT OVERVIEW

The Hydrologic Simulation Program – Fortran (HSPF) is an extensive watershed model that simulates both stream flow and water quality. Initially released in 1980, this model has evolved over the years. It is a versatile software system that now contains sediment transport, nutrient interactions, provision for atmospheric deposition, a forest nitrogen module, and other capabilities. Computationally intensive, it was originally programmed for Unix workstations; and in 1988, it was ported to the PC platform. However, the fundamental equations used to simulate the hydrologic water budget for pervious land segments, which are based on the Stanford Watershed Model (SWM) developed in 1966, have remained essentially unchanged. The main subsurface storages in the model are empirical and have little relationship to measurable, physically defined soil-water parameters; likewise the transfer functions among the hydrologic components are only loosely based on soil-hydrology concepts. EPA has recently requested that an alternative scheme for modeling soil-water processes be developed and tested, one that conforms to current soil-water theory.

Our investigation is very much in progress, and this presentation is primarily a discussion of the concepts, pitfalls, and possible benefits associated with the inclusion of a physics-based soil water submodel within HSPF program system.

We envision a new soil-water submodel to be an option that the modeler can invoke in place of the classic, SWM-based hydrologic model for all pervious land segments or just for selected segments in the watershed. The modeler can set a switch to read in the alternative parameters and set up the alternative relationships. During the simulation, for each time step when the PERLND subroutine is called to simulate subsurface processes in the pervious land segment, the modified model can switch to the alternative soil-water submodel. The alternative submodel will route subsurface water to the atmosphere via evapotranspiration, to interflow storage, and to groundwater storage – all components in the standard HSPF model.

The alternative submodel is based on the governing expressions for unsaturated flow: Darcy's law adapted to unsaturated flow and the continuity equation, which together form the Richards equation. Although there are many computer models that solve the Richards equation, they are all relatively computationally intensive, therefore unsuitable for inclusion in the HSPF where soil water processes constitute just a part of a complex and computationally demanding system. Instead of a standard numerical solution, we are incorporating the Wetting Front (WF) model which is a simplification of Richards equation. The underlying equations of the WF model are

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actually models of individual soil processes, such as infiltration, evaporation, uptake by plant roots, and vertical drainage. These process-oriented models are linked together using a simplified soil-water profile, represented by a series of moisture blocks of uniform wetness. The blocks advance downward into the soil profile in response to infiltration and subsequent redistribution following infiltration. The rate of infiltration is simulated using the Green and Ampt infiltration model, a standard equation which has been shown to be a vertically integrated form of Darcy's law. In addition, the WF model simulates soil-water evaporation using the Continuous Similarity model, which can be considered to be a "the Green-and-Ampt infiltration model in reverse." At the bottom of the soil column, vertical drainage is depicted by gravity-only vertical flow or by drainage to a water table, two standard bottom boundary conditions. Transpiration loss (i.e., water uptake by plant roots) is modeled as a simple two-stage process. For an initially wet soil, there is climate control of transpiration until the soil wetness decreases below a threshold at which point transpiration becomes a simple function of the diminishing soil wetness. Figure 1 shows a hypothetical soil-water profile generated from a conventional finite difference solution to Richards equation and two WF representations.

The mechanics of the WF model are as follows: At each time step in the HSPF model, the simple soil-water profile is initially checked and modified as needed. A new wetting front (i.e., a new moisture block) is added at the surface at the beginning of a storm, and old wetting fronts are "averaged away" as they descend into the profile. Subsequently, the rate equations for the advance of the moisture blocks are computed and integrated with respect to time over the time step. Incremental amounts of interflow and groundwater recharge are computed and routed to the respective storages in the HSPF model. Figure 2 shows the progress of the WF model during a single time step.

In the presentation we discuss some of the complexities that will be addressed in the current phase of modeling or that must be postponed to a later modeling endeavor. For instance, there must be provisions for estimates of variables like the upper-zone and lower-zone storages that the HSPF model uses in many other algorithms for water quality computations. Spatial variability in soil parameters within an individual pervious land segments can be very important and must be considered. In other words, it may not be realistic to model soil water processes using only mean parameter values. Lastly, the current modifications pertain only to soils that are uniform with depth, and the problem of soil layering must be addressed. We also discuss how soil parameter values may be estimated and how the modified model may be calibrated.

We are striving to add more flexibility to the HSPF model which, over the years, has been a mainstay in hydrologic analysis and watershed planning. By including the WF model as an optional method for determining subsurface flows, modelers will be able to use the ever-growing resources of digital soils maps and databases of soil hydraulic properties in place of the empirical parameters that are part of the standard HSPF.

Clapp Figs 1 & 2

IMPROVING WATER QUALITY FROM A MUNICIPAL PERSPECTIVE: AN OVERVIEW OF THE CHATTANOOGA STORMWATER PROGRAM

J. Douglas Fritz[1]

Since its inception to meet federal NPDES regulatory requirements, Chattanooga Stormwater Management has attempted to improve water quality through various education and regulatory programs. The program is funded by a utility charged to property owners in the City. The City is divided into over 500-subbasins located in 6 major creeks and the Tennessee River. Stormwater personnel work closely with developers, facility operators and homeowners to comply with the City Stormwater Ordinance. Stormwater Management encourages pollution prevention through good housekeeping and commonsense. In addition, Chattanooga currently offers a free erosion control certification class for people involved in development.

Chattanooga has enlisted the assistance of the University of Tennessee-Chattanooga and the Tennessee Valley Authority to document the present water quality of its streams. UTC graduate students are conducting chemical sampling on over 50 sites and taking fecal coliform samples on 100 sites throughout the City. In addition, they are conducting biological monitoring on 22 sites in six subbasin watersheds. UTC is locating these sites and mapping our storm drainage system utilizing digital GPS technology. Stormwater management intends to use these findings to prioritize its efforts in further reducing pollution in our streams and the Tennessee River.

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ENVIRONMENTAL SETTING OF THE LOWER TENNESSEE RIVER BASIN: THE PRIMARY NATURAL AND CULTURAL FACTORS THAT AFFECT WATER QUALITY

James A. Kingsbury[1]

The National Water-Quality Assessment Program was initiated to describe current water- quality conditions for a large part of the Nation's water resources, identify water-quality changes over time, and identify the primary natural and human factors that affect water quality. The water- quality assessment of the lower Tennessee River Basin study unit began in 1997. To help meet the goals of the program, geology and physiography were used to subdivide the lower Tennessee River Basin into environmental settings in which natural factors such as rock type and physical setting are similar. This subdivision establishes a baseline for water-quality data within each setting, which then allows the effects of cultural factors on water quality to be assessed. Boundaries between the environmental settings in the lower Tennessee River Basin generally coincide with Level III and Level IV ecoregion boundaries delineated in the basin.

Water-use, wastewater discharge, and agricultural-activities data were summarized by environmental settings within the basin to identify water-quality issues and to aid in the overall study design. Public-supply water use and wastewater discharges are greatest in the Eastern Highland Rim and the Nashville Basin settings within the basin. Estimated agricultural chemical use and unit-area nutrient loads from agricultural activities also were largest in these settings.

Ground- and surface-water-quality data collected between 1980 and 1996 available in digital databases (for example STORET and WATSTORE) were aggregated and analyzed as part of a retrospective data analysis for the project. Data for major inorganic constituents, nutrients, bacteria, and pesticides were summarized by environmental setting to determine the spatial distribution of existing data, identify any data gaps, and characterize water quality within each setting.

Surface and ground water in the basin is predominantly a calcium bicarbonate type. Specific conductance values were between about 20 and 300 microsiemens per centimeter for surface-water samples and between about 100 and 1,000 microsiemens per centimeter for ground-water samples. Median specific conductances were higher in areas of carbonate geology for both surface and ground water. Nitrate was the most commonly analyzed nutrient in the data set. The highest median nitrate concentrations (about 1 milligram per liter) were for surface-water samples collected from the Eastern Highland Rim, Nashville Basin, and Cumberland Plateau settings. Nitrate concentrations exceeded the maximum contaminant level of 10 milligrams per liter in less than 1 percent of about 5,500 samples collected. The highest median concentrations (about 1 milligram per liter) were for ground-water samples collected from the Eastern and Western Highland Rim and the Cumberland Plateau. The maximum contaminant level for nitrate was exceeded in 2 percent of about 3,200 samples collected.

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COMPARISON OF NONPOINT AND POINT SOURCES OF NUTRIENTS WITH INSTREAM TRANSPORT FOR SELECTED WATERSHEDS IN THE LOWER TENNESSEE RIVER BASIN, 1992

Anne B. Hoos[1]

INTRODUCTION

The plant nutrients nitrogen and phosphorus are present in surface waters and are essential to aquatic life, but high concentrations of these nutrients impair use of surface-water resources. Excessive growth of aquatic plants in water bodies causes depletion of oxygen, adverse effects on other aquatic life, increased cost of water treatment, and loss of recreational value. Nutrient contamination is listed as a cause of impairment in one-third of the 15,000 impaired river miles in Tennessee, and in nearly one-half of the 121,000 impaired lake acres (Tennessee Department of Environment and Conservation, 1996). A recent study of nutrient contamination in surface waters, which focused on long-term monitoring data from more than 300 rivers and lakes across the United States, reported that nutrient concentrations in surface waters generally are related to land use in the upstream watershed: the highest nutrient concentrations occurred downstream from agricultural and urban areas (Mueller and Helsel, 1996). As part of an ongoing investigation of the lower Tennessee River Basin by the U.S. Geological Survey's National Water Quality Assessment program, this same approach was applied to historic nutrient data from the basin to compare instream transport with watershed sources. The purposes of this paper are to describe the spatial variation in instream transport of nutrients in the lower Tennessee River Basin, to describe the spatial variation in the major sources of nutrients in the basin, and to relate spatial variation in transport with variation in sources and land use.

APPROACH

Historic data for streamflow and instream nitrogen and phosphorus concentrations at 16 long- term monitoring sites in the basin were summarized as annual estimates of nutrient instream load, also referred to as nutrient export (John A. Robinson, U.S. Geological Survey, written commun., 1998). For comparison with these estimates of export, quantitative estimates of land use, land cover, and various watershed sources of nitrogen and phosphorus were compiled or computed for the watersheds contributing to 11 of these sites. The sources estimated for this analysis included anthropogenic sources (wastewater discharge, fertilizer application, and livestock production) and atmospheric deposition; natural sources and other anthropogenic sources could not be quantified. Data from 1992 were used for comparison where possible, because more data were available in the data sets for instream concentration, nutrient sources, and land use for this period, and because use of a common period provides for better spatial comparisons among sites. To further facilitate spatial comparisons, estimates of sources and export were converted to unit-area loads.

RESULTS AND DISCUSSION

Unit-area export of nitrogen in 1992 at the 11 sites ranged from 1.0 to 3.5 tons per square mile. Estimates of nitrogen contributed as wastewater ranged from 0 to 0.61 tons per square mile. The ratio of nitrogen wastewater input to total nitrogen export for a watershed was as high as 0.26:1, but the correlation between wastewater input and export for the set of all sites was low (correlation coefficient, r, was 0.2), indicating either significant instream processing of wastewater, or larger contributions from other sources, at most sites. Input/export ratios for the other estimated sources (atmospheric deposition, fertilizer application, and livestock waste) were for the most part much larger than 1:1; however this ratio has less physical significance for these latter sources because the estimated input is the mass deposited or applied to the land surface, rather than mass discharged directly to the water body. The correlation between input and export for the set of all sites is of more interest than the at-site ratios of input to export for these sources. Of the three sources, livestock waste showed the highest correlation to export ($r = 0.6$). The strong correlation between the percentage pasture land cover within the watershed and nitrogen export ($r = 0.7$) may be a

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related result. Correlations of nitrogen export with the percentage of other land use/land cover types were much lower, r = 0.1 and 0.2 for the percentage cultivated and percentage urban land, respectively.

Unit-area export of phosphorus ranged from .03 to 1.14 tons per square mile in 1992. The ratio of phosphorus wastewater input to total phosphorus export was even higher (as high as 1.3:1) than the ratio for nitrogen at most sites, but correlation of input to export was low (r = -0.2). Correlation between input and export was low for the other quantified sources as well, indicating that other factor(s) control instream transport of phosphorus in these watersheds. The influence of a known natural source, phosphate-rich limestone in the lower Duck and Elk River Basins, was examined by excluding sites in these areas from the correlation data set. These sites had the highest phosphorus export, but were not among the highest for any of the estimated inputs. The very strong correlations of phosphorus export with wastewater and with fertilizer application for this reduced data set (r > 0.9 for both sources) support two related conclusions: (1) one or both of these sources control instream transport of phosphorus in watersheds where the natural phosphorus source is not present, and (2) the natural source is the largest contributor to instream transport of phosphorus in watersheds where it is present (the lower Duck and Elk River Basins).

REFERENCES

Mueller, D.K., and Helsel, D.R., 1996, Nutrients in the nation's waters--too much of a good thing?: U.S. Geological Survey Circular 1136, 24 p.

Tennessee Department of Environment and Conservation, 1996, The status of water quality in Tennessee--The 1996 305(b) report: Nashville, Tennessee, Division of Water Pollution Control, p. 54-58.

ASSESSMENT OF WATER QUALITY IN THE LOWER TENNESSEE RIVER BASIN

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The goals of the National Water-Quality Assessment (NAWQA) Program are to assess the status and trends in the quality of the Nation's ground- and surface-water resources and to develop an understanding of the natural and human factors affecting water quality. Consistent data collection and analysis methods throughout 59 of the Nation's most important river and aquifer systems provide uniform and comparable information to address water-quality concerns at local, regional, and national scales. The study design of the lower Tennessee River Basin NAWQA incorporates surface-water, ecological, and ground-water studies to help understand water-quality conditions and issues affecting the lower Tennessee River Basin.

The surface-water component consists of nine stream sites located throughout the lower Tennessee River Basin. Water-quality samples will be collected at these sites on a monthly basis and during selected storm events for about two years. Water-quality samples will be analyzed for major ions, nutrients, and suspended sediment. At one site, water-quality samples will be collected on a weekly basis during the growing season and analyzed for pesticides. Ecological studies will be conducted at all sites to describe relations between water quality and the aquatic biological community. Ecological studies include aquatic and riparian habitat assessments and annual surveys of fish and benthic invertebrate communities. The ground-water component consists of sampling about 30 shallow domestic wells in both the Eastern Highland Rim and the Central Basin. These wells will be sampled for major ions, nutrients, pesticides, trace elements, bacteria, and volatile organic compounds. Additionally, about 30 shallow wells will be drilled in agricultural areas within the Eastern Highland Rim. These wells will be sampled for major ions, nutrients, and pesticides.

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SPRING CITY FLOOD DAMAGE REDUCTION PROJECT

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INTRODUCTION

Flash floods along the Piney River at Spring City, Tennessee, have resulted in adverse social and economic impacts and have the potential to cause loss of life. During the period from June 1989 to March 1993 the town experienced four major flood events which brought considerable media attention to the hardship and suffering of local residents. Following the March 1993 flood, United States Senator Harlan Matthews requested assistance from federal and state agencies to explore ways to help residents of the town. The Tennessee Valley Authority was asked to lead an Interagency Task Force to evaluate alternatives to reduce flood damages. At the same time a local Flood Study Committee was formed to provide local input to the planning and evaluation of potential alternatives.

Over a period of six months the two planning groups collectively settled on a plan to reduce the threat to loss of life, social disruption and economic losses. The plan involved construction of a levee, targeted property acquisition with relocation of residents; environmentally sensitive Piney River corridor modifications, including restoration of flood flow paths; and an enhanced flood warning system. The levee was later eliminated due to local concerns over future maintenance and a lack of funds to construct the levee.

BACKGROUND

Spring City is located in eastern Tennessee at the base of the Cumberland Escarpment. The Piney River drains a steep rugged 94 square mile area above the city. Elevations in the head water tributaries such as Pond Cove Creek range up to 3100 feet. The river falls rapidly as it flows through a narrow gorge and emerges just upstream of Spring City at elevation 800 feet. The river flows about 2 miles along an alluvial flood plain before reaching the backwater of Watts Bar Lake. At normal summer pool elevation of 741feet, the backwater of Watts Bar Lake extend up the Piney River to about Mile 5.9.

Flash floods inundate Spring City with little advance warning and with extremely high velocities of up to 13 feet per second. For example, the Piney River inundated portions of the city as high as 8 feet in one hour during the flood of November 18, 1957. The largest floods occurred in 1957, 1990, 1929, 1973 and 1946. The most recent flooding took place in June and July 1989, in December 1990 and in March 1993.

In a 1991 study of the city, the U. S. Army Corps of Engineers identified 371 structures within the corporate limits situated in the 100-year floodplain. An additional 84 flood prone structures were identified outside the city limits across the Piney River in Rhea County. Of the total 455 structures, 50 were non-residential. Total annual existing damages were estimated at $253,000, with about 40 percent of these damages occurring between the 10- and 50-year flood events.

PROJECT PLANNING

Senator Matthews secured federal funding of $3.5 million to implement the flood risk reduction project for Spring City, including a portion of Rhea County located across the river outside the city limits. At the beginning of the project a detailed workplan and budget were developed, based on recommendations of the interagency and local flood committees. The workplan and budget were approved at a joint meeting of the Spring City and Rhea County Commissioners. Responsibilities of TVA, Spring City and Rhea County were specified in the workplan along with planned expenditures for each area of work. Project funds were deposited in a trust account which requires approval of withdrawals by both TVA and Spring City.

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Project planners determined that only properties in the most hazardous areas would be acquired. Individual tracts were evaluated for potential loss of life based on the speed and depth of the floodwater. Water velocity and depth were calculated for flood prone tracts. If the product of the velocity and depth was greater than or equal to 9.0, the potential for a person to be swept away was considered high, and the property was targeted for acquisition. A few tracts in the project area had products between 30 and 20, and several had products in the 16 to 12 range. Occupied houses were targeted for acquisition first since they represented the greatest potential for loss of life.

Appraisal and acquisition of lands was to be at fair market value and in accordance with standards established by the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. Uninhabited structures and vacant land were to be acquired only if funds were available after all residents had been relocated. Commercial property, which consisted of automotive repair and paint and body shops, was not targeted for acquisition because of lower potential for loss of life, larger expense in relocating a business and expectation of environmental contamination. If funds were available after acquisition, relocation and site cleanup were completed, the remaining funds were to be used for future project maintenance, construction of a high flow diversion and recreational development of open space.

PROJECT IMPLEMENTATION

The process of acquiring properties was initiated in January 1995. TVA was responsible for property appraisal, title research, negotiations with landowners, property boundary surveys, deed preparation and recording and delivering payments to owners. Fifty-seven tracts with habitable structures were acquired with 38 located inside the city limits and 19 located in an area under county jurisdiction known as Sandtown. Acquisition costs ranged from $86,000 for a tract with multiple buildings to under $10,000 for a small tract with an older mobile home. Including vacant lots a total of 69 tracts, totaling almost 100 acres, were acquired by the project at a cost of $1.77 million.

During the relocation process, TVA was responsible for the research within a 50-mile radius for available housing, determining relocation assistance payments, assisting in finding replacement housing and delivering assistance payments. A total of 61 families (58 children and 94 adults) were relocated out of harms way. Under the Federal Relocation Assistance Program, relocated persons are entitled to comparable housing that is decent, safe and sanitary. Within the corporate limits of Spring City, 41 families were relocated and in Rhea County 20 families were relocated.

The amount of financial assistance allowed for relocation varied from up to $22,000 for homeowners to up to $5,000 for renters. Homeowners and renters were also reimbursed for reasonable moving expenses. Forty-one homeowners and 20 renters were relocated by the project. All families were very satisfied with the relocation program which provided improved housing conditions outside of a floodplain. Three families that were renting prior to the project became homeowners through a combination of their own labors and the assistance provided. A total of $860,000 was spent on relocation.

TVA was responsible for removing structures and preparing the open space for mowing and maintenance. Spring City, Volunteer Electric Coop, Middle Tennessee Gas and other utility providers assisted with timely disconnects at all structures. TVA held public auctions to sell houses, mobile homes and camping trailers acquired by the project. Only four houses were in a condition to be moved to another site and these were sold at the auctions along with 19 mobile homes and 3 camping trailers. When the project was initiated the city planned to burn any remaining structures as part of a training program for local fire fighters. Rules of the Tennessee Division of Air Pollution Control prohibited using this method for routine demolition and another approach was needed. Several local residents expressed an interest in salvaging building materials from the houses so a plan was developed to sell (almost give away) as much salvageable material as possible to reduce the volume to be hauled to the landfill. A contract was signed with each person removing salvage specifying obligations and describing the "raked clean" condition required after salvage removal. After the first round of salvage contracts, a $200.00 deposit was collected from those purchasing the salvage to ensure more timely completion of the salvage operations.

The Rhea County Sanitary Landfill was nearly full when cleanup began and the County requested that remaining space not be taken up with demolition materials from the project. Fortunately, the Cumberland County landfill located about 30 miles away agreed to accept the demolition materials for a reasonable charge. Local contractors were used to perform the demolition, hauling, grading and seeding. Approximately 700 tons of demolition materials were hauled to the landfill, consisting mainly of wood scraps, roofing, insulation, floor coverings, siding, drywall, brick and concrete block rubble. Concrete from sidewalks, steps, porches and driveways was buried onsite. Overall $54,000 was raised from the sale of mobile homes, houses and salvage and deposited in the project trust fund.

During the cleanup process some unwanted surprises were encountered. About 500 tires and 65 automobile gasoline tanks were found on project lands. Tires were hauled to the Rhea County landfill, where they were shredded prior to disposal and gasoline tanks were transported to a company that specializes in recycling automotive tanks. In addition a deep channel where the Piney River once flowed had been used as a trash dump for over twenty years. Over 200 tons of trash and other dumped materials were removed from this site and taken to the landfill.

Another unanticipated cost involved abandoning 21 wells which were used by residents in the Sandtown area for water supply. There were seven hand-dug wells averaging about 15 feet in depth and 14 drilled wells with steel casings, averaging about 30 feet in depth. Wells were abandoned according to guidelines provided by the Tennessee Division of Water Supply. Steel well casings were cut off 30 inches below the ground level to avoid future contact with machinery during site cleanup and clearing. Costs for well abandonment, demolition, cleanup, clearing, grading and seeding of lands was $84,000.

Once the acquisition, relocation and cleanup were completed, attention turned to construction of a high flow diversion. Modeling by TVA predicted that construction of a high flow diversion near Piney River Mile 7.35 could reduce the flood elevation between Piney River Mile 7.35 and Piney River Mile 6.9. The diversion consists of a trapezoidal shaped notch with a bottom width of 150 feet, top width of 200 feet and depth of about 7 feet. The notch is cut through an existing levee along the left river bank and the ground leading from the notch is graded to the same elevation as the invert of the notch for about 400 feet to transition to the former floodplain. During flood conditions a portion of the flow will overflow through the notch onto floodplain property acquired by the project before rejoining the river near Piney River Mile 6.9. Erosion and deposition primarily during high flow events make the behavior of Piney River very unpredictable as past channel modifications have shown; thus any efforts to modify the river must be undertaken with an understanding of the potential risk of failure. Knowing these concerns, Spring City Commissioners still wanted to proceed with the diversion. An Aquatic Resource Alteration Permit for the diversion was obtained from the Tennessee Department of Environment and Conservation.

The diversion was designed by TVA and constructed by Varner Construction of Dayton, Tennessee. The bottom of the diversion notch was established at elevation 783 feet to allow water to begin overflowing into the diversion before water rises to the low point in the top of the right riverbank along Jackson Avenue. The exact location along the right bank where overflow usually starts was shown to TVA by Spring City rescue personnel, who monitored the low point to guide evacuations. The notch opening is protected by large 4,000-pound riprap to withstand the erosive force of the river. Construction was started at the end of October 1998 and completed in December1998 at a cost of $156,000.

In connection with the project, TVA provided funds to install a new flash flood warning system. The system, completed in May 1996, consists of a water level monitor above the city near Piney River Mile 9.0 with a telephone link which notifies City Hall with a voice message when the water level reaches predetermined elevations.

Almost 50 acres of project lands are located in the heart of downtown Spring City and provide an ideal opportunity for recreational use. With input from the Spring City Recreation Committee a conceptual plan was developed which included a walking trail, ball fields, playgrounds, tennis courts and a practice field. In June 1998, Spring City was awarded a $130,000 grant from the Tennessee Department of Environment and Conservation to begin work on a recreational park.

CONCLUSIONS

This project illustrates how far a limited amount of money can be stretched by federal, state and local people working together. Major floods will continue to impact the town of Spring City; however, the threat to loss of life to 152 men, women and children has been eliminated. Future property damages to 57 structures have been eliminated. Some 100 acres of flood prone property have been turned into open space and are available for public use and recreation. A new system has been installed to provide better warning of impending flood conditions. A high flow diversion is complete and capable of providing some relief for Spring City residents along a 2,000 foot reach of the Piney River. The project was completed with almost $500,000 left in the project fund. The funds are presently available for future maintenance and recreation improvements on project lands.

FLOODPLAIN MAPPING NEEDS INVENTORY

Harold E. Clarkson, PE[1]*

ABSTRACT

Properly managed and administered, the National Flood Insurance Program (NFIP) can be an effective tool for protecting source waters. The key regulatory tool of the NFIP is the Flood Insurance Rate Map, but the maps can be riddled with mapping and hydrologic and hydraulic study errors. And although the Federal Emergency Management Agency (FEMA) makes a gallant effort to produce new maps and update incorrect maps, they are not equipped, staffed or funded to keep up with the demand for these products. It is necessary for communities with active floodplain management programs to take a more proactive role in the assessment and production of their flood maps. The first step in this process is to complete an inventory of a community's floodplain mapping needs.

INTRODUCTION

A fundamental method of protecting source waters is to protect the land area adjacent to the water body. Through proper management of these land areas, the quantity of pollutants entering the source system can be controlled and the quality of the source can be more effectively managed. A primary, if sometimes overlooked, tool in managing these land areas is the National Flood Insurance Program (NFIP).

The National Flood Insurance Program began in the early 1970's as a means of minimizing the financial burden posed by flooding disasters on the American taxpayer. The program established the Federal Emergency Management Agency (FEMA) as the lead agency and set minimum compliance criteria for all participating communities. By virtue of a community's participation in the NFIP, flood insurance is made available to residents in that community and the community becomes eligible for certain hazard mitigation and disaster relief funds.

The NFIP, however, can provide more benefits than simple protection of structures from floodwaters. An active floodplain management program can also serve to protect the beneficial natural functions of floodplains that are protecting adjacent source waters. Through proper floodplain management this natural buffer can be maintained in an efficient and healthy manner.

THE NATIONAL FLOOD INSURANCE PROGRAM

Communities choosing to participate in the NFIP must adopt a flood damage prevention ordinance that meets or exceeds the minimum requirements of the NFIP. A flood damage prevention ordinance establishes standards for development activities in the 100 year floodplain. These standards apply to all development, which is defined by the NFIP as any man-made change to the floodplain.

Within designated floodplains there are more highly regulated areas in which development is generally prohibited, termed floodways. The floodway is the land area adjacent to the stream considered necessary to carry the 100 year flood, assuming full development of the remaining flood fringe, without causing more than a one foot increase in base flood elevations.

There is a tremendous amount of flexibility built into the NFIP, allowing communities to tailor their flood damage prevention ordinance to meet their specific needs. Protecting the natural functions of floodplains is a normal product of the Program, but this aspect can be strengthened in the local flood damage prevention ordinance. Floodplain managers have the authority and the tools necessary to provide increased protection to a waterbody's natural buffer.

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The cornerstone of the NFIP is the Flood Insurance Rate Map (FIRM). Through these maps the 100 year floodplain is delineated and regulated. The following statement from the Technical Mapping Advisory Council 1996 Annual Report illustrates the importance of the Flood Insurance Rate Maps (FIRM) to the National Flood Insurance Program (NFIP).

"Flood Insurance Rate Maps serve the NFIP's two distinctly different purposes. FIRM's are intended to (1) describe the geographical area in which land-use regulations are to be enforced by local government; and (2) identify areas in which flood insurance is a prerequisite for prospective buyers to obtain a federally-backed mortgage. FIRM's, therefore, are important to the environment and to
the national economy. Properly prepared and used, they guide new development away from land that is subject to flooding and avoid costs to taxpayers for repair of flood damage that would otherwise occur. FIRM's also are the official document used in combination with local tax maps and property surveys by lending institutions and insurance agents in deciding whether a structure must be insured against flood damages. The timely production and distribution of these maps, therefore, are critical in making wise decisions regarding the purchase or development of the nation's land."

Therefore, the effectiveness of the Program depends upon the accuracy of the FIRM. Unfortunately, the FIRM is often of questionable accuracy, reducing the ability of local floodplain managers to adequately manage these critical resources.

STATE OF THE FLOOD INSURANCE RATE MAP

In the initial years of the NFIP, the Federal Emergency Management Agency went about the task of identifying special flood hazard areas throughout the United States. To date, FEMA has produced approximately 100,000 flood map panels. FEMA continues its efforts to produce maps for previously unmapped areas, while attempting to maintain the current map inventory. The task is enormous.

According to the Agency's Flood Hazard Mapping Modernization Plan, approximately 45% of the nation's maps are at least 10 years old, and 70% are 5 years or older. In Tennessee, approximately 70% of the Flood Insurance Rate Maps are at least 10 years old and 90% are over 5 years old. In addition, the inherent limitations and errors of the maps often make them difficult to use as an effective floodplain management tool.

The most common complaint regarding the maps is simple mapping errors. Typical complaints include; roads depicted in the wrong location or not at all, insufficient detail to accurately locate a new development, and inaccurate stream alignments. Although these types of errors may seem innocuous and easily remedied, they create doubt in the user as to the accuracy of the entire study – and with good reason.

The flood studies on which the maps are based were created using the best available data at the time of the study. Flood study standards do not allow for consideration of projected future conditions within the watershed. Therefore, in rapidly developing watersheds, this data is often outdated and inaccurate as soon as the map is made public. Topography has been altered, impervious surfaces have increased, open channel systems have been piped, and new roads have redefined watersheds. These issues, along with advancing techniques in study methods can make even the most recent maps obsolete.

STATE AND LOCAL RESPONSIBILITY

Flood Insurance Rate Map corrections and updates can be initiated by either the user or by the Federal Emergency Management Agency. User initiated changes occur through the Letter of Map Correction process. FEMA initiated changes are processed through the Restudy process or through the Limited Map Maintenance Program (LMMP).

User initiated revisions and amendments are typically made in response to a proposed development in the floodplain and only address the changes caused by the project. These revisions also address relatively small areas and are difficult to track at the local and state level. For this process to be effective, notations must be made on the Flood Insurance Rate Maps at both the local and state level and individual holders of the maps must also be notified.

Restudies are a part of an on-going process by FEMA to maintain updated maps. The number of communities undergoing a restudy each year, however, is extremely limited. LMMP projects address small watersheds with known errors in the flood study. A community can receive funding for one LMMP project per year and the level of funding per project is capped.

In order to direct FEMA in its' restudy and LMMP project funding, it is critical that communities be aware of their own mapping needs and communicate those needs to the State NFIP Coordinators Office. A comprehensive and analytical inventory of the floodplain mapping needs in each community is essential to this effort.

A MAPPING INVENTORY

A flood mapping needs inventory can be used to set community restudy priorities, create a systematic program for applying for LMMP funding and to assist in the evaluation of a community's overall floodplain management program. Prepared properly, the inventory can be easily and quickly updated.

Although making a personal visit to each community to interview those involved in the floodplain management program is the best way to evaluate a community's mapping needs, a personal visit to every community within a state is neither feasible nor necessary. Therefore, three levels of data collection and analysis should be considered. These levels are fully described in Step 2 of the following process.

Step 1. Gather and Evaluate Community Baseline Data: General data regarding a community's flood hazard, insurance risk, and participation in the NFIP should be gathered tabulated and evaluated. The information being gathered in this step is readily available and is used to determine which level of assessment is required. Communities that are growing rapidly, have a high percentage of Special Flood Hazard Areas, and a large number of flood insurance policies receive greater consideration and a more detailed evaluation than communities that have been recently studied or that have a fewer number of structures at risk.

Step 2. Assign Communities to One of Three Levels for Evaluation: A Level One Analysis consists of an on-site visit including; a review of the FIRM's with community officials for known mapping errors and suspected study problems, an inspection of floodplains for existing development, high water marks, unmapped dams and crossings, and a public meeting to gather input from local engineers, land surveyors and other interested parties regarding mapping and study errors.

A Level Two Analysis is similar to the Level One Analysis except that an inspection of Special Flood Hazard Areas is not conducted and comments from the general public are solicited, although a public meeting is not held.

The least detailed analysis is a Level Three Analysis. This review is often a phone interview of the local floodplain administrator. Known mapping and study errors are discussed and noted by the interviewer for further consideration. The results of the phone interview may indicate no further investigation is warranted or that a higher level analysis is needed.

Communities ranking in the top ten (10) percent, as determined in Step One, are assigned to Level One. The next forty (40) percent should be assigned to Level Two and the last fifty (50) percent to Level Three. These are recommended ratios and can be adjusted to meet the needs of each community, state or region.

Step 3. Compile Detail Mapping Needs Data: During the community analysis, more specific information regarding each community's Flood Insurance Rate Maps and potential flood damage are determined and recorded. Mapping deficiencies, suspected study errors, and locations of structures in the floodplain are marked on the flood insurance rate maps. A summary report, complete with financial and technical resources the community can contribute to the study effort and annotated maps, are then generated based on the results of the community assessments.

Step 4. Prioritize Communities for Restudy and Limited Map Maintenance Projects: By considering the potential for flood damage posed by the known deficiencies and the resources the community can contribute to the study process, communities can then be prioritized for mapping efforts. Potential projects can be categorized as either mapping, limited study or restudy efforts.

USE OF THE INVENTORY REPORT

As funds to produce more and better maps remains limited, competition between communities for these funds will intensify. The community (and state) that can best demonstrate its' need for mapping efforts will be in a much better position to receive funding. A statewide Mapping Needs Inventory places the participating communities in a better position to compete for restudy and LMMP funding in the region. Communities will benefit from an individual assessment as well.

A comprehensive inventory, however, goes beyond merely prioritizing communities for mapping efforts. A thorough assessment will provide valuable insight into the overall NFIP program management in the community. Strengths and weaknesses in program management will become apparent and additional opportunities for source water protection can be identified.

Short of creating your own maps, the best method for correcting Flood Insurance Rate Map deficiencies is to take full advantage of FEMA's recent emphasis on map modernization. Position your community to take advantage of restudy efforts, the Limited Map Maintenance Program and the new Cooperating Technical Communities Program. You begin this process by assessing your community's floodplain mapping needs, your ability to contribute to the mapping and study process and then by making these needs known to the State NFIP Coordinators Office and the Federal Emergency Management Agency Region serving your State.

REFERENCES

Federal Emergency Management Agency. "Flood Hazard Mapping Modernization Plan". (Online) Available http://www.fema.gov/mit/9131996.htm. January 10, 1999.

Federal Emergency Management Agency. "Flood Insurance Program Community Status List". (Online) Available http://www.fema.gov /nfip/tennessee/htm, January 5, 1999.

FLOODPLAIN ANALYSIS AND POLICY DEVELOPMENT FOR SINKHOLES IN URBAN AREAS

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ABSTRACT

Flooding in karst areas that serve as primary drainage outlets for stormwater runoff can cause significant property damage and threaten human welfare. Urbanization, poor maintenance, and construction practices, such as filling, blasting and lack of erosion control, can alter drainage areas in karst terrain resulting in increased runoff and reduced outflow efficiency of sinks and caves. These factors, combined with seasonal hydrologic conditions, such as saturated soils and periods of heavy rainfall, result in increased potential for flooding. A study was performed to evaluate the hydrologic characteristics of, and to present flood mitigation alternatives for, flood-prone sinkholes located in a suburban area in Knox County, Tennessee. The Dutchtown Road study area is a 3.3 square mile area that drains to a group of approximately forty sinkholes. In the past 15 years, the area has experienced periodic flooding of residential and commercial areas, and several major roadways as development of the area increased. Hydrologic analysis of the area included a 100-year storm event and a flood event that occurred in April 1998. Flood mitigation alternatives were presented for those roadways and residential areas already prone to flooding. To combat future flood problems, a Policy for Development in Sinkhole Areas was written. The policy addresses development and construction of areas adjacent to sinkholes. The policy contains erosion and sediment control provisions, and requirements for the establishment of and adherence to "no-build" (i.e., floodplain) and "no-fill" boundaries. The policy also limits the volume of stormwater leaving a property developed in a sinkhole drainage area.

INTRODUCTION

The Dutchtown Road area, located in west Knox County (the County), Tennessee, is a 3.3 square mile area that drains to a group of approximately forty sinkholes. This area has experienced flooding in the past several decades during heavy rains. Recent flood events have forced the County to close major and intermediate roadways, and respond to complaints of flooding in several buildings and numerous yards located in close proximity to overwhelmed sinkholes. Past flood events, the potential for further development in the area, and a lack of knowledge of the subsurface drainage characteristics of the area prompted Knox County officials to request a study of the Dutchtown Road area in an effort to discover solutions that will prevent future flooding.

Prior to the study, the County identified three goals for the study area: (1) provide alternatives to protect buildings and roads, (2) evaluate alternatives that modify runoff and reduce flood elevations in sinkholes that tend to flood, and (3) increase and protect sinkhole throat efficiency. A two-phase approach was performed in an effort to reach these goals. The first phase addresses existing sinkhole flood problems through hydrologic analysis of the area, and evaluation and development of flood mitigation alternatives for flood-prone sinkholes. The second phase addresses the future flood potential through development of a policy addressing urbanization in karst areas. In an effort to limit storage volume loss and runoff volume increases, the policy places special drainage and construction requirements on new developments adjacent to or upstream of volume sensitive sinkhole areas.

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CAUSES OF FLOODING IN KARST AREAS

Flooding in the Dutchtown Road area is caused by a number of factors. First, there is no surface drainage feature (i.e., stream) in the area; therefore the numerous sinkholes serve as the primary drainage outlets for stormwater runoff. Second, heavy residential, institutional (e.g., schools and churches) and commercial development has occurred in the study area during the past 10 to 15 years. This development continues at the present time, increasing the volume of runoff that the sinkholes must handle. Finally, construction practices that may alter the karst terrain, such as sinkhole filling, blasting, and inadequate erosion control, can increase the potential for flooding by reducing the outflow efficiency of sinks and caves in the region. These factors, combined with seasonal hydrologic conditions, such as saturated soils and periods of heavy rainfall, result in increased potential for flooding.

THE APRIL 1998 STORM EVENT

The Dutchtown Road area experienced significant rainfall and subsequent flooding between April 16 and April 19, 1998. According to a rainfall gage operated by the City of Knoxville approximately 2 miles from the study area, 7.4 inches of rain fell during a 72-hour period. Local accounts of 10 inches in the Dutchtown Road area were common, as reported in the local newspaper. Wet antecedent conditions contributed to the flooding. According to rainfall data collected at the local airport (Tyson-McGee Airport), normal rainfall for the month of April had already occurred prior to the April 16 event. Figure 1 shows the extent of flooding resulting from the April event and identifies three flood prone areas. The high water marks shown were either surveyed or field estimated based on 2-foot topographic mapping.

Area 1 is where Dutchtown Road, a major west Knoxville roadway, crosses through the largest sinkhole in the area. The flood elevation peaked at 940.5 ft, covered a portion of Dutchtown Road and threatened several condominiums located near the sinkhole. Sandbags and pumps were used to keep the condominiums dry. Floodwaters did not recede quickly, and the road remained impassable until late May.

Floodwaters rose to an elevation of 931.8 ft in Area 2. Two major roadways, Cedar Bluff Road and Fox Lonas Road, were impassable for two to three days after the event. A portion of Pensacola Road was closed for over a week, eliminating roadway access to a newly developed 5-house subdivision. Resident interviews and field observations during the storm indicate that upstream sinkholes and the stormwater drainage system for the major roadways in the area were overwhelmed during the storm, causing inlets to surcharge and sinkholes to overtop and send water downstream to the flooded area.

Area 3 is also located along Cedar Bluff Road. Floodwater rose to an elevation of 935.7 ft, which resulted in the closure of a portion of Cedar Bluff Road and some flood damage in a commercial business located in close proximity to the sinkhole. Flooding in this area receded several days after the event.

HYDROLOGIC ANALYSIS

A runoff vs. storage volumetric analysis was performed in an effort to gain some insight into the rainfall-runoff process and the surface to subsurface drainage characteristics of the area during extreme flood events. An elevation/area/storage relationship was determined for each sinkhole using topographic maps. The loss of storage in sinkholes known to impound water during dry periods was considered, as was surface overflow (i.e., flooding) from one sinkhole to another. Due to the lack of data on the discharge capacity of sinkhole throats, the analysis was performed assuming zero discharge to the subsurface environment.

Surface runoff volumes to each sinkhole for the April 1998 event were determined using SCS curve number methodology. A total rainfall depth of 8 inches was used in the analysis and curve numbers were adjusted for AMC III (wet) conditions. Predicted floodplain elevations were compared with survey data and adjusted to account for sinkhole overflow and potential resurgence. A similar analysis was performed to determine floodplain elevations for the 24-hour, 100-year (1% annual chance) rainfall event.

The analysis indicated that for the majority of the sinkholes, water surface elevations resulting from the April 1998 storm event were equal to or exceeded the 24-hour, 100-year event under drier (AMC II) conditions. It was concluded that a storm duration of 24 hours was not appropriate for sinkhole analysis in this area.

The analysis also concluded that factors other than direct runoff should be considered based on observations of the April storm. Resurgence was observed at several sinkholes in the flooded areas, therefore additional water, other than direct runoff, contributed to the high water elevations. In some cases, the high water from the April storm was probably a reflection of the groundwater table. This is most evident in Area 1, where the length of time required for water to recede indicates significant groundwater influence on flood elevations.

FLOOD MITIGATION ALTERNATIVES

A variety of potential remedial alternatives for flooding in the Dutchtown Road area were considered. Alternatives assessed included no action, raising road elevations, constructing floodwalls, buying flooded property, excavating sinkholes that have inadequate storage volumes, and detaining and/or diverting runoff. General maintenance activities such as cleaning clogged sinkhole throats and preventing sediment and debris accumulation were included as general recommendations for all sinkholes in the area.

Because of the difficulty in assigning an appropriate frequency and duration to the design storm to predict flooding in the Dutchtown Road area, the April storm was used as the design event to evaluate alternatives. An appropriate Factor of Safety, used to allow for increase runoff volumes that may result from large storm events or future development, was utilized for the analysis and preliminary design of each alternative.

The final options that were proposed to the County are for the most part "avoidance alternatives". The recommended alternatives reduce flood potential by diverting flow away from streets and buildings, raising flooded roads, and installing local flood protection in the form of floodwalls. The recommended alternatives included:

Area 1: Raise Dutchtown Road 1 foot above the historical high water mark. Construct floodwalls around vulnerable residences.

Area 2: Divert runoff originating east of Cedar Bluff Road to an undeveloped sinkhole area south of Fox Lonas Road and raise Pensacola Road above the 1 foot above the historical high water mark.

Area 3: Pipe excess water in flooded sinkholes to a currently undeveloped sinkhole area south of Fox Lonas Road.

In general, the lowest cost alternative was chosen at a location if it provided a benefit equal to or greater than other alternatives. Excavation and pump stations were not recommended primarily because of the high cost associated with these options. The primary objective of eliminating roadway flooding for the design event was accomplished with the selected alternatives. Because of the geologic and topographic restrictions in the Dutchtown Road area, reducing flood stages by diverting stormwater to a surface drainage feature would require pumping or channeling through highly populated areas. These options were found to be very expensive and have a low feasibility for implementation.

SINKHOLE POLICY

A regulatory policy was developed to address future development in sinkhole areas. The purpose of the policy is to protect existing and future development from flooding, protect subsurface drainage systems, and protect groundwater resources from contamination due to polluted runoff. The policy is designed to protect existing and future development as well as public roadways from flooding. The general requirements of the policy address dumping, filling, erosion control, and construction in sinkhole areas. The major requirements of the policy are directed at (1) new developments adjacent to sinkholes, and (2) new developments constructed in sinkhole drainage areas.

REQUIREMENTS FOR DEVELOPMENTS ADJACENT TO SINKHOLES

A drainage study must be performed by a Registered Engineering of the State of Tennessee for all new constructions in areas adjacent to sinkholes. The purposes of the study are to establish "no-build" (i.e., floodplain) and "no-fill" elevations, set permissible structure elevations, determine the need for State and/or Federal permits, and insure that adequate sediment and erosion control are used during construction.

The floodplain line for a sinkhole is defined by the highest closed contour elevation, referred to as the sinkhole lip elevation. The storage volume beneath this elevation is the sinkhole floodplain storage volume. The policy requires the pre-development floodplain storage volume be preserved under post-development conditions. Therefore, any fill added below the floodplain elevation must be compensated for by excavation elsewhere in the floodplain. The finished floor elevation of any habitable structure adjacent to a sinkhole must be at least one foot above the established floodplain elevation.

The no-fill line is defined as the elevation below which construction is prohibited. It is established by the contour line or interpolated contour line for the elevation that defines sixty (60) percent of the floodplain storage volume. This provision is similar to FEMA floodways, where fill is generally prohibited.

REQUIREMENTS FOR DEVELOPMENTS IN SINKHOLE DRAINAGE AREAS

This portion of the policy establishes a performance standard for new development in sinkhole areas, as it places a limit on the volume of runoff from new developments constructed upstream of volume sensitive sinkholes. A drainage study is required to define the drainage area for the proposed site, establish a plan to control the runoff volume from the site, and insure adequate sediment and erosion control. In short, developments in volume sensitive areas are required to limit the volume of runoff leaving the site for the 24-hour, 100-year event under post-development conditions to the volume of runoff leaving the site for 100-year event under pre-development conditions.

SUMMARY

A number of flood mitigation alternatives were evaluated for relief of flooding in the Dutchtown Road area. Alternatives that provided the most benefit at the lowest cost were recommended. A policy for new development located in karst areas was written to reduce the future flood potential by placing guidelines on structure location adjacent to a sinkhole, and on site construction practices and stormwater controls.

A PARTNERSHIP APPROACH TO WATERSHED IMPROVEMENT

Susan Robertson[1]

ABSTRACT

A partnership-based approach to watershed improvement demands a shift in organizational culture. The approach to improvement efforts must be watershed-based, community-driven, and sustainable. Engaging the user public, limiting science and technology, and incorporating societal issues into the planning process are necessary components of this new world order. This presentation will introduce you to strategy and cite examples of success stories.

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UPDATE AND STATUS OF
TENNESSEE'S WATERSHED MANAGEMENT APPROACH

Richard E. Cochran[1]* and David Duhl[2]*

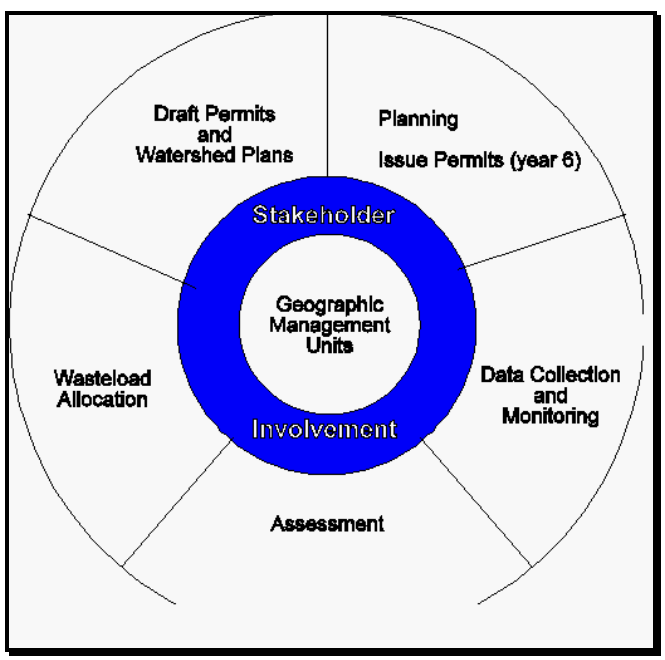
ABSTRACT

Tennessee is in the third year of its ongoing watershed-based approach to controlling water pollution and improving water quality. Tennessee has five watershed groups, each beginning a five year cycle between 1996 and 2000. In 1999, draft Watershed Management Plans are being prepared for Group 1 Watersheds, water quality assessments are being reviewed for Group 2 Watersheds, data collection is beginning for Group 3 Watersheds and initial monitoring strategies are being developed for Group 4 Watersheds. The status of each of these watershed groups is presented.

OVERVIEW

In 1996, Tennessee began a watershed approach to water quality. In the watershed approach, Tennessee's 54 watersheds (8-digit HUCs) are arranged into five groups, each group beginning its five year cycle in a different year. Activities in this five year cycle include planning, data collection, monitoring, assessment, wasteload allocation/TMDL development, drafting permits and writing watershed management plans.

In the Watershed Approach, NPDES permits are synchronized to expire (available for renewal) in Year 5 of the watershed cycle. At that time, a public hearing will be held in the watershed to afford the public an opportunity to comment on the draft permits and draft Watershed Management Plans. These plans will address water quality assessments, proposed TMDLs and proposed control strategies for the next five years.



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GROUP ONE WATERSHED STATUS

Assessments of water quality in Group 1 Watersheds were completed and incorporated into Tennessee's 1998 303(d) list to EPA. The Group 1 watersheds are: Nonconnah (08010211), South Fork Forked Deer (08010205), Harpeth (05130204), Stones (05130203), Emory (06010208), Watts Bar (06010201), Upper Portion of Lower Tennessee (06020001), Ocoee (06020003) and Watauga (06010103). These assessments were based on the data collection and monitoring by the Department's Environmental Assistance Centers. Public meetings were held in all 9 watersheds to report these findings.

The next step for the Group 1 watersheds is to prepare watershed management plans and develop TMDLs for impaired streams shown in Tennessee's 1998 303(d) list.

GROUP TWO WATERSHED STATUS

Assessments of water quality in the Group 2 Watersheds are currently being developed. Some Environmental Assistance Centers are concluding monitoring and data collection in their watersheds. The Group 2 watersheds are: Loosahatchie (08010209), North Fork Forked Deer (08010204), Pickwick Lake (06030005), Lower Elk (06030004), Upper Elk (06030003), Wheeler Lake (06030002), Collins (05130107), Caney Fork (05130108), Hiwassee (06020002), Ft. Loudoun Lake (06010201) and South Fork Holston (06010102).

The next step for the Group 2 Watersheds is to assess water quality, then conduct local public meetings to review these results.

GROUP THREE WATERSHED STATUS

In the fall of 1998, planning meetings were held in the Group 3 Watersheds to introduce the Watershed Management Approach to local interests. Monitoring and data collection will begin in these watersheds in 1999. The Group 3 watersheds are: Wolf (08010210), TN Western Valley (KY Lake: 06040005), TN Western Valley (Beech River: 06040001), Buffalo (06040004), Lower Duck (06040003), Upper Duck (06040002), Middle Portion of Lower Tennessee (06020001), Lower Clinch (06010207), Little Tennessee (06010204) and North Fork Holston (06010102). Assessments for these watersheds will be produced in early 2000. It is currently our plan that these will be completed in time for the Year 2000 303(d) list.

GROUP FOUR and FIVE WATERSHEDS STATUS

Group 4 Watersheds will begin their planning phase in 1999. Existing data will be reviewed, a monitoring strategy developed and primary sampling sites selected. Similar planning activities will be conducted for Group 5 Watersheds in the Year 2000.

PUBLIC PARTICIPATION IN TDEC'S WATERSHED APPROACH LESSONS LEARNED AND DIRECTION FOR THE FUTURE

Callie Dobson[1]* and David Duhl[2]

ABSTRACT

There are three scheduled opportunities for the public to provide input in Tennessee's Watershed Management Approach to water quality, and this input is vital to the success of drafting and implementing watershed management plans in each watershed. Two public meetings and one public hearing are held in each watershed during the five year process, yet the popular movie line "If you build it, they will come," doesn't necessarily hold true for these meetings. More emphasis needs to be placed on media diversity. In the past, methods for soliciting public comment have been limited to direct mail and press releases to local newspapers, asking residents to attend meetings in the watersheds in which they live or work. Now, more of an effort is being placed on reaching communities through local civic and environmental groups and key community leaders via their publications and websites. Citizens should also be more strongly encouraged, through the information that is distributed, to participate by commenting directly in writing or by e-mail via the TDEC website.

PARTICIPATION IN THE PROCESS

There are three scheduled opportunities for public input in TDEC's Watershed Management Approach. Input and feedback from the people who live and work (stakeholders) in each watershed are considered vital to the success of drafting and implementing the management plans. The first scheduled opportunity for public input is in Year 1 of the five-year cycle. There are two important reasons for this first "Public Outreach" meeting. Firstly, stakeholders receive an overview of the whole five-year cycle, including the activities that will be taking place in various years, future opportunities for participation, how NPDES permits will be re-issued, and the benefits for both TDEC and stakeholders of adopting the approach. Secondly, TDEC receives comments and questions from stakeholders that provide valuable information about the concerns they have regarding water quality in the watershed, as well as their level of interest and potential for involvement in working toward solutions to problems that are identified.

The second "Public Update" meeting (in Year 3) begins with a review of the Year 1 Outreach Meeting, including the concerns that were expressed. A discussion of the assessment of water quality in the watershed that has taken place over the previous two years follows a review of streams that were sampled and their support status in terms of designated uses. Once again, the stakeholders are asked for comments regarding the assessment and, specifically, whether they feel that their concerns are being addressed by the approach. The meeting ends with a reminder about the third opportunity (in Year 5) for stakeholders to review draft management plans and provide feedback during the "Public Hearing" for each watershed.

SOLICITING PUBLIC INVOLVEMENT

Until now, the main method of transferring information to stakeholders in the watershed has been by direct mail. The mailing list for each watershed includes:

A. Elected Officials
- ◊ Mayors
- ◊ City Managers
- ◊ County Executives

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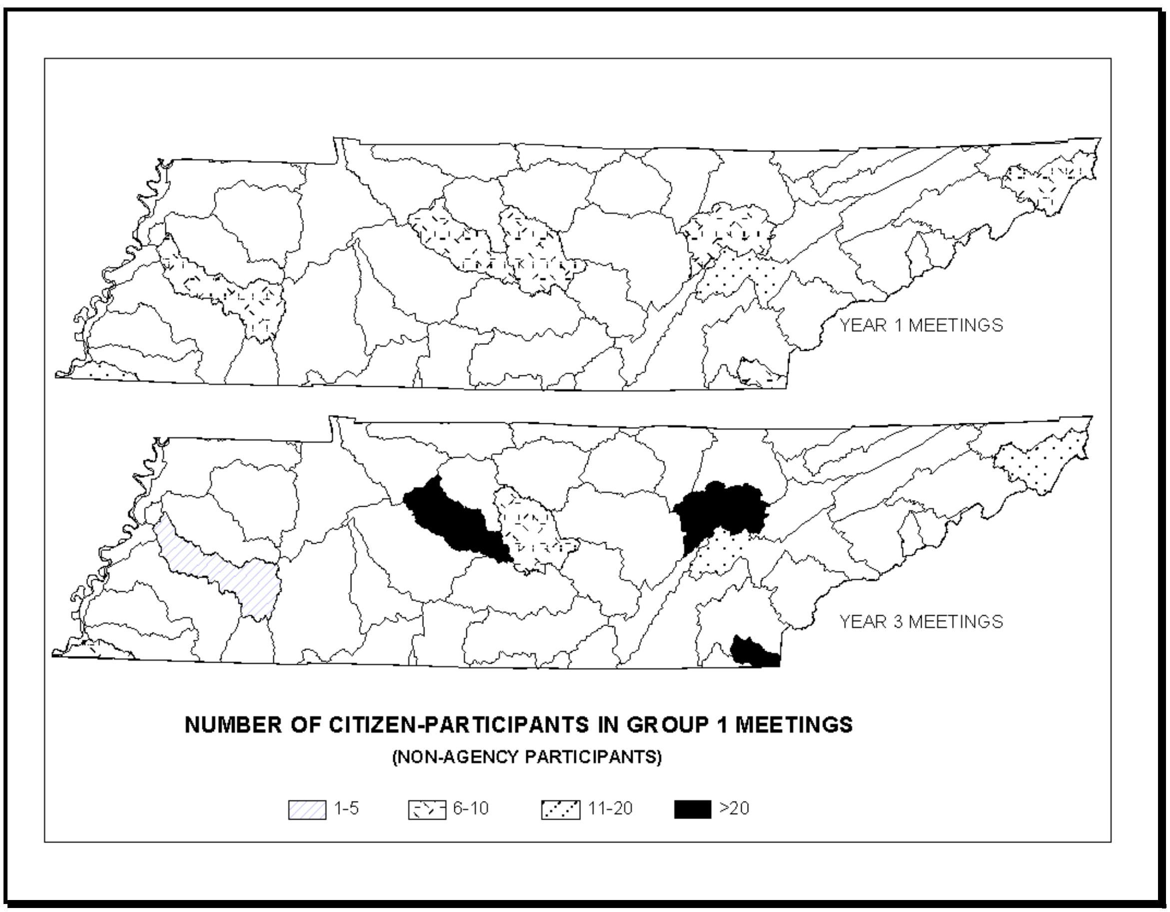
B. NPDES Permit Holders
C. Public Works Directors
D. Federal and other State Agency representatives
E. Agricultural interests
F. Environmental groups
G. Local citizen groups with conservation interests
H. People who have requested documents from TDEC previously [*e.g.*, 305(b) reports]
I. Commercial businesses that are directly tied to water quality [*e.g.*, rafting outfitters, marinas]

The Division of Water Pollution Control uses a one page flyer to invite citizens to attend these meetings. This flyer, patterned after the one used in South Carolina, is easy to read and clearly presents the agenda, importance of the meeting and who should attend.

In addition to direct mail, some Environmental Assistance Center staff have posted information in public places within the watershed. Press releases are also provided to TDEC's Public Information Officer for distribution, although not all newspapers choose to print the notice. All meeting times are posted on the TDEC website at least two months in advance, and environmental groups with home pages are encouraged to post meeting dates and times.

RESPONSE IN THE FIRST THREE YEARS

The chart below shows attendance statewide for the outreach and update meetings held for Group 1 watersheds in years 1 and 3 of the watershed cycle. In the majority of watersheds, attendance has been low. In the Harpeth and Emory watersheds, citizens requested an additional meeting so that elected officials and other residents could attend.



In general (with two exceptions), for any watershed, attendance in Year 3 is the same or better than in Year 1. This is to be expected as citizens learn about the watershed approach in Year 1 and develop an interest in participating by Year 3.

LESSONS LEARNED

Many watersheds are strongly divided, either by county lines, age-old differences, or just varying land uses and general way-of-life. It is important to recognize these divisions early. The location of meetings can feed these long standing differences in some watersheds. A choice of meeting location that does not recognize these differences can severely limit attendance.

In addition, environmental interest groups and business interest groups may both be present at the same meeting, along with a distrust for each other. It is very important to conduct the meeting in a completely neutral way, not siding--or appearing to side--with any point of view.

False information about the true intent of these meetings can spread quickly in areas prone to distrust of the government. It is critical that all elected officials (especially local and county representatives) are aware of the meeting's date, time, location, and agenda. Attendance among elected officials statewide has been poor, and the absence of elected officials has been noted in several meetings. Follow-up watershed meetings were held in the Harpeth and Emory watersheds specifically to encourage the attendance of politicians.

Almost everyone in attendance at the meetings thus far represents a group, company, or specific interest. The average citizen whose sole reason for attending is concern for water quality in the area where he/she lives and works has been the least represented.

These meetings are an opportunity for the public to address water quality concerns in the watersheds where they live and work. For this reason, some general knowledge of problems, whether they have a direct impact on water quality or not, must be anticipated at public meetings. It is, therefore, helpful to schedule meetings so that Water Pollution Control staff with knowledge of these problems or situations can attend.

FUTURE DIRECTIONS

- More emphasis should be placed on publicizing the meetings through direct contact with local residents
- Attempts should be made to publicize the meetings through local groups' newsletters and publications (e.g., environmental groups, civic groups, etc.)
- Participation via TDEC's website should be expanded to include an opportunity for citizens to comment on water quality issues directly

WATER QUALITY MONITORING AT ECOREGION REFERENCE STREAMS

Gregory M. Denton
Division of Water Pollution Control
Department of Environment an Conservation

ABSTRACT

In 1992, the Division of Water Pollution Control faced an important decision on how water quality assessment would be done in the future. One choice was to continue assessment the way it had been done for twenty years--by comparing existing ambient water quality data with statewide criteria derived from EPA's national database, the one-size-fits-all approach. While we generally had good results with this approach, there were problems likely to be amplified in the future. For example:

- Tennessee was being strongly encouraged by EPA to convert to a watershed approach for issuance of water quality permits. Without a sense of regional variability in water quality, we were at a disadvantage in goal setting for these watersheds. Statewide criteria are clearly overprotective in some parts of the state, but arguably underprotective in other areas.

- Tennessee's Antidegradation Policy requires that high quality waters be identified and protected from degradation. We had spent a considerable amount of effort identifying poor water quality, but had very little experience identifying good water quality on a regional basis.

- Accurate water quality assessment requires the ability to interpret Tennessee's narrative water quality criteria. (Narrative criteria are based on a verbal description of water quality, rather than a number.) We felt that regional interpretations would be more accurate and defensible. Included in those narrative standards is a statewide biological integrity criteria that states that "*the waters shall not be modified through the addition of pollutants or through physical modification to the extent that the diversity and/or productivity of aquatic biota within the receiving waters is substantially reduced*". This criteria is an important tool for aquatic ecosystem protection.

The Division needed to be able to compare the existing conditions found in a stream to what conditions should be if it were not impacted. This least impacted stream is often referred to as "reference conditions". This comparison should be made within a similar area, to avoid "apples and oranges" comparisons. It was determined that the *ecoregion* is the best geographic basis upon which to make this assessment.

An ecoregion is a relatively homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, and other ecologically relevant variables.

The "Ecoregions of the United States" map was developed in 1986 by James Omernik of EPA's Corvallis Laboratory and delineated 8 ecoregions in Tennessee. The Division arranged for Omernik and Glenn Griffith to sub-regionalize and update the state's ecoregions. The Ecoregion Project began in 1993 and has three phases:

PHASE 1 Delineate Sub-Ecoregion Boundaries

This part of the project involves geographic data gathering, development of a draft sub-regionalization scheme, and ground-truthing/fine-tuning of the draft into a final product. This product included new maps, digitized ecoregions for use in the Division's GIS system, and assistance in choosing reference streams. This part of the project began in 1993 and was completed in 1996. (See the ecoregion map.)

A reference stream is a least impacted waterbody within an ecoregion that can be monitored to establish a baseline to which other waters can be compared. Reference streams are not necessarily pristine or undisturbed by humans.

Phase II   Reference Stream Selection

EPA and Division staff identified potential reference streams. Reference streams were selected that were typical for that ecoregion, with relatively unimpacted watersheds. Whenever possible, watersheds within state or federal protection were selected.

Division staff visited each candidate stream. Water and benthic macroinvertebrate samples were used to cull the list of streams down to the final list. Three reference streams per sub-ecoregion was considered a minimum number. A map of these streams appears below.

Phase III   Intensive Monitoring of Reference Streams

Beginning in August 1996, the final reference sites have been monitored on a quarterly basis. Water chemistry has been monitored using grab samples collected on three consecutive days (if possible). Chemical sampling follows a modified clean technique methodology as outlined in the Division's *Chemical Standard Operating Procedure: Modified Clean Technique Sampling Protocol*.

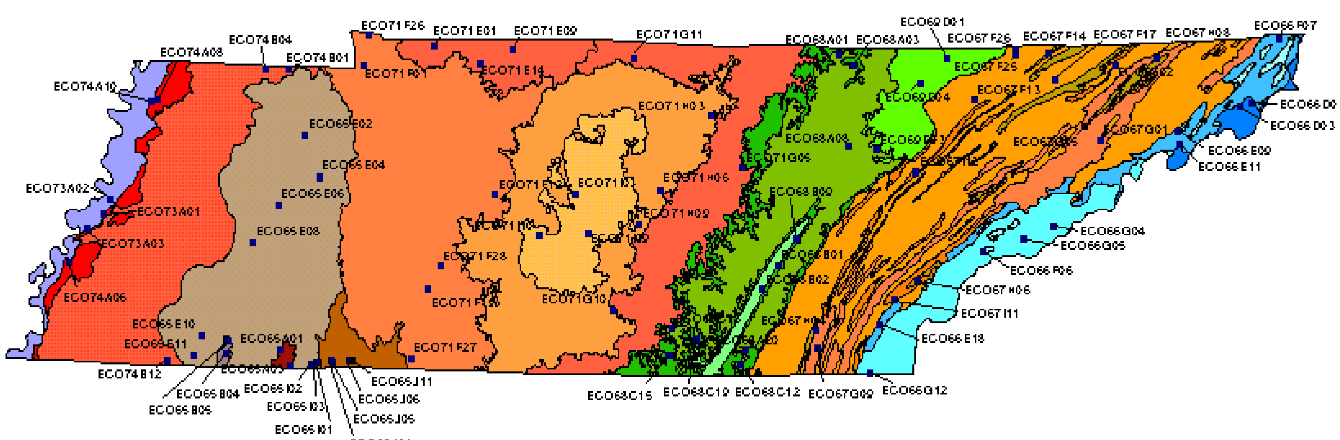
Semi-annual macroinvertebrate samples will be collected at the ecoregion reference sites beginning in August 1996. Habitat and flow will also be assessed. Outside expertise will be sought to analyze the monitoring data to determine how the subregions aggregate by aquatic habitat and biological community to form ecosystems or bioregions. This step is essential to assess the benthic communities accurately and consistently.

How Will the Reference Stream Data Be Used?

For the first time, the Division of Water Pollution Control has chemical, physical, and biological data representing least impacted conditions in Tennessee. These data are important to our program and have multiple applications.

For some time, it has been known that an ecoregion specific approach to certain water quality standards would be more accurate. The ecoregion project has provided the data necessary to initiate these discussions. Some specific short and long term applications of the ecoregion data are discussed on the last page.

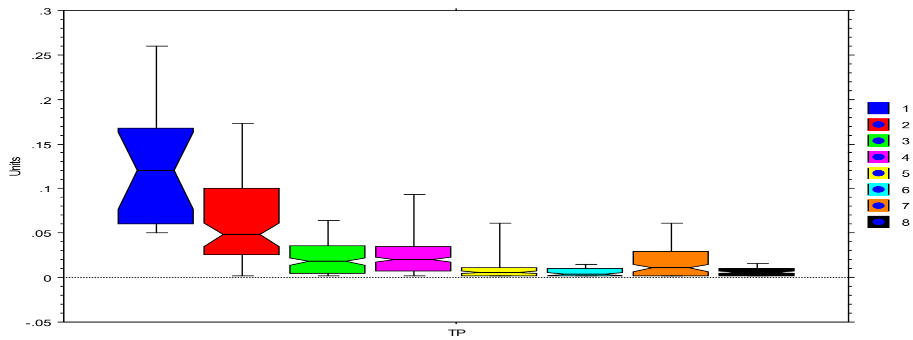
LOCATIONS OF ECOREGION REFERENCE STREAMS



The figure below illustrates the levels of total phosphorus documented at reference streams within each ecoregion. A key to deciphering the ecoregions is below the figure.

The figure, a "Box and Whisker Plot", shows the mean measured concentrations along with statistical ranges. It is apparent that at least impacted streams, total phosphorus levels are generally higher in West Tennessee than Middle and East Tennessee.

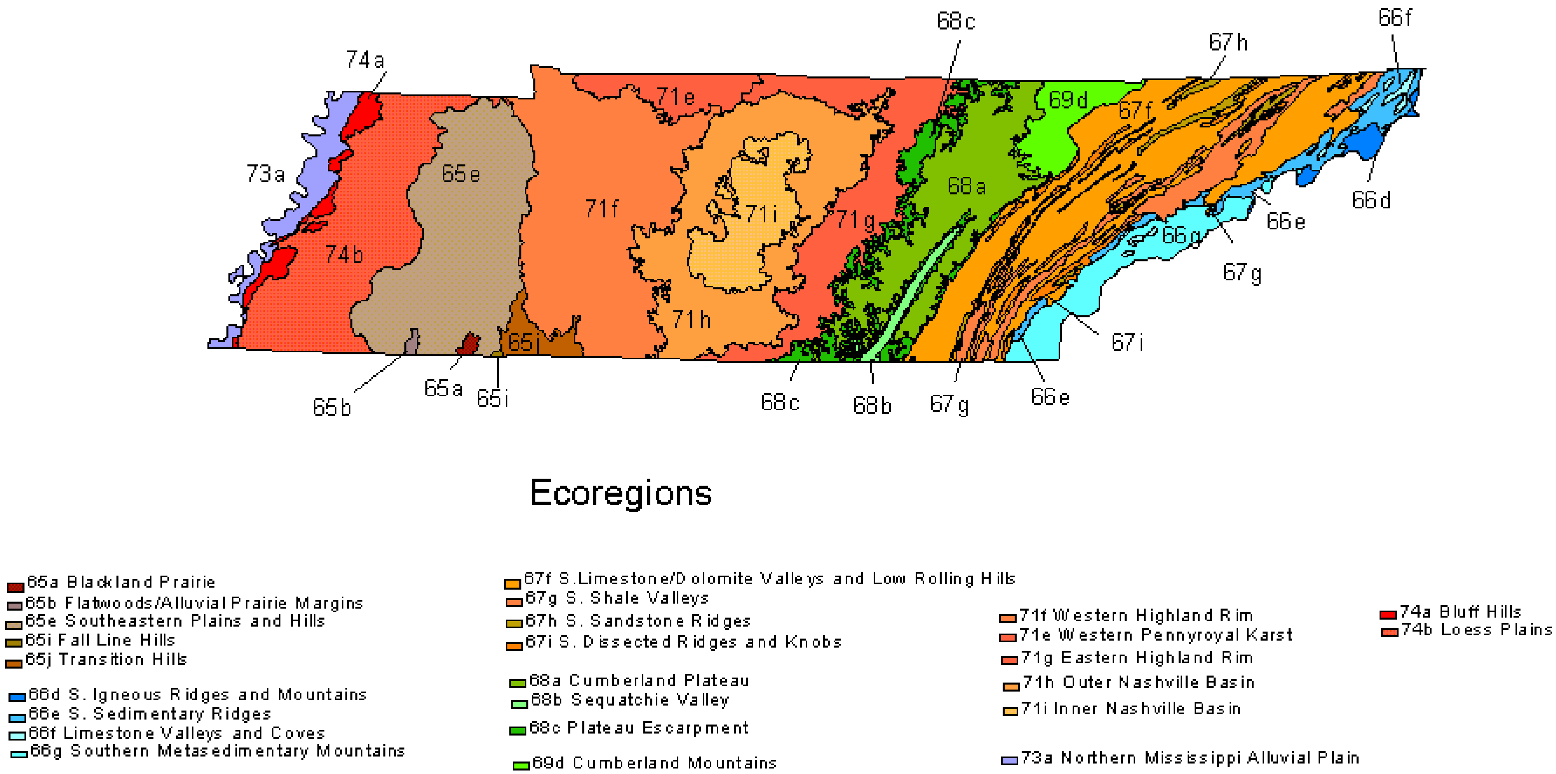
ECOREGION TOTAL PHOSPHORUS LEVELS



Key to Figure 1 = Mississippi Aluvial Plain; 2 = Mississippi Valley Loess Plains; 3 = Southeastern Plains; 4 = Interior Plateau; 5 = Southeastern Appalachians, 6 = Central Appalachians; 7 = Ridge and Valley, 8 = Blue Ridge Mountains.

The Obed River
was considered as a reference stream for Sub-ecoregion 68A (Cumberland Plateau.) Unfortunately, the Obed River has been stressed by activities in the Crossville area. Two high quality tributaries, Daddy's Creek and Clear Creek, were selected instead.

Level III and IV Ecoregions of Tennessee



SELECTED ECOREGION REFERENCE STREAMS

WEST TENNESSEE

Ecoregion Number	Stream Name and General Location
73	Cold Creek at Crutcher Lake Road
74B	Wolf River near La Grange
65J	Right Fork Whites Cr. near Walnut Grove
65E	Harris Creek near Jackson
65E	Marshall Creek near Hickory Valley

MIDDLE TENNESSEE

Ecoregion Number	Stream Name and General Location
71E	Buzzard Creek near Cedar Hill
71F	South Harpeth River near Fairview
71H	Clear Fork near Liberty
71I	West Fork Stones near Barfield

EAST TENNESSEE

Ecoregion Number	Stream Name and General Location
66D	Laurel Fork near Dennis Cove
66E	Clark Creek near Bumpas Cove
66F	Abrams Creek in Cades Cove
66G	North River, Cherokee National Forest
67G	Little Chucky Creek near Warrensburg
68A	Mullens Cr. in Prentice Cooper St. Forest

Practical Applications of Ecoregion Data

APPLICATION	STATUS	PERSPECTIVE
Increasing the Number of Assessed Stream Miles	Ongoing	In the process of looking for suitable reference streams, the Division dramatically increased the number of assessed streams reported in the 1996 and 1998 305(b) Reports.
Establishing True Background Conditions	Ongoing	Some potential pollutants, especially metals, are naturally found in trace amounts in the water. The wasteload allocation of a stream is based on the water quality standard minus the background concentration of the chemical. Documenting the background condition is a part of the decision process used to establish permit limits for dischargers. As a simplified example, if 10 mg/L of copper is the water quality standard for a stream, and the background "natural" copper level of the stream is 5 mg/L, then dischargers can only add the equivalent of 5 mg/L more copper to the stream. The nature of background conditions in Tennessee has been the subject of conjecture and debate. In most situations, data collected upstream of a new or expanded discharger are available to be used to establish background concentrations. In some small streams, these data may not be available and the Division has used one-half of the water quality standard as a default value. Data from reference streams in the same ecoregion provides a much higher quality default value.
Water Quality Assessment	Ongoing	The 1998 303(d) List contained biological assessments based on a comparison of stream data to reference stream conditions.
Establishing Clean-up Goals	Ongoing	Unfortunately, some Tennessee streams have been polluted by historical activities. Where clean-up activities are necessary to restore the public's use of the waterbody, data collected at reference streams can provide a useful guide to how clean the stream needs to be in order to be considered fully restored.
Establishing Numeric Nutrient Criteria	Underway	Most states, including Tennessee, have narrative nutrient criteria. The Federal Clean Water Action Plan instructed EPA to develop regional numeric nutrient criteria for streams, lakes, wetlands, and estuaries. Under the current timetable, Tennessee will be required to have established nutrient criteria by 2003. Our ecoregion data provides a head-start on the development of these criteria.
Developing biocriteria	Under consid-eration	Tennessee has a narrative biological integrity standard. Biological sampling at reference streams will establish a range of least impacted conditions on an ecoregion basis. These data could form the basis of an ecoregion-specific biological criteria.
TMDL Development	Underway	According to EPA, each TMDL must incorporate a "margin of safety". Ecoregion data will assist in determining this margin in the various areas of the state.

(The author would like to acknowledge the assistance of Sherry Wang, Joy Broach, and Linda Cartwright.)

WATER QUALITY ASSESSMENT FOR GROUP 2 WATERSHEDS

Jonathan Burr[1]* and Jimmy Smith[2]*

ABSTRACT

Tennessee began its watershed management approach to water quality in 1996. Water quality in the second group of watersheds was assessed in 1998. Data are from one or more of four types of survey: 1)Chemical, 2)Biological, 3)Bacteriological and 4)Watershed characterization including habitat assessment. Specific case studies for Group 2 Watersheds will be presented along with examples of how the data will be used.

OVERVIEW

One of the Division of Water Pollution Control's most basic responsibilities, delegated to States by the Clean Water Act, is water quality assessment. Assessment data are used in determining use attainment status, in compiling the 303(d) list and 305(b) report, and in the formation of watershed management plans for alleviation of pollution problems identified. Under our current five-year Watershed Cycle strategy, the second and third years are designated for data collection and water quality assessment.

In 1998-1999, the second set of watersheds were assessed. These watersheds include the Loosahatchie (08010209), North Fork Forked Deer (08010204), Middle Fork Forked Deer (08010206), Hiwassee (06020002), Fort Loudon Lake (06010201) and South Fork Holston (06010102). In the Environmental Assistance Center-Nashville region, watersheds included are the Caney Fork (05130108), Collins (05130107), Pickwick Lake (06030005), Upper Elk (06030003), Lower Elk (06030004) and Wheeler Lake (06030002) watersheds.

In developing an assessment strategy for each of these Group 2 watersheds, the Nashville Environmental Assistance Center (EAC-N) utilizes USGS-designated 11-digit HUC sub-watersheds as the primary organizational and cataloging geographical unit. As an example, the Caney Fork River (HUC = 05130108) is comprised of 25 eleven-digit HUC waterbodies, such as the Calfkiller River (05130108043). For each of these smaller waterbodies, the first step is to gather all recent existing water quality and habitat information. This data synthesis may include the GIS plotting of known NPDES dischargers, Aquatic Resource Alteration Permits (ARAPs) issued, previous WPC surveys, and current support status, including waterbodies listed as "Not Assessed." It may also involve the review of data from other agencies (e.g. TVA, USGS, COE).

Once all current information for each waterbody within the larger basin has been collected, the next step is to prioritize and plan survey strategy. Waterbodies designated as "High Priority" will, in general, be allotted more assessment resources, while lower priority units are assessed as time permits. The highest priority is assigned to streams with a status of "Unknown" or "Not Assessed," in which very little current information exists. Other high-priority factors include prior listing on the 303(d) impacted streams list, and heavily-used waterbodies, those with major dischargers, high instream waste concentrations, or clusters of ARAP activities. Lower priority for EAC-N survey work include streams known to be high quality, waterbodies with extensive outside agency data, and nonwadable aquatic systems such as lakes and the mainstems of very large rivers.

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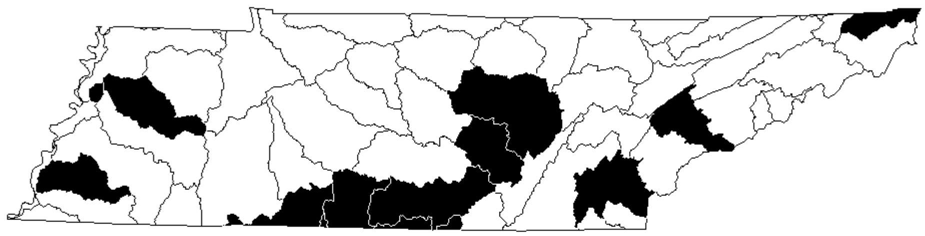


TENNESSEE'S GROUP 2 WATERSHEDS

METHODS

The methodology used to assess the water and habitat quality of a waterbody, and ultimately its support of designated uses, is an evolving process that was refined when assessing the previous Group 1 watersheds in 1998. The survey methodology and focus for an individual stream often includes variations based on the nature of the watershed's land use and gaps in current knowledge. In general, however, the assessments involve four main survey types:

1. Watershed/Site Characterization: the simplest survey type, this involves field observation of the land use patterns within a watershed, and a cursory site habitat characterization with photographic documentation. Some of the parameters examined include siltation, riparian status, channel alterations, and streamside activities such as livestock or fertilized lawns. Visible water quality impacts such as metal staining of rocks or algal mats enriched by nutrients are also recorded.

2. Waterbody Assessment: In addition to the above parameters, a cursory examination of the instream biota using benthic macroinvertebrates is included to provide a better resolution of stream health. The benthic collection methodology is identical to the Biorecon described in the next survey type, but less time is spent preserving and recording every individual taxon observed. The community as a whole is examined and compared to other sites observed in adjacent watersheds and to reference sites. Some field water quality parameters may also be recorded, such as pH and dissolved oxygen content.

3. Biorecon: This level includes the above watershed characterization, and an in depth, quantitative habitat assessment. More thorough documentation of these land-use and physical site parameters are recorded on prepared forms. Field water quality parameters are measured. A more in depth macroinvertebrate survey is performed using

the Biorecon method. This involves a semi-quantitative composited multihabitat sample, which is processed in the field for 45-60 minutes. All observed taxa are identified (usually down to Family), relative abundances are assigned, and voucher specimens are preserved and brought back to the lab. Simple metrics such as total taxa are calculated and compared to other Biorecon sites in the basin and to Biorecons performed at appropriate reference sites.

4. Additional/Follow-up work: This survey type involves any additional work needed due to inconclusive or borderline results from one of the other survey types, or due to the discovery of an impact where the cause is unknown. It may involve the periodic collection of water samples for chemical analysis, sediment sampling, or other types of supplemental data collection which may help clarify the exact nature of an observed problem.

In any given 11-digit waterbody, the EAC-N survey strategy will usually be to place one or two Biorecon sites lower on the mainstem of the drainage. Based on the health status observed at this site, several Waterbody Assessment sites are located on the larger tributaries upstream in the watershed. These sites are then compared back to the primary Biorecon sites to isolate sources of pollutants or confirm continued support status. Finally, Watershed/Site Characterizations continue throughout the upper headwater streams to complete the total assessment and identify any small areas of concern.

All the information gathered during the course of these survey types is later processed and synthesized at the EAC-N office, organizing field forms, notes, photographs, and specimens. The locality and other data from field forms are entered into a tracking database. Maps are made, plotting all survey points using GIS coverage, which eventually should include all data and site photos. Finally, designated use support status is assigned for all reaches within an 11-digit waterbody, and causes and sources of impacts are defined and coded. The overall support status is mapped for each entire 8-digit major Group 2 basin. This assessment information will be used in the State’s bi-annual 305(b) Water Quality Report, and in a variety of permitting and planning issues within these basins. Beginning in the year 2000, the information will be used in Tennessee’s watershed management plans.

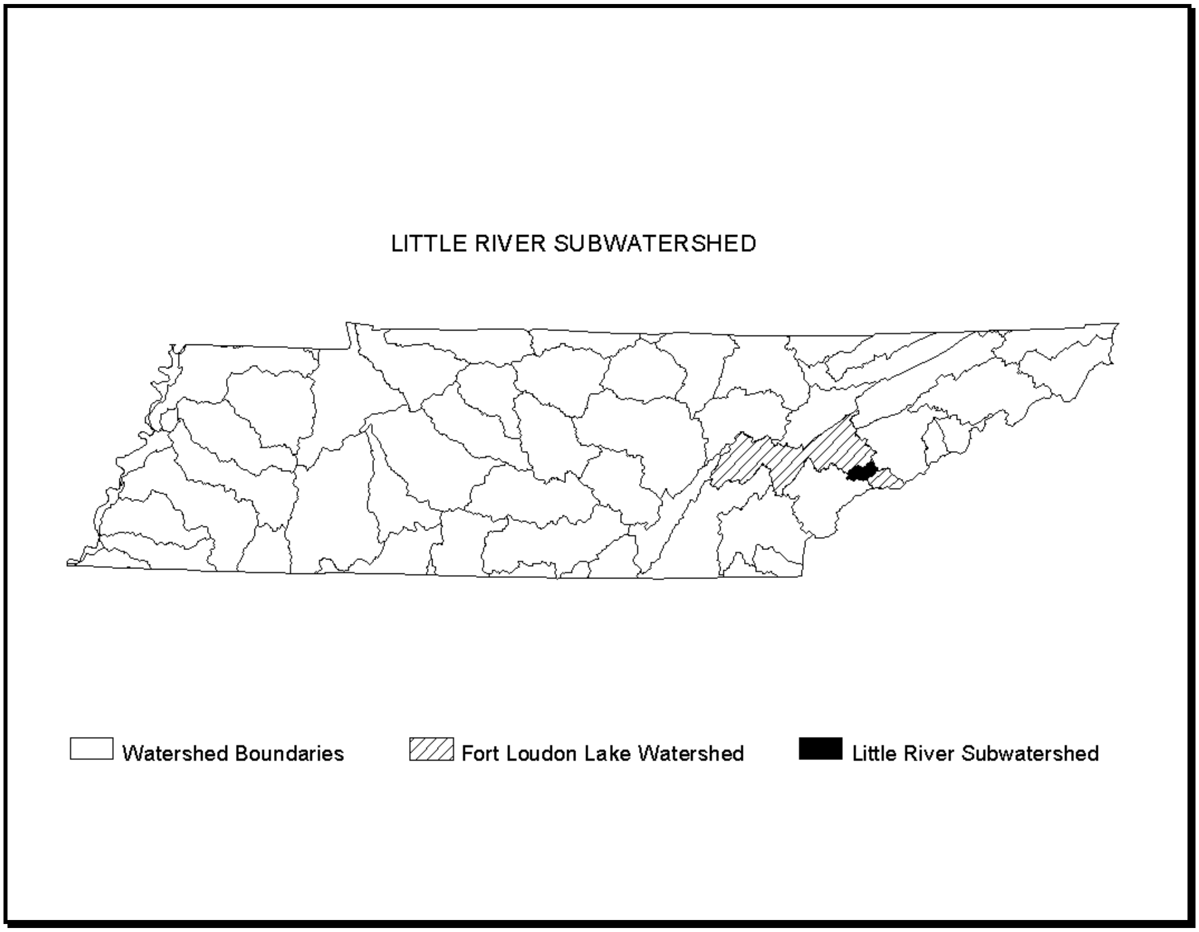
CASE STUDY: LTTLE RIVER WATERSHED

The first year of data collection in the Little River Watershed began in February of 1998. Sixteen water quality sampling sites were selected, six on the mainstem of Little River itself, and one site near the mouth of each of the ten major tributaries. The study plan included chemical, biological (both benthic and fish community), and bacteriological sampling.

Chemical sampling frequency was bi-monthly, changing to monthly during the low-flow months (June-Oct.). Bacteriological sampling frequency was weekly from June-Oct., with bi-monthly collection the remainder of the year. Benthic sampling was conducted at each site in August of 1998. Fish community data (IBI) was available via TVA.

Chemical sampling parameters were selected based upon local professional familiarity with the watershed. Due to a lack of industrial activity (current and historical) in the watershed upstream of Maryville, priority organics and metals were not considered parameters of concern. Sampling efforts were focused more on nutrients, solids, and pathogen indicators.

As a result of the first year of data collection, at least two tributary waterbodies will be added to the 303(d) list as “Not Supporting”, and one stream previously listed as “Partially Supporting” will be downgraded to “Not Supporting”, all three due to pathogen levels above State criteria as well as siltation. Two tributary streams previously listed on the 303(d) list are now considered “Fully Supporting” and will be removed from the list. Little River itself is still considered “Fully Supporting”, but comparison with 1994-96 data shows a negative trend in solids, nutrients, and aquatic life support that warrants a listing of “Threatened” in the lower half of the watershed.



The second year of sampling will begin in February 1999, and will concentrate on better defining causes/sources in those subwatersheds where problems were identified in the 1998 sampling. In addition, some monitoring will be conducted upstream/downstream of pollution remediation projects that have already been initiated in the watershed to gauge their effectiveness.

BASINS MODEL AND ITS APPLICATION TO DEVELOPING TMDLs

Bruce Evans[1]* and Sherry Wang[2]

ABSTRACT

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) is used as a tool for the development of TMDLs (Total Maximum Daily Loads). This presentation will discuss BASINS as it is used in Tennessee's TMDL program and strategy.

BASINS is a multipurpose system that supports three goals: 1)Facilitate examination of environmental information, 2)Support analysis of environmental systems and 3)Provide a framework for examining management alternatives.

The BASINS program supports the development of TMDLs by testing different management options after integrating point and nonpoint sources of pollutants. The system can access national environmental information and update it with locally-collected data, apply assessment and planning tools, and run a variety of proven and robust nonpoint loading and water quality models.

A Geographic Information System (GIS) is the integrating framework for BASINS, so spatial relationships between land use, point source dischargers, instream monitoring, gauging stations and water supply withdrawals can be made and compared to other variables (*i.e.*, weather events).

A TMDL is a strategy for bringing a waterbody back into compliance with water quality standards. TMDLs take into account both point sources of pollution as well as background levels of pollutants. TMDLs specify the amount of a pollutant that needs to be reduced to meet State water quality standards and they allocate pollution control needs among pollution sources in a watershed.

Section 303(d) of the 1972 federal Clean Water Act (as ammended) requires states to develop a list of waterbodies that cannot meet water quality standards without application of additional pollution controls. Water quality limited waters requiring the application of TMDLs are identified in the 303(d) list as approved by EPA.

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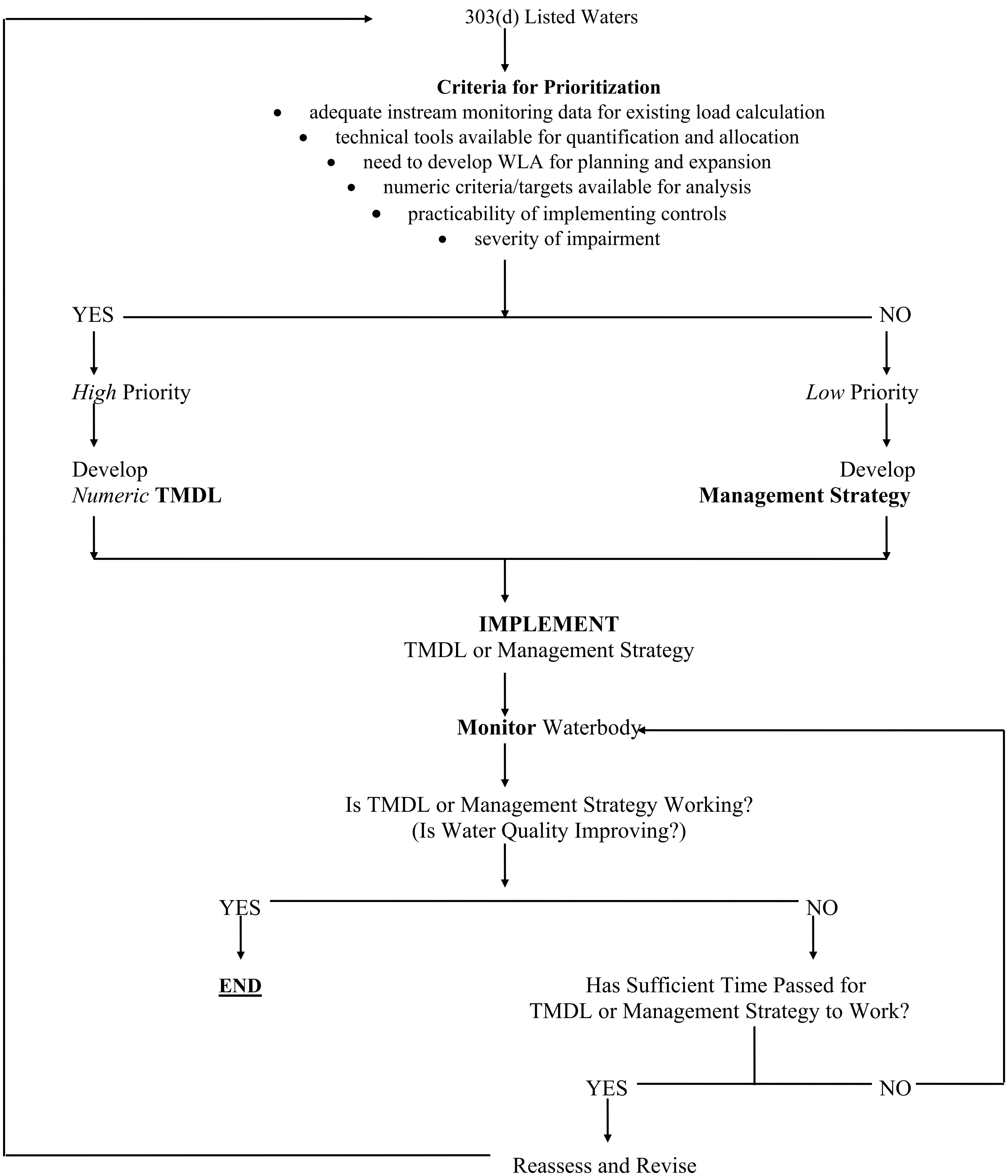

Flow Chart for TMDL/Management Strategy Development

Impaired waters in each of Tennessee's five watershed groups (Watershed Management Approach) have been prioritized for TMDL development:

WATERSHED	HIGH PRIORITY	YEAR OF COMPLETION	LOW PRIORITY*	YEAR OF COMPLETION
Group 1	14	2000	53	2005
Group 2	20	2001	49	2006
Group 3	12	2002	44	2007
Group 4	7	2003	60	2008
Group 5	17	2004	58	2009

**Low priority TMDLs will be addressed by management strategies as summarized in the accompanying flow chart.*

This presentation will review the use of BASINS in developing TMDL strategies.

MAKING PROGRESS WITH THE TENNESSEE WETLANDS CONSERVATION STRATEGY

Melanie Catania[1]*

ABSTRACT

In October 1998, the Governor's Interagency Wetland Committee published the third edition of the Tennessee Wetlands Conservation Strategy. The United States Environmental Protection Agency has recognized this Strategy as a national model for wetlands planning. The Strategy was developed, implemented, and revised through a consensus-based process involving state and federal officials from multiple agencies, academic experts, and non-profit interest groups. Now in its fourth year of implementation, the Strategy continues to guide state policy for wetlands conservation, preservation, and restoration. New emphasis has been placed in the third edition of the strategy on developing a reliable method of monitoring restoration successes and inventorying the state's current wetland base.

OVERVIEW

The Tennessee Wetlands Conservation Strategy, first published in February 1994 and revised in January 1996, is a blueprint to guide agency and organizational decisions, research, and actions to better understand and conserve Tennessee's wetlands resource. The third edition of the Strategy, published in October 1998, was developed to provide a progress report on implementation of the Strategy and to identify new goals for the upcoming years.

The development of a Wetlands Strategy in Tennessee began in the fall of 1989, when Governor Ned McWherter appointed an Interagency Wetlands Committee (IWC) to advise him concerning the status of the state's wetlands. Members of the Committee are the leaders of state and federal agencies with program responsibilities related to wetlands, and the leaders of private user groups and organizations. The Committee's purpose is to exchange information and coordinate the programs of federal, state, and local agencies, conservation organizations and private landowners to manage, conserve or restore wetlands for beneficial uses.

The Committee appointed a Technical Working Group (TWG), consisting of professional staff members from each agency or organization, to carry out necessary research and technical analysis. Members include: the Tennessee Departments of Agriculture, Environment, and Transportation, the Tennessee Wildlife Resources Agency, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the Tennessee Valley Authority, the U.S. Army Corps of Engineers, the U.S. Geological Survey, the Rural Development Agency, the Natural Resource Conservation Service, the Tennessee Conservation League, the Nature Conservancy, the Tennessee Farm Bureau, the Tennessee Forestry Association, and Tennessee Technological University.

In December 1989, the IWC recommended that the State develop a comprehensive statewide Wetlands Conservation Plan for Tennessee. Their decision was partially based on guidance from the 1987 National Wetlands Policy Forum, which recommended that all states develop conservation plans. In July 1990, EPA awarded a $102,910 Wetland Program Development Grant to the State to initiate the planning process.

Tennessee was one of the first two states in the nation to attempt development of a State Wetlands Conservation Plan (WCP). As work on the state plan progressed, it became quickly apparent that data needed to formulate quantified objectives were not available. The TWG concluded that it was not possible to produce a comprehensive State Wetlands Conservation Plan as originally conceived, but that it was possible to develop a comprehensive conservation *strategy* to guide statewide wetlands policy and technology development.

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At about the same time, the World Wildlife Fund (WWF) convened an advisory panel, including Tennessee and 16 other states, to formulate State Wetlands Conservation Plan Guidelines. WWF's advisory panel also agreed that a Strategy rather than a comprehensive plan was the most viable option.

The TWG decided to prepare a Wetlands Conservation Strategy following the 1992 WWF strategy guide. A strategy defines a process that can be used to adopt a statewide goal and define objectives; to review the current status of the state's wetlands resources, and the programs affecting them; and to develop an action plan to meet the State's objectives.

The TWG developed the state strategy through an interactive and iterative process. Members of the group worked intensively to capture the group's knowledge and advice, and to draft a Strategy that the State can use to guide policy decisions.

On August 24, 1993, the Clinton administration issued a wetlands policy document entitled "Protecting America's Wetlands: A Fair, Flexible and Effective Approach." The policy paper proposed a series of improvements to the federal wetlands regulatory programs, and other programs. The proposed actions were intended to simplify regulatory programs, improve interagency coordination, and decrease uncertainty for landowners and the regulated community. The 1993 proposal confirms the previously adopted "no overall net loss" policy, and the policy "to increase both the quantity and quality of the nation's wetland resource" as a long-term goal.

After finding the Strategy to be consistent with the President's policy, the final document was approved by the IWC. On February 22, 1994, Governor Ned McWherter endorsed the Strategy as an official instrument of state wetland policy.

Governor Don Sundquist recognizes the value of the consensus approach taken by the IWC, as well as the importance of executive level sponsorship of the Strategy. His leadership in supporting two additional editions of the Strategy has enabled the IWC and the TWG to continue to work toward fulfilling its objectives.

The Strategy has been extremely successful at leveraging federal funding for implementation of its goals and objectives. Since 1989, the State has received $2,209,227 in grants from EPA for the development and implementation of the Strategy.

The bulk of the Strategy consists of its nine main goals, as follows:

1. Characterize the state's wetlands resource base more completely and identify the critical functions of the major types of wetlands in each physiographic province.
2. Identify and prioritize exceptionally high quality, or scarce wetland community types and sites for acquisition.
3. Identify priority wetlands restoration sites in each river corridor and explore appropriate restoration methods for each wetland type, including the restoration of "natural" floodplain hydrology.
4. Restore 70,000 acres of wetlands by 2000.
5. Achieve no overall net loss of the wetland acreage and functions in each USGS hydrologic unit.
6. Increase the level of benefits to landowners.
7. Create more urban / riparian greenbelt areas.
8. Increase wetlands information delivery to local government, the public and schools.
9. Establish meaningful state wetlands use classifications and water quality standards.

Implementation of the Strategy is predominantly on schedule, and we have advanced our wetlands knowledge base through targeted research and advances in geographical information system data collection. The focused, action-oriented structure of the Strategy has enabled it to be a working plan, rather than just a policy document. Its broad-based support and cooperative tone have helped to diminish negative perceptions of wetland conservation. It has also encouraged numerous state program actions and has increased federal and state coordination.

Overall, the atmosphere for wetlands conservation in Tennessee has been very positive since initiation of the Strategy. Acquisition of targeted wetlands by the Tennessee Wildlife Resources Agency has continued. Increased cooperation among other wetlands interests to purchase and protect unique wetlands has also occurred. In 1995, local organizations, state agencies and national conservation groups banded together to purchase a largely pristine, 4000 acre tract of bottomland hardwood and cypress-tupelo swamp wetlands on the Wolf River in Fayette County. In 1997 Governor Sundquist named the Ghost River section of the Wolf River a State Natural Area.

Important advances also continue to be made through the efforts of the West Tennessee Tributaries Steering Committee. Their restoration demonstration project seeks to restore over 21 miles of river meanders along a previously channelized river. EPA wetland grants received through the Strategy will result in implementation of a restoration demonstration project at Stokes Creek in 1999. The West Tennessee Tributaries Steering Committee originally proposed this project.

Federal and state sanctioned mitigation banking, with a strong emphasis on wetland restoration as opposed to creation, continues to grow. Renewed emphasis on greenways and wildlife corridors also offer new opportunities for wetland conservation in rapidly urbanizing areas.

Challenges in wetland conservation still exist. As the state continue to grow, more local governments are faced with tough planning decisions and the need to balance resource protection with economic development. Regulatory decisions concerning wetlands protection have resulted in several high profile court cases. Exotic species such as purple loosestrife threaten the ecological integrity of Tennessee wetlands. In addition, the increased fragmentation of natural areas and floodplains disturb the delicate balance required for wetlands function. There also continues to be a lack of conclusive data on the success of restoration projects and the acreage of wetlands restored since the plan was first implemented.

It is clear, after four years of plan implementation, that cooperation can effectively focus a broad array of resources and expertise on a mutually agreed set of objectives and actions. The end result however, must be actual conservation and restoration of wetlands in Tennessee. Data on the actual wetlands acreage in Tennessee is difficult to collect. Several experts agree that wetlands losses in Tennessee have stabilized, and that wetlands acreage may actually be increasing. Continued implementation and active data collection on the status and trends of Tennessee's wetlands over the next two years will hopefully reveal the progress of this Strategy and associated conservation efforts.

EFFECTS OF CHANNEL ALTERATIONS ON BOTTOMLAND HARDWOODS IN WESTERN TENNESSEE

Timothy C. Wilder[1]*

Dr. Thomas H. Roberts[2]

PURPOSE

Most of the rivers on the Coastal Plain of Tennessee have been subjected to channelization through much of their length during the present Century. The most comprehensive channelization effort was conducted between 1961 and 1970 by the US Army Corps of Engineers, and was known as the West Tennessee Tributaries Project (WTTP). The purpose of this study was to determine if differences exist in the plant communities adjacent to channelized and unchannelized rivers.

METHODS

Study sites were selected after an aerial and ground reconnaissance in the spring of 1995. Sites dominated by young timber or in which the forest was dying due to semi-permenant ponding behind levees, or those with evidence of recent disturbance were rejected. Six sites were selected for comparison. Data were collected using a stratified design. Plots in which vegetation data were collected were classified into 2 groups based on hydrologic setting; natural (NAT) (control), channelized (CHA) (treatment); and 1 of 3 floodplain zones. Floodplain zones were collapsed into three classes and were termed depressions, flats, and ridges. Depressions were defined as any concave feature, flats as level areas of the active floodplain, and ridges as convex features. Depressions included swales, scoured areas, sloughs, old oxbows, and beaver ponds. Ridges included natural levees, old ridges from point bars, and terraces. Flats included the majority of the active floodplain, the portion generally referred to as backswamps. Three elements of vegetation of interest were defined (Canopy trees -trees > 25 cm diameter at breast height (DBH); Subcanopy trees -trees > 10 cm < 25 cm DBH; Midstory layer trees > 2.5 cm < 10 cm DBH.

Vegetation was sampled inside 20m2 plots, divided into four equal subplots of 10m2. Species and DBH of canopy and subcanopy trees were recorded within the full 20m2 plot. Also at this scale, midstory vegetation was identified and tallied. The null hypothesis of no difference between control and treatment (NAT, CHA) was tested for each layer of vegetation within each zone of the floodplain. Neither between zone nor between vegetation strata comparisons were made. Differences in vegetation richness and abundance were tested for using Kruskal-Wallis One Way Analysis of Variance (KW). Vegetation composition was tested using the Multi-Response Permutation Procedure (MRPP). Significance was accepted at an alpha of 0.05.

RESULTS

Overall, the data show variation between the control and treatments that suggest that channelization, the WTTP in particular, has initiated changes in the BLH communities of western Tennessee. The vegetation established prior to the WTTP, the trees of the canopy layer, did not vary among groups in abundance or average size, and generally did not vary in composition. The most striking feature of the data was dominance by red maple (*Acer rubrum*) of the subcanopy and midstory layers in the flats and depressions of the treatment. Red maple was virtually absent from these two zones in the control. This condition did not carry into the ridge zone, where red maple was present in similar proportions among the groups. Channelization has resulted in changes to the characteristic flood-pulse

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hydrology of the lower zones of the treatments, effectively reducing the most important factor in determining future species composition.

IMPLICATIONS

This study suggests that in a relatively short time after channelization, dramatic changes can begin without any disturbance to the vegetation itself. The abundance of red maple beneath the canopy of the treatment sites provide a window to the future. If all the study sites were cleared of vegetation, the subsequent forest communities would certainly be different, because the environmental gradients, especially the hydroperiod, have been altered. Because the manner in which the channelized rivers transport, erode, and deposit sediments has also been altered, other gradients (e.g. soil texture, permeability, fertility, etc.) have been profoundly affected, and the plant communities of the future will reflect these changes.

HGM LACUSTRINE FRINGE MODELING PROCESS

Kim Pilarski[1]

This paper will describe the progress of a joint effort between the U.S. Army Corps of Engineers Tulsa District, the Tennessee Valley Authority, U.S. Fish and Wildlife Service, and Natural Resources Conservation Service to develop a hydrogeomorphic (HGM) model for lacustrine fringe wetlands. This model is designed to assess the specific physical, biological, and chemical functions provided by wetlands located at the margins of man-made reservoirs. The initial effort was begun in 1997, when a regional assessment team (A-Team) was assembled. The A-Team was composed of members from the agencies listed above, and individual members brought with them regional expertise in wildlife biology, soils, biogeochemistry, hydrology, and botany.

Initial meetings in late 1997 and 1998 focused on selecting and defining the ecological, chemical, and physical/hydrological functions specific to lacustrine fringe wetlands in eastern Oklahoma. Based on field reconnaissance of a large variety of lacustrine fringe wetlands, the initial set of functions was defined below:

PHYSICAL/HYDROLOGICAL FUNCTIONS

- energy dissipation
- export of organic carbon
- removal & sequestration of imported elements & compounds

BIOGEOCHEMICAL FUNCTIONS

- retention of particulates diversity
- maintain characteristic wildlife community
- maintain fish habitat
- maintain characteristic detrital mass
- maintain habitat interspersion & connectivity

ECOLOGICAL FUNCTIONS

- maintain characteristic plant

Additional field work conducted in the fall of 1998 prompted the A-Team to refine the initial functions. Functions removed from consideration included maintenance of habitat interspersion and connectivity and maintenance of characteristic detrital biomass. At this point the A-Team is focused on selecting independent quantitative measures that will be used to measure the functions described above. For example, variables used to measure the wildlife habitat function include V_{STRATA} (a count of the number of vegetational strata present), V_{BTREE} (basal area of trees), V_{TOPO} (a measurement of microtopographical features), V_{LOGS} (number of logs present), V_{LITTER} (a measurement of % cover of leaves and woody debris), V_{WIDTH} (the width of the continuos forested fringe), and V_{REFUGE} (a measurement of cover above maximum pool).

As work progresses on the model during 1999, the A-Team will continue to refine the variables and measurement protocol, select reference standard wetlands, and field test the model. The end product will be a written regional guidebook that can be used by regulators, planners, and others requiring a functional assessment of lacustrine fringe wetlands. The ongoing participation of the Tennessee Valley Authority in this effort is intended to foster development of a similar model for lacustrine fringe wetlands in the Tennessee Valley region.

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PESTICIDE AND NUTRIENT REMOVAL IN CONSTRUCTED WETLANDS

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D.B. George[3]

ABSTRACT

Subsurface flow constructed wetland cells were used to removal pesticides, nitrogen and phosphates from runoff water from a container plant nursery at Baxter, Tennessee. Pesticides, simazine and metolachlor were applied to the container nursery at 4 lb/acre and 2 lb/acre, respectively. Simazine, metolachlor, nitrate and phosphate removal were measured and evaluated based on existence of bulrush (*Scirpus validus)* plants, hydraulic retention time and depth of wetland. Hydraulic retention times for the wetlands cells were 2, 3, 4, 6, 8 and 12 days. Pesticides were measured daily in the wetland cells for the first two weeks and three times a week until pesticide concentrations were below 10 ng/mL. Pesticide removal was close to 90% in the cells with plants and at hydraulic retention times greater than 3 days. More than 80% of the nitrogen was removed by the wetland cells containing bulrush plants. Phosphate removal was also greater in the cells with plants. In a related environmental growth chamber study using mesocosms filled with gravel that mimicked the wetland cells, bulrush plant height did not increase at simazine and metolachlor rates of 1,000 ng/mL or higher, and when applied together at 750 ng/mL. Bulrush new shoot germination declined to zero at rates of 600 ng/mL and above. Simazine and metolachlor were applied at rates from 100 to 2000 ng/mL.

INTRODUCTION

The objectives of this study were to: (1) determine the removal of herbicides, simazine and metolachlor from a container nursery using constructed wetlands and (2) observe the survival of *Scirpus validus* plants when simazine and metolachlor were present. Subsurface flow constructed wetlands have received much attention recently in treatment of municipal wastewater. In this project subsurface flow constructed wetland cells were used as a treatment to remove pesticides and nutrients from container nursery runoff water. The hydraulic retention time, the constructed wetland depth, and the presence or absence of bulrush plants were evaluated in the constructed wetlands to determine conditions for maximum removal of pesticides and nutrients.

MATERIALS AND METHODS

Seven of the fourteen constructed wetland cells were 30 cm in depth and seven of the cells were 45 cm in depth. The cells were filled with gravel. One-half of the cells were planted with bulrush plants while the other half of the cells contained no plants (Figure 1). All cells were 4.9 m in length. Twelve cells were 1.2 m in width and two cells were 2.4 m in width. Runoff from the container nursery was pumped into the wetland cells at 2.0, 1.0, and 0.5 L/min for two hours per day. Hydraulic retention times were approximately 2, 3, 4, 6, 8, and 12 days.

The container nursery was constructed by spreading 8 cm of 0.6-1.3 cm sized gravel over a 20 mil plastic liner, 16 m x 32 m. The plastic liner was used to represent a “worst” case scenario as the applied irrigation water could not leach downward in the soil and was susceptible to runoff. A plastic collection tank (1,900 L) was buried downgradient from the container nursery. A pump in the tank was used to transport the collected runoff water to the holding tanks prior to pumping the water into the wetland cells at the various flow rates. The container nursery was

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irrigated with an overhead sprinkler system at the rate of 1.3 cm/day, except when rainfall was adequate. Six hundred, one gallon pots containing japanese holly, monkey grass and spirea plants were placed on the container nursery gravel. Herbicides, simazine and metolachlor were applied July 9, 1998, at rates of 4.48 and 2.24 kg/ha, respectively (total applied was 220 g of simazine and 110 g of metolachlor).

Glass mesocosms were used to mimic the gravel constructed wetland cells in a controlled environmental growth chamber (80% humidity, 23^o C, 16 hours of light per day). Twenty-eight mesocosm containers (76 cm depth and 15 cm diameter) were filled with gravel to a depth of 30 or 45 cm. Bulrush plants were grown in the mesocosms and fertilized with Miracle Grow fertilizer (15 g/25 L). Water was replaced and analyzed weekly in the mesocosms. Herbicides, simazine and/or metolachlor were applied at rates of 100 - 2000 ug/L to determine bulrush tolerance. Each herbicide concentration was repeated for two consecutive weeks on the same mesocosm. Plant height and germination of new bulrush shoots were recorded weekly.

Simazine and metolachlor were analyzed using enzyme immunassay analysis and ten percent of samples confirmed by gas chromatography. Nitrogen was measured by ion chromatography. Phosphorus was analyzed colorimetrically using the ascorbic acid method. Dissolved oxygen (DO) and pH were measured using their respective meters in millivolts. Plant stem density was counted per square meter.

RESULTS AND DISCUSSION

The pH of the water in the constructed wetland cells ranged from 6.26-7.45 and the cells with plants were generally about 0.3 pH units lower than cells without plants. Weekly measurements of dissolved oxygen (mg/L) were below the detection limit of 0.5 mg/L in all cells (except for one cell which read 0.74 during one week) indicating the cells were anaerobic. Nitrate entering the cells from the nursery runoff ranged from 6-9 mgN/L and nitrate leaving the cells ranged from below the detection limit of 0.02 to1.4 mg-N/L. Ammonium (NH_3) in the cells with plants ranged from below the detection limit of 0.05 to 2.8 mg-N/L . Ammonium in the cells without plants ranged from 0.16 to 9.2 mg-N/L. Phosphorus ranged from 12 -1100 ug-P/L in the cells with plants (all but one cell were below 200 ug-P/L) and 36-2300 ugP/L in the cells without plants. Simazine removed was from 48-85 percent in the cells with plants, and from 50-75 percent removed without plants. Metolachlor ranged from 48-87 percent removed with plants, and from 26-90 percent removed without plants.

In the mesocosm study the number of new bulrush stems increased with simazine concentrations from 100 to 400 ug/L and did not significantly decline at concentrations up to 1,500 ug/L. Bulrush height generally increased at simazine concentrations at or below 800 ug/L and did not significantly decrease until concentrations of 1,500 ug/L were applied. Bulrush plants also tolerated metolachlor concentrations up to 1,500 ug/L, although new shoot growth was absent at concentrations above 1,000 ug/L and plant height did not increase at these higher metolachlor concentrations.

Simazine runoff from the container nursery entering the wetland cells was approximately 4,000 ug/L immediately after application and through the first week (concentrations were measured daily). Simazine runoff concentration was approximately 1,000 ug/L during the second week and then dropped to 200-500 ug/L during the third week after application. During the fourth week simazine was below 30 ug/L entering the wetland cells.. Metolachlor from nursery runoff was approximately 3,000 ug/L during the first week after application and then was reduced to 400-700 ug/L during the second week, and further reduced to 100-160 ug/L during the third week after application. During the fourth week after application metolachlor was below 70 ug/L in runoff water. By the sixth week herbicide runoff concentrations entering the wetland cells were below 10 ug/L in runoff water.

There was little difference between the 30 and 45 cm wetland depth in herbicide removal by the wetland cells. Cells with hydraulic retention times of 4 days or more had significantly more herbicide removal than cells with retention times of 2 or 3 days (Figure 2). With the high initial herbicide concentrations entering the wetland cells there may not have been enough time for microorganisms to adjust to these relatively high herbicide concentrations. Therefore, herbicide removal was limited by retention time. Perhaps the high initial herbicide concentrations inhibited microorganism growth. Cells with plants had significantly higher removal rates for simazine, especially at the longer retention times when more herbicide was removed. With metolachlor removal there was no difference with plants at the longer retention times, but at shorter retenction time (6 days or less) the cells with plants removed significantly more metolachlor than cells without plants (Figure 2).

Constructed wetlands removed more than 80 percent of herbicides in runoff water from a container nursery over a two month period after herbicide application. Optimum retention time for maximum herbicide removal was approximately 8 days and wetland cells with plants generally removed more herbicide. The wetland cells with plants removed more than 80 percent of the nitrogen and phosphorus in runoff from the container nursery. This study will be repeated in the Spring and Fall of 1999.

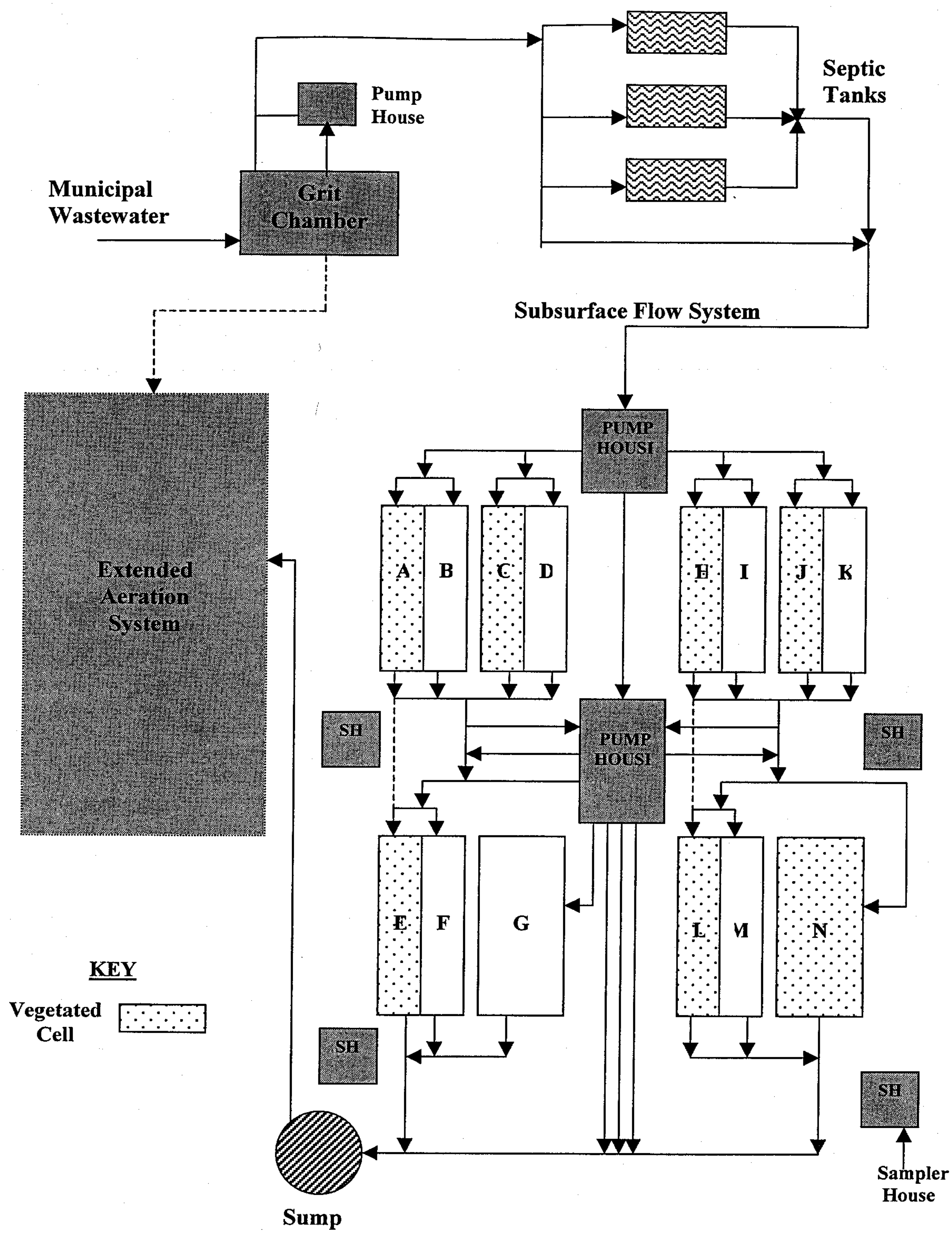

Figure 1. Constructed Wetland Design

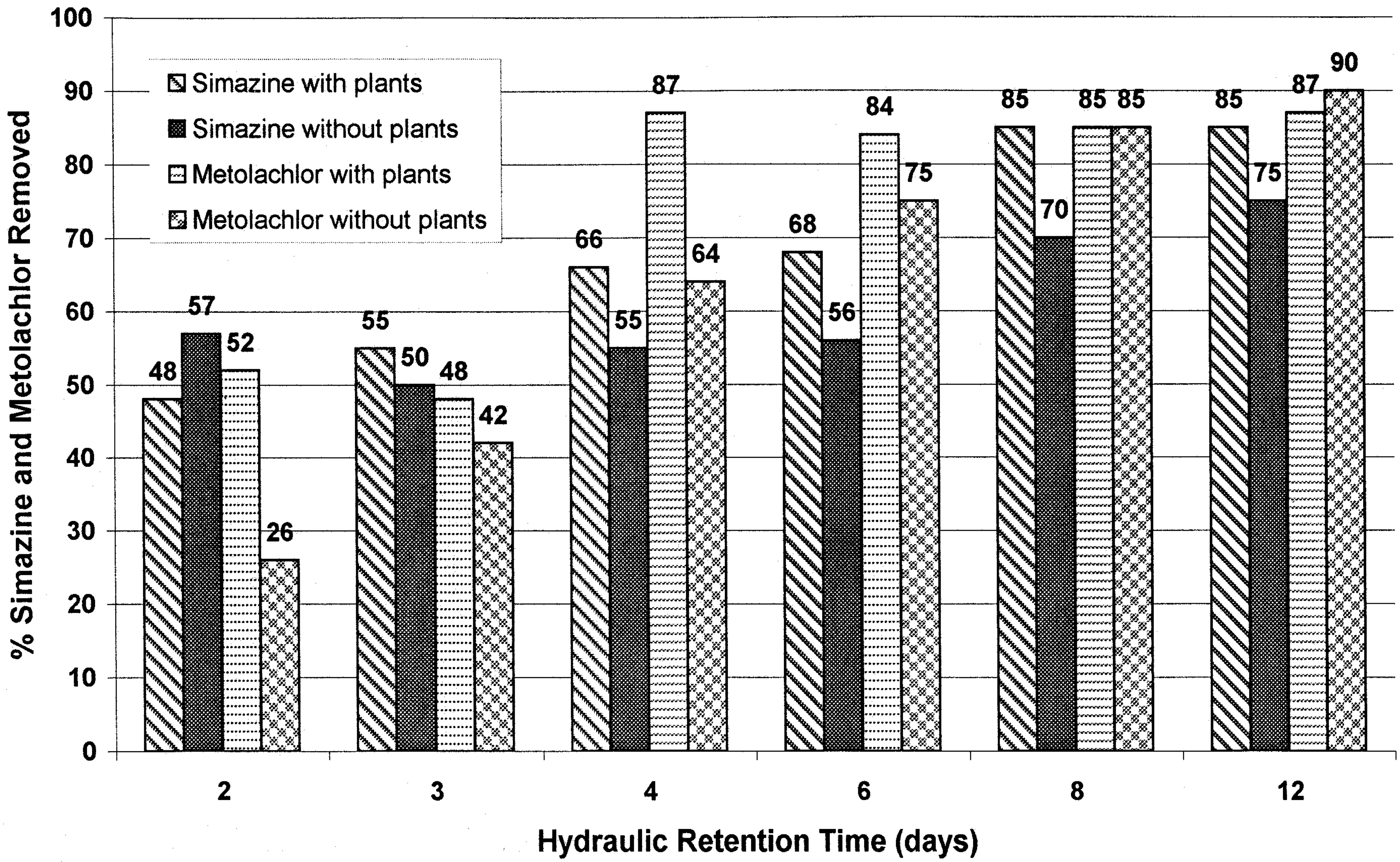

Figure 2. Percent Simazine and Metolachlor Removed in Constructed Wetlands as a Function of Hydraulic Retention Time and Presence of Plants

WETLANDS BANKING AND MITIGATION : A CURRENT REVIEW

Mark A. Ray[1]*

ABSTRACT

This paper will present a brief history of the development of mitigation banking over the past decade. A summary of the technical, social and economic phenomena that have shaped the modern mitigation banking movement will be offered. A sampling of case studies of mitigation banks developed by the author and his colleagues in three different states will be given to explain the particulars of the practical implementation of a variety of banks. This review will also illustrate some of the obstacles that can get in the way of making wetland mitigation banks work. The case studies will include: a county-wide plan encompassing 10 bank sites in 4 different watersheds; A private bank for a utility company; A single large-scale site for a single county agency (sanitary engineering dept.); a private bank for a sand and gravel operator to sell credits to his development partners; and a dual site mitigation allowing stepwise development of a large wetland impact while providing excess credits for sale to others. Other historical banks, from private to state managed, will be compared to the banks the author has personally been involved in developing. The paper will conclude with a review of the First National Mitigation Banking Conference in Washington D.C. Many new ideas and innovative methods will be shared from this conference, such as "bank & trade" and "in lieu of fee" strategies. You will walk away from this presentation with a nice set of tools to consider when bank development is appropriate and how to build one, both administratively and technically.

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EASTERN KENTUCKY ENVIRONMENTAL INFRA-STRUCTURE (531 PROGRAM)

Douglas Radley*[1]

ABSTRACT

This paper presents a discussion of a unique program to the Corps of Engineers which offers design and construction for water related environmental infrastructure and resource protection to 27 counties in eastern Kentucky.

INTRODUCTION

Southern and eastern Kentucky is an area of the country that has natural beauty and abundant natural resources. Historical development patterns have been primarily influenced by the growth of the timber and coal mining industries. Many of the today's cities had their origin as small coal camps or lumberyards. Mountainous topography and the lack of land use controls contributed to the development of many communities in the floodplains of the rivers and streams on relatively small building lots. Coal mining and timbering practices coupled with unsanitary living conditions have polluted the land and streams of the area. Many of the streams are unfit for swimming or fishing due to siltation and acid mine drainage caused by the extraction industries. At the same time, the disposal of wastewater into the same rivers and streams through "straight pipe" discharge compounded the problem.

Congress began to address this problem in 1996 with the passage of Public Law 104- 303. Section 531 of that law provides a program of federal assistance through the U.S. Army, Corps of Engineers. Specifically, the law states that assistance may be provided for design and construction of water-related environmental infrastructure and resource protection and development projects. Congressman Harold Rogers is the author of this legislation and is committed to solving this problem. At present this type of assistance is only available in the following counties of southern and eastern Kentucky: Bell, Breathitt, Clay, Floyd, Harlan, Jackson, Johnson, Knot, Knox, Lawrence, Laurel, Lee, Leslie, Letcher, Magoffin, Martin, McCreary, Menifee, Morgan, Owsley, Perry, Pike, Pulaski, Rockcastle, Wayne, Whitley, and Wolf.

Kentucky Department of Water Secretary, James Bickford, has formed a partnership with Congressman Rogers to add state resources to address this problem. Together, they have formulated a multifaceted program, which combines resources from federal, state and local governments with private organizations and individuals. They call the program Eastern Kentucky PRIDE (Personal Responsibility In a Responsible Environment). Initial efforts of the PRIDE program focused on setting up local organizations in each county. Every eligible county appointed a PRIDE Coordinator. A PRIDE program office was established and staffed to administer the program and support the county coordinators. Various work groups were formed to help define the extent of water resource problems and formulate possible solutions. Programs of public education and awareness were developed. Local clean-up projects were held.

The Section 531 falls within the boundaries of three Corps of Engineers districts (Huntington, Louisville and Nashville) of the Great Lakes and Ohio River Division. Representatives of each of the districts and the division met on numerous occasions with the congressman's staff, and representatives of the state and local governments to develop a strategy and priority of activities. Pollution of the rivers and streams primarily through "straight piping" wastewater into streams was identified as the most critical problem. Initial effort assessed the extent of the problem in the region and examined various technologies for dealing with the problem. Four committees were formed to gather information on various topics. The Planning Committee was tasked to gather base information to determine the number of structures that were "straight piping" sewage into the streams on a county basis. The Technical Committee investigated different types of wastewater treatment systems and determined their applicability to the mountainous areas with relatively low population densities. The Finance Committee researched federal and state

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funding sources that could be used for possible local matching funds. The Solid Waste Committee was tasked to investigate the extent of illegal dumping in every eligible county.

The Huntington and Nashville Districts proposed projects to demonstrate innovative wastewater treatment facilities where flood control projects are currently under construction. The Nashville demonstration project will use the constructed wetland technology to treat effluent from twelve homes that are presently "straight piping" into the river. This project is located in the "nonstructural protection area" of the Section 202 Harlan, Ky. Flood control project. Huntington District will demonstrate sand mound technology to treat effluent from homes in the "nonstructural protection areas" in McCarr, KY. And Lovely, KY. These two demonstration projects are part of Section 202 flood control projects currently under construction.

Once the decision was made to focus on the elimination of "straight pipes", the next task was to identify potential projects and develop a scheme to rank them The six area development districts responsible for regional planning in the 27 eligible counties were used to identify potential projects. Concurrent with the identification of projects, criteria were developed to rank order them. For the first year implementation, criteria were developed for three different groups of potential projects. Potential projects were placed in the following three categories: (1) projects that use innovative technology to treat wastewater; (2) projects that will be implemented in primarily rural areas that are not likely to be addressed in the near future and (3) projects that are eligible for funding from other sources but need a relatively small amount of financial assistance to be implementable.

PRIDE Coordinators in each of the eligible counties were requested to submit applications for projects for implementation beginning in 1998. Applications for twenty-seven projects with estimated federal costs of approximately $15 million were submitted. The applications were rank ordered using the criteria described above. Nine projects with estimated federal costs of $3 million were selected. It is anticipated that in succeeding years, applications for projects will be received at the beginning of the federal fiscal year. Selection of projects will be made within the first quarter.

INNOVATIVE TECHNOLOGY (CONSTRUCTED WETLAND)

The Tennessee Valley Authority developed an innovative method of sewage collection and secondary treatment called a constructed wetland that was selected for use in the mountainous area of eastern Kentucky. The septic system consists of a septic tank, a collection system and a secondary treatment facility. Traditionally, the collection system consists of gravity fed pipe between the septic tank and a drain field.

Septic Tanks A septic tank is generally a prefabricated watertight tank made of concrete or fiberglass. It removes solids through settling and greases through skimming. The settled materials, or septic sludge, are decomposed by anaerobic bacterial action. The effluent from the septic tank contains microorganisms and can be a major source of waterborne disease particularly where the effluent contaminates ground water feeding drinking wells. Aerobic (Aeration) tanks can be used in lieu of septic tanks to serve a similar purpose. They operate by aerobic rather than anaerobic digestion and produce a cleaner effluent reducing the size of subsequent secondary systems. However, they cost two to five times more than a septic tank.

When a septic tank is properly sized, constructed and operated, the anaerobic bacteria will keep pace with the influent wastewater solids, reducing the accumulation of septic sludge, and minimizing the requirement for periodic pumping of the tank. When the bacteria are killed or inhibited by chemicals in the wastewater, such as chlorine, or when they become overloaded, anaerobic digestion of the solids can be suppressed or eliminated necessitating frequent pumping of the septic tank. When the bacteria are totally destroyed, they must be reintroduced into the tank through inoculation. Anaerobic bacteria do not digest non-organic solids, which will accumulate in the tank and require eventual removal by pumping. Consequently, successful septic tank operations require minimizing the presence of non-organic solids in the wastewater.

Although common, burial of the septic tanks is not required. Burying is required by the need to place the tank below the lowest point in the home's sewer lines to take advantage of gravity flow. Tank burial is also more aesthetically pleasing. Where buildings are being raised due to flooding or where underground construction is not possible they may be placed on the ground surface, or even elevated. Septic tanks are generally associated with individual homes, but where hydraulic conditions permit; several homes could be connected to a common septic tank. Single home septic tanks are "off the shelf" units and range from $1,000 to $1,500. A multi-home tank would be larger and could require special construction.

Collection System Septic tanks are connected to the secondary treatment system by an unpressurized or gravity fed collection system. Pressurized collection systems are more expensive and more complex but may be required in situations where the effluent is piped long distances or up hill. Two common types of pressurized systems are force mains and STEP systems.

Force mains use small grinder pumps at each residence to feed sewage under pressure to collection main, which may be either pressurized, or gravity fed.

STEP (Septic Tank Effluent Pump) is a special type of force main. A high head pump mounted in a screened vault in the septic tank pump liquids through a small diameter collection system to the nearest collection junction. Pressurized systems use smaller pipes and may save construction costs over a long distance. In addition, pressurized systems can change the hydraulics of some secondary systems allowing them to be smaller.

Typical collection system costs are $35-45 per linear foot of gravity main, $4-8 per linear foot of force main and $2-5 per linear foot of STEP mains. Force mains also require grinder pumps at $5,000 per home and STEP systems use pumps costing $1,500 - 3,000 per septic tank.

Secondary Treatment Secondary treatment is necessary to protect the environment and health and safety. They work by biologically breaking complex organic materials into simple, more stable and less harmful substances. The output of secondary systems consists of gasses, water and nutrients. Gasses infiltrate the soil and are released into the atmosphere. Nutrients are picked up and used for growth by the plants. Water evaporates from the soil directly, is transpired from the plants, or is filtered through the soil to a ground water or surface water source.

Constructed Wetlands (CW) Constructed wetlands can be used for secondary treatment where space allows. Normally the wetland consists of two surface cells approximately one foot deep. The first cell is lined and filled with gravel. The second cell is unlined and filled with sand. Both are covered with 1-3 inches of organic material such as topsoil or straw, which is used to grow typical wetland plants such as water primrose, cattails or bulrushes. The plants help treat the effluent by utilizing the nutrients in growth, and reduce water volume through transpiration. Water that is not evaporated or transpired passes through the bottom of the wetlands into the soil, and eventually to a surface or ground water source. While essentially maintenance free, periodic harvesting or plant management is required and burrowing animals such as muskrats should be discouraged from destroying the liner. Wetland size and cost depend upon influent volumes. A single family home would require a wetland of approximately 450 square feet and would cost in the range of $3-5,000.

CONCLUSION

The Section 531 program provides the Corps of Engineers with both an opportunity and a challenge to assist the people of eastern Kentucky to improve the quality of their lives and their environment.

Radley Fig. 1

Radley Fig. 2

STOKES CREEK, CROCKETT COUNTY, TENNESSEE: A STREAM RESTORATION DEMONSTRATION PROJECT

Leslie A. Turrini-Smith, [1]*

and

Douglas P. Smith[2]

The Stokes Creek restoration demonstration project is an in-progress restoration of a channelized stream reach located in western Tennessee. The objective of the project is to reproduce 2.3 miles of a naturally meandering and functioning river system. Project goals are to apply, evaluate, and improve techniques for the physical restoration of a channelized river using fluvial geomorphic principles and traditional hydraulic engineering tools; determine appropriate biological and physical parameters for evaluating project success; and develop a model for future restoration efforts in western Tennessee. Successful stream restoration can reverse the loss of bottomland hardwood forests, which is a critical component to wildlife and wetland management.

Stokes Creek is a tributary to the North Fork Forked Deer River located in Dyer County, in northwestern Tennessee (Fig 1). Both Stokes Creek and the North Fork Forked Deer River were channelized initially in the early part of this century and several times again until the 1960's. They are located in the West Tennessee Tributaries Project area, a US Army Corps of Engineers drainage and flood control project with a long and complex legal history.

Restoration design methodology utilizes fluvial geomorphic and traditional engineering tools to develop appropriate channel dimensions (cross-section), pattern (planform), and profile (gradient). A recently developed western Tennessee fluvial geomorphic regional curve is used to develop the restored channel design with a channel cross-sectional area of 107 ft^2, bankfull width of 23 ft and mean bankfull depth of 4.6 ft. (Fig 2). The restored channel design is typical of an E6 stream type (Rosgen stream classification system), with a deep and narrow channel (w/d ratio 5.0) and steep side banks (approximately 1:1 slopes) similar to the reference reach (Fig 2). The low width/depth ratio ensures efficient sediment and water transport. The selected reference reach, Lagoon Creek, is similar to Stokes Creek with a low valley gradient (.0005), watershed landuse (agriculture-dominated), sediment type (mud), and strong influence by backwater from the mainstem river (Hatchie River) to which it drains.

Restored channel pattern and profile parameters are developed by detailed surveys of the reference reach and scaling to the Stokes Creek drainage area of 27 mi^2. The restored Stokes Creek channel pattern has an average radius of curvature of 55 ft, average belt width of 530 ft, and sinuosity of 1.7 (Fig 3). The restored channel profile has a slope of .0004. Bedforms, such as pools and runs, are dominated by the presence of woody debris, similar to Lagoon Creek. Placement of woody debris within the restored channel aids pool formation and maintenance, provides channel roughness for energy dissipation, and creates valuable aquatic habitat.

The project is funded by a $329,000 grant from the U.S. Environmental Protection Agency. Construction will be supervised by the West Tennessee River Basin Authority and is scheduled to commence in fall of 1999.

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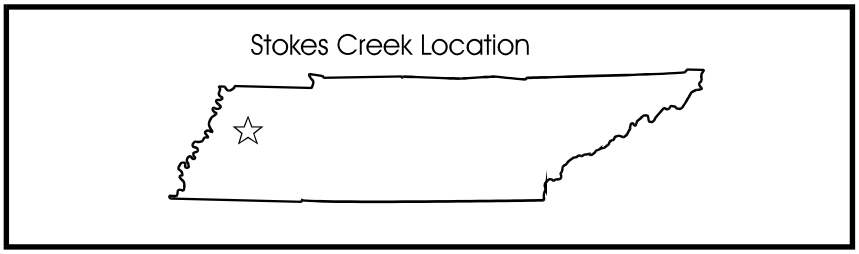
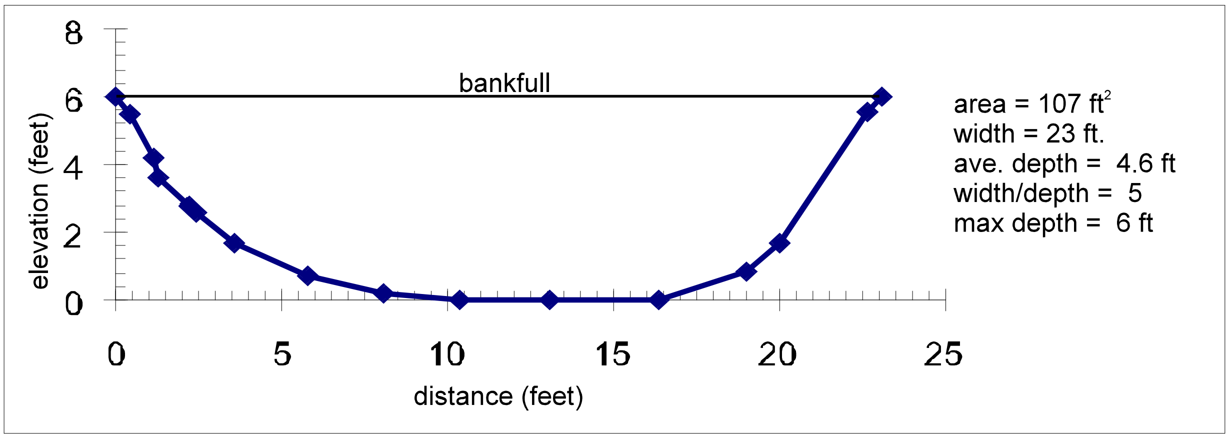
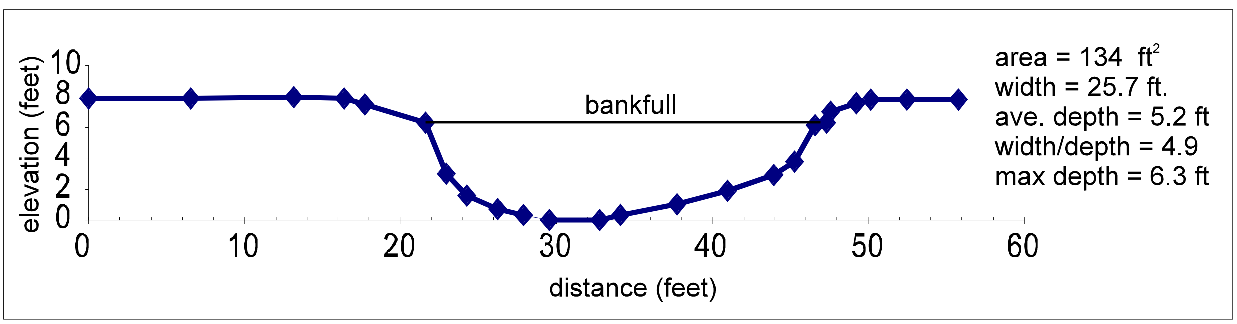


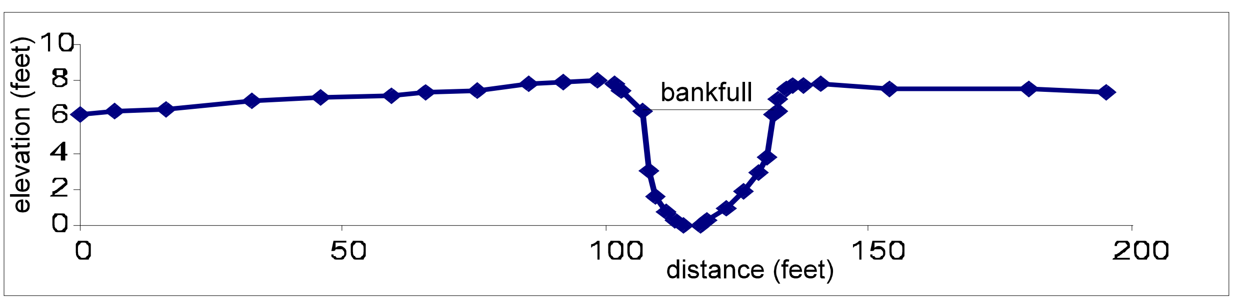
Figure 1: Location Map of Stokes Creek restoration project



Typical cross-section of restored Stokes Creek Channel (no vertical exaggeration)



Typical cross-section of reference reach at Lagoon Creek (no vertical exaggeration)



Typical cross-section and natural levees at Lagoon Creek reference reach (vertical exaggeration = 3.5)

Figure 2: Typical cross-sections of Stokes Creek restored channel and reference reach

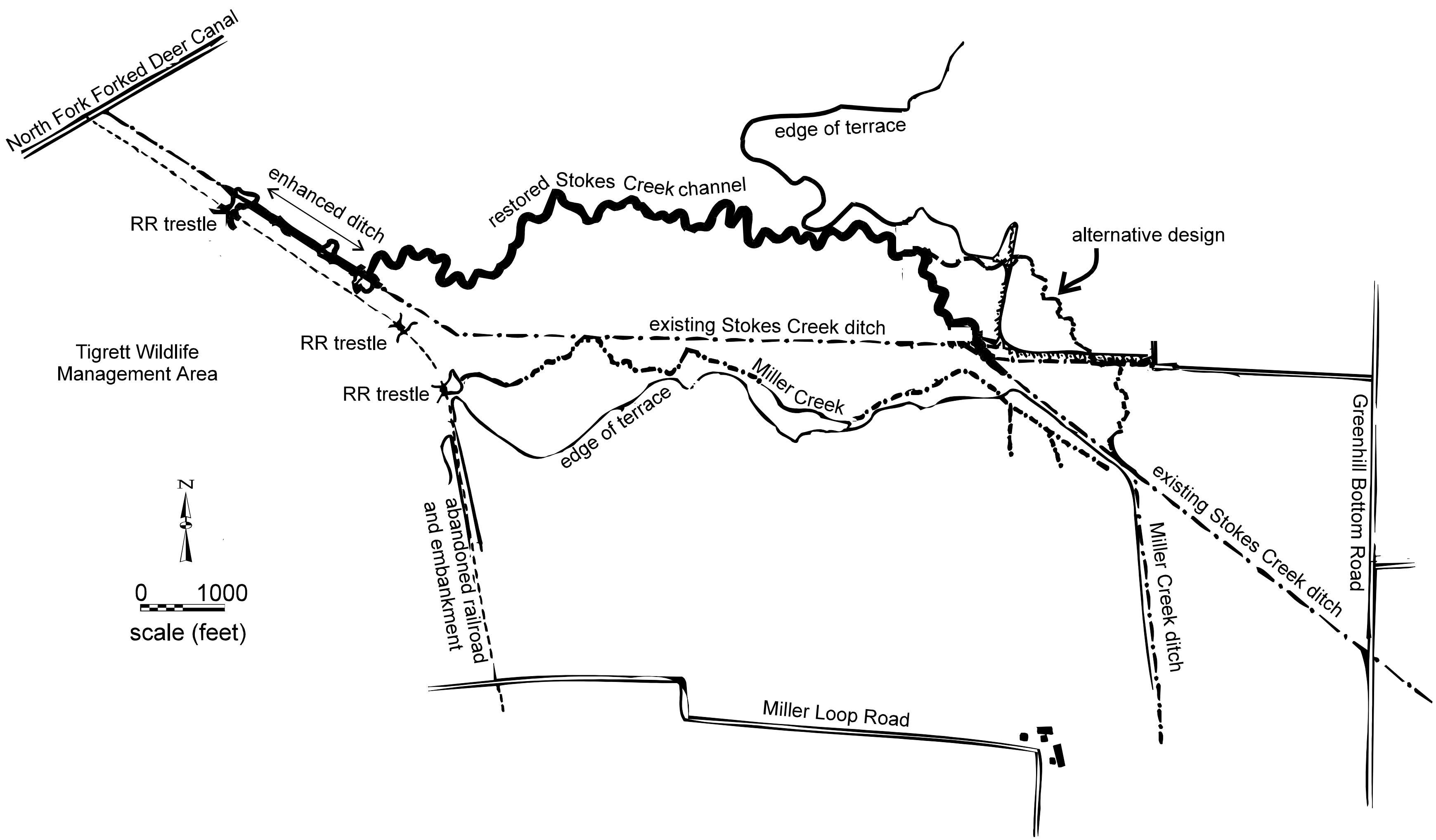


Figure 3: Stokes Creek channel restoration design

STREAM CLASSIFICATION FOR HABITAT ENHANCEMENT IN EAST TENNESSEE

Hollings T. Andrews[1]

[Presented at November, 1998, meeting of Tennessee Academy of Science]

ABSTRACT

An 850m reach of Coker Creek, in southeast Monroe County, Tennessee, was selected by the USDA Natural Resources Conservation Services as a site for stream habitat enhancement. Disturbances in the drainage area (anthropogenic alluviation) occurred in the mid-1800's by gold mining. In the mid-1900's the reach was altered by earth moving equipment. The braided channel which meandered through a wetland of approximately 2 ha was consolidated, displaced, and straightened; and the wetland was drained. The immediate concern is bank stabilization and (fish) habitat enhancement. Initial field work has included setting control points and surveying 30 cross-sections (differential and trigonometric leveling), surveying the longitudinal profile of stream bottom and water surface (differential leveling), studying reference reaches, and formulating regional curves. Emphasis of field work has been to gather data which can be used to accurately describe the geometry of the stream, and which will serve as a basis for the design of modifications to the channel.

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NASHVILLE DISTRICT CORPS OF ENGINEERS TAILWATER IMPROVEMENT EFFORTS

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BACKGROUND

The water released from Nashville District Corps of Engineers (CE) projects, in particular water that has passed through the hydropower turbines, is often deficient in its oxygen content. The quality of water within and released from these lakes is at the mercy of water quality conditions in the watershed and the tributary streams. When relatively high levels of nutrients, originating from both point and non-point sources, are exposed to the extended retention times prevalent in CE lakes, the resulting oxygen depletion can become severe. Water quality conditions in turbine releases can become critical due to the design of the hydropower system where most of the water released originates from deep in the water column where dissolved oxygen (DO) levels tend to be at a minimum. The DO problem is seasonal in nature. Typically, low tailwater DO concentrations are first observed in late spring or early summer and persist until the corresponding lake destratifies in the fall.

None of the ten Nashville District multipurpose projects are immune to this problem; however, the extent and significance of the problem varies tremendously among projects. Currently, low DO levels are more of a concern at the storage (tributary) projects than those located along the Cumberland River main stem. This hasn't always been the case. Prior to the development and implementation of a water quality routing model violation of the DO standard along the Cumberland River was not all that uncommon. Now, through the application of this tool, low DO events are anticipated allowing the appropriate water control measures to be implemented. Thus, the reservoir system can be operated to prevent any DO violations along the navigable reach extending from Celina, TN through the Cordell Hull, Old Hickory, Cheatham, and Barkley projects to the river's mouth at Smithland, KY. The tributary storage projects are another story. Specifically, Wolf Creek (Lake Cumberland), Dale Hollow, Center Hill, and J. Percy Priest all have severe DO problems. Unlike the main stem projects where operational changes facilitated DO improvements, the tributary projects will require structural measures. DO depletion is more severe in tributary storage projects due to the manner in which they are operated. Water tends to pass through a main stem navigation project in a matter of a few days. However, the observed retention time for a tributary project is measured in months and in some cases exceeds one year. Therefore, the natural processes responsible for DO depletion within the water column have more time to develop resulting in a higher degree of DO depletion and ultimately lower release DO concentrations.

The DO standard for a warmwater stream is a minimum instantaneous value of 5.0 mg/l. The applicable standard for coldwater streams or "trout water" is 6.0 mg/l. On the Cumberland River the warmwater standard is applicable from the KY/TN state line along the entire length of the main stem to its confluence with the Ohio River. As mentioned above DO problems along this reach have been addressed through operational modifications and are not currently a problem. The river reaches below Martins Fork and J. Percy Priest are also considered warmwater streams. Martins Fork has a selective withdrawal system that allows for the discharge of acceptable water from both a temperature and DO standpoint. At J. Percy Priest release DO values less than 3.0 mg/l are observed on an annual basis. The exception being in 1998 when repair activity on the generator resulted in project releases being made from the spillway gates instead of the Power Plant. As a result DO concentrations in excess of 7.0 mg/l were maintained from late July through early December when the turbine was brought back on line. The Laurel, Wolf Creek, Dale Hollow, and Center Hill tailwaters are all classified as coldwater habitat, and as such are subject to the 6.0 mg/l criteria. While DO values less than 6.0 mg/l have been observed in releases from Laurel River Dam the hydraulic conditions resulting from the downstream channel capacity are of a bigger concern for aquatic life. In recent years DO concentrations as low as 3.0 mg/l have been observed below Wolf Creek Dam. DO values less than 1.0 mg/l have been recorded at both Dale Hollow and Center Hill.

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1998 DISSOLVED OXYGEN INITIATIVE

The DO Initiative that was instituted in 1998 has addressed several water quality problem areas. Currently, studies are in progress and/or turbine modifications are being performed at the Wolf Creek, Dale Hollow, and Center Hill Power Plants. The DO and related water quality problems at J. Percy Priest are unique and will be addressed through an independent analysis.

The DO situation within the Cumberland River Basin is not unlike conditions observed in the Tennessee River Basin about a decade ago. At that time in response to mounting pressure from State and Federal regulatory and wildlife agencies and private environmental interests the Tennessee Valley Authority (TVA) launched its Clean Water Initiative. Ultimately this program lead to the expenditure of approximately $50 M to identify, evaluate, and fix a variety of water quality problems. The primary emphasis was on DO conditions below TVA power plants. In recent years a decline in DO conditions has been observed within the Cumberland Basin. Coincidentally, concern has developed on the part of Federal, State, and private interests to do something about our DO problems. We are now at the point TVA was prior to their Clean Water Initiative. Our unique challenge is to make meaningful water quality improvements without adversely impacting other project purposes, and to do so within existing budget and program constraints. Unlike TVA, the Corps of Engineers does not have the capability to redirect hydropower revenues to address water quality problems. However, in addition to traditional O&M efforts we do have options including Hydropower Major Rehabilitation studies or perhaps Congressional Directives as possible avenues to perform this work.

The CE has drawn on the technical expertise developed by TVA to address DO concerns in the Cumberland River Basin. TVA is the best single source for reaeration expertise in the country. They are currently working for several private sector utilities and Corps of Engineers districts in addition to Nashville. Through discussions held with TVA reaeration personnel a phased approach has been developed to address Cumberland Basin DO issues. The first step is to perform whatever studies are necessary to define and implement low cost, preliminary treatments of existing DO problems. These actions are limited to those that can be executed within the existing resource climate. It is realized that these preliminary measures will probably not bring an individual project into compliance with applicable DO standards, but will result in significant improvements to the DO regime.

For Wolf Creek, Dale Hollow, and Center Hill the first DO enhancement action to implement is turbine venting (also referred to as hub baffles). Turbine venting is generally the most cost-effective means of augmenting the DO concentration in releases made from hydropower facilities, and as such is a good first step in the process. It is a simple, low cost action that increases the amount of air introduced to the turbine and results in significant improvement to the release DO concentration. Turbine venting is site specific in nature, and requires a detailed engineering analysis prior to implementation. Physical modifications required to implement turbine venting consist of the installation of hub baffles on the vacuum relief ports and/or modification to the air supply system. The baffles, which are typically fabricated out of stainless steel plate or piping, create a zone of negative pressure that results in more air being pulled into the unit (turbine). Air supply modifications may consist of relatively simple modification of the existing system or the installation of additional piping. The sole intent is to provide more air to the unit. Turbine venting is passive in nature. It is inexpensive to install and results in a relatively small efficiency loss. TVA experience with turbine venting at several of their plants has indicated that efficiency losses in the range of 0.5-2.0 % can be expected.

CENTER HILL

At a March 1998 meeting with Federal, State, and private wildlife and environmental interests the CE committed to a schedule that would result in the installation of hub baffles on one unit at the Center Hill Power Plant in 1998. The CE does not take modification of a well-maintained, fully functional 50-year old turbine lightly, and reserved the right to discontinue the effort if an engineering evaluation indicated any problems. The next step was to contract with TVA to perform a feasibility report addressing the potential of implementing turbine venting. This effort began with a site visit to the Center Hill Power Plant. Fortunately, one of the three units was dewatered at the time allowing direct visual inspection of both the scroll case/penstock and turbine areas. In a subsequent report prepared by TVA it was determined that turbine venting was a viable option for Center Hill and warranted further investigation.

In early August TVA returned to the Center Hill Power Plant to perform the tests necessary to evaluate and subsequently design the hub baffle installation. The TVA field crew consisted of technical specialists from the Norris Engineering Laboratory. They brought equipment that allowed them to continuously (5-second interval) monitor a wide range of parameters including wicket gate opening, power output, head cover pressure, headwater elevation, tailwater elevation, head, penstock DO, and tailwater DO. The information was logged into a spreadsheet running on a laptop computer that had been set up in the Powerhouse in proximity to the unit (unit #3) being tested. In addition, airflow measurements were collected manually and added to the database. CE personnel contributed to the execution of the study by providing technical assistance within the powerhouse and collecting detailed water quality profile information from the reservoir in proximity to the Unit #3 intake. Following an analysis of the "pre-test" data TVA personnel returned in September to assist in the fabrication and installation of hub baffles. All fabrication and installation work was performed by CE personnel. TVA provided invaluable technical oversight based on years of experience with similar installations. Following installation of the eight hub baffles TVA performed a "post-test" in the same manner that the "pre-test" had been performed. They will prepare a summary report of project activity that details tailwater DO improvement and impacts to turbine efficiency resulting from installation of the baffles. Preliminary results indicate that the hub baffles have resulted in an increase of approximately 2.0 mg/l to the tailwater DO during single unit generation. When all three units were in use the increase achieved by Unit #3 was limited to about 0.7 mg/l. Impacts to turbine efficiency were acceptable with a maximum efficiency loss on the order of 0.3 %.

Center Hill Unit #3 will be dewatered at approximately six-month and one-year post baffle installation points to inspect the integrity of the unit. Particular interest will be paid to cavitation patterns in the vicinity of the turbine blades and hub baffles. Providing no adverse impacts are identified the plan is to install hub baffles on the two remaining units. Meanwhile, analysis will continue on the feasibility of modifying the air supply system to provide more airflow.

The installation of hub baffles at Center Hill is a good first step toward addressing DO deficiencies. However, the project can not be brought into full compliance through only the use of baffles. There is developing turbine technology that greatly increases the reaeration characteristics of hydropower turbines. These new turbines, known as auto-venting turbines (AVTs), have been observed to increase DO values by about 4.5 - 5.0 mg/l. The installation of AVTs for DO improvement is a very costly proposal. It would be more cost effective to install some form of an oxygen injection system in the lake. However, if the turbines were to be replaced for energy production purposes, then the incremental cost for utilizing auto-venting technology over a more traditional design makes this a very attractive option. The Center Hill Power Plant is scheduled for a major rehabilitation Study in FY 99. During this study AVTs will be evaluated as a means to improve both the efficiency and environmental characteristics of the hydropower installation at Center Hill. Meanwhile, the CE will continue to pursue DO restoration utilizing turbine venting technology.

WOLF CREEK

Not long after the Center Hill turbine venting work was initiated the opportunity arose to address similar problems at Wolf Creek. Prior to performing the turbine venting analysis at Center Hill it was recognized that the units at Wolf Creek were identical and that lessons learned at Center Hill could in large part be transferred to Wolf Creek. Thus, based on the turbine venting work performed at Center Hill it appears that hub baffles will prove beneficial at Wolf Creek. In addition, the ongoing Wolf Creek Hydropower Uprate Study at Wolf Creek has provided more opportunity to evaluate water quality restoration options.

TVA was brought in to perform a preliminary DO restoration evaluation. As a first step a briefing was held at the Wolf Creek Power Plant with participation from CE hydropower and water management personnel, the US Fish and Wildlife Service, Commonwealth of Kentucky fishery and water quality interests, and representation from Trout Unlimited. TVA reaeration experts discussed various options available for implementation at Wolf Creek to address both DO and minimum flow concerns. To date no site specific tests like those performed at Center Hill have been completed at Wolf Creek.

In conjunction with the Wolf Creek Hydropower Uprate Study TVA has been tasked with evaluating a wide range of potential methods of improving outflow DO conditions. One of their recommendations for analysis in the ongoing uprate study is to replace the existing units with AVTs having a higher generating capacity. Again, with the similarity in units between the Wolf Creek and Center Hill plants this AVT evaluation will be beneficial to both projects.

DALE HOLLOW

In September the CE arranged for TVA to perform a feasibility level evaluation of the potential for implementing turbine venting at the Dale Hollow Power Plant. A briefing was held at the Dale Hollow Powerhouse to familiarize project personnel with turbine venting technology. Dale Hollow Unit #2 was dewatered for maintenance at the time, which allowed for a direct inspection of the unit. The units at Dale Hollow differ significantly in terms of capacity and design from those at Wolf Creek and Center Hill. TVA submitted a report that found turbine venting to be a viable option and recommended further investigation.

During the Dale Hollow site visit an informative discussion was held on the potential of operating the units there with the vacuum breaker system blocked open. This was suggested by power plant personnel as an effective means of introducing more air into the turbines. The following week a study was performed to determine the magnitude of DO enhancement that could be obtained through operation of the vacuum breaker system. This study performed by CE personnel evaluated a range of wicket gate openings with the vacuum breaker operated in both the normal and blocked open position. DO increases of as much as 2.0 mg/l were observed. This prompted the CE to revise project operations resulting in the units being operated with the vacuum breaker blocked in the open position. This operation was followed until the lake destratified and resulting low DO conditions were eliminated in early December.

In mid October a “pre-test” turbine venting evaluation was executed. TVA Norris Engineering Laboratory personnel performed the same type of test that had been done at Center Hill in August. The Dale Hollow Power Plant staff provided technical assistance. District Water Quality staff with assistance from the Dale Hollow Resource Management Office monitored reservoir and tailwater water quality conditions during the test. The “pre-test” was very successful indicating that turbine venting could increase DO concentrations by as much as 3.0 mg/l. Preliminary indications are that impacts to turbine efficiency (1.5 – 2.0 %) are more significant than those observed at Center Hill, but still in the acceptable range. A report will be prepared of findings and recommendations. The installation of baffles and modification of the air supply system to increase airflow to the units are planned for 1999.

FUTURE DO RESTORATION ACTIVITIES

Over the past several years numerous changes that benefit water quality have been made to the way the Cumberland River Basin reservoir system is operated. These modifications, based on knowledge gained through the application of system water quality models, have proven to be an effective mechanism to improve DO and temperature conditions along the main stem of the Cumberland River. The DO restoration activities that were initiated at individual tributary projects in 1998 will continue over the next several years. In the short-term water quality restoration projects will be limited to those actions that fit within existing CE budget and program constraints. Generally, short-term initiatives will be limited to operational modifications and turbine venting, both the installation of hub baffles and the modification of air supply systems. The magnitude of the DO problem at some of the tributary projects is beyond what turbine venting alone will alleviate. In these cases more permanent or long-term solutions such as the installation of a reservoir forebay oxygenation system or replacing existing hydropower units with auto-venting turbines will be required to meet downstream water quality standards. The cost for long-term solutions is beyond that supported by the current CE O&M Budget. However, there are several funding options currently being investigated that may prove to be successful in supporting these projects. If so, the technology exists to alleviate existing water quality problems associated with releases from CE dams within the Cumberland River Basin.

EXTENSIVE FIELD SCREENING: ORGANIZATION, GIS INTEGRATION, DATA AND LESSONS LEARNED

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ABSTRACT

The Metropolitan Nashville-Davidson County (Metro) has implemented an extensive program to field screen over 3700 locations in the Davidson County storm water system. This program was made manageable and feasible through the integration of a new storm water infrastructure geographic information system. Metro has screened over 973 sites to date and found the impact from dry weather flow to be less than originally anticipated. Metro has worked during the initial stages of the field screening program to learn how to identify on office maps the most efficient and effective sampling locations within a grid cell. This optimizes both the numbers of sample sites and grid cells that can be visited per day and the ability to actually detect illicit discharges. Metro has also expanded upon the original scope of the state-mandated requirements, so that the aim has shifted from a statistical sampling exercise to a more comprehensive illicit discharge screening activity.

INTRODUCTION

Metropolitan Nashville-Davidson County (Metro) was issued a National Pollution Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit in 1996 from the Tennessee Department of Environment and Conservation (TDEC). The Metro Department of Public Works (MDPW) has a series of work efforts planned and under way to address mandated conditions.

Illicit connections are improper/illegal entries into the storm drainage system. These are exclusive of any allowable discharge such as groundwater, irrigation, and potable water discharges. A key component of the NPDES MS4 permit implementation is an ongoing effort to identify any non-allowable stormwater entries, or illicit connections, into the storm drainage system and locate their sources. A dry weather field screening program can be used to identify illicit connections, where dry weather is defined as a 72 hour or more period where no more than 0.1 inches of rain has fallen. The following are examples of illicit connections that are being located and their source identified.

- Accidental or intentional connections that convey pollutants to the MS4 under dry or wet weather conditions.
- Leaks from the sanitary sewer system into the stormwater system.
- Regularly occurring spills or leaks from industrial processes.
- Any discharge to the stormwater conveyance system not authorized under a separate NPDES permit or ordinance.

This paper presents the rationale for site selection, an overview of Metro's field screening program procedures, Geographic Information System (GIS) methods used to track and report the investigations, a summary of the field screening and investigation results, and lessons learned.

SITE SELECTION

Davidson County is broken into two grid patterns, by land uses, which, are used to organize drainage system screening. The minimum level of surveillance for the field screening program, as required by the NPDES MS4 permit, is based on a 0.50-mile grid system, with each grid area containing at least one field screening location. In industrial and heavy commercial areas, the minimum level of surveillance is based on a 0.25-mile grid system, with each grid area containing at least one field screening location. Under this surveillance program, all grid areas of the MS4 must be screened once during the permit term. The newly developed stormwater infrastructure GIS was used in coordination with two grid system overlays that resulted in the creation of 3,791 possible sampling grids.

Metro recognized that a watershed approach should also be part of the selection process. The storm water GIS facilitated this through the mapping of creeks, channels, ditches and piped storm water conveyances. After the field screening grid was established and the storm sewer system in the area was mapped, the screening site(s) could be selected so that it represented an largest amount of drainage area from that grid cell. The screening sites include outfalls from a piped storm water conveyance, as well as ditches or other appropriate channels. At least one (often more) site is selected in the grid cell, further increasing the drainage area represented. Without applying this watershed technique, randomly selecting a site within the grid may have resulted in a site that is not representative of the overall grid area.

Additional potential illicit connection sites are located and entered into the GIS from the following sources: infrastructure inventory and observations and discoveries made by Metro personnel while conducting field screening.

FIELD SCREENING PROCEDURES

After a map has been produced for field staff and potential sites have been selected for a grid, the field crew visits the grid area. At this time, the site with the largest drainage area in that grid cell is checked for any dry weather flow. If the site can not be accessed then one of the other sites or an alternative site determined by the field crew is visited. If there is a dry weather flow then it is sampled using Hach® field testing equipment and other observations are made. These sites are visited a second time 4 - 24 hours later when any dry weather flow is resampled and other observations are made. If there is dry weather flow during both visits and any of the sampling data exceed action levels, then the site is classified as having a “non-allowable stormwater entry.”

A series of “windshield inspections” are then performed, especially near sites or facilities known or thought to have a possible storm water impact. A “windshield inspection” is a brief visual inspection made by a field crew that surveys the general area of the field screening site or other areas of interest. This ensures that any other storm water quality problems in the area, that Metro was not already aware of, are not overlooked.

Once a “non-allowable stormwater entry” is located, it is important to identify any non-allowable stormwater sources so that corrective measures may be implemented. The program is designed to detect, locate, and ultimately remove illicit discharges to the MS4 with GIS and field investigations. Identification of sources is facilitated by the integration of the GIS with field and laboratory sampling data. If corrective measures are not implemented then stormwater quality can not be improved and maintaining stormwater quality may not be achievable.

The investigation program prioritizes sites first according to complaints or observations made during the infrastructure inventory, then by contaminated field screening sites. The locations and activities of the investigation program are tracked, organized, and analyzed by computer through various databases linked to the storm water GIS. The Metro Nashville Department of Public Works (MDPW) uses this information in the investigation and subsequent elimination of illicit discharges. Upon discovery of an accidental illicit discharge, MDPW contacts the discharger to solve the problem. Should the discharge be considered a recurring or negligent event, the Tennessee Department of Environment and Conservation (TDEC) Division of Water Pollution Control (DWPC) is contacted by MDPW for direction and possible assistance in dealing with the discharge.

GIS TOOLS

Metro's Department of Public Works is conducting a storm water GIS conversion project that is serving as a base tool for several NPDES MS4 activities including the field screening program. The storm water GIS is an Environmental Systems Research Institute (ESRI) ArcView and Microsoft Access based system. It uses a base map maintained by the Metro Planning Department. The base map contains building footprints, edge of pavement, property lines, topography and other layers of similar data. The storm water GIS contains spatial and attribute data on stormwater features including creeks, ditches, cross drains, culverts, catch basins, inlets, outfalls, detention ponds, and other storm water infrastructure. The storm water infrastructure attributes include physical characteristics such as size and shape; and condition information including structural, erosion or obstruction problems. The storm water GIS also contains information related to other NPDES MS4 permit tasks including industrial facilities, spills, landfills and other solid waste related sites.

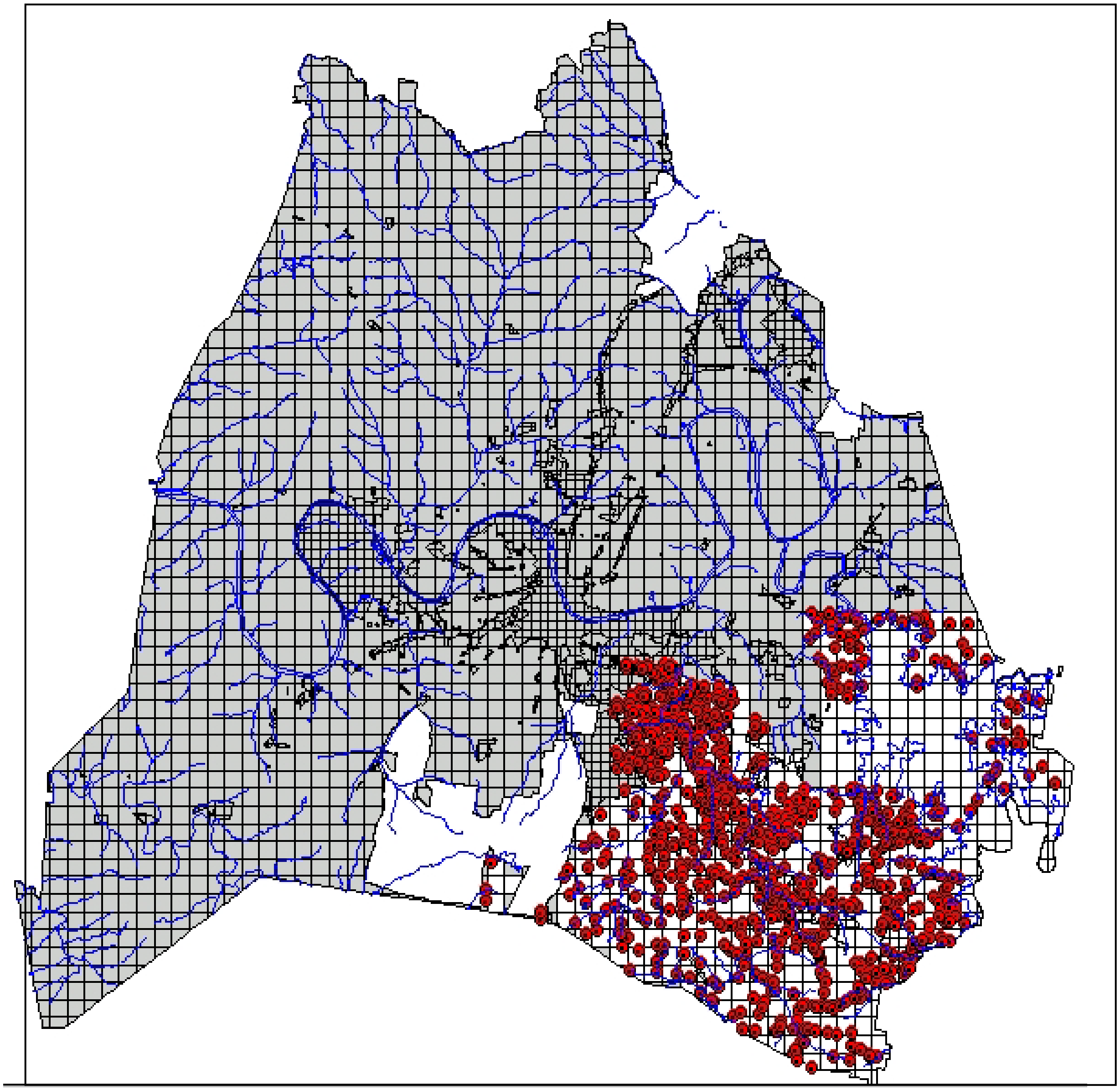
As discussed above, the GIS was helpful in selecting field screening sites. With the aid of the GIS, Metro was able to produce systematic grids with different densities that were unevenly distributed throughout the county to match land use conditions. This seemingly simple automated task was key to being able to integrate the other data sources without exorbitant labor costs. Figure 1 presents the field screening sites that have been visited to date and illustrates the grids used in site selection.

The GIS tool allows Metro to

- Produce maps for use by field crews. The maps present information including the Planning department base map, storm water infrastructure, industrial sites, landfills, solid waste transfer stations, spills, etc.
- Track which grids were visited.
- Track which grids have been prepared for field work indicating that sites have been selected.
- Track all sites that were visited and associate that site with the nearest infrastructure feature.
- Display photographs of each site.
- Review observations made at each site.
- Review any analytical data for that site.
- Track sites with dry-weather flow.
- Produce maps that present "hot" sites (a dry weather flow with a parameter that exceeds an acceptable threshold or action level).

The GIS tool's capabilities are used to implement the field screening program in an organized way so that Metro may complete the permit deadline of screening the entire permit area (Davidson County minus satellite cities) by the end of the five year permit term. The GIS is also used to develop maps and figures to focus efforts to improve storm water quality and demonstrate compliance with the permit requirements.

Figure 1
Metropolitan Nashville-Davidson County
Dry Weather Field Screening Sites



RESULTS SUMMARY

Tables 1 and 2 summarize the activities and related data. Metro plans to complete the screening by the permit cycle completion in 2001.

Table 1
NPDES Program Field Screening Information
(Activities through January 8, 1999)

Type of Field Screening Sites	**1A Number of Sites**
Total	3791
Total Grids Visited	764
Total Sites Visited	973
Total Sites Sampled (with flow)	66
Total Sites Requiring Source Tracking	12
Industrial Sites	1633
Industrial Sites Visited	258
Non-Industrial Sites	2158
Non-Industrial Sites Visited	506

Table 2
NPDES Program Field Screening Analytical Data Summary
(Sites requiring source tracking - through January 8, 1999)

Parameter	**1B Number of sites**
Unusual Odor	6
Unusual Color	6
Turbidity Present	5
Oil Sheen Present	10
Stain on Structure	9
pH outside Action Level	0
Dissolve Oxygen Below Action Level	11
Temperature Above Action Level	5
TRC Above Action Level	4
Copper Above Action Level	12
Phenols Above Action Level	9
Detergents Above Action Level	1
Ammonia Above Action Level	3
Fluoride Above Action Level	10

LESSONS LEARNED

Metro learned several things during the design and first six months of implementing the dry weather field screening program including efficient site selection, field mobilization and land use relationships. These realizations should enable Metro to make future field screening activities more expedient to cost effectively improve the overall storm water quality in Davidson County.

The most important lesson learned was how to properly choose sampling locations by screening GIS maps in the office prior to going into the field. Metro is able to produce detailed maps, through the new stormwater GIS, that provide a field crew with information to prepare them for potential problems ranging from access to probable point source impacts. The maps also show topography and stormwater infrastructure (with flow direction) enabling the field crews to quickly trace sources or find alternative sites to sample.

Metro has worked to optimize the field crew schedules to consider sampling events and locations that will cover as many grid cells as possible in a day. This is a critical task if Metro expects to visit the over 3,700 grid cells by the end of the permit term. Using a watershed approach and selecting grid cells groups along major transportation thoroughfares reduces the field crew mobilization time. The GIS helps Metro find the ways to get the most field screening grid cells visited in the shortest time possible.

Another problem Metro has learned to deal with is the difficulty of maintaining consistent field screening activities during prolonged wet weather periods. The permit requires that field screening can only take place after a “dry weather period”, defined as 72 hours with less than 0.1 inches of precipitation, precluding field activities for several weeks at a time. Metro has learned that preparation is key to get the field crew mobilized when the dry weather finally does arrive. In addition to wet weather related field activities, Metro uses the time to produce a backlog of grid cell maps to be used in the field. Metro has found that this preparation makes the most of the dry weather time available.

Metro has come to further understand how field screening considerations vary greatly according to land use; with residential, commercial, and industrial areas each having different nonpoint source pollution issues. The permit writers rational for smaller grid cells for industrial and high-density commercial area has been confirmed in the field screening program implementation. As expected, older more concentrated industrial and commercial developments have significantly more illicit discharges than residential areas. While the screening grid is less dense for residential/low-density commercial land use significant illicit discharges are much less frequent to warrant the next permit application to consider increasing the grid cell size for residential and low-density commercial land uses. Field screening results may even indicate that certain "non-problem" areas be eliminated from field screening requirements entirely, so that additional energies may be directed toward field screening areas that are significantly more prone to contain impacting illicit discharges.

URBANIZATION AND WATER QUALITY: A GIS-BASED STUDY

Judith L. Grable[1]

ABSTRACT

Urbanization spreading eastward from Springfield, Missouri has transformed a small (59 km^2) drainage basin from primarily rural to a mixture of rural, suburban and urban land uses in recent decades. This study tracks the locations and types of buildings in each decade from the mid-1960s through 1990. Building locations served by centralized wastewater treatment versus those with on-site wastewater treatment were recorded, as were sites within areas of increased risk for water pollution. The latter include close proximity to sinkholes, geological faults, lineaments, and streams, as well as septic system use in soils not suited for such use. Different combinations of risk factors and various methods of quantification of upstream urbanization were used to compare the amount and location of urbanization in each decade to the results of various chemical/physical and macroinvertebrate-based water quality tests. Biological indications of water quality generally showed statistically significant degrees of correlation with urbanization, but chemical test results did not. The inclusion of multiple spatial factors into longer term water quality studies offers potential for better understanding the role of each risk factor in affecting water quality. This approach becomes simpler and more practical to implement as Geographic Information System (GIS) use becomes more common. The importance of consistency in water quality test types and locations becomes apparent when attempting to understand trends in water quality.

INTRODUCTION

Land use in the Pierson Creek drainage basin, located on the eastern side of Springfield, Missouri (Figure 1), has been changing in recent decades as urban and suburban areas expand. Negative impacts on water quality in the basin are important to local residents for several reasons, not the least of which is that part of the city's water supply is drawn from a river only a few hundred meters downstream of the point of entry of Pierson Creek. In addition, bedrock underlying the Pierson Creek drainage basin is predominantly carbonate, and soils are generally shallow, so the potential for groundwater contamination is high. Surface/ groundwater interchanges have been demonstrated with dye-tracing techniques in many sinkholes and springs within the basin (Aley and Tomson, 1981; Thomson, 1995).

Youngsteadt (1994) noted a deterioration of macroinvertebrate fauna in lower Pierson Creek over several decades and ascribed the decline to increased urbanization within the drainage basin. This study focuses on discovering how much urbanization occurred during the time span mentioned by Youngstead, the relationship between urbanization and water quality, and the examination of whether or not wastewater treatment method or development within areas of higher risk of water pollution has had a demonstrable effect on water quality in Pierson Creek.

METHODS

Data were gathered to test for statistical correlation between urbanization and various measures of water quality from the mid 1960s to 1990. Geographic Information System (GIS) software was used to compile and manipulate urbanization and most other data used, and to produce maps.

A combination of topographic maps and aerial photographs was used to plot the locations of buildings in the Pierson Creek drainage basin for each of the last four decades. Houses were entered into an electronic database as points, while larger buildings and their associated impervious areas, generally parking lots and driveways, were outlined. Outlined areas were classified as either apartment/business or commercial/ industrial. Schools were included in the apartments/businesses category. Familiarity with the city and some field work aided these classifications.

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In order to directly compare the numbers of houses with the impervious areas of other buildings, I developed a method of relating building categories and their typical associated percent impervious areas as given by Jens and McPherson (1964) to a theoretical density of buildings (Grable, 1995). This enabled me to compute the theoretical number of buildings at sites in each category of land use.

Risk factors related to urbanization and water quality were also investigated. The method of wastewater disposal has great potential of affecting water quality, as most soils in the basin are rated by the Soil Conservation Service as having severe or moderate limitations for septic system use (Hughes, 1982). On the other hand, centrally treated wastewater is pumped out and discharged into a steam in a different drainage basin. Areas served by the centralized wastewater treatment system in the 1960s, 1970s, 1980s, and 1990 were mapped. The suitability ratings of soils for septic systems were also mapped, and the maps electronically overlain with the wastewater treatment maps and building location maps. Buildings without centralized wastewater treatment were assigned a small weight factor if they were located in areas designated as having moderate soil limitations, and a larger weight factor in areas where severe soil limitations for septic system use exist.

Digital maps of sinkholes and geologic maps showing faults and lineaments (Waite and Thomson, 1993) were employed in combination with urbanization maps to further assess the effects of urbanization in or close to areas considered to have increased risks of water pollution. Buildings within 122 m (400 ft) of faults, fracture trends, lineaments, or the rim of sinkholes were assigned a small weight factor. Setbacks of this distance are recommended by local water-quality investigators (Aley and Thomson, 1981). A larger weight factor was assigned to buildings within 30.5 m (100 ft) of streams, or within 61 m (200 ft) of faults, fracture trends, lineaments, or the rim of sinkholes. These smaller distances are based on Greene County prohibitions for on-site wastewater treatment and disposal systems. As this study deals with the location of houses, not disposal systems, and because such disposal systems would be located on the downhill side, which would be the creek or sinkhole side of houses, the distances have been increased in this report from those set by the county.

Water quality data were obtained from both chemical/physical and biological studies conducted in the 1960s, ‘70s, ‘80s, and ‘90s (Missouri Water Pollution Board, 1965; Missouri Clean Water Commission, 1973; Emmett, et al., 1978; Youngsteadt and Gumicio, 1986; City Utilities Central Lab, 1990; and Youngsteadt, 1994). Test results for nitrogen (as nitrate), total phosphorus, chloride, sulfate, potassium, and sodium were used for correlation with urbanization, as levels of these substances are generally affected by human activities. Specific conductance was included as an indication of the degree of mineralization of the water. Data from four biological tests using macroinvertebrate riffle fauna to indicate water quality were also used. These tests were the biotic index, taxa per 100 organisms, total taxa in a sample, and the total numbers of stonefly, mayfly, and caddisfly found in each sample area.

Water quality data were collected at the sites shown in Figure 2. The basin area draining to each test site was defined and the resulting subbasins were given the same number as the sampling site at their outlets. Test site nine is located at a perennial spring which flows to a tributary of Pierson Creek. Although the area shown as subbasin nine does not have surface drainage to test site nine, sinkholes throughout that area have been shown to drain to the spring (Aley and Tomson, 1981; Thomson, 1995).

A dilution factor based on average stream discharge was applied to the number of houses in each subbasin such that houses distant from a test site would not be counted as heavily as houses nearby (Grable, 1995). After house numbers were calculated in this fashion, four different ways of calculating urbanization were employed. Method one uses the total number of houses upstream of a test site, but no weight factors. Method two uses the total number of houses plus applicable weight factors only for houses with on-site wastewater treatment. Method three omits all houses served by centralized wastewater treatment, and includes applicable weight factors for the remaining houses. Method four uses total number of houses with applicable weight factors for all houses. The Pearson Product-Moment correlation was used with the resulting data from each method in conjunction with water quality data to determine relationships between urbanization and water quality.

RESULTS

Three of the four biological indices yield statistically significant negative correlations between the number of houses and the water quality test results (Table 1). Correlations using total stonefly, mayfly, and caddisfly numbers and total taxa data give significant results no matter which of the four methods of calculation listed above is used. Taxa per 100 organisms is significantly correlated with number of buildings except when method three, the omission of houses connected to sewers, is used. Bioindex data show no statistically significant correlation with the number of houses, no matter how calculated. None of the chemical/ physical data showed statistically significant correlations with house numbers.

Table 1. Correlations between urbanization and water quality data

Water Quality Test	Method Used to Represent Urbanization			
	1	2	3	4
Nitrate	0.14	0.16	-0.07	0.19
Total P	-0.69	-0.67	-0.24	-0.69
Chloride	0.16	0.16	-0.07	0.18
Sulphate	-0.1	-0.03	0.21	-0.04
Potassium	-0.44	-0.38	0.6	-0.44
Sodium	-0.17	-0.09	0.8	-0.11
Specific Conduct.	0.54	0.56	0.31	0.58
Taxa per 100	-0.87*	-0.85*	-0.66	-0.85*
Stonefly, etc.	-0.79*	-0.82*	-0.84*	-0.81*
Total Taxa	-0.82*	-0.83*	-0.83*	-0.81*
Bioindex	0.43	0.44	0.42	0.44

*Marked correlations are significant at $p < 0.05$

CONCLUSIONS

Certain macroinvertebrate-based water quality data appear to closely correlate with urbanization in the Pierson Creek drainage basin. Chemicals commonly associated with water pollution from urbanized areas, such as nitrogen and phosphorus, are not significanly correlated with urbanization.

Methods intended to indicate the effects on water quality of development in areas of increased risk of water pollution showed no discernable differences. This might indicate the amount of development in these sensitive areas is not great enough to affect water quality, or it might be that the methods used in this study to detect water quality problems from these areas need refinement.

The results in this study must be viewed with caution partly because of the paucity of consistent long-term water quality data. The importance of maintaining sampling sites, parameters tested, and methods of testing that yield comparable results cannot be overstated. Techniques utilizing advancing technology, such as the use of Geographic Information Systems for spatial analysis, will help us decipher complex situations involving multiple factors, but technology will not help us if we do not have data to analyze. Our understanding of long-term changes in water quality basically depends on consistent water quality testing programs.

REFERENCES

Aley, T. and Thomson, K. C., 1981. Hydrologic Mapping of Unincorporated Greene County, Missouri, to Identify Areas Where Sinkhole Flooding and Serious Groundwater Contamination Could Result From Land Development. Ozark Underground Laboratory, Protem, Missouri.

City Utilities Central Lab, 1990. Water Quality Analysis. Unpublished data, City Utilities, Springfield, Missouri.

Emmett, L. F., Skelton, J., Ludkey, R. R., and Miller, D. E., 1978. Water Resources and Geology of the Springfield Area, Missouri. Water Resources Report Number 34,

Grable, J. L., 1995. Water Quality and Urbanization: A Multitemporal Study of the Pierson Creek Drainage Basin, Greene County, Missouri. Unpublished M.S. thesis, Southwest

Hughes, H. E., 1982. Soil Survey of Greene and Lawrence Counties, Missouri. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

Jens, S. W. and McPherson, M. B., 1964. Hydrology of urban areas in Chow, Ven Te (ed.), Handbook of Applied Hydrology. McGraw-Hill Book Company, New York.

Missouri Water Pollution Board, 1965. Water Quality of the James, Spring, and Elk River Basins, Appendix D, Water Quality Data. Department of Public Health and Welfare, Missouri Water Pollution Board, Jefferson City, Missouri.

Missouri Clean Water Commission, 1973. Water Quality of James, Elk, and Spring River Basins, Appendix C, Biological Data. Department of Public Health and Welfare, Missouri Water Pollution Board, Jefferson City, Missouri.

Thomson, K. C., 1995. Personal Communication, March 7, 1995. Dr. Thomson is a Professor of Geology at Southwest Missouri State University, Springfield, Missouri.

Waite, L. A., and Thomson, K. C., 1993. Development, Description, and Application of a Geographic Information System Data Base for Water Resources in Karst Terrane in Greene County, Missouri. U.S. Geological Survey, Water-Resources Investigations Report 93 4154, Rolla, Missouri.

Youngsteadt, N. W., 1994. The deterioration of the macroinvertebrate fauna of lower Pearson Creek along the eastern edge of Springfield, Missouri, with comparison to other local sampling points under varying influence from Springfield. Eighth Annual Watershed

Youngsteadt, N. W. and Gumicio, R. J., 1986. Water Quality in the Upper James River in 1984-85 with Comparisons to 1964-65. City Utilities of Springfield, Missouri.

USING GIS TO EVALUATE THE HETEROGENEITY OF AN URBAN WATERSHED FOR A WATER QUALITY STUDY

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INTRODUCTION

One of the most difficult tasks that hydrologists face is analyzing the spatially variable elements of a watershed. Over the land area of any watershed there are numerous significant variables, including topography, soil type, and land use. These variables, and others, work together to describe the hydrologic character of any given watershed. The same factors have a direct relationship to water quality.

Today, nonpoint source pollution (NPS) is considered to be perhaps the leading cause of water quality degradation. This is pollution that moves into the waterways from many diffuse sources but cannot be traced back to one particular source. Often the contaminants are widely dispersed at low concentrations over the entire landscape. Storm event runoff is the most common transport mechanism for moving the contaminants from the land into waterways. Typical urban contaminants and sources include:

- Hydrocarbons from parking lots and roads
- Nutrients and pesticides from lawns and gardens
- Bacteria and viruses from animal feces, leaking sewer mains, or septic systems
- Sediment from building sites, lawns, or uncovered areas

Identifying and quantifying the watershed characteristics affecting water quality is the first step in controlling NPS pollution. However, because these landscape characteristics have an extremely high spatial variation, this is a daunting task. Furthermore, analyzing the interrelationships of these characteristics can be overwhelming.

In many cases, Geographic Information Systems (GIS) can be utilized to make this task simpler. In a GIS application, one can take a data set and create a digital three dimensional spatially variable database. The user can then manipulate this database with a power not possible with traditional databases or paper maps.

Currently, a water quality study is underway in Knoxville, Tennessee. The watershed, locally known as the Sanford Watershed, is the subject of this investigation. It is a relatively small suburban drainage encompassing 178 acres. Though the area contains a few commercial stores and an elementary school, for the most part it is a wooded residential area with houses evenly distributed over the landscape.

The purpose of this paper is to investigate the application of a GIS system to an analysis of the topography, soils, and land use of the Sanford Watershed. Historically, GIS systems have not been easy to use. Recently this has begun to change, but are the results gleaned from these powerful programs worth the time necessary to learn how to use one of them? This paper seeks to answer three main questions. First, how easy are the GIS systems to use? Second, what are the basic processes and data necessary to create a spatial database? Third, how well does the GIS model what is really there?

SOFTWARE

To answer our first question we wanted a software package that was both powerful and easy to use. As GIS technology has rapidly expanded over the past few years, there are many companies that now offer GIS programs. Some well known manufactures include AutoDesk, Intergrapgh, MapInfo, and Environmental Systems Research

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Incorporated or ESRI[4]. Information about these and other GIS providers is available on the web. ArcView, a product of ESRI, was already loaded on the computers in our lab; therefore we decided to work with what was available. ArcView is a windows based program that is graphical in nature and most everything the user does is executed by clicking an icon or a selecting an action from a simple pull down menu. Because it is so graphically based, it can be quite useful for visual analysis and presentations. In addition ArcView has a number of utility functions called extensions that can be loaded. These greatly increase the power of the program. An easy to use, yet powerful tool for analyzing spatial data is quite useful in a number of situations including hydrology and land planning. For this investigation, ArcView 3.1 was used.

DATA

After choosing the software, our next problem was to collect the necessary databases for analyzing the watershed in ArcView. Typically, the required information is difficult and expensive to assemble in a usable format. Without a database, the GIS software is worthless. In this case, however, building an initial database was quite easily accomplished by downloading a comprehensive database for the Watts Bar HUC. The data set is available from the EPA's web site, located at: HTTP://www.epa.gov/ost/basins. Although many databases were included in the set, we selected the digital elevation model (DEM), the soil series, and the land use databases for characterization. The data were preformatted for ArcView and the EPA's ArcView extension, Basins, automatically built the themes. Getting started using the information was quite easy.

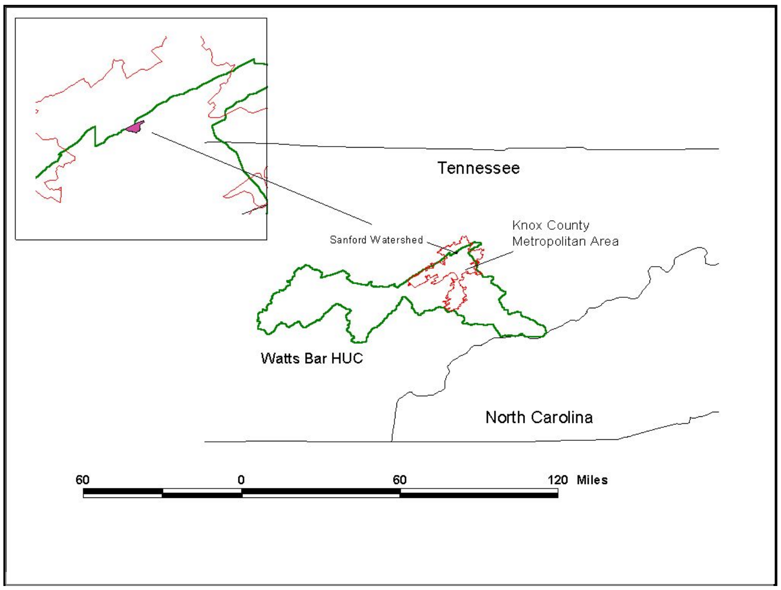

Figure 1. Scale of EPA Data

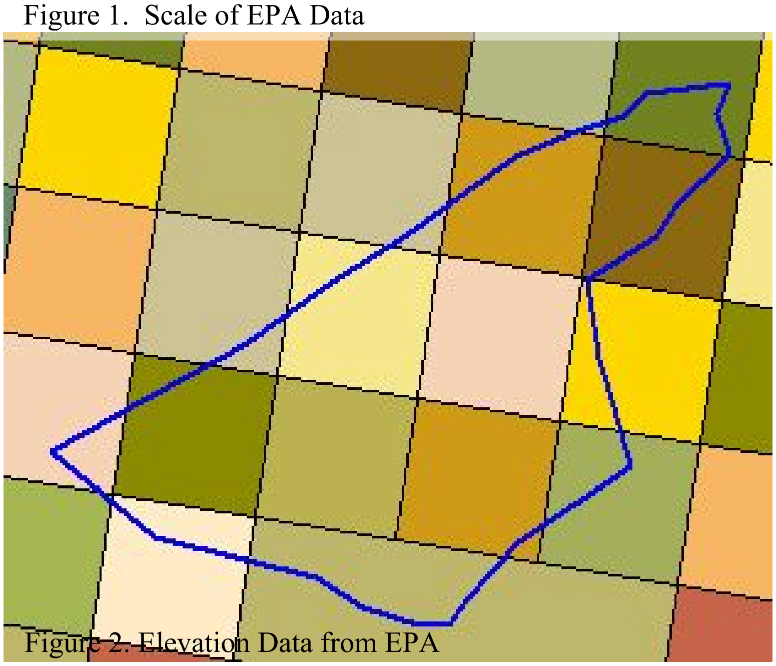

Figure 2. Elevation Data from EPA

On examination, however, the data only appeared useful at the kilometer or larger scale. Figure 1 illustrates the scale of the downloaded data contrasted with the scale of the study watershed. It was readily apparent that the large scale, low-resolution data were unacceptable. For example, the digital elevation model reported only eight different elevations within the watershed. That model used a cell size of 300 square meters, which does not capture the true nature of this watershed. Figure 2 illustrates this problem. Similarly, the soils database listed the entire area as a single soil series, which also was unacceptable.

While finding broad data was not difficult, the problem of getting sufficiently high-resolution data to characterize the water-shed remained. Unfortunately, developing the topographic, soil, and land use databases did not prove as simple as

4 Any products mentioned or used do not constitute any endorsement by The University of Tennessee or the authors.

building the Watts Bar database provided by the EPA.

TOPOGRAPHY

Since the EPA data found on the web was not very useful in this investigation due to the relative scale of the information, the focus of the search shifted to finding or developing a database appropriate to the scale of the Sanford watershed. There were three sources of topographic data that were investigated: smaller scale DEM's, GPS data, and digitized USGS quad sheets.

Having decided that the intermediate scale map was not going to work for the watershed in question, the next step was to find a DEM with a smaller scale. For this purpose a 7.5 minute DEM would have been very useful. Finding a usable map at this scale turned out to be a difficult and confusing process. Essentially there is no easy way to obtain these maps short of buying them from the USGS. There are sites on the Internet where you can download 7.5 minute DEMs, but the files are in a format that is difficult to understand and apply to ArcView. Currently a standardized format for transferring spatial data is being developed known as the Spatial Data Transfer Standard or SDTS, but to date this standard has not been fully implemented. One of the goals of this investigation was to find data sources that were accessible and simple to use. Downloading DEMs did not meet these criteria.

Another possibility for developing a database was to collect data and develop a new map. With the advent of GPS this possibility has become much more practical. Data collected with a GPS unit can be exported into ArcView, where it can then be used to develop a topographic model.

Before data was collected, several decisions had to be made. The first question was how should the data be collected? Since single family residences essentially cover the watershed there is a fairly comprehensive street network. Therefore we used a rooftop antenna to receive the data as a vehicle was driven over all the streets in the watershed. Data points were collected at a rate of one per second. Three independent trips were made over the same streets so that an average could be calculated. This would insure that systematic error within the GPS system could be minimized.

After the data was collected and downloaded into the computer, the data had to be manipulated in ArcView before it could be used. The first step was to differentially correct the data. The next step was to "clean up" the data. This process involved identifying and eliminating error points from the GPS data set. We then averaged the points from each of the three trips. Once the data had been processed, it was used to develop a topographic map using ArcView's built in interpolation routines.

The first interpolation method that was tried was an Inverse Distance Weighted (IDW) method utilizing a radius of 225 meters and a power of 1. Basically, it interpolated an elevation value for a particular point based on the elevations of known points within a 225-meter radius.

The map created using this method did not accurately represent the surface of the site. This map had an elevation difference from the highest point to the lowest point of about 75 meters, whereas the actual elevation variation at the site is about 90 meters. The IDW interpolation essentially "flattened out" the map. The radius had to be set so high that quite a few points are taken into account when figuring each cell. This produces an averaging effect that moderates the highs and the lows.

Since the IDW calculation did not return the desired result, a spline interpolation was tried. Though sometimes more difficult to manage, a spline can produce accurate results. Basically, a spline interpolation evaluates all the elevation points and uses a polynomial equation to fit a contour line across the surface.

Unfortunately the results of this model were also unsatisfactory. The spline function did produce an undulating surface that was more characteristic of the site, but there were some problems. The calculated surface had several areas where there were unusual depressions. This was most likely caused by a combination of the data collection method and the spline function itself.

Overall, the maps made from the GPS data did not work very well. Does this mean that the GPS points were wrong? No, in fact the GPS data collected were quite accurate. The problems arose when the data were analyzed in

ArcView. The method in which the data was collected (continuous data points) made it difficult to interpolate. If we had had a grid of data points as opposed to the "lines" of data points that were collected, the interpolation methods may have worked much better. All this illustrates that the data source and the form in which data is imported will have a definite effect on ArcView's ability to accurately process information. A possible solution to the problem would be to go back to the site and take discreet point data as opposed to continuous data. Stopping the vehicle at important locations – hilltops, valleys, slope changes, etc. – would produce a data set that would be easier to interpolate.

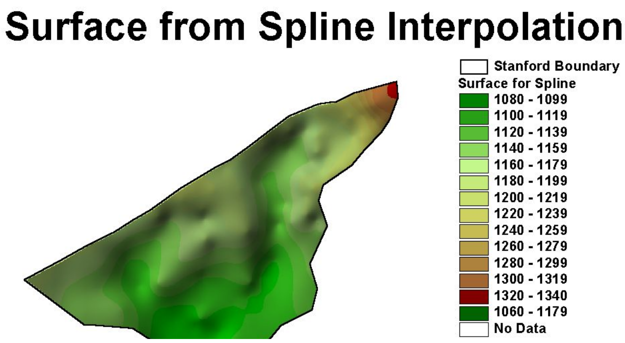

Figure 3. Surface from Spline

So, having decided that the first two methods did meet our needs, a third data source was considered. Probably the most common reference for determining the topographic features of an area is the USGS 7.5 minute quad sheet. For the most part, quad sheets are accurate representations of the earth's surface. They do have imperfections, but for the purposes of this investigation it will be assumed that the topography represented by the quad sheet is accurate.

In order to develop a data set that could be used in ArcView to generate a surface, points from the quad sheet were entered with a digitizer. Using the digitizing extension along with an electronic drawing board, several points were entered for each contour. Each point was given an elevation so that the computer would be able to create a three dimensional model. Once a sufficient number of points were digitized, an interpolation method was chosen. For this data set 4 different interpolations were run. We visually compared the resulting maps and determined that the spline interpolation returned the most accurate result (see Figure 3).

Figure 4 illustrates one of the ways that ArcView could be quite useful in hydrological analysis. The flow path from any point on the watershed can be calculated by selecting that point. ArcView then calculates the path that water will take to reach an outlet. In this case two points were selected – one at the top of the hill in the northeast corner and one at the top of the ridge on the western end of the watershed. The black dots indicate the selected points. The black lines then trace the path the water will take to reach the outlet. ArcView's estimation compared very well with reality. This tool could be quite useful in determining times of concentration or flow distances for use in hydrologic equations such as the Rational Equation.

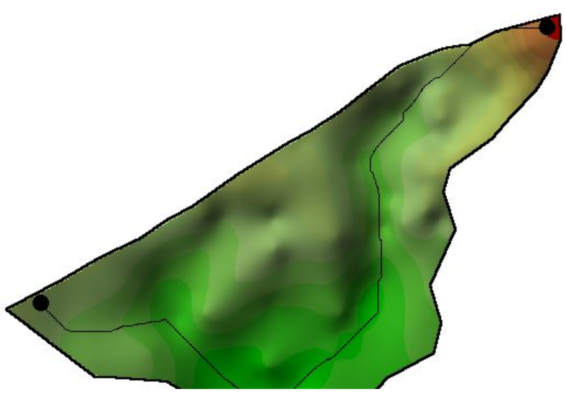

Figure 4. Flow Paths

This analysis is only the beginning of what ArcView can do. There are numerous other functions built into the program that can be used to analyze spatial variation. This flexibility makes ArcView quite powerful.

SOILS

Once we built the topographic database, the next step was to gather the soil data. First, we tried to obtain a digital form of the Knox County Soil Survey from the NRCS; however, the map is only in paper form. Although we could have digitized the relevant sections, we decided to try a different method to further investigate ArcView. Our first step was to scan a 2.5 min^2 section of the map. After verifying there was no distortion, the scanned image was opened in ArcView. Using the soil map image as a background display, we traced polygon shapes of the different soil type boundaries using ArcView's drawing tools. The soil information from the soil survey was then entered into a database table associated with the drawing.

At this stage, the new soil image was just shapes representing soil types and had no geographic coordinates or dimensions. To set the drawing to scale and give it geographic coordinates we identified similar points representing the same physical location on both the drawing and a map. We then used a polynomial equation to fit the drawing to the map. Basically, this turned the soil drawing into a map with geographic coordinates, and accurate lengths and areas. The error generated by this method was relatively small (9.48 map units).

While the EPA soil database indicated a single soil series, the county soil survey showed 17 different soils. The contrast in resolution or detail makes a difference in the Sanford Watershed study since the soil characteristics heavily influence the watershed hydrology and therefore affect runoff.

LAND USE

The City of Knoxville GIS Department has a land use designation for parcels within its system. However, Knoxville uses an Intergraph GIS system and the data is not readily transferable to ArcView. Therefore, we obtained a paper land use map from a previous study on the Sanford Watershed. After ground-truthing the map, we converted it to a digital form using the same techniques used for the soil map.

With the land use data in digital form we were able to classify small and difficult to measure areas. By drawing polygons over roads we were even able to get accurate measurements of paved areas. Figure 5 shows a gray scale illustration of the land use classifications used on the watershed.

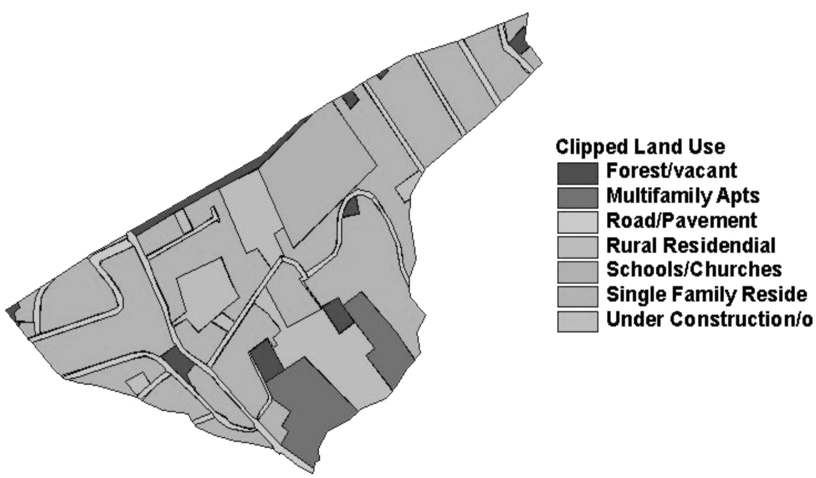

Figure 5. Land Use

DISCUSSION

There are both positive and negative aspects in using ArcView. On the negative side, we had a difficult time finding high-resolution data, managing software instability, and accommodating the long learning curve.

As with any investigation, one's deductions can only be as good as the information from which they were made. Finding the usable data and then applying it within ArcView became the most difficult task in the process of developing these models. The EPA data was not difficult to find and easily applied in ArcView, but clearly the database was not sufficient to accurately characterize a 178 acre watershed. We found that high-resolution data, if available, is in a difficult to use format. However, with the advent of SDTS and similar standards the availability of usable data should increase.

Another problem we encountered in this investigation was in the instability of ArcView. For example, file management was not efficient. This made it difficult to copy or transfer projects between computers or work sessions. Also there were unexplainable software crashes and printing problems.

Another negative aspect of using a GIS is the learning curve involved. It basically took a semester-long course to begin to feel comfortable using the program. The learning curve should decrease as the technology becomes more user friendly. While using a GIS doesn't seem to save time in the short term, it allows more flexibility to manipulate data.

ArcView allows powerful analysis of the spatial data. While the maps produced are not more accurate than the source data, they are more easily manipulated. For example, figure 5 illustrates expected high runoff areas based on topography, soil types and land use. This map was developed using a spatial query in which all three levels of information were considered. We also limited our query to those areas within 50 meters of a stream. The gray areas represent areas of high runoff potential. This allows us to pinpoint areas within the watershed that may require special management practices. Using this utility we performed spatial queries that would not be possible with paper maps. The real power of ArcView is how it analyzes spatial data and presents them in a visually understandable way.

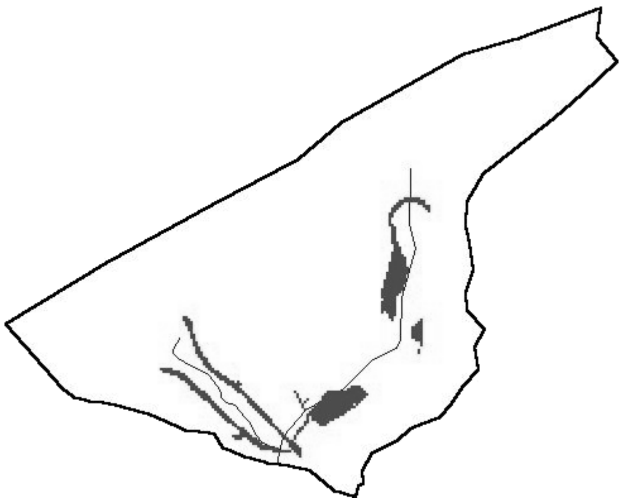

Figure 6. High Runoff Areas Within 50 Meters of a Stream

CONCLUSION

At the outset of this investigation there were three questions that we wanted to answer:

1. How easy are they to use?
2. What are the steps necessary to create a database?
3. How well does the GIS model what actually exists?

Even with difficulties, GIS systems are very powerful tools that are well worth the time to learn how to use. There is no doubt that they are here to stay. The amount of data available in an easy to use format is rapidly expanding. Also GIS systems are quickly becoming easier to use. As the ease of use and the amount of information increases, GIS applications such as ArcView will become an even more important tool for the hydrologist.

Developing a database is the most challenging aspect of using a GIS. As discussed, there are several steps necessary to complete these procedures and often this is a frustrating task. But once a usable database is complete, the power of the software can be used to analyze the data in ways not possible with traditional maps.

Finally, we did not find that using a GIS significantly improved our map accuracy. In fact, land areas determined using a planimeter were virtually the same as those calculated by ArcView. This was expected since our data sources were paper maps. The GIS generated maps could not be more accurate than the source data. But, the GIS greatly increased our power to analyze data. We were to overlay and combine spatial information quickly and easily. Learning to use a GIS system can be complicated and time consuming the benefits of working with data in a digital form far outweigh the drawbacks.