VIRGINIA WATER RESOURCES RESEARCH CENTER

VIRGINIA WATER RESEARCH SYMPOSIUM 2002 DRINKING WATER SUPPLIES ASSESSMENT AND MANAGEMENT STRATEGIES FOR THE 21ST CENTURY

PROCEEDINGS

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A copy of this proceeding is available on our website
Virginia Water Resources Research Center
10 Sandy Hall
Blacksburg, VA 24061
(540)231-5624
FAX: (540)231-6673
e-mail: water@vt.edu
website: http://www.vwrrc.vt.edu

Tamim Younos, Interim Director

PROCEEDINGS

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DRINKING WATER SUPPLIES ASSESSMENT AND MANAGEMENT STRATEGIES FOR THE 21st CENTURY

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VIRGINIA'S APPROACH TO SOURCE WATER PROTECTION

Christopher D. Adkins
Geologist Supervisor
Virginia Department of Health
Division of Drinking Water
1500 E. Main St. RM 109
Richmond, VA 23219
804-786-5568; fax 786-5567
cadkins@vdh.state.va.us

KEYWORDS: source water protection

ABSTRACT

Source water protection takes many forms in the Commonwealth. The Virginia Department of Health, Department of Environmental Quality, and Department of Conservation and Recreation are just a few of the agencies that are directly or indirectly involved in source water protection. Virginia has not adopted one method for implementing a Source Water Protection Program, but instead uses the framework of source water protection and lets the local decision-makers determine what level of source water protection meets their needs. The concept, definitions, authority, and components will be discussed.

UTILIZING VDH'S DIGITAL SOURCE WATER ASSESSMENT DATA TOWARD SOURCE WATER PROTECTION.

David L. Bradshaw
GIS Manager
Olver Incorporated
1116 South Main Street
Blacksburg, Virginia 24060
(540) 552-5548, Fax (540) 552-5577
dbradshaw@olver.com

Douglas F. Canody, PE.
Engineering Services Manager
Washington County Service Authority
P.O. Box 1447
Abingdon, Virginia 24212-1447
(276) 628-7151 (ext. 214), Fax (276) 628-3594
dcanody@wcsa-water.com

KEYWORDS: Source Water Assessments, Source Water Protection, and Geographic Information Systems (GIS).

ABSTRACT

Section 1453 of the 1996 Amendments to the Safe Drinking Water Act (SDWA) requires each state to develop Source Water Assessments (SWA) for every public water system. This involves delineating the boundaries of assessment areas, inventorying Land Use Activities (LUAs) and Potential Sources of Contamination (PSCs), and making the information easily accessible to the general public. A SWA may be viewed as a tool for increasing public awareness about water quality and as a building block that initiates the ultimate effort of Source Water Protection (SWP) activities.

To comply with the May 2003 deadline, the Commonwealth of Virginia, through the Virginia Department of Health (VDH), developed its SWA program in October 1999. The VDH has spent a large amount of public money gathering critical information regarding public source waters. The majority of the data collection was performed internally. There were, however, several grants awarded to individual or groups of cooperating water utilities allowing them to have more direct participation in the process. Many utilities contracted with professional engineering firms to coordinate additional data collection and prepare the SWA. Regardless of who collected the data, it was compiled into a VDH Geographic Information System (GIS) and used to rank the potential threats that the LUAs and PSCs imposed on the various source water intakes throughout the watersheds of Virginia.

So what will happen when the SWA reports are on the shelf? The VDH reports and data sets are just the tip of the iceberg. The data is there and available for those interested. During the

presentation, examples will be given of three utility companies who are using the data to develop building blocks toward source water protection. The examples include:

- How utility companies are specifically using their reports and the GIS data viewer.
- How to store this information in your own user-friendly custom GIS.
- How to add travel-time models to better identify the cause and effects of a LUAs and PSCs on your water quality.
- How to keep your SWA data up-to-date.

A USABLE AND AFFORDABLE PRODUCT: A PLEA FOR CONSULTANT DERIVED GEOLOGIC DELINEATIONS OF DRINKING WATER SOURCES IN KARST TERRAIN THAT DO NOT GATHER DUST

Josh Rubinstein
Ground Water Technician
Virginia Rural Water Association
2845 Shiffletts Mill Road
Crozet, VA 22932
434-964-1072
josh@bzfoundation.org

ABSTRACT

Following the Environmental Protection Agency's suggestion, the Virginia Department of Health in its Source Water Assessments has delineated a circumference around a wellhead as the source area for its water. While such delineation may have practical use in the sand and gravel aquifers of the shore, they have little value in forming a source water protection plan in karst aquifers. Communities, who are living on karst terrain and are concerned about the protection of their drinking water, have hired consultant geologist to delineate the source area for their wells. The resultant products have varied in quality and price. The first part of this talk will review some of these consultant reports.

Almost all consultants' reports have delineated source areas at such a vague resolution that they are impractical for communities in devising a Source Water Protection Plan. The purpose of this paper is to begin a discussion between consultants and communities on how to prepare a usable and affordable product. The author proposes a basic delineation for a well's source area in a karst aquifer. Dye tracing would be used to identify discrete inputs into the system. A simple water balance would be used to determine how much of the water at the well or spring is accounted for by the discrete inputs. Analyzing the water for chemical signatures of its origin would be used to track down non point sources. A professional trained in karst hydrology would analyze the data.

GIS APPLIED TO VIRGINIA'S SOURCE WATER ASSESSMENT PROGRAM

Steve Sedlock
Virginia Department of Health
Keane, Inc.
Division of Drinking Water
1500 East Main Street, Suite 109
Richmond, VA 23219
804-371-2700; Fax: 804-786-5567
ssedlock@vdh.state.va.us

KEYWORDS: Source Water Assessment Program, SWAP, GIS, Virginia, Virginia Department of Health, ground water, surface water, water supply, drinking water, mapping.

ABSTRACT

Virginia's Source Water Assessment Program (SWAP) requires automated, high-speed processing involving spatial analysis, polygon overlay, buffering, geographic feature selection, and automated mapping/reporting. Geographic information system (GIS) technology is designed for this type of work. GIS applications, based on the SWAP criteria, are in place at the Virginia Department of Health's (VDH) Central Office in Richmond. These applications include field map and report generation, data entry, quality control, assessment area viewing, final map and report generation, spatial analysis, feature processing, and other functions.

WATERSHED PROTECTION FOR DRINKING WATER SUPPLIES: A REGIONAL TOOL

Scott R. Emry
Shonia M. Holloway
Hampton Roads Planning District Commission
723 Woodlake Drive
Chesapeake, VA 23320
757-420-8300; FAX: 757-523-4881
semry@hrpdc.org

KEYWORDS: drinking water, watersheds, database, GIS

ABSTRACT

The protection and management of drinking water supply watersheds is crucial for the development of successful communities. Water supply watersheds are essential to providing communities with a safe and reliable source of drinking water and their protection is critical for the health and safety of the public. A successfully managed and protected watershed can also provide the community with recreational opportunities, wildlife habitats, developmental opportunities, economic benefits and a healthy and pleasing environment for the surrounding residents and businesses.

In the first regulatory efforts to recognize the importance of developing programs to protect drinking water sources, the 1996 Amendments to the Safe Drinking Water Act require that all states develop a Source Water Assessment Program to determine the susceptibility of all community drinking water sources to pollution. The Hampton Roads Source Water Assessment Program (HRSWAP) focused on eight water utilities in the Hampton Roads area of Virginia. The 8 water utilities are comprised of 21 surface water sources, 31 conjunctive use wells, and their associated watersheds. The water supply watersheds vary in character from rural to urban and from tidal surface water to ground water. The source watershed management and protection techniques needed depend largely on the existing and projected land uses, which vary widely from agricultural and low density housing to high density industrial and commercial uses with high percentages of impervious surfaces. Multi-jurisdictional watersheds and complex purveyor and host relationships further complicate protecting water supply watersheds in the Hampton Roads area.

The HRSWAP is a foundation for future water supply watershed protection measures in Hampton Roads. This presentation will focus on the HRSWAP Data Management System as a tool to support water supply watershed management and protection. This case study will provide valuable insights for using the Virginia Department of Health's SWAP data in other communities within the Commonwealth of Virginia.

WELL AWARE: AN INNOVATIVE PROGRAM TO HELP RESTORE VIRGINIA'S WATERS

Rob Arner
Pollution Prevention Specialist
Southeast Rural Community Assistance Project, Inc.
1925 Ridge Hollow Rd
Edinburg, VA 22824
540-094-3707; Fax 540-984-3915
rarner@shentel.net

ABSTRACT

Southeast Rural Community Assistance Project, Inc. (Southeast RCAP) has developed a program to reduce agricultural and homeowner pollution as part of an EPA Region III Environmental Justice Pollution Prevention Grant. This program, called "Well Aware", encourages homeowners and farmers to initiate water quality improvement efforts in the Smith Creek watershed located in Virginia's Shenandoah and Rockingham counties. Southeast RCAP's program examines rural home site and farmland use impacts on local groundwater and surface water sources and provides a corrective action plan for pollution prevention where necessary. This pollution prevention program includes citizen water sampling of household drinking water and a surface water sampling program, farm (Farm*A*Syst) and homeowner (Home*A*Syst) risk analysis, technical assistance and public educational efforts. Also, Well Aware promotes best management practices in a karst geographic region, which is particularly sensitive to land use activities. Program adaptations were implemented as a result of the lessons learned from the Holmans Creeks watershed restoration efforts and during the course of this grant.

ENGAGING PUBLIC PARTICIPATION

Household water testing prompts citizen action by providing direct feedback as to the quality of their water. When people are provided with their household drinking water quality results and educated on what these results mean, they are motivated to change their behavior regarding land use and water protection measures. A watershed cannot be managed and fully protected without awakening citizens to the relationship between daily land use practices and their direct impact on water quality. Southeast RCAP's Well Aware program raises the participants' questions and concerns about their individual water and waste issues and their land use activities and as well how they may profit from pollution prevention from both a health and financial standpoint. For example, a large sector of the program's participants was unaware that they must pump out their septic system and that the lack of maintenance may contaminate their drinking water. Some participants had buried wellheads and poorly situated springs due to old construction and did not know of the preventive measures to keep surface water from contaminating their well or spring. Well Aware educates that the hydrologic process takes hundreds of years to purify water while human activity can alter this process in just minutes. The behavior and actions of each resident of a watershed is an integral part of either improving or degrading the quality of both the groundwater and surface water traveling within the watershed. The increasing population, severe drought conditions, and increased land use activities and development place an enormous pressure on a limited and finite resource, water. Critical to local watershed efforts is changing people's behavior to champion water protection, whether groundwater or surface water.

The Well Aware Program provides public participation, which is fundamental to improving our water quality. There is growing agreement that long-term environmental protection can only happen if citizens are receptive and engaged at the local level. Southeast RCAP's partnership with volunteer citizen monitoring groups such as the Friends of the North Fork of the Shenandoah and the Well Aware Household Drinking Water Testing program is a successful example of engaging this type of public participation.

Getting people involved not only will result in better land and resources management but also has a domino effect. The process of protecting and managing water resources can also be viewed as a community economic development endeavor. Federal, state and local government budget cuts offer us an ingenious opportunity to develop low cost water quality initiatives by defining strategic private/public partnerships. Yet, we often do not utilize appropriate tools and partnerships to work with local citizens in water protection initiatives. The Southeast RCAP Well Aware Program engaged the Smith Creek Watershed community and local agencies in water quality protection initiatives.

Southeast RCAP developed partnerships to successfully implement this program. Some of our partners include: the Environmental Protection Agency; the U.S. Department of Agriculture's Natural Resources Conservation Service; the Virginia Department of Conservation and Recreation, the Department of Environmental Quality, Virginia Department of Health, local county health departments; local Soil and Water Districts, citizen monitoring groups; Virginia Tech Cooperative Extension Service; and local social service agencies. Coordinating pollution prevention and watershed initiatives with myriad organizations had its challenges. However, by creating such multi-sector partnerships and piggybacking on existing efforts provided 1) a sharing of resources, 2) introduced key players already working in the watershed to new potential partners and their resources and 3) provided Southeast RCAP a footing in the watershed to perform program work and 4) partners in which we can collaborate on future efforts. Southeast RCAP has found that this type of relationship has been an effective way to meet our overall mission of working with rural communities to assist in resolving their water and waste problems

SOUTHEAST RCAP'S WELL AWARE APPROACH TO PUBLIC INVOLVEMENT

Participation is essential to the proper management of water. The Well Aware program provided a $200 hundred-dollar water test for only five dollars to local watershed citizens. The Well Aware program included 1) public speaking, news articles, press releases, 2) workshops on topics such as pollution prevention, surface water sampling, water sampling, 3) rural farm and home site land use evaluations (Farm*A*Syst &

Home*A*Syst) with a survey geared to identify potential sources of pollution and 4) a corrective action plan to correct potential sources of pollution. Insightful survey questions encourage residents to fully examine how they use their land, and manage their wastes.

Information in itself often does not have effect upon behavior nor does education necessarily change attitudes or behavior (McKenzie-Mohr & Smith 1999). Southeast RCAP has determined that household water testing provides a springboard for local residents to become interested and concerned parties in the local watershed and protection measures. Southeast RCAP held two household water-testing events in conjunction with our partner the Virginia Tech Cooperative Extension Service. We send out mailers to watershed residents and made local arrangements for the meetings to provide water sample kits and sampling instruction. Virginia Tech, our partner, provided lab services, collected and summarized data in a database, and presented results of data at two subsequent workshops. At these workshops, participants were also educated on pollution prevention and in some cases signed up for the Farm*A*Syst evaluations. Direct participation of citizens in sampling their own water was a key element to engaging local residents in becoming more aware of water quality and pollution prevention measures and as well as participating in this program. In addition, asking participants their opinions and working with the citizens' one on one to correct pollution problems on their own property helped them to build greater decision making capacity. Building this type of capacity is more likely to lead to change of behavior, as citizens develop, learn, and test new skills themselves. By facilitating such a dialogue with local citizens whether through water testing, farm and home site evaluations, or workshop participation these endeavors increased water protection awareness.

DEVELOPMENT OF STAKEHOLDER GROUP

In December, Southeast RCAP performed extensive planning, development, and outreach to solicit diverse partners to attend a kick-off meeting of this grant. Southeast RCAP talked and contacted by mail over 50 individuals regarding this Environmental Justice Pollution Prevention (EJPP) Grant. On January 9, 2002, 18 stakeholders representing diverse but interested organizations came together in New Market, Virginia, to provide guidance and assistance to key facets of this project.

Topics covered at this meeting included the following: selection of the watershed, grant purpose, Farm*A*Syst implementation and evaluation process, water quality sampling, wells and surface water, information dissemination, state and federal agricultural cost sharing programs, and workshops. This core group acted to provide project direction and individually provided feedback and expert advice regarding specific details to this project.

FARM*A*SYST EVALUATIONS PERFORMED

A total of 6 farms and 12 homes have been evaluated thus far using the Farm*A*Syst program. This totals 18 evaluations completed out of the 10-20 sites proposed in the grant. The Farm*A*Syst program (<u>Virginia Farmstead Assessment System</u>, Pub. 442-900, Virginia cooperative Extension) was difficult to implement as it was too complicated in nature and a number of modules (Module No. 11-Milking Center and Wastewater Treatment Management) did not apply in most cases. The program shifted to using the Home*A*Syst (Home*A*Syst An Environmental Risk-Assessment Guide For The Home, ISBN No. 0-935817-30-1, University of Wisconsin System) and the Farm and Home Water (Protecting Your Water Through a Farm and Home Assessment, Virginia Cooperative Extension, DRAFT) manuals together. Southeast RCAP worked closely with the Virginia Tech Cooperative Extension staff regarding the implementation of the household water testing events and the farm and home site risk analysis evaluations for pollution. Owner confidentiality was safeguarded with respect to both the water tests results and the risk analysis evaluations. This was also important to citizen participation.

The Farm*A*Syst program was used to evaluate several farms. As mentioned above, due to the nature of the farming types, most modules did not apply. In addition, a major avian flu outbreak on poultry farms prevented staff from evaluating some farm candidates. Hence, providing risk analysis evaluations to homeowners was easier to implement. Eventually, the draft Virginia Farm*A*Syst manual was modified and a risk analysis method was developed from the sources mentioned above. Distinct questions and answers in each of the following areas of analysis were utilized:

- Identification of soil utilizing county soil and drastic index maps
- Examination of physical characteristics of the site
- Drinking Water Well Management
  1. Well Location
  2. Well Construction
  3. Maintenance and Water Testing
  4. Unused Wells
- Household Wastewater: Septic Systems and Other Treatment Methods
- Managing Hazardous Household Products
- Yard and Garden Care

The success of this portion of the Well Aware program became identifying and asking the pertinent questions for each individual site. Some typical questions included:

- Is the soil sandy or gravelly?
- Does the well casing extend less than 12 inches from the ground?
- Is there a depression around the well casing?
- Does the well cap or casing have any cracks or holes?
- Is there an on-site wastewater disposal system?
- Has it been longer than three years since the septic tank was cleaned out?
- Is food waste, grease, oil, or leftover household cleaning materials disposed of down the drains?

Responses indicating there may be a potential for pollution or a need to assist with pollution prevention measures were used to provide specific information to assist the owner in resolving the problem and as well an action plan was developed and provided to reduce pollution risk. Most participants had a good environmental awareness of pollution prevention. On the other hand, many of the questions were helpful in getting the participants to think in a risk reduction mindset. Most of these assessments did provide participants with useful advice and technical information. There was much favorable comment of this process. Below is an example of some good housekeeping suggestions provided to participants:

TABLE 1: SUGGESTED BEST MANAGEMENT PRACTICES

- Prevent entry of surface water to your well to protect it from contamination with bacteria. A properly protected well is evidenced by well casing at least 12-inches or more above the surface of the ground and the ground sloping away from the well. The top of the casing should have a tight-fitting well cap with a sanitary seal. Also the well casing should be well sealed with cement grout to a necessary depth to prevent rainwater from contaminating the well.
- A properly protected spring has a well-protected and sealed spring box. The spring box is located so that surface water does not run into it. It is developed underground and the water typically channeled to the sealed spring box via a pipe.
- Make sure your rain downspouts and animals are not located or housed in close proximity to your well or spring.
- Dispose of household hazardous products such as used motor oil at local recycling centers such as auto part stores or auto repair centers.
- Use limited amounts of fertilizers, pesticides and compost.
- Plant buffer or filter strips near water and prevent erosion.
- Waste less, reduce and reuse water.

Twelve of the Farm*A*Syst participants were recruited as a result of the water testing workshops. Outcomes from these evaluations resulted in participant's having their septic tanks pumped, putting up animal fencing, uncovering their wellheads, securing their well caps, and purchasing water treatment systems.

As part of the Farm*A*Syst evaluation, Southeast RCAP requested that participants answer both pre and post survey questions. Four additional questions are posed in the post survey to evaluate performance in providing the Farm*A*Syst assessments. Seven participants made highly favorable comments while all participants indicated their approval of the Well Aware technical assistance.

In addition, this project was fortunate to participate with two on-farm demonstrations thanks to the Friends of the North Fork and the Potomac Conservancy. Both demonstrated the benefits of stream bank stabilization, riparian buffers, filter strips, and wildlife habitats.

WATER QUALITY SAMPLING PERFORMED

Household Drinking Water Wells/Springs Testing Program

Southeast RCAP contracted with the Virginia Tech Cooperative Extension to deliver the Well Aware household water testing workshop in the Smith Creek Watershed to homeowners using private water systems. The purpose of the workshop and testing program was to 1) promote awareness of watershed and wellhead protection 2) educate safe land use activities and pollution prevention and 3) provide private household well/spring/cistern drinking water quality sampling.

In an effort to reach the low income population located in the Smith Creek Watershed, Southeast RCAP staff met with several social service agencies in Shenandoah and Rockingham counties to review the Well Aware well testing opportunities and available technical assistance grant opportunities provided by Southeast RCAP for water and onsite wastewater improvements. Most civic, town, church, and sanitary organizations were contacted with helpful information.

Two informative brochures (spring and fall events) were mailed to Smith Creek watershed residents of Shenandoah and Rockingham counties. The second mailing included an instructive flyer on how and where to safely dispose of household hazardous waste. In addition, press releases, newspaper articles and other media outreach were conducted to spread the word of a watershed household water-testing program. Two household drinking water testing programs were held in New Market, Virginia. Participants were invited to attend these educational meetings to be instructed on how to take a water sample and to receive their water sample kit. Several follow-up meetings were held weeks after the samples were analyzed to explain test results and to provide an opportunity to sign up for the Farm*A*Syst evaluation to assess their environmental risks.

The drinking samples were then taken to the Virginia Tech Cooperative Extension Service for analysis at a low cost of $5 per sample for the homeowner (Southeast RCAP paid $36 per sample). The water samples were analyzed for 14 constituents that included: iron, manganese, copper, hardness, sulfate, sodium, chloride, total dissolved solids, pH, fluoride, corrosion level, total coliform, E. coli bacteria and nitrate. Virginia Tech summarized all household drinking water quality data and information gathered from the questionnaire and provided the results. A questionnaire was also provided to the homeowner to be used to gain information regarding the taste and odor of their water, well construction, land use, and septic system information.

The results of the Spring 2002 Smith Creek Water Testing Program showed that 57% of the water samples taken tested positive for total coliform bacteria (52 of the 92 samples) and 25% tested positive for E. coli bacteria (23 of the 92 respondents). The presence of E. coli is an indication of fecal contamination and the possible presence of disease causing pathogens or organisms. The bacterial source of this contamination may come from inadvertently contaminating while sampling, surface water contamination due to poor well/spring construction, household plumbing contamination, or water table contamination.

Results of the questionnaire showed that 97% of the samples came from wells and 3% came from springs, which have a much higher susceptibility to bacterial contamination. Respondents noted that 81% of the wells were drilled while 17% of the respondents did not know their well type and 2% were dug. Seventy-eight percent (78%) answered that their wells were deeper than 50 feet. Seventeen percent (17%) of those responding indicated that their well was installed before 1970, while 67% had their well installed between1970-1989 and 17% participant's wells were constructed after 1990. Wells constructed prior to 1981 may not have been sealed with grout and may be vulnerable to surface water contamination. Eighty-six percent (86%) of the respondents indicated that the area around their well or spring properly sloped to drain surface runoff away from their water supply. Sixty-five percent (65%) of the participants indicated that they have had their septic tanks pumped every 3-5 years while 32% said they did not have their septic tank pumped during this time period. Thirty-six percent (36%) of participants have septic systems 15 years old or less, 32% have septic systems between 16-30 years old, and 31% of respondents have septic systems 30 years and older. Finally 10% of the respondents had unused wells on their property. The correlation between contaminated wells and some of the responses for which may be positive for the potential of pollution to a well or spring has not been evaluated.

Once the water tests were performed, the homeowners were sent a copy of their results. All results are confidential since protecting the names of participants is critical to the success of this program. Twenty-one phone calls from participants regarding the test results were answered.

In addition to the questionnaire as mentioned above, a post evaluation was provided to workshop participants after they received sample results to determine if they had gained additional knowledge regarding their household water supply via the workshop. Only 22 of the 92 participants participated in this survey. Finally, information was disseminated to participants regarding water quality, water treatment, pollution prevention, land use and karst landscape was given out in context to stimulate water restoration. Another household testing program is set again for New Market on October 7th, 2002.

Surface Water Sampling

Southeast RCAP, in conjunction with Friends of the North Fork of the Shenandoah (The Friends) and the Tenth Legion Ruritans, has established a surface water-sampling regime as part of this grant. Surface water samples are taken once each month at four locations for six months from May to November. The Friends sample locations were previously established and these grant dollars are being used to continue existing sampling efforts. The Southeast RCAP sample sites are the same location as the Friends sample sites and included sampling for fecal coliform, an additional constituent, at four of the sites for six months.

Information Disseminated and Other Workshops

Information regarding pollution prevention, land use, water quality and water treatment in the form of mailers, brochures, flyers, booklets and, other printed materials have been disseminated in the Well Aware household water testing workshop, in local newspapers, editorials and during the course of the Farm*A*Syst evaluations. Three direct mailings were made to watershed occupants. Two were for water testing workshops; one included pertinent household hazardous disposal events and the third septic and water

TABLE 2: SMITH CREEK WATERSHED SURFACE WATER SAMPLING FOUR SITES

Parameter	Responsible Party	Frequency
Water Temp	The Friends	Monthly: May-Nov
Dissolved Oxygen	The Friends	Monthly: May-Nov
Orthophosphate	The Friends	Monthly: May-Nov
pH	The Friends	Monthly: May-Nov
Ammonia nitrogen	The Friends	Monthly: May-Nov
Nitrate-nitrogen	The Friends	Monthly: May-Nov
Phosphate	The Friends	Monthly: May-Nov
Fecal coliform	Southeast RCAP	Monthly: May-Nov

improvement information. Various outreach materials to stimulate public conversation and citizen participation were developed. Additional information will be provided during the course of the project at future workshops and during additional Farm*A*Syst evaluations. Other numerous types of educational outreach efforts was provided to numerous county meetings, public hearings, and conferences regarding what homeowners can do to reduce pollution.

Workshops not only included the two above-mentioned household water-testing workshops but also include the following:

- *Bugs and Bacteria* workshop for benthic testing and E-Coli testing (Coliscan) represented a low cost example how citizen can became easily trained to monitor surface water. Held on **August 3rd**
- An additional Well Aware Household Water Testing workshop is being conducted on **October 7th**,
- *Well Care Forum* to be held in Staunton, Virginia on **October 30th**.
- A community event with The Friends in Shenandoah County will feature groundwater family education on **November 3rd**.
- A workshop will be held with the Shenandoah County Cooperative Extension Service for Pesticide Recertification Training, on **December 5th**.

CONCLUSION

Working one on one to educate the public with respect to pollution prevention activities, watershed protection and water quality is effective but somewhat costly. Utilizing partners within a community and developing tools, such as the Well Aware Household Water Testing program, can not only successfully engage citizens but also reduce costs as a result of shared resources. The development of better and more engaging self-help tools such as a revised Farm*A*Syst manual for the individual homeowner which is much less complex, will facilitate the public education process at a reduced cost. In addition, the use of interactive web sites, workshops, and other forms of training and technical assistance support may be beneficial. The protection of drinking water is central to economic and community development, agriculture and natural resources management and public health. Behavioral relationships can be developed, cultivated and fostered in the local watershed to cause citizens to become active participants in protecting their environment. Developing programs that change citizen behavior is necessary if we wish to restore Virginia's waters. Every Virginian is integral to the solution to Virginia's point and nonpoint source pollution challenge. For further information refer to www.well-aware.org

REFERENCES

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EPA Region III – Lorna Rosenberg, Project Manager, and Monica Jones, Quality Assurance Officer – for assisting in technical aspects of this program.
Virginia Tech, Cooperative Extension Service – Blake Ross – for directing the household water testing program and Virginia Farm*A*Syst technical support
Friends of the North Fork – for surface water monitoring and community events.
Well Aware Project stakeholders – for assisting with guidance to accomplish grant objectives
Southeast RCAP VISTA Volunteers – Paul Moyers and Mary Corbett – for household water testing program
Southeast RCAP Program Director –Trina Mastran – for project management.

SOURCE WATER PROTECTION THROUGH LOCAL PROGRAMS, POLICIES, AND COMPREHENSIVE PLANNING

Terri Brown
Terrane Environmental Company
PO Box 2218
Weber City, VA 24290
423/378-6146;fAX: 423/247-5127
tlbrown@naxs.net

ABSTRACT

The Augusta County Service Authority (ACSA) supplies water service to approximately 25,000 customers from a varied array of sources that include 12 production wells, 3 springs, and a surface water reservoir. The ACSA maintains mutual back-up agreements with the other major public water suppliers in the county, the towns of Waynesboro, Staunton, and Craigsville, which are also dependent upon wells and springs. Approximately 68 additional community and non-community water systems serve rural schools, businesses, subdivisions, trailer parks, and campgrounds from wells and springs scattered throughout the county (SDWIS 2001). Emery & Garrett Groundwater, Inc. (EGGI) has provided technical assistance in the exploration and development of public groundwater supplies in the county since 1993.

The 1994 County Comprehensive Plan laid the foundation for a local source water protection program by recommending the designation and protection of public water supply source areas. The subsequent Master Water and Sewer Plan (CDM, 1996) reiterated the need for a zoning overlay to protect water supply sources and their critical recharge areas. As requested by the County Board of Supervisors, ACSA contracted this report to refine and detail these recommendations for inclusion in the 2002 County Comprehensive Plan (Fanfoni 2001). The current Comprehensive Plan update coincides neatly with the enhancement and local implementation of the Source Water Assessment and Protection Program (1996 Safe Drinking Water Act Amendments, Mastran 1999). Establishment of a county-wide Source Water Protection Program is one of the fundamental recommendations of the groundwater protection strategy report.

Proposed revisions to the Comprehensive Plan reflect long-range protection goals for key water supply sources, as well as those areas identified as having significant potential for future water supply development (EGGI 1995; Hinkle and Sterrett 1978). Tools available to the county include zoning overlays, special district designations, ordinances, policies, design standards, and easements (Liner et al. 1994). The ACSA must work closely with the county to develop and fully implement these tools, in addition to the procurement of source water delineation and aquifer evaluation studies, land acquisition, purchase of development rights, and partnerships with agencies, industries, and grassroots organizations. As the Source Water Protection Program develops, the ACSA will find common ground with other organizations concerned with the protection of natural resource values, farmland and forest preservation, sprawl control, and maximization of infrastructure efficiency.

SOURCE WATER PROTECTION CASE STUDY: THE TOWN OF KENBRIDGE

Albert Crigger
Source Water Technician
Virginia Rural Water Association
Rt. 3 Box 3130
Cedar Bluff, VA 24609
276-991-2011
albertcrigger@hotmail.com

ABSTRACT

This presentation will describe the steps Virginia Rural Water Association took to complete a Source Water Protection Plan for the town of Kenbridge. We started the process in the spring of 2001 and completed the plan in the winter of 2001. We used an incomplete Source Water Assessment Plan from the Virginia Department of Health, our own field research, and knowledge from local citizens to complete the plan. The plan includes: a delineation map, general geology of the area, general soil information of the area, a list of potential sources of contamination, a contingency plan, and suggestions to protect the drinking water source. A copy of the Source Water Protection Plan will be provided for participants to view.

CAP IT - A PRIVATE WELL ABANDONMENT PROGRAM

Lisa Meddin
Water Conservation Coordinator
James City Service Authority
P. O. Box 8784
757-253-6859
Fax: 757-253-6859
lmeddin@james-city.va.us

ABSTRACT

This paper provides an overview of Cap It, the James City Service Authority's private well abandonment program. The goal of the program is to help protect local groundwater resources and the Chesapeake Bay by educating residents about the dangers of old, open, and improperly abandoned wells. Under the Cap It program, the JCSA will abandon qualifying private wells at no cost to the well owner. This overview covers the goals, strategies, implementation, results, and costs of establishing and managing Cap It and provides a model for utilities to follow to establish their own private well abandonment program.

INTRODUCTION

Cap It is a source water protection program that educates James City County residents on the dangers of open, old, and improperly abandoned wells and provides free well abandonment to private well owners.

James City County is the largest municipality in Virginia reliant almost solely on groundwater for its public drinking supply. The James City Service Authority (JCSA) maintains 30 well facilities and 6 independent well systems supplying water to over 17,000 residential and commercial customers within the Primary Service Area (PSA). County residents who reside outside of the PSA rely on private wells.

The JCSA draws water from the Chickamoniny Piney Point Aquifer and the Middle and Lower Potomac Aquifers. Private wells draw water either from the shallow table water aquifer or from the Chickahominy-Piney Point Aquifer.

The JCSA estimates that the county is home to over 400 old, unused, or improperly abandoned private wells. These wells pose an immediate threat to our groundwater resources, our streams and rivers, and the Chesapeake Bay. Many private well owners are not aware that Virginia law requires wells not in use to be abandoned. Many cannot afford to close the wells, and some simply do not care.

In order to make it easy for well owners to abandon their wells, the JCSA developed Cap It, a private well abandonment program.

Goals:

1. Protect James City County's groundwater resources from pollutants and contamination via unused or improperly abandoned private wells in James City County.
2. Protect the Chesapeake Bay and local rivers and watersheds by reducing the threat of groundwater contamination.
3. Reduce the threat to humans and animals that may become trapped in an open, unused well.

Strategies:

1. Educate county residents through an ongoing public relations and education campaign
2. Use the JCSA's existing Let's Be Water Smart logo and position statement for name recognition and the Let's Be Water Smart campaign format (ads, website, etc.) as a vehicle to disseminate information. See attached examples of Water Smart material.
3. Provide free well abandonment to county residents who, upon joining the public water system or drilling a new well, agree to properly abandon their old well, giving priority to wells within 1000 feet of JCSA public wells.
4. Provide free well abandonment to county residents with an unused well on their property, giving priority to wells within 1000 feet of JCSA public wells.

IMPLEMENTATION

Successful implementation relies on an effective educational and marketing campaign to raise awareness of the dangers of open wells, and an efficient method of closing the wells. We contracted with an advertising and public relations company to help us develop the message and educational materials. We also decided to "brand" the Cap It as a Water Smart program.

1. Marketing Plan

    a. Brochure
    b. Print ad campaign
    c. PR/media relations
    d. Web page on www.bewatsersmart.org/capit with link from JCSA website on www.jccEgov.com
    e. County communications outlets including county newsletter, cable TV channel and employee newsletter.
    f. Dedicated Info Line
    g. Application Forms (hard copies and on website)
    h. Acceptance/Notification Process

2. Well Identification and Prioritization

    a. Identify Old Wells

The JCSA and the Virginia Department of Health (VDH) worked together to identify properties with unabandoned old wells. The VDH used new well and septic drain field permit records and the JCSA used new well inspection records to identify these properties.

b. Prioritize Abandonment

To best protect groundwater resources, improperly abandoned wells located within a thousand-foot radius of a public wellhead received priority. The JCSA used GIS mapping to identify properties known to contain old wells and targeted the well owners with a direct mail letter informing them of the program and inviting them to participate.

3. Abandonment

The JCSA contracted with a local well driller to abandon the wells at a fixed price per type of well. The JCSA established a scope of services, published a request for bid, hired a well driller, and submitted work orders to the well driller as applications were processed. The well driller abandoned the wells according to the state and county code, and a JCSA inspector was present at each abandonment.

FUNDING

The JCSA is committing up to $20,000 annually toward Cap It. In 2001, Cap It's first year, we applied for and was awarded $16,550 in grant monies from a 106 Ground Water Protection grant from the Virginia Department of Environmental Quality. In 2002, the DEQ awarded another $15,000 to Cap It.

BUDGET

YEAR ONE – 2001/2002	
Well Abandonment	$29,150
Marketing Plan	$ 5,850
Total	$34,191
YEAR TWO – 2003/2003	
Well Abandonment	$33,000
Marketing Plan	$ 2,000
Total	$35,000

RESULTS – 2002

In the first year, the JCSA received 83 applications. We abandoned 52 wells, with 24 already scheduled for 2003. Of the wells approved for abandonment, 62 were thirty-inch bored wells and 12 were two- or four-inch deep wells. Nine applications were rejected due to the condition of the wells.

RECOGNITION

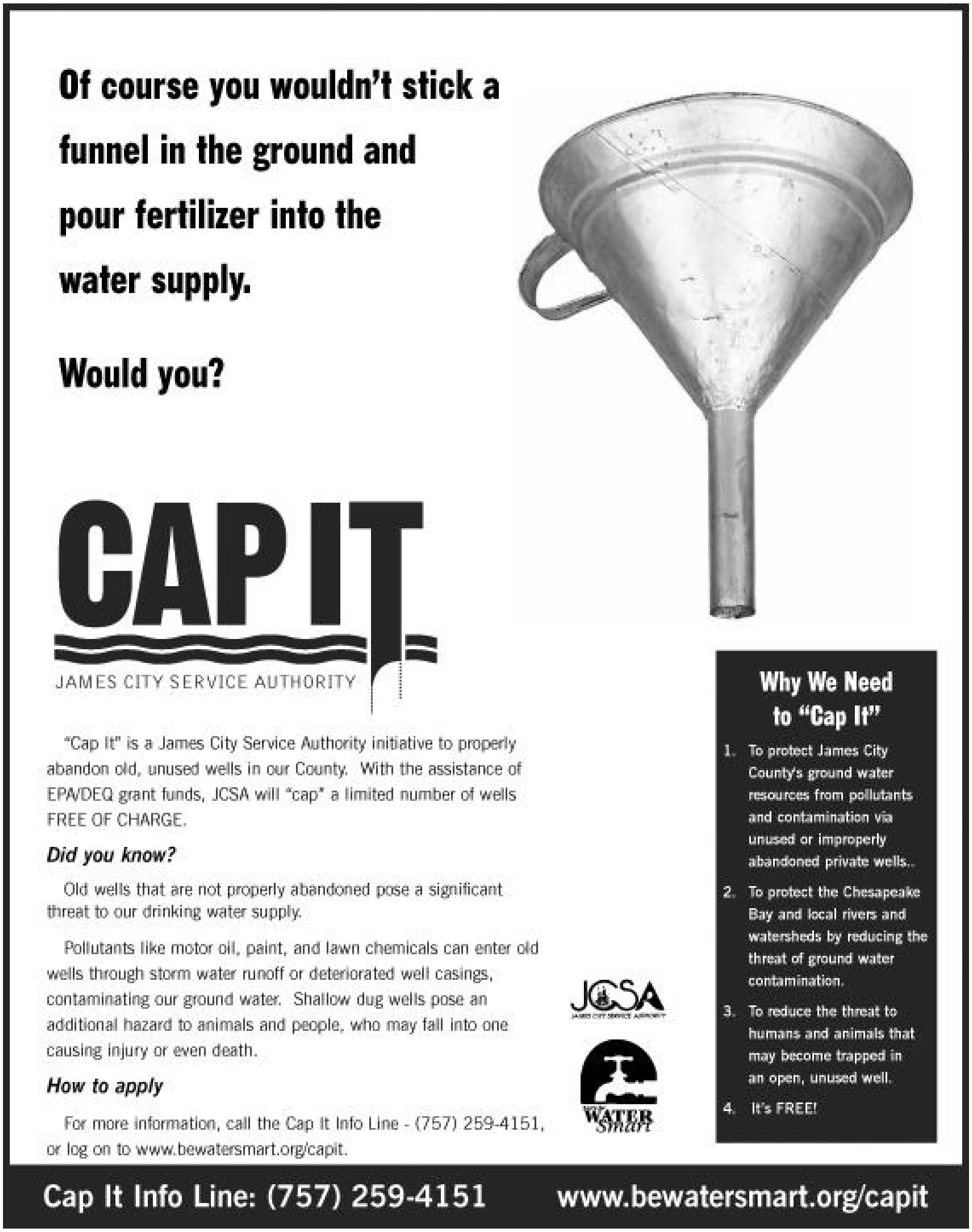
The Environmental Protection Agency for Region III awarded Cap It the 2002 Source Water Protection Award for Virginia.

LESSONS LEARNED

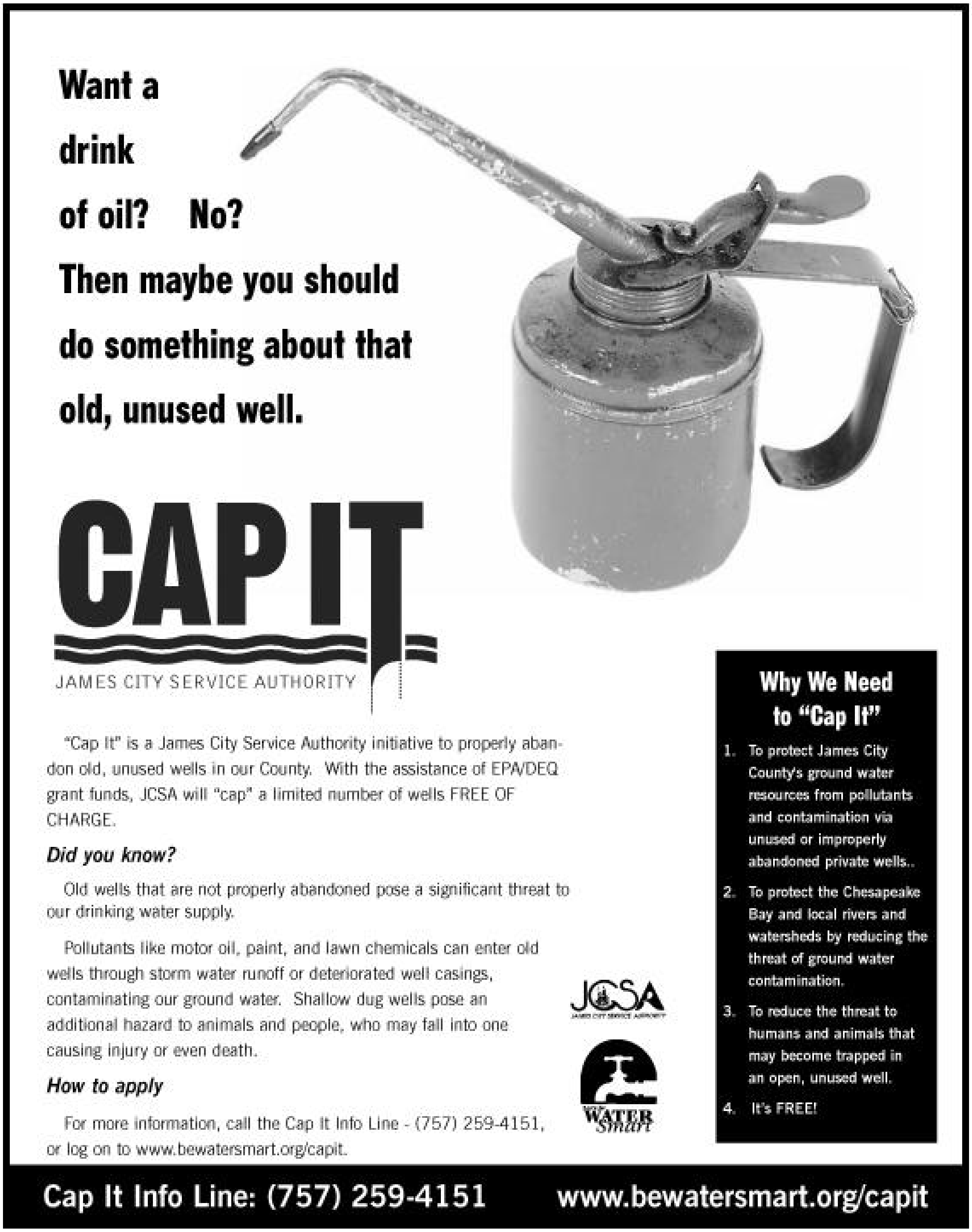
1. Develop a Scope of Services to hire BEST well driller for job, not necessarily lowest bidder.
2. Schedule abandonment for winter months, when the driller's business is slow.
3. Develop application approval guidelines at the beginning of program and clearly state guidelines in marketing materials.

CONCLUSION

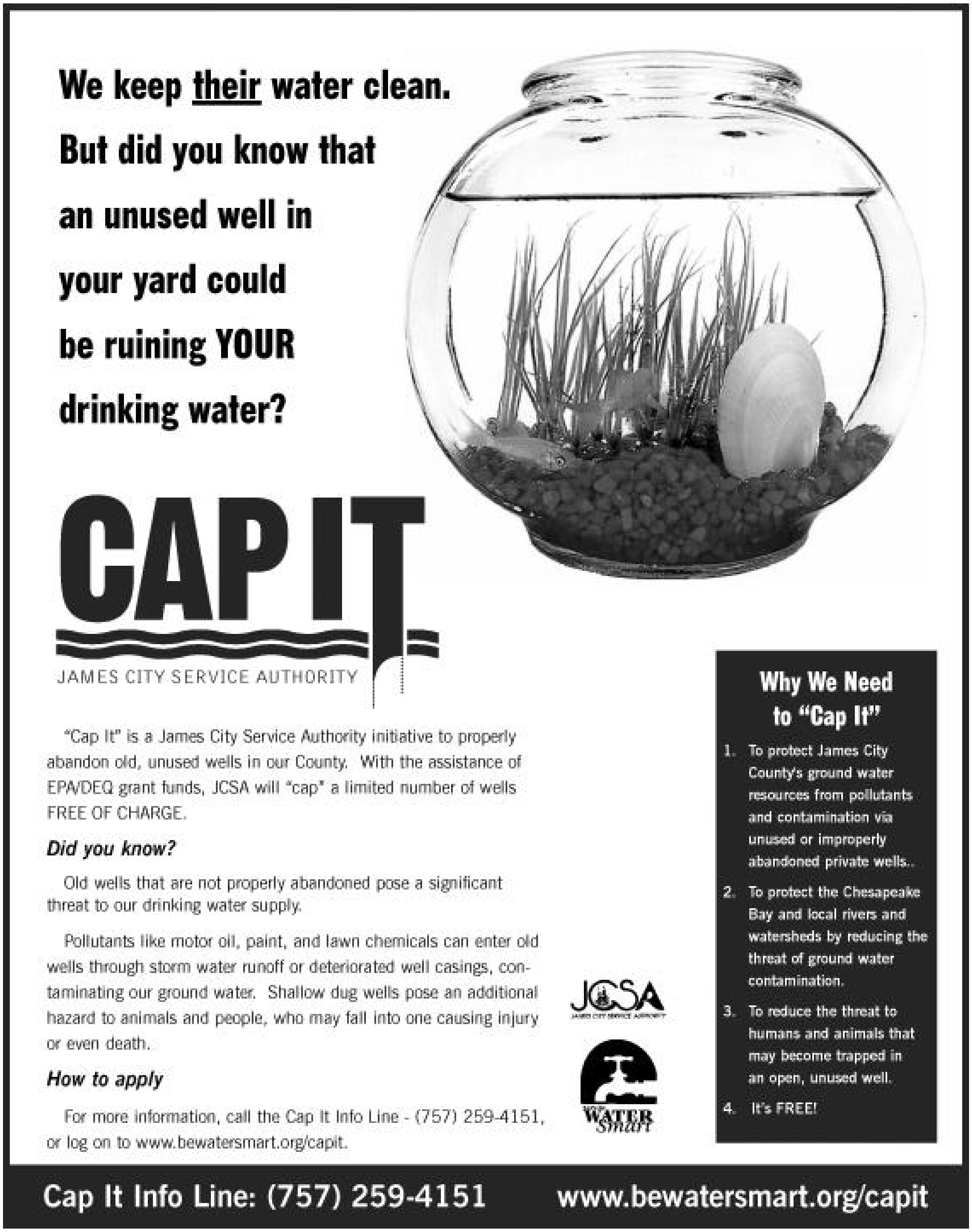
Utilities and municipalities of any size can improve source water protection efforts through a program like Cap It. It is an inexpensive yet effective way to protect groundwater resources while providing a valuable service to residents.



Cap It Print Ad 1: Fertilizer



Cap It Print Ad 2: Oil Can



Cap It Print Ad 3: Fish Bowl

SOURCE WATER ASSESSMENT FOR FIVE TOWNS IN SHENANDOAH COUNTY, VIRGINIA

George Sylvester
4839 Conicville Road
Mt. Jackson, VA 22842
540-477-3672; Fax: 540-477-2364
gsylvest@shentel.net

Michael C. Collins and John Rice
Formerly of ENSAT Corporation
Culpeper, Virginia 22701

KEYWORDS: Source, water, wellhead, karst, groundwater

ABSTRACT

Five reports were published in the spring of 2001 on source water protection in Shenandoah County, Virginia. The projects were funded by Shenandoah County as a first step toward the long-term protection of groundwater resources for the towns of Edinburg, Mount Jackson, New Market, and the Toms Brook/Maurertown and Stoney Creek sanitary districts. This work was developed concurrently with Virginia's own source water protection program taking place in other areas of the state. Due to the county's unique hydrogeology, the Shenandoah County Board of Supervisors felt compelled to develop their own, specialized approach.

The purpose of the project was to provide education, awareness, and recommendations to protect groundwater within land areas that recharge public water supplies in Shenandoah County. Most of the field data analyzed in this report was collected from the efforts of the Shenandoah County Water Resources Advisory Committee. A hybrid hydrogeologic mapping technique was used to delineate potential recharge areas for 10 wells serving each of the areas. Volunteers were trained to undertake a reconnaissance survey for potential contaminant-causing activities within the potential recharge areas and identified 325 areas. These areas were characterized, and ranked, using state and federal databases in conjunction with field inspection and GIS analyses. Specific recommendations to protect groundwater for each of the five areas were provided to the county.

COLLABORATIVE WATER SUPPLY PLANNING: A SHARED VISION APPROACH FOR THE RAPPAHANNOCK BASIN – PANEL DISCUSSION

ABSTRACT

Panel Members: William Cox, Civil Engineering, Virginia Tech; Lauren Cartwright, Institute of Water Resources, US Army Corps of Engineers; Jeffrey Connor, Engineering Fundamentals, Virginia Tech; Eldon James, Rappahannock River Basin Commission; Kurt Stephenson, Department of Agricultural and Applied Economics, Virginia Tech; William Werick, Institute of Water Resources, US Army Corps of Engineers

Water supply planning involves a complex mixture of technical analysis and value judgments. Technical analysis is needed to determine current and future water availability, risks, and water use patterns. Value judgments are required to determine how water will be allocated and shared between localities, identify acceptable water shortage risks, and agree on acceptable water uses. Conflict in water supply planning arises when there are fundamental conflicts in the under-lying values held by participants. These conflicts are often obscured and persist because participants argue as if technical analysis alone will resolve the problems. This session will review recent efforts of the Rappahannock River Basin Commission to alternative approach to water supply planning, called "Shared Vision Modeling" (SVM). By design, SVM integrates technical analysis into a collaborative planning and negotiation process, and relies on stakeholders representing a wide range of interests to help construct a computer simulation of the river basin system. By jointly constructing a "shared vision model", the process encourages participants to identify mutual gains and identify and address underlying fundamental goals and values. The simulation utilizes a user- program and interface that provide stakeholders an opportunity to investigate the consequences of future economic, demographic, and climatic conditions on water supply management and in-stream uses. The review of the RRBC's efforts will include an overview of the issues and objectives of the commission and an overview of the SVM process. The majority of the session will be devoted to explaining the structure, content, and capabilities of the RRBC's shared vision simulation model. A mock planning exercise will be used to demonstrate the model.

SECURING VIRGINIA'S WATER INFRASTRUCTURE – A SHIFT IN PRIORTIES

Mark Anderson
Virginia Department of Health
Division of Drinking Water
1500 East Main Street, Room 109
Richmond, Virginia 23219
Manderson@vdh.state.va.us

KEYWORDS: Asset based, Association of Metropolitan Sewerage Agencies, terrorist, threat, vulnerability assessment, Vulnerability Self Assessment Tool™, water infrastructure

ABSTRACT

Waterworks are now required by federal law to conduct vulnerability assessments. Vulnerability assessments can be conducted by using several available methodologies. The Association of Metropolitan Sewerage Agencies developed tools to assist wastewater utilities conduct vulnerability assessments. One is a detailed, asset based vulnerability checklist and the other is a software tool that provides a systemic approach to identifying, organizing, documenting, and presenting complex information in a clear and logical manner.

INTRODUCTION

The Terrorist Threat

The water infrastructure in the United States (US) has faced threats that potentially could disrupt service. In this context, water infrastructure describes both drinking water and wastewater. Major concerns were naturally occurring ones— hurricanes, earthquakes, and flooding. Man-made threats included pollution, vandalism, power loss, and spills of hazardous materials. An internal man-made threat was the disgruntled employee or the embezzler. The external threat was the thief or vandal. Recent tragic events point to a possible external threat of terrorism causing a shift in priorities when utilities assess vulnerabilities and mitigation measures.

An attack on the US water infrastructure by a terrorist organization is feasible in principle and a real threat in practice. Multiple terrorist objectives are likely in executing such an attack; yet achieving any objective would represent success. A multiple objective attack has been referred to recently as a swarming attack. The last few years witnessed both the intent and capability of terrorism to increase the scale of consequences of its attacks. In theory, the deliberate tampering of US water supplies by a terrorist organization might meet the quest for increased scale.

In this operational construct, the media is the terrorist's greatest ally and conversely, a grave threat. The terrorist organization wants media coverage of every one of its successes and every failure to pass with little or no comment.

In terrorist operations against economic targets, the attack does not have to be 100% successful to impact business confidence. That the attack has taken place is impact enough. Obviously, the level of success increases the impact, but every attack, no matter its level of success, will impact the overall situation.

Waging a campaign against economic targets differs greatly from waging a campaign against military ones. An economic campaign could achieve its effect by what could be described as "sporadic economic vandalism." Any organization, any group or disgruntled individual can join in at any time and any place. This is smart terrorism at its most dangerous and devising countermeasures is extremely difficult.

Characteristics of smart terrorism may include:

- Focused terrorist strikes aimed at inflicting maximum effect in terms of loss of human life and economic cost
- A strategic concentration on the threat of, or the use of, Weapons of Mass Destruction (WMD)
- Tactical strikes to create diversions from the WMD threat
- Decentralized, networked terrorist organizations
- Sources of financial and technical support, whether government or non-state actors, which have plausible deniability
- Maintenance of momentum, in the event of successful counter-terrorist activity, by commencing a new operation. (The effect of this is to keep anti-terrorist forces in constant uncertainty and at full alert.)

Terrorist Targets

From a terrorist's perspective, to be really worthwhile, targets should have a high visibility and be easy to attack (soft). Attacking well-defended (hard) targets increases the chance of failure and is more likely to result in negative press. Target intelligence and reconnaissance is the key and, where possible, intelligence collection and reconnaissance will take place over weeks rather than days. A well-orchestrated terrorist attack will generate a ripple effect throughout the US culture, as seen with the attacks of 9/11. Various groups would operate against targets in the following sectors:

Political. These are very obvious high profile targets such as the White House, Congress, Camp David, etc. The majority of these targets reside in the metro Washington, D.C. area. Isolated, sporadic attacks against federal targets inside the US will always have much more impact than an attack on a state political target.

Economic. These targets have a direct (almost immediate) bearing on the value of the economic indicators

Technological. The most immediate targets here are the mobile telephone networks following by the fixed communication networks including exchanges and message carrying facilities. Inside this target array are the cyber targets and a prolonged assault at low levels on e-commerce. Hackers will be active and, as the hacking skills spread across the terrorist world, “hacking attacks” will become more frequent. One cannot assume that SCADA systems are immune.

Social. This sector would include the entire infrastructure that supports daily life such as medical, education and utilities such as provision of drinking water. National events with high international media coverage, such as the Super Bowl, could also be targeted.

Military. These would be large well-known targets with a high international profile such as Fort Knox or Fort Bragg (associated with the XVIII Airborne Corps and Special Forces). These targets are almost impossible to attack directly because they are among the best defended. However, indirect attacks are possible and will have an enormous international media impact if successful.

Terrorism and the Water Infrastructure

If the objectives of terrorism is to disrupt society, destroy the US economy, and create fear, then our water infrastructure could be targeted readily. Wastewater and waterworks assets are easy targets and not particularly protected, yet hazardous chemicals are delivered, stored, and used on site. Additionally, wastewater gravity sewers could provide covert access to other key assets and critical buildings. Threats to the environment and public health are real. Wastewater treatment plants are downstream of significant economic activities and upstream of many raw water intakes.

Security threats from terrorist and related events are relatively new to the water infrastructure, so industry-wide, standard protocols are just now being developed. Serious security practices have evolved out of the water industry, such as with high-risk government buildings, nuclear power plants, and airline terminals. Water infrastructure physical assets are typically dispersed, so standard approaches to security (developed for enterprises with highly centralized assets, such as dams or nuclear weapons production facilities) are difficult to apply. Managers must then face a balancing act between demands for security and the resources needed to enact and finance those actions.

The water infrastructure is one of the original eight critical infrastructures identified in the Presidential Decision Directive 63. Presidential Decision Directive (PDD) 63 issued on May 22, 1998, calls for “...vulnerability assessments...for each sector of the economy and each sector of the government that might be a target of infrastructure attack intended to significantly damage the United States...”, and “...within both the government and the private sector to sensitize people to the importance of security and to train them in security standards...” Concern for this critical infrastructure extends to the US Congress. Waterworks serving populations over 3,300 are required by Congress to conduct vulnerability assessments. Small systems (serving populations between 3,300 and 49,999) have until June 30, 2004, and medium systems (populations between 50,000 and 99,999) have until December 31, 2003, to complete vulnerability assessments. Large drinking water systems serving populations over 100,000 have until March 31, 2003.

VULNERABILITY ASSESSMENTS

In developing a methodology to conduct vulnerability assessments, the Association of Metropolitan Sewerage Agencies (AMSA) decided that an approach that reflected both the way utilities think about their facilities and one that would be straightforward to employ would be most useful. AMSA, through funding provided by the USEPA, brought together subject matter wastewater utility and security experts that developed an asset based vulnerability assessment checklist. (This *Asset Based Vulnerability Checklist for Wastewater Utilities* is available free of charge from AMSA on their web site at http://www.amsa-cleanwater.org/. Also available for order on this page, is *Legal Issues in a Time of Crisis Checklist*, which was not developed with EPA funding.) The value of the vulnerability product is that it is asset based— enabling us to assess our vulnerabilities on those assets that we consider most important.

The AMSA Checklist identified five categories of assets — physical assets, the information technology (IT) platform, employees, the knowledge base, and customers.

Physical Assets

Though considered assets to the water industry, some assets represent pathways for threats as well. If terrorist groups intend to use the infrastructure against us, the water infrastructure in the US provides that opportunity. The bulk delivery and storage of hazardous chemicals, such as elemental chlorine and ammonia, represent a weakness that can be exploited. Fortunately, over recent years a lot has been accomplished in the control of hazardous materials. But still many facilities have railcars and one-ton cylinders of elemental chlorine and bulk storage of ammonia on site. A wastewater works collection system offers access to other facilities— not just to the publicly owned treatment works (POTW).

Deliveries to treatment plants are not only chemicals, but also deliveries of spare parts, express mail, and contractor parts and equipment. Access to the facility may include tour groups, contractor personnel, media personnel, and inspectors from state and federal agencies. Imagine the opportunity presented to a potential terrorist for access to a large POTW by the number of trucks entering and exiting a day removing biosolids. Also, how is access controlled at remote sites such as water storage tanks that might have microwave and other antennae situated on top?

Raw water sources may be hard to secure, but difficult to contaminate. Raw water intakes, transmission lines, and pumps are easier targets to attack and their loss would disrupt production. Contamination of raw water promises the terrorist a low probability of success because of dilution and the treatment processes that follow.

Information Technology (IT)

Even smaller waterworks and wastewater works have highly automated operations. Maintaining the necessary control to IT platforms may not be adequate. Many personal computers have direct access to the Internet through modems. Wireless operations present a whole new set of security problems. A recent innovation allows for remote access to the SCADA system from an operator's or supervisor's home or other location. An accepted practice of contractors installing

SCADA systems is the installation of Ethernet cards, whose presence may be unknown to the owner, which allows contractor personnel to upgrade and work on the SCADA system from a remote location and not have to conduct a site visit. Hardening of SCADA systems may be required. A firewall alone may not be enough so IT security needs to layered.

Disruption to the telephone network is a concern. Depending on the target and its proximity to other utilities, a terrorist attack can cause collateral damage to other infrastructure or utilities in the immediate area. If the telephone network goes down, is there a redundant means of communication to contact first responders? If the lines go down, is SCADA telemetry affected?

Database security also needs layered security. Terminals or PCs having access to employee and customer databases are likely to be connected to at least a LAN and have Internet access. Does the public or other employees have access to those buildings or rooms in which the servers (or terminals) are located? If you're a security manager at a POTW who relies on the waterworks or utility department for your billing, do you know what security precautions are in place?

Employees

Employees need to be well trained. Training activities need to focus on the employee's role in security and how to protect themselves. A known or suspected terrorist weapons of mass destruction (WMD) attack requires a different response from the employees than how they normally might respond to an emergency. In addition to knowing how to respond to an incident, the operating staff may have to understand alternative means of operating the plant, especially if the SCADA system is no longer functioning or power is lost. If new equipment, such as the standby generator, or personal safety gear is to be used, do employees know how to properly use and maintain the equipment?

Employees need to understand their role in maintaining security. The new steel door with cyber locks installed does not provide much security if propped open with a brick. Countermeasures that involve people and procedures can be enacted right away to reduce vulnerability. Procedures need to be simple enough to follow and not so disruptive that employees will bypass them to get their job done.

Distinctive name badges and/or uniforms should identify employees. Personal means of identification should include a photo ID. Some personal ID cards also have magnetic strips that can be used for access control. Employee uniforms can be colored coded so at a glance one can tell whether the visitor is a mechanic, electrician, operator, or heavy equipment operator.

Human resource policies need to consider whether background investigations are necessary. Besides privacy concerns are whether the background investigations are just for new employees. Should only operators or all employees having access be investigated and, if so, at what time intervals? Other issues are cost, delays in hiring and promotions, and what type of investigation meets security concerns. Are social security numbers on job applications checked? Witnessed in licensure applications for the trades are the submissions of bogus social security numbers on applications. Investigation reveals that immigrants have paid an agent a fee to assemble all the necessary documents, work visa, etc. Many of these brokers are unscrupulous people who provide the immigrants social security numbers of deceased personnel.

When an employee leaves, how is he or she processed out of the organization? Are keys collected? Is there an exit interview? Does the interview include a nondisclosure policy? Are uniforms, ID badges, and swipe cards collected? Are vehicle and equipment keys collected? Does the human resource office notify the network administrator so that passwords and access rights are terminated on the last day of work? How is an employee, who is discharged for cause, processed?

Knowledge Base

Knowledge base assets are those needed to be able to function, such as critical business documents and standing operation procedures or emergency response plans. Other people, besides employees will need access to your knowledge base. Consultants will need access to drawings, specifications, and plans. Contractors also will need certain documents critical to the design and operation of the facility. Often these documents are not accounted for when they go out for requests for proposals. Change of custody documentation and the return of these documents by the unsuccessful bidders provide a measure of security. First responders need access to the knowledge base. Response times may be too long if a relationship is not fostered with local law enforcement, hazardous material (HAZMAT) response teams, fire departments, and emergency medical teams. Coordination with hospital emergency rooms is required because ER personnel may be the first to detect a waterborne disease or illness.

In the event that critical documents are destroyed, backup documents may be needed. Is the location of the duplicate files known and covered in the business recovery plan? If duplicate copies are not available within the utility, consulting engineering firms, contractors, and the regulatory agency may have complete or partial sets of critical documents with their files.

Proper planning will address the above concerns. During an emergency, staff can refer to plans to know whom to contact, where to find critical documents and important phone numbers, and procedures to follow. Planning will also identify training needs and performance measures to test in tabletop exercises and actual exercises. For example, verify, through testing, that the police can locate remote assets, and get to the site, within the estimated response times.

Customers

Customers are an important asset as the primary source of revenue. Business continuity plans need to mitigate consequences and restore service as rapidly as possible. Unless a large cash reserve is maintained, restoring service quickly sustains the revenue stream. If the revenue stream is disrupted, how long will it be before you are out of business? Three weeks? Four weeks? With the customer asset it is important to note the interdependency between the drinking water and wastewater industries especially for billing and source of revenue.

Good channels of communication with the customer is important, especially so during an emergency. During any emergency, but especially with a terrorist attack, authorities must portray the image that they are in control. Establishing and maintaining ties with the media can support you in this task.

Seeking the assistance of the customer in surveillance is another way that the customer is an asset. Solicit residents living near a remote water storage tank to report any unusual or suspicious activities. If an asset is located along a well-traveled jogging path, park lane, or other area visited frequently by joggers, bikers, walkers, and dog owners, signage with a phone to call to report suspicious activity is another way or enlisting customer support.

For the drinking water industry, the first indication that there may be a problem in the distribution system is the customer complaints. The customer better than anyone knows when the water tastes, smells, or appears different. If not already in place, develop and put into place a procedure that responds to customer complaints immediately.

Vulnerability Self Assessment Tool (VSAT)™

After AMSA produced and published its vulnerability checklist, the development of a software application program was next. With continued funding from USEPA, AMSA, in collaboration with the PA Consulting Group and SCIENTECH, Inc., developed a software application that provides the user with a Vulnerability Self Assessment Tool (VSAT™). The software is flexible, customizable, and user friendly. It is equally applicable to deliberately caused or natural disasters. In addition to a library of prototypical assets included in the software application are threat and countermeasure libraries. As the user proceeds through the self-assessment, the program automatically documents the analysis process during each step. The tool helps the user identify the critical asset(s) and any single points of failures (SPF). The utility of the VSAT™ culminates in a risk-cost report presenting the data in a clear and concise way. This is important, because the goal is business continuity and, at the end of the day, business continues as usual. A detailed overview is located on AMSA's web site at http://www.vsatusers.net/overview.html.

The software tool was made available at no charge to all publicly owned wastewater treatment plants beginning on July 23, 2002. Training on the software, via web cast, becomes available in August. At the time of this paper, VSAT™ for the drinking water industry is under development.

Vulnerability Assessment Steps

A vulnerability assessment provides security managers the big picture. Regardless of the methodology used, it consists of several steps. We will continue to examine the AMSA developed methodology. It has been distributed to the wastewater industry for all system sizes and will be distributed to small and medium-sized waterworks to use. Many large waterworks, serving populations over 100,000, are using the Sandia National Laboratories RAM-W℠ methodology. Remember that the product we are working towards is a risk/cost analysis on which to base our decisions and ensure our business continuity plan addresses readiness, response, and recovery.

The first step is to identify the assets. A "standard" asset listing is provided in the VSAT software, as are a reference set of potential threats and countermeasures. Assets are grouped into the categories of Physical, IT, Employee, Knowledge Base, and Customers. In addition to listing all the assets, examples of questions to raise at this time follow. Which assets are critical to business continuity? Which assets can I do without? Where are my single points of failure? Which assets, if lost, would not endanger business continuity? Do I have functional redundancy?

What assets fall on the critical process path? Does an asset have a geographic importance or another way to ask is what percent of demand does this asset represent? Do I have critical customers and do I need to do something special to accommodate their needs. The customer could be a water-dependent industry, a military installation, or a government facility. There are many examples of these in Virginia.

The next step is to identify the threats. This is similar to that done in emergency disaster planning. Threats may be natural disasters or man-made including both internal threats, and external threats. Internal threats include employee and contractor sabotage, theft, and collusion with others. External threats are hackers, theft, low-level vandalism, and terrorist sabotage. The terrorist threat becomes most dangerous when collusion with an insider occurs. You cannot protect against everything. Work towards a specific design basis threat thinking hierarchically. What threat takes you down the quickest? What's the easiest target? Where are the interdependencies with other critical assets and infrastructure? For example, access to other potential targets using gravity collectors during low flow as detected under the US Embassy in Rome. Keep in mind that there may be differences between a target's value as we see it and from a terrorist's perspective. A war-gaming or "red team" approach has merit in viewing the facility from a terrorist viewpoint.

The third step is to determine each asset's criticality given the threat being evaluated. Repeat for each asset category. Anticipate the consequence(s) for the asset if it fails or is compromised. Consequences to consider are mission failure and whether loss of life, massive irreversible damage to the environment, widespread destruction of property and or erosion of community wellbeing could occur. In determining whether you can recover, consider how severe, long lasting, and widespread the consequences might be. The VSAT™ software has evaluation tables to assist in determining the criticality and in documenting the analysis. Criticality will be revisited in more detail.

Once criticality is established, examine those countermeasures that are in place currently, termed "existing countermeasures." Countermeasures can deter, detect, delay, decrease response time, and decrease recovery time. Identify what countermeasure(s) is in place now, and whether its effectiveness has been measured, tested, and maintained. Look at whether the staff is trained to use, maintain, or respond to the countermeasure. The value of deterrence has been questioned since it cannot be measured accurately and many in security planning do not rely on it. However, if international terrorists seek an attack option that promises a very high probability of success and low probability of compromise, deterrence may offer our industry greater returns than others. As the target is hardened, the required logistical and financial footprints of the terrorist cell increase to guarantee the same level of success as with a softer target. In wanting to keep the smallest possible footprint and not compromise the mission, the terrorist may move to a softer target. Countermeasures will be revisited when we try to reduce consequences and vulnerability.

After existing countermeasures are identified, the process moves to assigning vulnerability. For our purposes, four levels of vulnerability will be discussed. Sometimes three or five levels are used. A very high vulnerability may equate to no ability to survive a threat without failure. If some detection and delay is expected, but the response and recovery is limited or unreliable, the vulnerability is high. A moderate vulnerability has good probable detection and delay, but response and recovery may be slow. A low vulnerability has certain detection and strong delay with fast and reliable response and recovery. Similar to the criticality evaluation described above, the VSAT™ software has evaluation tables to assist in determining the vulnerability and in documenting the analysis. Again, remember that this process is repeated for every asset.

Next determine the risk level using a criticality rating found in step three and the vulnerability level. A four-by-four matrix works well. A three-by-three or five-by-five matrix can be used if preferred. Across the matrix, from left to right, are the criticality ratings of very high (1), high (2), moderate (3), and low (4). Down the matrix are the vulnerability levels of very high (A), high (B), moderate (C), and low (D). Thus, a 1A has a very high criticality and vulnerability. Conversely, a 4D has a low criticality and vulnerability. Color coding using red (high and very high), yellow (moderate), and green (low) is an effective way to visually recognize the relative risk levels. So, an example, for a low risk level of green, the corresponding criticality levels might be 3D, 4C, and 4D might be an acceptable level of risk for a particular asset.

TABLE 1. RISK MATRIX

Criticality				**Vulnerability Level**
1 Very High	2 High	3 Moderate	4 Low	
1A	2A	3A	4A	A Very High
1B	2B	3B	4B	B High
1C	2C	3C	4C	C Moderate
1D	2D	3D	4D	D Low

Those assets with risk levels determined to be high and very high should receive initial emphasis. If using the four-by-four matrix, start with the 1A, 2A, 3A, 1B, 2B, 3B, 1C, and 2C (criticality-vulnerability) risk levels that we need to take actions to bring the levels down to some acceptable level. We do this by looking at new or potential countermeasures.

Employing countermeasures can reduce criticality, vulnerability, or both. Besides physical countermeasures, such as perimeter fencing, there are other countermeasures equally or more effective that often incur no or minimal expenses. Examples are changing operational procedures, maintaining backup files, and storing duplicate drawings in a separate, secure location.

The decision as to what constitutes acceptable risk is based on the information that is available on the threat assessment, identification of potential consequences, evaluation of the vulnerabilities, advice on countermeasure effectiveness and cost. Attempting to reduce acceptable risk level to no risk is not practical. There is some level of risk in everything we do on a daily basis. Managers will mostly likely accept a low level of risk for most assets. Some risks can be reduced to low or moderate levels and, unfortunately, there may be some that cannot be reduced at all.

Risk reduction occurs by reducing consequences or reducing vulnerability. Look at countermeasures, in order, that involve people, processes, and technology.   Generally solutions involving people and processes are more efficient and less costly. However, expect cultural resistance to changes by staff unless management communicates the reason for the change(s). A security-training program is an effective way to accomplish this.   Countermeasures activities to consider include procedural changes, communication and response plans, close coordination with local law enforcement and other first responders, detection and delay systems, IT security, training and testing of personnel and plans.

The VSAT™ software provides a countermeasure library that gives reference information on considerations for implementing and relative costs and a place to enter the utility specific costs for each countermeasure. Using this software tool provides immediate feedback in seeing the resultant risk reduction for a countermeasure application. The data libraries, provided with the software (including countermeasures) can be customized by the user. So if the default reduction does not reflect conditions on the ground, the user can adjust the value or add a countermeasure not included in the original library. The user also has the option of documenting the rationale for the change in values for future reference. When costs are determined for the various countermeasures under consideration, the user can go back and update cost projections. The software allows the user ease to explore how much reduction results from each countermeasure or multiples of countermeasures.

The next to last step is conducting the benefit and cost analysis. There are several ways to analyze benefit— risk reduction, benefit cost analysis, risk/cost analysis, and regret analysis. Of these, risk/cost analysis is preferred. The approach with this analysis is to achieve the greatest reduction in unit risk for the money invested. The VSAT™ software can greatly assist the security manager in the analysis step and produces a risk/benefit report.

Now, after doing all the assessment and analysis, you want to be ready and you want to be able to respond. Well-crafted business recovery addresses readiness, response, and recovery. In the event that an asset failure occurs, you must have planned and prepared for recovery to continue operations with the least disruption to service as possible. The plan is comprehensive incorporating procedures, personnel, risk/cost-managed capital investments, communications plans, and the other actions needed to answer the following questions: Are we ready? Can we respond? Can we recover?

Depending on the size and complexity of the utility, there is a lot work to do in order to complete the vulnerability assessment requirement.   Any methodology used in conducting the vulnerability assessment requires assembling information about the threat, assets, and countermeasures. Although no software can automate all the work required, the availability of a software tool can assist in the process. To summarize, overview, VSAT™ helps to identify potential vulnerabilities, evaluate consequences of those identified vulnerabilities, and document the decision process, rational employed, and relative ranking of risks.

CRITICALITY

An asset is critical to your mission if in its absence, mission objectives would be significantly compromised. Map Physical Assets and equivalents in IT, Employees, Knowledge Base, and Customers to start. Seek single points of failure (SPF) leading to mission failure. Some examples are a main lift pump for sewage pumping and electrical substations. Even with multiple substations, if each substation serves only one portion of the plant, mission failure could result. Use criteria, such as, percent of service flow, a process bottleneck, or topography that has importance in your utility. Identify redundancies in your sources, treatment processes, collection system, or distribution system. However, depending on the threat, having a redundancy may not help reduce the criticality. Look for alternative ways to operate. Could a disruption to source water or treated water be made up through interconnections with neighboring utilities? If the SCADA system fails, can the utility be operated manually? Identify the number and location of spare parts and components.

Weighting Criticality Criteria

Completing a vulnerability assessment can be daunting, especially for a large or complex utility. Of course, using an automated tool like VSAT can help. One method that is useful is pair wise comparison. This is one way of prioritizing on which facilities to prioritize. It is a structured process to document why you applied the resources in the manner that you did. Create a matrix with those criteria that you identified as important.

Compare one criterion against the others. Use a scale like the following.

- 5 = Significantly More Important Than
- 4 = More Important Than
- 3 = Equally Important As
- 2 = Less Important Than
- 1 = Significantly Less Important Than

The matrix will look like the sample in Table 2. You will probably select criteria different from those shown. Note that once completed, the sums are complementary — the sum must equal number of levels of comparison or six (in this example).

TABLE 2. PAIR WISE COMPARISON OF CRITERIA.

	Percent service area	Critical customer	Access to others	Process bottleneck	Available alternatives
Percent service area		4	3	5	4
Critical customer	2		1	3	2
Access to others	3	5		4	3
Process bottleneck	1	2	3		4
Available alternatives	2	4	3	2	

Next, add the values across for each row to determine the sum. This sum will be use to weight the criteria. Once done, the matrix looks like the example in Table 3.

TABLE 3. FINDING MOST IMPORTANT CRITERION.

	Percent service area	Critical customer	Access to others	Process bottleneck	Available alternatives	Sum
Percent service area		4	3	5	4	16
Critical customer	2		1	3	2	8
Access to others	3	5		4	3	15
Process bottleneck	1	2	3		4	10
Available alternatives	2	4	3	2		11

Applying Criteria to Order Critical Facilities

The highest sum becomes the most important criterion. Previously, the most important criterion was percent service area (with a weight of 16) and it is used for this example. Now list all major facilities. In this wastewater example, two collection systems, two treatment plants, and a biosolids farm have been identified from physical assets. Apply pair-wise comparison for the facilities considering first the percent service area. Repeat for all other criteria—critical customer, access to others, process bottleneck, and available alternatives. Check for symmetry of comparisons (complements add up to six).

TABLE 4. PAIR WISE COMPARISON OF FACILITIES.

Percent Service Area (Weight = 16)	North Bay Collection System	South Bay Collection System	North Bay Treatment Plant	South Bay Treatment Plant	Biosolids Farm
North Bay Collection System		2	1	2	2
South Bay Collection System	4		2	3	2
North Bay Treatment Plant	5	4		2	3
South Bay Treatment Plant	4	3	4		5
Biosolids Farm	4	4	3	1	

Next, sum across the rows as shown in Table 5.

TABLE 5. FINDING MOST IMPORTANT FACILITY.

Percent Service Area (Weight = 16)	North Bay Collection System	South Bay Collection System	North Bay Treatment Plant	South Bay Treatment Plant	Biosolids Farm	Sum
North Bay Collection System		2	1	2	2	7
South Bay Collection System	4		2	3	2	11
North Bay Treatment Plant	5	4		2	3	14
South Bay Treatment Plant	4	3	4		5	16
Biosolids Farm	4	4	3	1		12

Weight the sums by applying the roper weight for the criterion. In this case, multiply the sums by 16 or the weight for the percent service area. Seven times 16 is 112 and continue down the rows. Record the weighted sums in a new column as shown in Table 6.

TABLE 6. WEIGHTING FACILITIES FOR PERCENT SERVICE AREA.

Percent Service Area (Weight = 16)	North Bay Collection System	South Bay Collection System	North Bay Treatment Plant	South Bay Treatment Plant	Biosolids Farm	Sum	Weighted Sum
North Bay Collection System		2	1	2	2	7	112
South Bay Collection System	4		2	3	2	11	176
North Bay Treatment Plant	5	4		2	3	14	224
South Bay Treatment Plant	4	3	4		5	16	256
Biosolids Farm	4	4	3	1		12	192

Repeat for all remaining critical criteria looking at critical physical assets. Enter the results in the matrix. Enter results into the matrix, shown as Table 7.

TABLE 7. ENTERING FACILITY SCORES.

Facility Level Priorities	Percent service area	Critical customer	Access to others	Process bottleneck	Available alternatives
North Bay Collection System	112	98	111	51	135
South Bay Collection System	176	72	199	67	172
North Bay Treatment Plant	224	101	81	88	156
South Bay Treatment Plant	256	123	89	112	187
Biosolids Farm	192	77	65	73	103

Sum across the rows and rank the facilities from highest to lowest. Final product will look like Table 8. The South Bay Treatment Plant is the most important facility for this criterion. Once finished with physical assets, continue the process for customers, knowledge base, information technology, and employees for all criteria.

TABLE 8. RANKING CRITICAL FACILITIES.

Facility Level Priorities	Percent service area	Critical customer	Access to others	Process bottleneck	Available alternatives	Sum	Rank
North Bay Collection System	112	98	111	51	135	507	5
South Bay Collection System	176	72	199	67	172	686	2
North Bay Treatment Plant	224	101	81	88	156	650	3
South Bay Treatment Plant	256	123	89	112	187	767	1
Biosolids Farm	192	77	65	73	103	510	4

Now that you want to work on the South Bay Treatment Plant, you want to go deeper into criticality looking at potential threats to each asset. Threats can be categorized as naturally occurring, man made with insider information, and man-made external. During the entire process of determining the design basis threat, keep in mind that what is an attractive target to us (knowing our critical assets) may not be an attractive target to an outsider. Different assets may have different countermeasures depending on the threat.

COUNTERMEASURES

Begin by looking at the criticality matrix. Concentrate on the high-risk combinations. These are the color-coded red and yellow ones. It will be impossible to have zero risk you may be able to accept the risks of the low risk combinations, like 4C, 3D, and 4D. Most of the time, you will be considering countermeasures that reduce vulnerability.

Countermeasures That Reduce Vulnerability

An aspect of vulnerability (V) is that it is a function of detection time (T_{dc}), response time (T_{rs}), and recovery time (T_{rc}), the probability of deterrence (P_{dt}), the probability of detection (P_{dc}), the probability of delay (P_{dl}), and delay time (T_{dl}). Appreciating the following relationship can clarify ways in which vulnerability can be reduced.

$$V \propto \frac{(T_{dc}+T_{rs}+T_{rc})}{P_{dt}+P_{dc}+P_{dl}(T_{dl})}$$

This is not an equation as used with some other methodologies introduced to the water industry— where values are entered and a calculation occurs. Instead, it describes a relationship, so what is important to understand is that vulnerability varies directly with the numerator and inversely with the denominator. So when you start thinking about countermeasures to reduce vulnerability, naturally think about ways to decrease the numerator and to increase the denominator. To decrease the numerator, we want to decrease our detection, response, and recovery times. To increase the denominator, we want countermeasures that increase delay times and the probability of deterrence, detection, and delay. Delay time is defined as the time when an event begins and when it is completed.

You can reduce detection time by process monitoring, installing closed circuit televisions (CCTVs) with some time of an alarm such as motion and using a card detection system for people being in "unusual part of plant" or in a place at the wrong time. A bank of monitors being "watched" by an operator in a control room who is operating the plant using his SCADA monitor is not recommended.

Delay times can be increased by installing fencing, adding razor wires to fence tops, and sealing manholes and vault boxes. A bitumastic sealant is a great way to seal a manhole compared to tack welding. It takes some time to break the seal and leaves a sign of forced entry. Countermeasures to increase delay times are considered hardening the asset in question.

TABLE 9. COUNTERMEASURES THAT REDUCE VULNERABILITY

	P_{dc}	P_{dl}	T_{dc}	T_{dl}	T_{rs}
Procedural Changes	✓		✓		✓
Communications Plans	✓				✓
Response Plans			✓		✓
Links to Law Enforcement					✓
Training and Testing	✓	✓	✓		✓
Passive/Active Barriers	✓	✓	✓	✓	
Area Lighting	✓	✓	✓	✓	
IT Security	✓	✓	✓	✓	
Security Force	✓	✓	✓	✓	

Decreasing response times will involve more coordination with outside agencies. Most responders are outside of your direct control. You will need to know whom they are, how to get in contact with them. Many police forces may not even know the location of the wastewater treatment facility, the elevated storage tank, or the pump station.

Procedural and organizational countermeasures have different effects on the independent variables than do structural countermeasures. Table 9 illustrates this. The first five countermeasures are procedural and people oriented. You can implement these countermeasures first because they are in your control and, for the most part, are inexpensive. Training and testing are used in concert with other countermeasures. Security forces are often one of the first countermeasures implemented, yet, are very expensive— perhaps the most expensive countermeasure used.

Countermeasures That Reduce Criticality

Countermeasures that reduce criticality provide a workaround for those critical assets, such as the elimination of a single point of failure (SPF). Examples of countermeasures that reduce criticality are:

- System Redundancies
- Duplicate Documents, Backup Files
- Physical Interconnections
- Alternative Routings
- Wastewater and Raw Water Storage
- Spares for SPF Equipment
- Contract Workforce
- Multiple Communications Channels
- Remote Operations Capability

Countermeasures vary in both effectiveness and cost. Countermeasures can decrease vulnerability, criticality, or both. Obviously, a countermeasure that decreases both has advantages.

DEVELOPING A BUSINESS CONTINUITY PLAN

Risk Acceptability

The classical definition of risk is the probability of an event times its consequences or costs. Concerned with preventing failure, risk more specifically is the probability of occurrence times the probability of failure times the cost of failure. But, these variables are difficult to quantify. Probability of occurrence is functions of historical patterns, 100-year floods, current warnings, target exposure and susceptibility, deterrence, are used. Determining the probability of occurrence becomes problematic in a quantitative analysis. Failure, a function of vulnerability, is typically pretty high. In many cases, the probability is one. The probability of consequences, or cost of failure, is a function of economic losses, response costs, restoration costs, lawsuits, etc.

In revisiting the qualitative risk matrix, risk is reduced by

- Reducing Criticality across the rows,
- Reducing Vulnerability down the columns or
- Reducing both diagonally.

So when is risk acceptable? This is a local decision, of course, but it must be based on the best available data on:

- A rational threat assessment,
- Recognition of all of the consequences,
- A thorough evaluation of vulnerabilities,
- Professional advice on countermeasure effectiveness, and

- Cost.

Costs that are of concern are:

- Readiness and response costs,
- If the event occurs, all direct replacement costs to utility property, collateral property damages, etc.,
- Loss of life and illness,
- Environmental damages and the restoration of ecosystems,
- Utility costs of disruption (restoration of temporary service), and the
- Social costs of disruption or costs to some other entity, not just the waterworks or wastewater works, such as, traffic delays, loss of political confidence, loss of customer confidence, and customer outage.

Alternative Decision Variables

There are four cost filters that are used to decide how much risk is acceptable. In reducing risk, there is little alternative, but to consider cost.

- Risk Reduction is best defined by "I will take whatever prudent steps are necessary to reduce this risk, since I cannot accept it at any cost." Risk reduction is applicable to large risks with unacceptably high consequences, but will still use cost to guide investment in countermeasures. Consequently, this criterion will rarely be used in its pure form.
- Benefit/Cost Analysis or "I will reduce this risk using the approach yielding the greatest net benefits" depends on the ability to express benefits in dollar terms. This may be difficult for some benefits, such as, lives saved. Also, benefit/cost analysis does not capture easily, non-market benefits, like environmental protection.
- Risk-Cost Analysis or "I will reduce this risk using the approach yielding the greatest risk reduction per dollar invested" is very common where risk is qualitative and risk reduction is relative. It is useful where benefits cannot be translated into monetary terms. Risk-cost analysis works well where budgets are fixed in the short run. It is also easy for decision makers to understand. Risks can be quantitative or qualitative.
- Regret Analysis or "I will reduce this risk using the approach that minimizes the expected value of residual losses" is useful for complex decisions where the cost of being wrong is catastrophic, such as failure of the Hoover Dam. It works well where the probability of an event is not known, but requires somewhat more detailed analysis than the others.

For most water utilities, it is recommended to use the risk-cost analysis. If a large dam is an asset whose failure would be catastrophic, the regret analysis might be used instead.

Business Continuity Plan

At the end of the day, the goal is to still be in business. A business continuity plan describes who has to do what to whom and where by when to ensure: that we are ready for conceivable threats, that we can respond if they occur, and that we can recover if we fail. Tasks to be accomplished in its preparation are: assigning a security director, organize the security team, assessing both threats and risks, planning for new countermeasures, setting an improvement schedule, training the staff, and periodically testing the plan. The improvement schedule is a function of the available resources, including staff and budget. When addressing recovery operations, questions to ask are: 1) how long can I be out of service?; 2) How long can I maintain operations while responding and/or recovering?; 3)What is at stake is recovery is slow? Keeping in mind that you may well be understaffed in recovery operations. Therefore, consider bringing in outside resources to help. Remember assets include more than the physical plant. The business continuity plan needs to identify the organization that will manage the aftermath. An effective organization should be in place to deal with all phases of the recovery from a disaster. The team must manage the crisis successfully, stabilise the business, and rebuild for the future. The plan also needs to develop a schedule that will manage the aftermath. Questions it needs to address are: 1) What equipment is needed where and when should it be available?; 2)Do we need a remote command center? By when should it be operational?; and 3) What must be rebuilt by when to assure business continuity? What is the critical path? As with many countermeasures, test the business continuity plan in order to have confidence in it. Some lessons learned after 9/11 were communications, communications, communications, and training and testing. Tabletop, tactical training exercises are a good way to test your plans. If room permits, include observers who are not part of the exercise to capture key points. Revise those shortcomings identified in the exercise.

SUMMARY

To protect the water infrastructure in the United States, a need exists to conduct vulnerability assessments. The approach that AMSA adopted was to use an assessment methodology that was based on assets. The five assets identified were: physical assets, information technology platform, employees, the utility's knowledge base, and customers.

The AMSA team believed that a methodology based on assets fits the industry better than traditional methods used by security managers in other industries and in use for some time. A comprehensive, asset-based, vulnerability checklist resulted. Knowing that conducting a vulnerability assessment is a time-consuming process, AMSA developed a software application tool to assist security managers. Originally developed for the wastewater industry, the merits of such a tool to assist the small – to medium-sized waterworks was apparent. The development team of the VSAT™ was approached to modify the software to address assets, threats, and countermeasures for the drinking water industry. Although the requirement to conduct a vulnerability assessment for a waterworks or wastewater works appears to be daunting, the availability of a self-assessment software tool can facilitate the process. As security planning and consequence mitigation is a work in progress, the utility of this software tool will be appreciated in years to come.

At the end of the day water utilities need to still be in business. This requires a business continuity plan to be developed, tested, and revised as necessary. The business recovery plans needs to address that the utility is ready, that it can respond, and, in the event of failure, recover.

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EVALUATION OF LAND USE AND POPULATION CHANGE ON NUTRIENT DELIVERY FROM AN URBANIZING WATERSHED IN NORTHERN VIRGINIA

Mark Dougherty
Civil and Envir. Engineering
312 Patton Hall, Virginia Tech
Blacksburg, VA 24061
540-231-4421; fax: 540-231-7532
mdougher@vt.edu

Randel L. Dymond
Civil and Envir. Engineering
216 Patton Hall, Virginia Tech
Blacksburg, VA 24061
540-231-9023; fax: 540-231-7532
dymond@vt.edu

Thomas J. Grizzard, Jr.
Adil N. Godrej
Occoquan Monitoring Lab (CEE)
9408 Prince William Street
Manassas, VA 20110
703-361-5606
grizzard@vt.edu
agodrej@vt.edu

Carl Zipper
Crop and Soil Environmental Scineces
Virginia Tech
363 Smyth Hall
540-231-9782
Blacksburg, VA 24061
czip@vt.edu

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ABSTRACT

This paper introduces ongoing research using 25 years of spatial and water quality data in a northern Virginia watershed to quantify the effects of changing land use and population on nonpoint source pollutant delivery. The study area includes the 130 km^2 Cub Run watershed, a rapidly urbanizing sub-basin within the Occoquan River watershed west of Washington, D.C., and three adjacent sub-basins that are less urbanized. Stream concentrations of total suspended solids, total nitrogen, and total phosphorus from 1975-2000 will be analyzed for relationships with several independent landscape variables, including impervious surface percent, land use type, population density, and other measures of urbanization. By contrasting relationships in the

urbanizing Cub Run sub-basin to those in the three adjacent sub-basins, critical factors driving pollutant delivery in urbanizing watersheds will be identified for use in time series forecasting.

INTRODUCTION

Since the 1950s, rapid population increases in areas surrounding a number of U.S. cities, including the northern Virginia region (Figures 1 and 2), have resulted in substantial land use changes. Agricultural and forested lands are routinely converted to residential housing, commercial, industrial, and other uses. In watersheds undergoing rapid urbanization, maintenance of local and regional water resources for adequate waste assimilation, public water supply, recreation, and wildlife habitat has become a pressing concern. According to the National Research Council (1999), a solid, scientific foundation of basic and applied research is needed to provide data, information, and tools for effective implementation of watershed management activities. In the midst of these challenges, the science of watershed management is evolving. Emerging analytical capabilities such as the use of remotely sensed image classifications have the potential to provide a nearly continuous level of land use monitoring and assessment. When descriptive spatial information is linked to verifiable in-stream data within a geographic information system (GIS), integrated watershed analysis can be accomplished at a higher resolution in time and space. Population statistics at the U.S. Census tract or block level can provide further spatial insight regarding the impacts of urbanization on pollutant delivery from a watershed.

The Occoquan reservoir has been a principal source of water and a major recreational resource for northern Virginia, which has been characterized as one of the fastest growing regions in the United States (Stein et al. 1998). Consequently, a principal land use management objective in the basin has been to enhance and preserve water quality to provide safe drinking water for present and future residents while also maintaining recreational values. As a consequence of increased urbanization within the Occoquan River watershed throughout the 1960s, the waters of the Occoquan reservoir (Figure 3) became increasingly eutrophic. A commissioned study by Metcalf and Eddy (1970) determined that a major cause of water quality impairment in the reservoir was nutrients, namely phosphorus and nitrogen from separate sewage treatment plant discharges. In addition, the Metcalf and Eddy study indicated that nutrients contained in natural drainage from forested, agricultural, and urban lands, particularly phosphorus, were sufficient to support nuisance algal blooms in the reservoir from time to time.

Water supply protection was implemented in 1971 through the establishment of the Occoquan Policy. Two key provisions of the policy were: 1) the mandated replacement of the watershed's 11 publicly owned wastewater treatment works with a single advanced wastewater treatment plant, and 2) the establishment of the Occoquan Watershed Monitoring Program (Randall and Grizzard 1995). Early results from the monitoring program established nonpoint nutrient pollution as a major cause of water quality impairment. These findings resulted in the implementation of nonpoint pollution controls throughout the watershed during the1970s. The advanced wastewater treatment plant went on line in July 1978. Since that time, tremendous population growth has continued in the environs of Washington, D.C. and Alexandria, VA, including urbanization within the Occoquan watershed. Population within the Occoquan basin has increased from less than 40,000 in 1972 to over 200,000 in 1992 (Randall and Grizzard

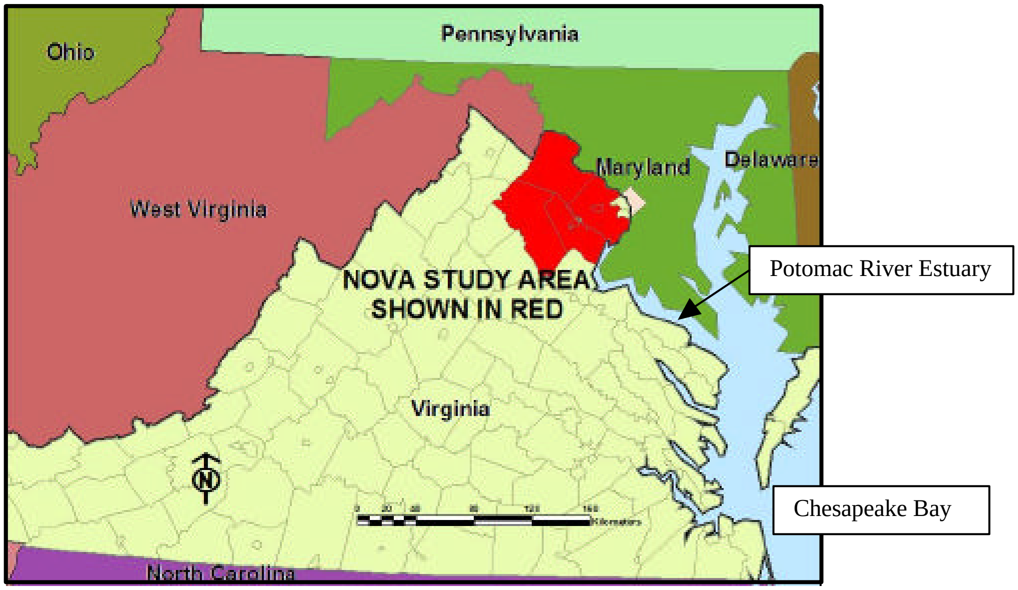

Figure 1. Location map. Northern Virginia's (NOVA) Occoquan basin study area includes parts of Loudon, Fauquier, Prince Williams, and Fairfax counties.

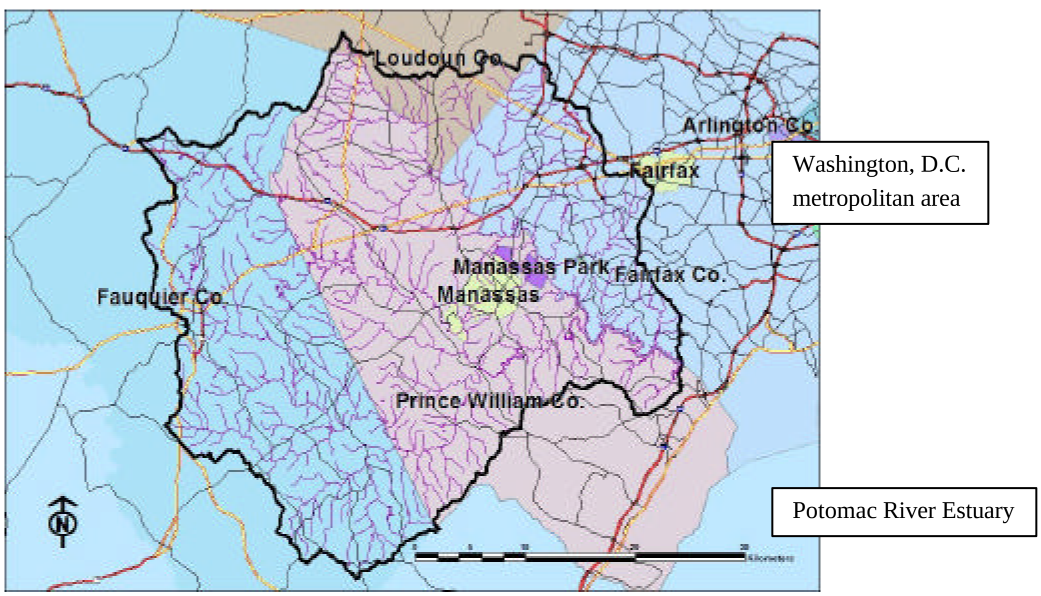

Figure 2. Occoquan basin (1470 sq. km): jurisdictional boundaries and major roads.

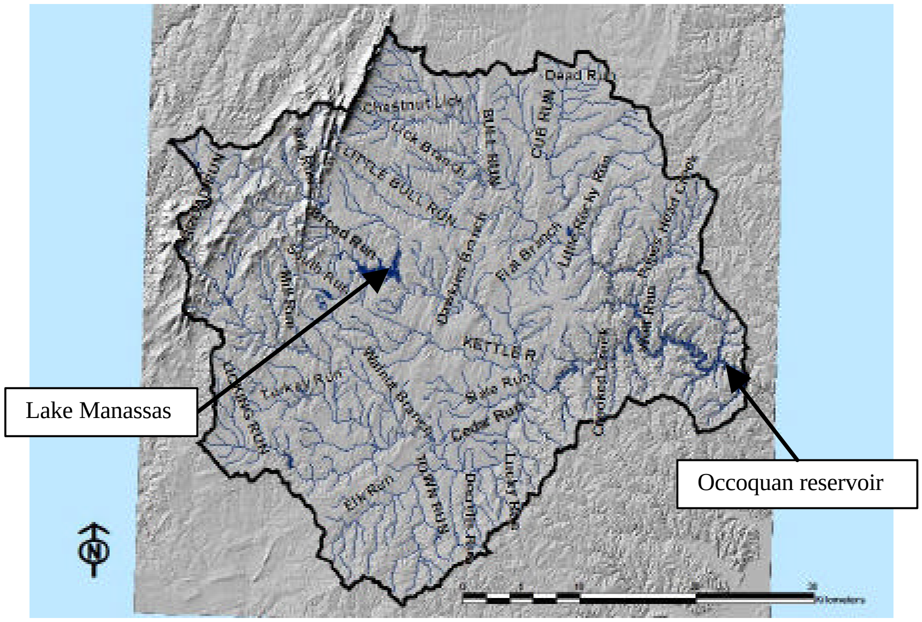

Figure 3. Occoquan basin (1470 sq. km): relief map showing major streams and water bodies.

1995), and in excess of 300,000 in 2000. The Fairfax County Water Authority currently utilizes the Occoquan reservoir as one of two principal supplies serving nearly 1 million persons in northern Virginia. Continued monitoring in the basin has demonstrated that ongoing control of both point and nonpoint nutrient sources are necessary to protect the water quality of the Occoquan reservoir. Additional control policies used to preserve the Occoquan reservoir as a drinking water supply have included land use management decisions based on results from watershed-reservoir linked computer models. According to Schueler (1996), one of the major recommendations for protective action in the Occoquan basin is the determination of present land use and impervious cover on a subwatershed basis. A new watershed model is currently being developed by others to predict water quality changes in the Occoquan reservoir resulting from land use changes within the basin.

OPPORTUNITY FOR NONPOINT SOURCE POLLUTION RESEARCH IN THE OCCOQUAN BASIN

Watershed research in this rapidly urbanizing basin is enhanced by the unique combination (some currently being assembled) of several long-term, consistent data sets, including:

- Nearly 30 years of historic stream flow and water chemistry data available from 8 strategically-placed monitoring stations within the Occoquan basin (Figure 4), provided by the Occoquan Watershed Monitoring Laboratory (OWML).

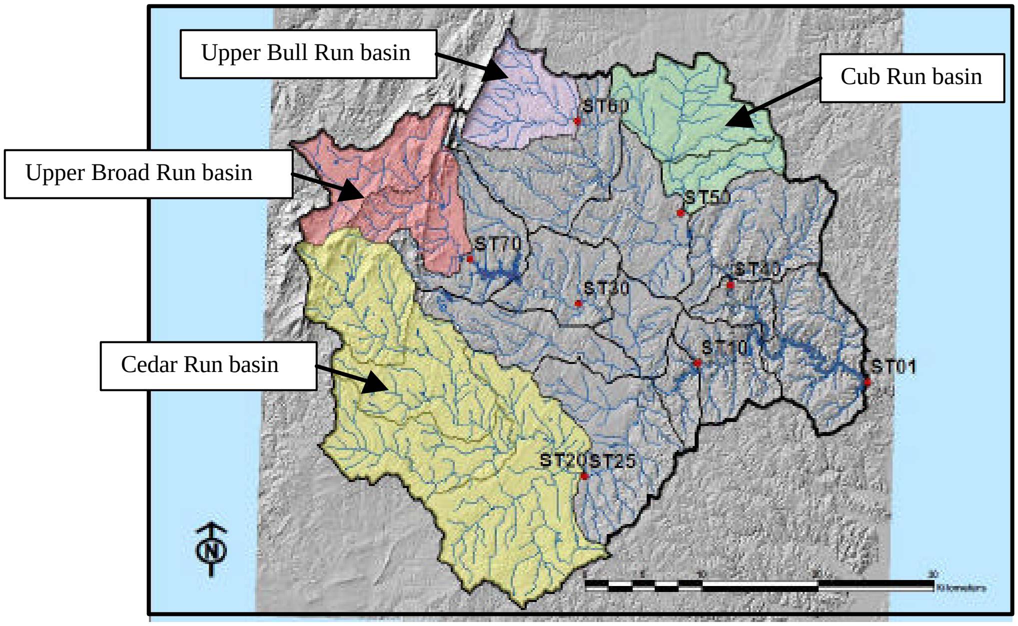

Figure 4. Occoquan basin (1470 sq. km): relief map showing the four-headwater basins of this study, including major water monitoring stations.

- The authors are currently assembling 20 years of consistent, historic land use mapping for the entire basin, based on 13 land use classes provided by the Northern Virginia Regional Commission (NVRC), as shown in Figure 5.
- Nearly 15 years of remotely sensed impervious surface estimates at 30-meter resolution, covering the entire Occoquan basin, available from the Mid-Atlantic Regional Earth Science Applications Center (RESAC), are shown in Figure 6. Each 30-meter pixel has been assigned a value corresponding to impervious surface percent, with values ranging from zero (black pixels) to an impervious threshold of 10 to 100 percent imperviousness (white pixels).
- The authors are currently assembling 30 years of population data, including population-based annual interpolations using the U.S. Census, Environmental Systems Research Institute, Inc. (ESRI), and Virginia Department of Education (VADOE) data. School enrollment data from VADOE is used to interpolate the decennial population count. The spatial population data sets produced by ESRI, shown in Figure 7, provide a ready estimate of the 100 percent population count within each sub-basin.

Additional measures of urbanization on a weekly or monthly time step, such as regional concrete sales, traffic flow, labor statistics, and/or housing starts, are currently being investigated as surrogate data sets for use in time series and forecast analysis. In addition to the assemblage of data described above, the Occoquan basin itself provides an opportune study site, located along a very active urban/rural fringe (Masek et al. 2000). Since 1972, active monitoring within the Occoquan basin has captured pollutant delivery from a wide variety of sources. The present research proposes to characterize the nonpoint sources of pollution delivered from this watershed, by selecting headwater sub-basins that are not significantly impacted by point sources, as described below.

Sub-basin study areas

Of direct importance to this study is the delineation of the Occoquan basin into four distinct headwater sub-basins (Figure 4), as follows.

1. Cub Run sub-basin: 130 sq. km, highly urbanizing sub-basin straddling Loudon and Fairfax counties, delineated from OWML monitoring station 50. Wastewater point discharges from this sub-basin were effectively removed in 1978, with the installation of an advanced wastewater treatment plant several stream miles below station 50. Average impervious surface in this sub-basin is currently estimated at 17 percent.
2. Upper Bull Run sub-basin: 67 sq. km, rural, agricultural basin characterized by low population density, delineated from OWML monitoring station 60. Average impervious surface is estimated at less than one percent.
3. Upper Broad Run sub-basin: 130 sq. km, predominantly pastured and forested area, with relatively moderate population density, characterized by moderate relief in some areas, delineated from OWML monitoring station 70, and drained by Broad Run. Average impervious surface is estimated at less than one percent.
4. Cedar Run sub-basin: 400 sq. km, relatively large sub-basin of predominantly agriculture and forest cover, with low population density, delineated from OWML monitoring stations 20 and 25, and drained by Cedar Run. Average impervious surface is estimated at one percent.

PRELIMINARY DATA ANALYSIS

Preliminary analysis of available project data will take two main pathways, spatial analysis and time series analysis. Initially, independent landscape characteristics of the four sub-basins will be tabulated for use as comparative explanatory variables. Characterization of the following spatial data sets will be accomplished mainly through conventional GIS operations.

- Annual population: Population data will provide the basic population density measures, at the census tract level, needed for basic comparative analysis of sub-basin urbanization.
- Impervious surface estimates: Impervious surface data will provide historic impervious surface estimates, at one percent increments, of the four sub-basins for use as an explanatory variable of sub-basin nonpoint pollutant delivery.

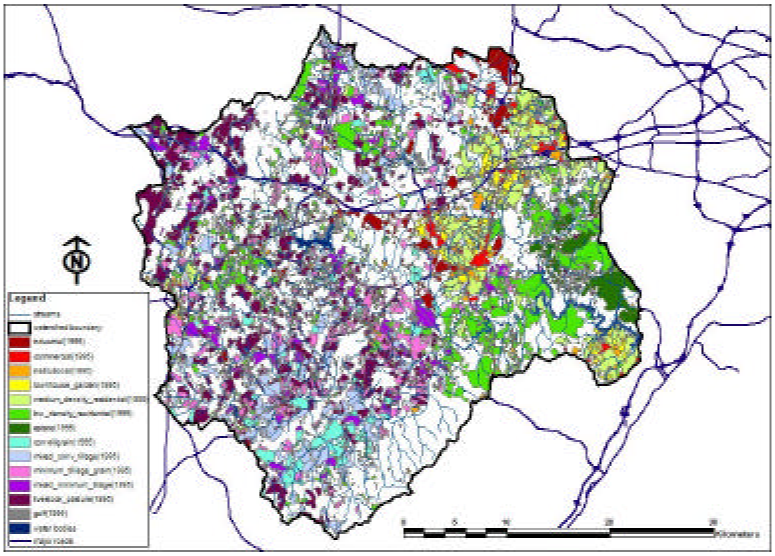

Figure 5. Occoquan basin (1470 sq. km): 1995 land use classification mapping (land use data: Northern Virginia Regional Commission).

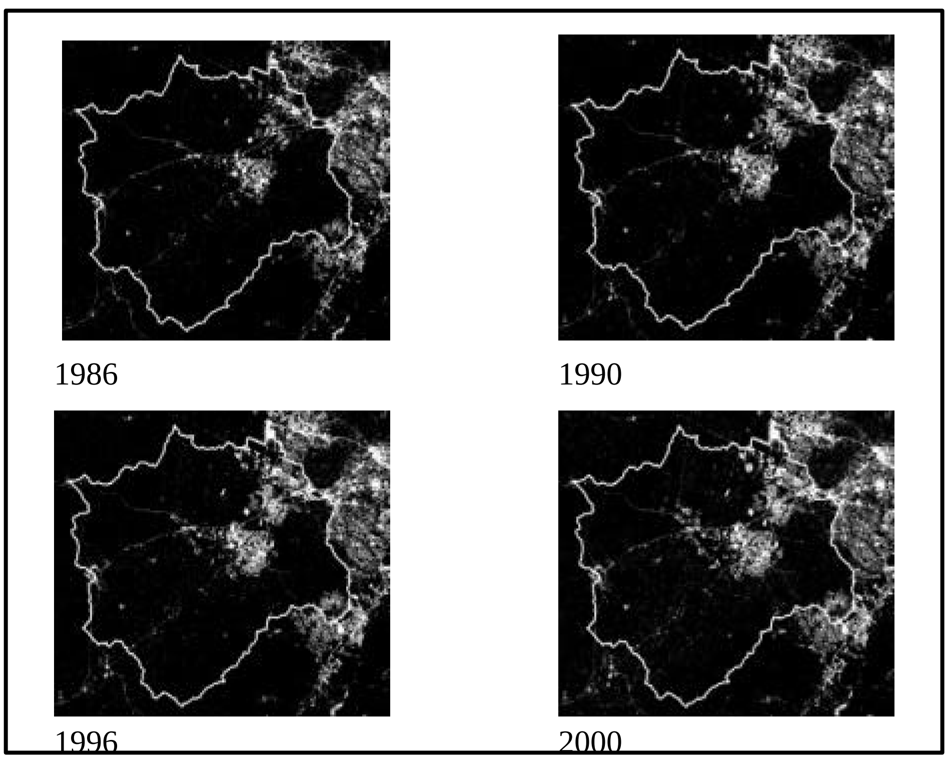

Figure 6. Occoquan basin (1470 sq. km): 1986 to 2000 impervious surface estimate time series with each white 30m pixel representing an impervious percent range from 10 to 100 percent (impervious surface data: Mid-Atlantic Regional Earth Science Applications Center).

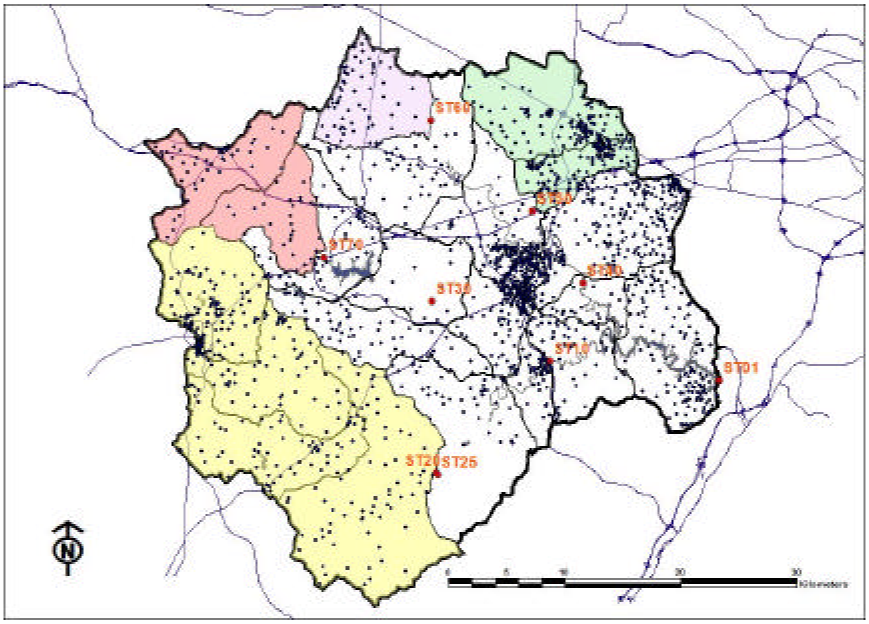

Figure 7. Occoquan basin (1470 sq. km): 1990 population map, sub basins, and major roads (each dot represents a varying number of persons).

- Detailed land use classification: Historic land use coverages currently being developed will provide several important explanatory variables of sub-basin pollutant delivery, including riparian buffers and land use adjacency and distance from stream.

The second type of preliminary analysis used in this project relates to historic water flow and chemistry data, all of which is in the form of monitored weekly (or near-weekly) time series samples. Storm event data will be tabulated and analyzed separately from base flow measurements because of the different pollutant delivery processes that occur during storm events. Preliminary characterization of water flow and chemistry data will be as follows.

- Seasonal median flows: generated from weekly flow data housed in the OWML hydrology database will characterize differences between each station's seasonal flow response.
- Seasonal median pollutant loads: generated from weekly pollutant concentrations of total nitrogen, total phosphorus, and suspended solids housed in the OWML water chemistry database, with corresponding stream flows, will be used as a response from each sub-basin.
- Loess smooth curves: displayed as trellis plots, are proposed as a graphic aid for visual comparison of average annual flow and pollutant delivery patterns in the four sub-basins.

PROPOSED ANALYSES

The following analyses are proposed as supportive measures for evaluating differences between the four sub-basins. Priority will be given to those methods which best quantify the relationship between causative factors and nonpoint source pollutant delivery in an urbanizing basin.

1. Seasonal trend analysis: pollutant (TN, TP, and TSS) concentration trends across time will be tested using the nonparametric seasonal Kendall analysis *tau* as a measure of monotonic trend. Land use change, impervious surface, riparian area, and other explanatory variables will be tested using advanced multivariate assessment (Smith et al. 1993).

2. Time series and forecast analysis: pollutant (TN, TP, and TSS) concentrations and loads across time will be tested against comparative measures of urbanization. Additional time series data will be collected as a surrogate data set to characterize urbanization. Proposed data sources include weekly or monthly building starts, concrete sold (or poured), labor statistics, active re-zoning applications, and/or traffic flow data. The forecasting model proposed is a causal forecasting model, which involves identification of causative variables other than those directly related to the predicted variable (nonpoint pollutant delivery of TN, TP, and TSS). Once related variables have been identified, the authors propose to develop a statistical model that describes the relationship between urbanization and nonpoint pollutant delivery in the Occoquan basin.

3. Accuracy assessment of remotely-sensed impervious surface estimates: comparison of impervious surface estimates generated by Fauss (1992) from aerial photography in the Cub Run sub-basin to RESAC-generated impervious surface estimates of the same area will provide an important link between land use type and impervious surface percent in the Occoquan basin. Estimates derived from this analysis are expected to be useful in ongoing basin and reservoir modeling efforts by others.

SUMMARY

This paper describes research to evaluate the impact of urbanization on a northern Virginia watershed using 25 years of assembled spatial and water quality data. The focus of the research is to quantify the critical factors driving nonpoint source delivery of total suspended solids, total nitrogen, and total phosphorus in an urbanizing watershed. A suite of visual and statistical tools is proposed to quantify comparative differences and trends between four headwater sub-basins, only one of which is highly urbanizing. Results include development of a statistical model that describes the relationship between urbanization and nonpoint pollutant delivery in the Occoquan basin. Accuracy assessments of remotely sensed imagery used in this project are expected to be useful in basin and reservoir modeling efforts currently underway in the Occoquan watershed.

ACKNOWLEDGMENTS

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WATER RESOURCE ISSUES OF DEVELOPING COUNTRY COMMUNITIES

Isai T. Urasa, Ph.D.
Professor of Chemistry and Chairman
Department of Chemistry
Hampton University
Hampton, VA 23668
Isai.Urasa@hamptonu.edu

ABSTRACT

The challenges that lie ahead as developing countries transition from agrarian to industrial-based economies call for sound environmental practices to encompass the impacts of those changes, particularly on water resources. Water resource concerns include several issues, namely: the availability of reliable and safe sources, water distribution systems, quality assurance monitoring, effective wastewater handling and disposal, and sanitation. These are key water utilization processes that in turn affect health, food security, food safety, energy security, and economic prosperity. Furthermore, the continuing population growth and the accompanying migration to urban areas will inevitably exert considerable strain on available water resources. Heavy metals, persistent organic pollutants, and fertilizers are examples of industrial and agricultural chemicals that are potentially harmful to water resources, but are poorly regulated in many developing countries. There must be ways by which these and other harmful materials can be prevented from entering water systems, as well as monitor their distribution, dissipation, dispersion, and fate, in environmental systems. Therefore, sustainability of water resources will not only require massive efforts to develop new and reliable sources, but effective management practices as well. The impacts of population growth, population migration, and industrialization on natural water resources require a compendium of case studies to establish environmental benchmarks, uncover existing environmental problems, and design improvement strategies. This paper will discuss case studies that examined water resources of urban and rural developing country communities, looking at the sources, processing, distribution, storage, use, and management practices of drinking water.

IMPACT OF CONSTRUCTION SITE RUN-OFF ON WATER QUALITY AND MACROINVERTEBRATE COMPOSITION IN VIRGINIA PIEDMONT STREAMS

Thomas D. Shahady
Cheryl Swackhammer
Lynchburg College
1501 Lakeside Drive
Lynchburg Virginia 24501
434-544-8545; FAX: 434-544-8646
shahady@lynchburg.edu

KEYWORDS: Sediment, Water Quality, Urban Streams, Macroinvertebrates.

ABSTRACT

Sediment pollution is an increasing and persistent problem plaguing our nations' streams, rivers and lakes. A major contributor to this problem particularly in the southeastern United States is sediment run-off from non-compliant construction sites. In this study we developed a scale to measure compliance of active construction sites along several streams in central Virginia. Above and below each construction site we sampled chemical water quality and macroinvertebrate densities.

We found that non-compliant construction sites increased sediment loading and decreased chemical water quality in adjacent streams. Additionally, aquatic insect populations showed an initial taxonomic shift from sediment intolerant species to sediment inhabiting species with increasing sediment pollution. Later, as sediment pollution decreased further down a stream segment, we observed a severe decline of all species. Based upon our evidence, we concluded that non-compliant construction activities contribute directly and indirectly to declines in water quality and macroinvertebrate densities.

INTRODUCTION

Sediment pollution is an ever-increasing problem plaguing our nations' streams, rivers and lakes. Sediment is now thought to be the number one pollutant impairing use of freshwaters (EPA 1994). Studies show that sedimentation degrades water quality, damages streams and contributes to the loss of aquatic macroinvertebrates (Quinn et al. 1992, Waters 1985, Henely et al. 2000). Biological costs not included, damage resulting from loss of recreation, water storage, navigation, commercial fishing and property range from $2.1-$10 billion per year (Clark 1985).

This is no longer only an agricultural problem. Studies estimate that urbanization and construction may equal or exceed all other sedimentation contributors (Farnworth et al. 1979). Clay soils typical in the Virginia piedmont are particularly harmful to aquatic systems. The small particle size of the clay, typical in Virginia piedmont soils, has a greater impact on stream macroinvertebrates than similar sandy soils (Richards et al. 1993). Clay is more challenging to maintain and control on construction sites. The small particle size of clay suspends longer and is transported further in aquatic ecosystems. Lemly (1986) suggested that control measures should be used in sequence to control these damaging small clay particles. Single control measures such as silt fence simply control large particulates allowing small particulates to enter the watercourse. The transport and imbedding of these fine particulates destroys macroinvertebrate and fish habitat (Waters 1985, Henely et al. 2000).

In this study we focused specifically on construction site impact on streams. In Virginia, the Department of Conservation and Recreation (DCR) is charged with controlling sedimentation from construction sites. The agency has developed 19 minimum standards specified in Virginia code (Section 4VAC50-30-40) directing land-disturbing activities (Virginia DCR 1992). While smaller in area than agricultural sites, construction sites erode at much higher rates (Waters 1995). Sediment often enters directly into a watercourse without riparian buffers or agricultural best management practices to slow or impede its progress. Additionally, sedimentation prevention measures are unequally maintained and enforced at construction sites (Personal Observations). Variability among enforcement agencies and the regulated community create a very disparate protection system. We hypothesized that this creates small but intensive sedimentation patches throughout stream stretches in landscapes.

Our intention in this study was twofold. First, we documented levels of sedimentation from construction activities in sections of two small piedmont Virginia streams. Secondly, we examined the potential impact this sedimentation creates on water quality and macroinvertebrate populations.

STUDY SITES

Two streams in the piedmont Virginia region of the Blackwater Creek watershed (Fig.1) were sampled between June and July 2001. The two streams, Dreaming Creek and Rock Castle Creek were both 2^{nd} –3^{rd} order streams, respectively. They were chosen due to the fact that they were located in an urbanized (> 50% developed) watershed with sites located upstream

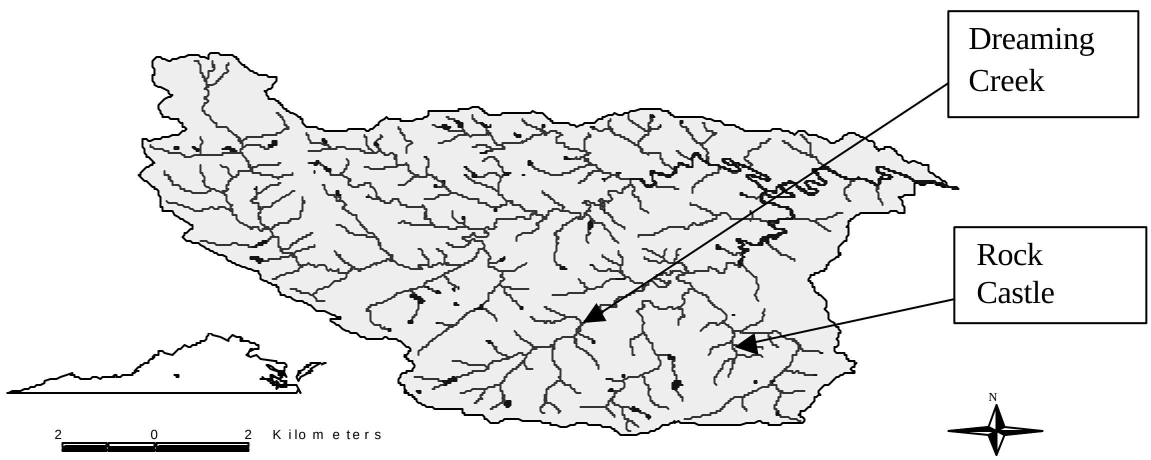

Figure 1 – The study sites on Blackwater Creek watershed in Lynchburg Virginia. Location of Dreaming and Rock Castle creeks are illustrated with arrows. Only construction sites impacting the study streams were included in our study.

CONSTRUCTION SITES

Construction site **DC-1** extends into the middle of Dreaming Creek (Fig.1) and the actual clearing boundaries are located about 150 feet from the stream. The construction covers 19.5 acres. There is a 4:1 slope gradient down to the stream. The northwest and southern areas drain into a natural channel that drains directly into Dreaming Creek. The remaining portion of the site drains directly into Dreaming Creek.

DC-2 construction site is perpendicular to Dreaming Creek. The property boundaries back up to the stream bank. The construction site (disturbed area) is severely sloped directly to the stream bank at a slope of 4:1. The construction site is 38 acres.

DC-3 site was chosen because it was the only construction site located below D-2. Unlike the previous two sites it was located approximately 1000 feet from the stream. It is 3.15 acres with a slope of about 2:1. It is the smallest site with the fewest erosion control measures in place.

RC-1 property boundaries run parallel to Rock Castle Creek in a highly urbanized area. The property line is approximately 50 feet from the stream and the site has a slope gradient of 2:1. The total clearing was approximately two acres.

We identified active construction sites based upon submitted plans. We reviewed each plan for erosion control measures prior to our inspection. Each site was inspected once following the Erosion and Sediment Control Handbook Guidelines (Virginia DCR 1992). A scale (Table 1) was created to evaluate each site with the same degree of accuracy. Each of the five categories consisted of an individual rating (from 0-5, 5 being the worst). Individual ratings were averaged together to achieve an overall rating for the site. We used the scale as a basis of compliance with erosion control law.

METHODS AND MATERIALS

Collected grab samples were preserved to a pH of less than two later testing for total phosphorus and total dissolved solids. Total phosphorus was analyzed using acid-persulfate digestion. Total dissolved solids were analyzed following methodology in Standard Methods (1998).

Dissolved oxygen, temperature and conductivity were measured in-situ using a Hydrolab. All meters were all calibrated prior to sample collection following instrument specifications. A pebble count was conducted to provide knowledge on the amount and type of substrate present on the bottom of the stream at each sampled site.

Macroinvertebrates were sampled in identified riffle sections in each stream using a Hess sampler. We took three replicate samples throughout the riffle pooling the samples into one composite sample. Total area sampled was 1.16m^2. All samples were immediately preserved in alcohol (Standard Methods 1998) and later enumerated in the laboratory. Organisms were identified to lowest possible classification using Merritt and Cummins (1996). Total diversity was calculated using the following equation:

$$\frac{N\,(N-1)}{\sum n_i\,(n_i-1)}$$

Where: N = total number of species collected
n = total number of species collected in the i^{th} group

TABLE 1: PRE-DETERMINED GUIDELINES FOR DETERMINATION OF COMPLIANCE FOR CONSTRUCTION SITES AND RATINGS. 1-5 RATINGS WERE BASED UPON DEGREE OF COMPLIANCE WITH PUBLISHED EROSION AND SEDIMENT GUIDELINES (VA DCR 1992).

1. Observed Control Technology	2. Installation of Sediment and Erosion Control Practices	3. Upkeep of Erosion Control Practices	4. Evidence of Erosion	5. Loss of Sediment
0-1=90-100% of proposed = excellent-good	0-1= excellent to good (all implemented practices were installed correctly according to EPA guidelines)	0-1= excellent-good (upkeep of ECP's according to EPA Regulation)	0-1= excellent to good (None to very minimal erosion, no more than 1" in an rill, very few rills evident)	0-1= excellent to good (none to 1m^2 visible beyond controlled area)
2-3 = 80-50% of proposed = good to moderate	2-3 = moderate to poor (no more than two implemented practices were not installed correctly according to EPA guidelines)	2-3 = moderate to poor (observed instances of inconsistent upkeep, observed deviations from EPA regulations)	2-3 = moderate to poor (some evidence of erosion, no more than 5 rills per disturbed area and no rill greater than 5" in depth)	2-3 = moderate to poor (more than 1m^2 but no more than 5m^2 visible beyond controlled area)
4-5 = < 50% of proposed = poor to very poor	4-5 = poor to extremely poor (> 2 implemented practices were not installed correctly according to EPA guidelines)	4-5 = poor to extremely poor (no upkeep on ECP)	4-5 = poor to extremely poor (wide spread evidence of erosion, greater than 5 rills per disturbed area, one to many rills greater than 5" depth)	4-5 = poor to extremely poor (> 5m^2 visible beyond controlled area)

On Dreaming Creek, a total of three active construction sites were inspected (DC-1, DC-2 and DC-3). We also sampled above and below the construction for a total of five sampling sites. One construction site (RC-1) was inspected on Rock Castle Creek. Again, we sampled above and below the construction for a total of three sites. We paid attention to habitat by choosing sites that were comparable in habitats with similar water depths and riffle habitat.

RESULTS

Upon inspection, DC-1 received a 3.4 rating. While this rating was one of our best scores overall compliance was very poor. Primarily, poor maintenance of silt fence, slope drains and other measures constituted this low rating. This site was particularly problematic because the property and limits of clearing went directly to the creek boundary with very little riparian buffer (< 10 meters). Erosion and stream siltation were evident on the site.

Water samples at this site (Table 2) showed an increase in phosphorus, temperature and conductivity when compared to the site above. Dissolved oxygen, total dissolved solids, diversity and substrate (loss of cobbles) declined. We observed siltation occurring in the stream from the site. These parameters are very suggestive of declining water quality as the stream flows through this construction site.

Macroinvertebrate abundances remained relatively unchanged at this site (Table 3). Both abundance and species were very similar to what we found above the construction site. This suggests macroinvertebrates were unaffected by declining water quality.

TABLE 2 - CHANGES IN PARAMETERS (EITHER POSITIVE OR NEGATIVE) AT EACH SAMPLING SITE. DATA FOR DC-1 REPRESENT DIFFERENCES FROM THE ABOVE SITE TO DC-1. DATA FOR DC-2 REPRESENT THE DIFFERENCES BETWEEN DC-1 AND DC-2. DATA SHOWN FOR DC-3 REPRESENT DIFFERENCES FROM DC-2 TO DC-3. DATA FOR RC-1 REPRESENT THE DIFFERENCES FROM THE ABOVE SITE TO RC-1. RATINGS DETERMINED FROM TABLE 1 ARE SHOWN FOR EACH CONSTRUCTION SITE.

Site	Rating of Sites	Δ Total Phosphorus	Δ Temp (°C)	Δ dissolved O_2 (mg/L)	Δ TDS (mg/L)	Δ Conductivity	Δ Total Diversity	Δ Substrate
DC-1	3.4	+ 0.10	+ 0.5	- 0.57	- 0.006	+ 10.6	- 1.14	- 14 %
DC-2	3.8	- 0.31	- 0.10	+ 0.36	+ 0.002	+ 16.0	+ 3.77	- 3.0 %
DC-3	3	+ 0.15	+ 1.0	- 0.51	+ 0.001	+ 57.8	- 3.7	- 8.0%
RC-1	4.2	+ 0.45	+ 0.06	+ 0.01	+ 0.05	- 18.0	+ 2.34	+ 17 %

TABLE 3 - TOTAL ABUNDANCE AND SPECIES COUNTS FOR ORGANISMS FOUND IN SITES TESTED ALONG DREAMING AND ROCK CASTLE CREEK. NUMBERS SHOWN ARE TOTAL COUNTS FOR EACH SAMPLE.

Macroinvertebrate	Above	DC-1	DC-2	DC-3	Below		Above	RC-1	Below
Total Abundance	50	45	200	16	13		19	39	14
Total Species	13	10	16	7	7		9	12	6

DC-2 was located in the middle of our testing sites along Dreaming Creek. When evaluated, it scored a 3.8. The site was severely sloped and considerable sedimentation occurred in the stream. Silt fences, slope drains and sedimentation ponds were inadequate on this site at the time of our evaluation. This site received our second lowest score. This site did contain a greater stretch of riparian buffer (approximately 50 meters) between the limits of clearing and the construction site.

Water quality indicators (Table 2) improved at this site. Increases in dissolved oxygen and macroinvertebrate diversity with decreases in phosphorus show some improvement from the previous site. Yet, increases in conductivity, dissolved solids and continued change of substrate toward sand/silt suggest the stream continues to show impact from sediment.

At this site we found our greatest diversity and abundances of macroinvertebrates (Table 3). Organisms not found previously in our study appeared at this site. Sediment dwelling organisms *Ephemerella*, Baetidae, Ephemeroptera and Elimidae contributed substantially to this increase**.**

DC-3 was the last site evaluated on Dreaming Creek. Small size, minimal slope and distance from the creek minimized the impact of this construction site. Overall, poor silt fence maintenance and sediment pond construction contributed sediment to Dreaming creek from distances of 300-400 meters. Overall rating for this site was 3 yet overall design of sediment and erosion control contributed to problems here.

Water quality again declined as the stream flowed past this site (Table 2). Phosphorus, temperature, conductivity and total suspended solids increased from the previous site. Further loss of cobble habitat and oxygen were evident. Macroinvertebrate abundance and diversity declined (Table 3).

An additional test was conducted on Rock Castle Creek for comparative reasons. Were our predictions from Dreaming creek consistent on another impacted stream system? RC-1 is a construction site directly above the creek. We observed very poor silt fence construction allowing most of the sediment mobilized on the site to enter the creek. RC-1 was given our worst rating (4.2) having the least compliance of all sites that were inspected (Table 2).

Our measurements at this stream site suggested degraded water quality (Table 2). When compared to the above site we observed increases in phosphorus, total dissolved solids, temperature and relatively no change in oxygen. Interestingly, conductivity and sand/silt habitat decreased. Macroinvertebrate diversity and abundance also increased (Table 3). Organisms responsible for the increase were similar to those at DC-2.

DISCUSSION

Assessing the impact of construction site runoff on stream water quality is a difficult task. Eroded soil not only consists of sediment, but also road salt, chemical fertilizers, and many different kinds of toxic materials that adversely affect macroinvertebrates (Waters 1995). Further, elevated phosphorus levels result from land disturbance, soil erosion and impervious surfaces in the watershed (Soranno et al. 1996). This leads to impacts on the trophic structure of aquatic food webs. It was our intention to examine changes in water quality from construction sites with varying degrees of compliance.

We found construction sites in our study area adhering to a very poor standard of compliance. Based on our evidence collected as the stream segments flowed through the construction site (Table 2), observed changes in water quality would be unavoidable when construction sites are not in compliance. Our results suggest that these construction sites do degrade water quality. It would have been useful to compare a well-maintained compliant construction site to a similar non-compliant site for impacts on water quality. Within the scope of this project (reviewed plans and sites within our study area) we could not locate a well-maintained compliant construction site. This evidence suggests current erosion control practices are inadequate to protect state water resources. Our observations during this project suggest jurisdictional overlap of federal, state and local government make it difficult to manage various soil types based on regional "watershed" variances.

From our data it can be inferred that these non-compliant construction sites do increase levels of conductivity, total dissolved solids, phosphorus, temperature and sand/sediment habitat. Degradation of water quality is often associated with soil erosion (Waters 1995). Red clay soils in particular are difficult to control on construction sites allowing fine sediment into streams (Lemly 1986). Sediment loading coupled with urban watersheds will elevate many water pollutants (Lenat and Crawford 1994). Our data seems to support these findings.

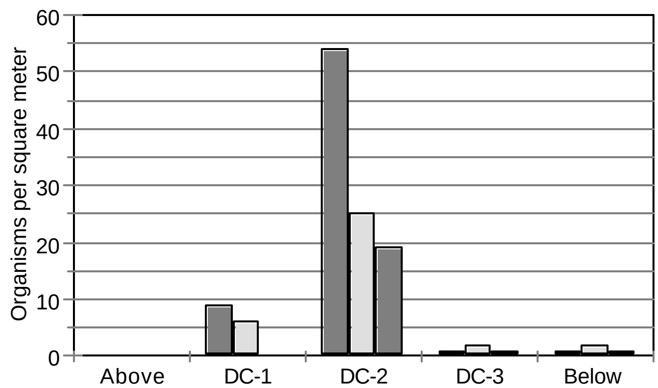

FIGURE 2 - CHANGES IN SEDIMENT DWELLING MACROINVERTEBRATES IN DREAMING CREEK. FIRST BAR REPRESENTS BAETIDAE, THE SECOND BAR *HYDROPSYCHE* AND THE THIRD BAR ELIMIDAE. EACH BAR ON THE GRAPH SHOWS TRANSITION FROM ABOVE THE CONSTRUCTION SITES THROUGH EACH SITE AND BELOW OUR STUDY SITE.

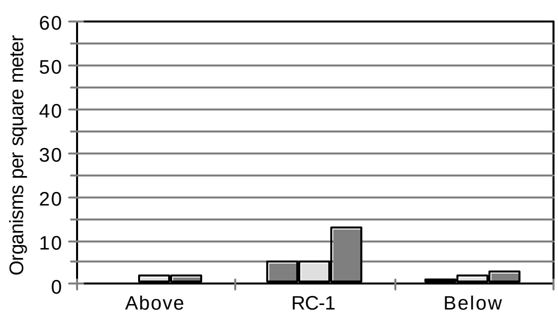

FIGURE 3 - CHANGES IN SEDIMENT DWELLING MACROINVERTEBRATES IN ROCK CASTLE CREEK. FIRST BAR REPRESENTS BAETIDAE, THE SECOND BAR *HYDROPSYCHE* AND THE THIRD BAR ELIMIDAE. EACH BAR ON THE GRAPH SHOWS TRANSITION FROM ABOVE THE CONSTRUCTION SITES THROUGH EACH SITE AND BELOW OUR STUDY SITE.

Construction site impacts on stream macroinvertebrates were more difficult to predict. Our data shows some areas of declining water quality on stream segments and improvement in others. Interestingly, we did see a shift of organisms at the point of construction disturbance. Our observations (Figures 2 and 3) suggest during an increase in sedimentation organisms that reside shift. Although there may be a positive change in the abundance and diversity of some organisms (suggested water quality improvement) at a point along the impacted stream, this change may be more reflective of habitat alteration. The changes we observed are quite possibly due to the excess sediment that is being deposited from the non-compliant construction sites.

Gurtz and Wallace (1984) showed similar results with *Ephemerella*, Baetidae and Ephemeroptera when an excess of sand was introduced to a habitat. This habitat shift may favor burrowing insects tolerant of sedimented conditions (Ryan 1991). Our observed shift in organisms (Elimidae, Baetidae and Hydrospyche) was possibly the result of increased sedimentation to the stream. Excess sedimentation could cause these organisms to drift (Runde and Hellenthal 2000) creating greater abundances at downstream stations. This would account for increased abundance and diversity at disturbed stations in the stream.

Additionally, EPT and similar diversity indicies may not be the best predictors of sedimentation impact in streams (Zweig, and Rabeni 2001). Similarly, although our diversity index's varied slightly the species diversity and type were the inconstant factors. There was an evident increase in densities but a noticeable variation in the type of species present (Table 3).

CONCLUSIONS AND RECOMMENDATIONS

From this study we hypothesize that non-compliant construction sites degrade stream water quality in several ways. Initial sediment inputs add phosphorus and other pollutants immediately degrading water quality. Often, macroinvertebrates drift during periods of high sediment loading (Lenat et al. 1981, Walters 1985) and this may have contributed to observed initial declines in our study. At some point sediment tolerant macroinvertebrates realize a benefit from the habitat shift and increase in abundance (Ryan 1991). Or sediment deposition causes organisms to drift and purge from the stream system (Fairchild et al. 1987). Either way, sediment intolerant species are now lost from the system. As the stream reach moves beyond the disturbance and sediment habitat is lost we see a complete decline in most species of macroinvertebrates. This rapid and uncontrolled sedimentation degrades streams within a very short reach.

The overall findings of this research suggest a relationship between water quality and the uncontrolled sediment leaving construction sites. While our evidence is largely circumstantial, the non-compliant nature of the sites evaluated and the observed changes in stream water quality at the construction sites does cause concern. In urban areas non-point pollutant loading to streams is difficult to control. We believe greater enforcement and regulation of existing sediment control laws will provide immediate and needed benefits to stream water quality in urban areas.

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LIMITATIONS OF GIS ELEVATION DATA FOR WATERSHED MODELING

Marco Caiado
Conrad Heatwole
Biological Systems Engineering
Virginia Tech
Blacksburg, VA 24061-0303
540-231-4858; Fax: 231-3199
Heatwole@vt.edu

KEYWORDS: DEM, flow direction, terrain analysis, hydrology

ABSTRACT

Terrain analysis functions commonly available in GIS use an elevation grid (DEM) to define the stream network and watershed boundaries for any selected location on the map. The commonly used algorithms first calculate a flow direction grid that is the basis for defining the flow pathways over the entire map surface. Flow directions are typically constrained to one of eight directions corresponding to flow into one of the adjacent eight cells (and commonly called a D8 algorithm). The flow direction, derived from aspect or by calculating the direction of the steepest drop, is sensitive to changes in the elevation grid. We found that a simple 3x3 mean filter used to smooth the DEM commonly resulted in different D8 flow directions for 30% of a 30m DEM. Our goal is to evaluate the impact that sensitivity in the flow direction derivation has on the sensitivity in the results of upland hydrology models that have flow paths defined by the flow direction grid. Specific objectives were to: a) characterize flow direction sensitivity as a function of error level of the DEM; b) identify patterns in flow direction sensitivity; and c) evaluate the potential impact on the length of overland flow paths as a factor important in modeling upland hydrology and water quality.

For the DEMs evaluated, changes in flow direction occurred in 20 to 40% of the cells. Between 31% and 45% of the cells did not have any change in flow accumulation between the original and smoothed DEMs, and almost 90% of the cells had difference less or equal to ten cells. Changes in flow length after smoothing was evaluated in 5 DEM's. Between 54 to 68% of the cells with flow length equal to 150 meters in the original DEM change after smoothing. Overall, about 35% of cells had flow length differences greater than 30 meters. These results illustrate how errors and uncertainty in flow directions derived from DEMs can be expected to affect hydrology models that are concerned with field-scale processes.

DISTANCE AND TRAVEL TIME ESTIMATES TO DEFINE POLLUTION RISK FOR SOURCE WATER PROTECTION

Conrad Heatwole
Biological Systems Engineering
Virginia Tech
Blacksburg, VA 24061-0303
540- 231-4858; Fax: 231-3199
Heatwole@vt.edu

David Bradshaw
GIS Manager
Olver, Inc.
Blacksburg, VA 24060

KEYWORDS: pollutant sources, risk, GIS model, terrain analysis

ABSTRACT

The Virginia Source Water Assessment Program defines the primary area of influence (zone 1) for stream intakes as the area in the watershed that is within a 5-mile radius of the intake. While this approach was selected for simplicity of implementation and a legal precedent, from the standpoint of hydrology, it has obvious limitations. The interest in source water protection is to identify potential sources of contamination and assess their risk to drinking water supplies. Thus, it will be more meaningful to define a critical upstream area on the basis of the stream network and flow distance or flow travel time. A variety of approaches can be used to define flow travel-time for rivers, typically requiring long-term flow records, extrapolation of data from neighboring watersheds, or regional generalizations about runoff and stream flow properties. GIS models can provide watershed-specific estimates of flow distances and flow travel times estimates for a watershed based on readily-available topographic and land use data. Travel times can be estimated without having gaged flow data, although when it is available, watershed specific data can and should be used to improve the models. The application to several intakes in Virginia illustrates the importance of considering the flow path in source water protection.

COMPARISON OF SEVEN METHODS FOR SOURCE-TRACKING ESCHERICHIA COLI

Kenneth E. Hyer
U.S. Geological Survey
1730 East Parham Road
Richmond, Virginia 23228;
(804) 261-2636
kenhyer@usgs.gov

Melvin V. Mathes
U.S. Geological Survey
11 Dunbar Street
Charleston, West Virginia 25301;
(304) 347-5130
mvmathes@usgs.gov

Donald M. Stoeckel
U.S. Geological Survey
6480 Doubletree Avenue
Columbus, Ohio 43229-1111
(614) 430-7780
stoeckel@usgs.gov

KEYWORDS: Bacteria Source Tracking; *Escherichia coli*; fecal contamination

ABSTRACT

Fecal contamination of drinking-water wells in the Shenandoah Valley poses a significant concern to local water-supply managers. The complex hydrology of this area and the diverse collection of potential fecal coliform sources make it difficult to link fecal contamination of ground water to the appropriate animal sources. An emerging technology, bacteria source tracking, can likely identify the sources of fecal contamination in these systems. Knowledge of the sources of fecal contamination will aid in the development of effective groundwater protection strategies. Although potentially powerful, bacteria source tracking is relatively new and no consensus is available regarding which method (or combination of methods) is most appropriate for a given situation. This study will compare the ability of seven bacteria source tracking methods to discriminate *Escherichia coli* isolates from the feces of nine different source-animal categories. The source tracking methods to be compared include ribotyping with *Hind*III (George Lukasik, University of Florida); ribotyping with *Eco*RI and *Pvu*II (Mansour Samadpour, University of Washington); antibiotic resistance analysis (Bruce Wiggins, James Madison University); pulsed-field gel electrophoresis with *Not*1 (Kriston Strickler, West Virginia Department of Agriculture); sole source carbon utilization with BIOLOG (Charles Hagedorn, Virginia Polytechnic Institute and State University); rep-PCR with REP primers (Donald Stoeckel, U.S. Geological Survey); and rep-PCR with BOX primers (Howard Kator, College of William & Mary).

These seven methods will be evaluated based on their ability to correctly identify 200 blind isolates using a library of 900 known-source isolates. The known-source library will be developed using fecal samples collected from nine sources: humans, dogs, beef cows, dairy cows, swine, chickens, horses, white-tailed deer, and geese. The collection of blind challenge isolates will test accuracy with new isolates from the nine sources represented in the known library, precision with replicates from the original known-source library, and robustness with a collection of new sources that are not represented in the source library (such as mice, cats, goats, and llamas). Each of the seven researchers will use his or her method of bacteria source tracking analysis to offer a presumptive identification for each of the 200 isolates in the challenge set. Method performance will be assessed by the rate of correct classification of isolates within each source group, the rate of false identification within each source group, and the ability of each method to handle the unrepresented sources. Currently, each laboratory is in the process of characterizing the known-source library. The challenge isolate set will be distributed to researchers in the summer, and data analysis will begin in the fall.

DECISION SUPPORT SYSTEM FOR SURFACE WATER QUALITY PROTECTION IN MOROCCO

Muriel Bouzinac
Senior Engineer
Ecology & Environment, Inc.
Arlington, Virginia
(703) 522-6065
mbouzinac@ene.com

Stephen H. Blair, P.E.
Chief Engineer
Buffalo, New York
(716) 684-8060
sblair@ene.com

Wadie Kawar
Associate Engineer
Ecology & Environment, Inc.,
Buffalo, New York
(716) 684-8060
wkawar@ene.com

ABSTRACT

The country of Morocco is experiencing rapid growth in the industrial sector, agricultural production, and population. This growth is an indicator of economic prosperity in Morocco; unfortunately, the resulting increase in water demand and water use is placing added pressures on the quality and availability of an already limited resource: water.

To address the problems of water quality in Morocco and to aid in planning for water quality and environmental protection, the Division de Qualité de l'Eau of the Ministère de l'Equipement, Direction Générale de l'Hydraulique, under a loan from the World Bank, has developed a decision support system for evaluating the quality of surface water on a watershed scale. This system, developed conceptually based on the Decision Support System for Integrated Pollution Control (DSS-IPC) developed by the World Bank, combines a pollution loading model, a water quality transport model and an economic evaluation tool (for comparing the cost of different protection strategies) in a GIS interface. System tools allow:

- evaluation of water quality at selected points in the watershed under various development strategies;
- development of engineering and institutional/legislative strategies to protect the quality of water in the watershed;
- application of strategies across socio-economic sectors or to individual pollution sources;
- cost analysis of strategies based on current and projected economic indicators;

- comparison of pollution protection and prevention strategies based on modeled improvement in water quality and strategy cost.

This decision support system represents an improvement over the DSS-IPC in that it considers industrial and non-industrial pollution sources and both point and non-point sources of pollution. Hydraulic and water quality transport models have been added to extend the DSS-IPC from the scale of a single water body to the watershed scale, incorporating a network of rivers, reservoirs, and associated drainage areas.

The tool provides a scientifically based approach for evaluating the relative merits and costs of various pollution control strategies. The utilization of a GIS environment allows more accurate physical representation of the relation between pollution sources and provides a user-friendly, visual environment to aid decision-making.

ANTHROPOGENIC SOURCES OF ARSENIC AND COPPER TO SEDIMENTS OF A SUBURBAN LAKE IN NORTHERN VIRGINIA

Karen C. Rice
U.S. Geological Survey
P.O. Box B
Charlottesville, VA 22903
434-297-0106; fax: 434-977-6751
kcrice@usgs.gov

KEYWORDS: arsenic, copper, lake sediments, urbanization

ABSTRACT

Nonpoint-source pollution from urbanization has long been recognized as a contributor of nutrients and toxic materials to streams and lakes. In several of Virginia's major urban centers, urban growth is expanding into watersheds that historically have been used as catchments for water-supply reservoirs. Results of this study suggest that contaminants such as arsenic and copper associated with urban development within a watershed are easily transported to reservoirs and can affect water quality.

Lake Anne is a 10.9-ha recreational lake situated in a 235-ha suburban watershed (1,116 people/km^2) in Reston, Virginia. Three lake-sediment cores were collected from Lake Anne during 1996 and 1997. An analysis of the cores documented increasing concentrations of arsenic and copper since 1964, when the lake was formed. Mass balances of sediment, arsenic, and copper were calculated for 1998 by sampling precipitation, streamwater, and road runoff. A laboratory leaching experiment on pressure-treated lumber indicated that sufficient arsenic and copper were released to influence the mass balance of these elements. The most important sources of arsenic to the lake during 1998 were in-lake leaching of pressure-treated lumber (52%) and streamwater (47%). Road runoff via streamwater was a greater (93%) source of copper than leaching of pressure-treated lumber (4%). Atmospheric deposition was an insignificant source (< 3%) of both arsenic and copper to the lake during 1998.

An annual historical reconstruction of the deposition of sediment, arsenic, and copper to the lake for 1964 through 1997 confirmed that urbanization of the watershed is a major cause of the increasing arsenic and copper concentrations in the lake cores. Aerial photography indicated that the area of roads and parking lots in the watershed increased to 26% by 1997 and that the number of docks on the lake also increased through time. The increased mass of arsenic and copper in the lake sediments corresponded to the increased amount of pressure-treated lumber in the lake, and the mass of copper also corresponded to the increase in paved surfaces in the catchment.

WITHDRAWALS OF WATER FROM DOMESTIC WELLS IN THE VIRGINIA COASTAL PLAIN

J. P. Pope
E.R. McFarland
R.B. Banks
U.S. Geological Survey
Water Resources Discipline1
730 East Parham Rd., Richmond, VA 23228
(804) 261-2627; fax: (804) 261-2659
jpope@usgs.gov

KEYWORDS: water use, domestic wells, ground-water withdrawal.

ABSTRACT

Reported withdrawals from aquifers in the Coastal Plain of Virginia currently total more than 100 million gallons per day (mgd), but the U.S. Geological Survey estimates indicate that an additional 30 mgd in domestic withdrawals from private wells are not reported, and little is known about the distribution of these withdrawals. Preliminary analyses of well construction data obtained from local health departments indicate that almost half of the private wells installed in the Virginia Coastal Plain in the last 20 years exceed 100 feet in depth, close to 30 percent exceed 300 feet, and more than 5 percent exceed 500 feet. Previous studies have assumed that most domestic wells draw water from the water-table aquifer that is subsequently returned through septic systems. However, the large percentage of deeper wells screened in confined aquifers suggests that private domestic withdrawals are contributing to declines in hydraulic heads and changes in hydraulic gradients throughout the Coastal Plain aquifer system. Consequently, well depth distributions were analyzed along with hydrogeologic framework information in order to assign domestic withdrawals to discrete aquifers in the Coastal Plain system. Demographic data reveal that more than 25 percent of the population of the Virginia Coastal Plain relies on self-supplied groundwater for domestic use; and this percentage is much higher in many rural areas, where domestic withdrawals typically are a large percentage of total groundwater use. While the spatial distribution of well depths across the Coastal Plain is controlled to some degree by local geology and hydrogeology, geographic and socioeconomic factors also appear to have substantial effects. Further study will be needed to better evaluate these factors as populations in this region continue to grow. The magnitude and distribution of domestic withdrawals indicate that properly quantifying this component will be important to understanding and modeling groundwater flow and effectively managing groundwater withdrawals in the Virginia Coastal Plain.

INSTREAM FLOWS FOR RIVERINE STEWARDSHIP

John Kauffman
Virginia Department Game and Inland Fisheries
900 Natural Resource Drive Suite 100
Charlottesville, Va. 22903
434-296-4731, fax 434-979-0927
jkauffman@dgif.state.va.us.

KEYWORDS: Public Trust Doctrine, riverine components, flow assessment tools

ABSTRACT

In 2002, a national team of 19 state and provincial fish and wildlife agency biologists produced a book to publicize appropriate instream flow strategies for managing, maintaining, or restoring riverine fishery and aquatic wildlife resources and processes. The Public Trust Doctrine (PTD) is an important component of state legal principles for air, water, and fish and wildlife resources management and the origins of the PTD and its role in Virginia is discussed. Stewardship responsibilities are entrusted to the states to manage those resources for future generations. In order to recommend flows, five components are important in shaping the physical, chemical, and biological process of the riverine environment. Use of an interdisciplinary team is necessary to address the five components: hydrology, biology, geomorphology, water quality, and connectivity. Historically, flow recommendations focused only on water quality and the biology. The other processes that create and maintain the habitat were not addressed. The Instream Flow Council identified tools for each of the components. Two tools or methods were identified for hydrology, thirteen for biology, five for geomorphology, three for water quality and four for connectivity. Two other tools address multiple components. Each tool was categorized as to whether it was useful for monitoring/diagnostic, standard setting, or an incremental method. Research demonstrates that flows should have inter and inter-annual variability to ensure that all components are addressed. Use of a single flow value will not ensure that all ecological processes can occur. No single tool exists to develop flow recommendations due to the variability within the state of geomorphic province, geology within a province, hydrology, and array of species present across the state. Opportunities exist to improve management potential. Virginia stream flow gaging stations have decreased in number over the last twenty years despite increased demand on the resource. Those losses have occurred in primarily the small and mid size watersheds. Training opportunities have declined. Agricultural use is not regulated and the interconnection between groundwater and surface water is poorly understood and poorly addressed by current techniques are flows necessary for tidal and estuary areas.

IMPLEMENTING GUIDELINES OF WATER INTAKE DESIGN CRITERIA IN VIRGINIA: THE TRIUMPHS AND HURDLES

Tom Wilcox
Environmental Services Section
Virginia Dept. of Game and Inland Fisheries
4010 West Broad Street
Richmond, VA 23230
804/367-8998; Fax: 804/367-2427
twilcox@dgif.state.va.us

ABSTRACT

Implementing the Virginia Department of Game and Inland Fisheries (DGIF) water intake design criteria has been a challenge with some successes and pitfalls. Our design criteria were developed to protect aquatic resources from entrainment and impingement. However, issues related to increased costs and engineering hurdles have sometimes been difficult to resolve between water users, permit agencies, and DGIF. Education and preliminary review of projects have lowered the height of some hurdles, but several remain. We are currently requesting that our criteria guidelines be reviewed by several engineers to gather a different point of view. We have also asked other scientist in Virginia to review our criteria. These findings will be presented at the conference to serve as an update and for possible revisions of our guidelines.

DETERMINING THE ECONOMIC VALUE OF A WATER RESOURCE PROJECT: AN APPLICATION OF THE CONCEPTS OF CAPITAL BUDGETING TO THE PROCESS OF WATER RESOURCE MANAGEMENT.

James P. Savage
Managing Director
Water Resource Advisors, LLC
PO Box 562
1521 Blue Ridge Road
Glasgow, VA 24555-0562
540 258 9946; Fax: 540 258 9956
jpsavage@ntelos.net

KEYWORDS: time value of money, net present value, net value flow, internal rate of return, cost of capital, investment decision, cost-benefit analysis.

ABSTRACT

To select the best economic value from a group of available water resource projects several variables must be determined. First the initial capital cost is estimated, followed by the estimation of the periodic expected future net benefits that are to be enjoyed as a result of the investment in the water resource project. The series of period net value flows accruing from the project are discounted at some interest rate to determine the present value of the stream of benefits. The discount rate that causes the present value of the series of periodic net benefits to equal the initial capital cost is the internal rate of return. The internal rate of return is the natural or "efficient" rate of return. In simple terms it is the discount rate that makes the cost equal to the present value of the expected net benefits. No project should be selected for consideration if the internal rate of return is below the market rate of interest. Of those projects for which the internal rate of return is greater than the market rate of interest the one that has the highest net present value is the preferred project. The net present value is determined by discounting the series of periodic net benefits at the market rate of interest to find its present value. The initial capital cost of the project is subtracted from the present value to obtain net present value.

INTRODUCTION

The value of any investment is uniquely determined by discounting the series of expected future benefits at some rate of discount to compute its "present value." (Gallagher and Andrew 2000; Stewart 1999) In order to arrive at a value for an investment, either environmental, water resource or other investment, the investor will estimate the future net benefits as a result of owning the investment. This involves estimating the future and that involves uncertainty. The further in the future the expected benefit, the more the uncertainty as to its value. The series of net benefits expected to be received at periodic intervals in the future will be discounted at some rate, either the market interest rate, some required interest rate imposed by the investor, or by a rate which is known as the internal rate of return. These different discount rates tell the investor different things about investment value. The present values thus determined will be the basis of the investment decision process. (Feather, et al. 1995)

Policy makers are usually faced with situations in which decisions have to be made under conditions of uncertainty. In the case of an investment in a water resource project, the amount and timing of the initial capital cost generally can be estimated with a fair degree of accuracy. On the other hand, the estimate of the amount and timing of the expected future benefits and operating costs will be subject to a degree of uncertainty. The expected future net benefits would be influenced by: environmental, technical, social and political considerations, as well as by economic factors. Some of these net benefits will be harder to quantify than others. (Dorfman and Dorfman 1993; Hanley and Spash 1993; McDonald and Jones 1999) However, the further in the future a benefit is to be received the smaller its "present value" will be at any given discount rate and thus the smaller its contribution to total "present value" of the project.

In the event that more than one water resource investment is available (that is, where more than one solution to a water resource problem is available to policy makers) the decision making problem may be complicated by the fact that the investments (viable solutions) may be interdependent, i.e., they may be able to be implemented in sequence; or they may be mutually exclusive. In any case, ultimately decisions must be made and alternatives selected.

SETTING OF THE WATER RESOURCE PROBLEM

The policy makers who are charged with the management of a regional water resource must first understand the nature of the watershed they inhabit. Unless they understand the system within which the water resource problem is set, they will not be able to manage the water resource effectively. At some point the viability of communities in the watershed may be threatened and development thwarted.

Communities, real-estate developers, industrial enterprises and individual landowners should try to understand the basic water resource relationships, particularly relationships between groundwater and surface water, when attempting to resolve a water resource issue. The parties to any water resource project should be willing to conduct a detailed analysis of the problem to be solved. Failing to understand the problem is the most important cause of bad decisions by policy makers. (Russo and Schoemaker 1990) Failure to analyze the problem has resulted in worse problems being created by the results of a solution's application. (Chapelle 2000) Policy makers should try to understand the relationship between the perceived problem, the existing conditions of their watershed, and the conditions in the specific part of the watershed where the perceived problem is believed to exist. The solutions that should be applied to the problem will be technically efficient, socially and politically acceptable, environmentally beneficial, and economically justifiable. The solution to be applied should be examined carefully to identify any unintended consequences that might result from its application.

Once a set of solutions has passed the various tests of acceptability, they should be ranked according to their economic value. The economic value will be a function of the initial cost, the expected future net benefits and their timing. To conserve scarce resources, economic criteria must be applied to the identification and selection of the most valuable solution from amongst the competing solutions. The most valuable solution will be the one that maximizes the "net present value" of the investment in the solution. That is, the most valuable solution will be the one where the quantity, “present value minus initial capital cost” is largest and most positive. The “most valuable” solution will also be the “efficient” solution. (Seneca and Taussig 1984)

The “most valuable” solution may be a single solution or a sequence of solutions. The timing of the sequence will be affected by the degree of damage or loss incurred by delaying the implementation of an alternative solution, as well as by the economic and technical savings or benefits to be gained from delaying the implementation of any given alternate solution.

Faulty Guidelines

The publication: “Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies,” was issued by the U.S. Water Resources Council, Department of the Interior, in February 1983. The purpose of the publication was to provide guidance for the implementation of the results of studies done in the process of solving water resource and other related resource problems. The guidelines presented in this publication are flawed in a number of important respects. In a previous paper on this subject (published in Kenney, ed. 2002) I discussed these flawed guidelines and the way in which they were invoked by governmental organizations in the upper Tygart Valley of Randolph County, West Virginia in the process of selecting a (bad) solution to a perceived water resource problem.

In this paper we will confine ourselves to the implications of “present value” determination by policy makers seeking an economically efficient solution. I will present a discussion of economic selection criteria. The implementation of the suggested selection criteria by project sponsors and their consultants should cause the decision making in water resource or other environmentally sensitive projects to be more rational and should result in projects being valued consistent with their costs and the present value of their expected future net benefits.

Economics, Investment Return, Uncertainty and Risk

Change in “national economic development” resulting from the project is the only economic variable that is required to be accounted for in the selection of an alternative, according to “Principles and Guidelines” (US Water Resources Council 1983). In fact, the measure that should have been accounted for is the “net present value” of the project. However, in the West Virginia case, no effort was made to determine national economic development or a related variable, “regional economic development.” These variables would require estimates and forecasts. This involves the future and the future cannot be known with certainty. To make matters worse “Principles and Guidelines” provides an erroneous and misleading definition of the terms “risk” and “uncertainty.” (Logical and consistent definitions of the terms “risk” and “uncertainty” are presented in my article in: Kenny, ed. 2002.)

At the time when projects are being considered, the amount and timing of the initial capital cost of implementing the project is usually known within a reasonable margin. However, the future expected net benefits (periodic net value flows) (See Hanley and Spash 1993) of a project cannot be known with certainty. The degree of uncertainty in the estimates of future costs and benefits of a project must be considered explicitly in any valuation scheme. The shorter the time period of the prediction the better the estimates of net value flows should be, all else being equal.

Time Value of Money

In order to understand the process of economic valuation, we need to do a review of the concept: "time value of money". In addition to being more uncertain, returns or benefits expected to be received sometime in the future have lower "present values" the further in the future is the period in which they are expected to be received, and also, the higher the interest rate used to discount the series of expected net benefits.

Interest

Since an amount to be received in the future is of less value than same amount in hand today, a fee, which we call "interest", is required in order to induce someone to part with money today that will be repaid sometime in the future. This fee will include a return for:

- Waiting (postponed consumption).
- The probability that interest rates might change (investment risk).
- Potential (or expected) inflation.
- The possibility that the borrower will not be able (or willing) to repay.

The fee or interest rate that the market exacts from seekers of capital is called the cost of capital. This fee is the rate of discount used to determine present value.

Present Value

"Present Value" is the value today (usually expressed in dollars) of an amount to be received at some specified time in the future discounted at some positive rate of interest.

Present Value (Single return)

$\$PV = \$1.00\left(\frac{1}{(1+i)^n}\right)$; i.e., PV is inversely correlated with the discount (interest) rate, "i", and the number of periods, "n", until receipt.

TABLE 1. PRESENT VALUE

$\frac{1}{(1+i)^n}$		Years=n	
		25	50
Discount	6%	.2230	.0543
Rate	20%	.0105	.0001

As $(1+i)^n$ becomes large $\frac{1}{(1+i)^n}$ approaches zero.

For example, assume you are to receive $100 three years from now and the market rate of interest is 5 percent. The present value of the $100 to be received three years in the future is:

$$\$100\left(\frac{1}{(1.05)^3}\right) = \$100\left(\frac{1}{1.157625}\right) = \$100(.8638) = \$86.38 \text{ For i=5\%, n=3 years.}$$

"Present Value" of a series of equal future returns, e.g., an annuity where each payment is received at yearend is computed as follows:

$$\$PV = \left(\sum_{t=1}^{n} \frac{\$1.00}{(1+i)^n} \right) = \left(\frac{\$1.00}{(1+i)} + \frac{\$1.00}{(1+i)^2} + \frac{\$1.00}{(1+i)^3} + ... + \frac{\$1.00}{(1+i)^n} \right) \text{ For non-zero “i”.}$$

The present value of a series of amounts to be received annually for a period of three years with a market rate of interest of 5% is:

$$\$PV = \left(\frac{\$100}{1.05}. + \frac{\$100.}{(1.05)^2} + \frac{\$100.}{(1.05)^3} \right) = (\$95.24 + \$90.70 + \$86.38) = \$272.32 \text{ for n = 3, i = .05.}$$

Valuing Investment Projects

Net present value is the difference between the initial capital cost of an investment and the present value of the series of net value flows to be received from the investment, discounted at the market rate of interest or “cost of capital.” The larger the net present value, given the market rate of interest, the more valuable the project. The discount rate that causes net present value to equal zero is called the internal rate of return. The internal rate of return is the “natural” or “implicit” rate of return of the investment project. We will use the symbol “k” to represent the internal rate of return and to distinguish it from “i” the market rate of interest (or “cost of capital”).

$$\text{NPV = 0 when } ICC = \left(\sum_{t=1}^{n} \frac{(NVF_n)}{(1+k)^n} \right) \text{ For } n = 3,\ ICC = \left(\frac{NVF_1}{(1+k)} \right) + \left(\frac{NVF_2}{(1+k)^2} \right) + \left(\frac{NVF_3}{(1+k)^3} \right)$$

- NPV is defined as the “net present value” or “the discounted sum of the NVF’s minus the ICC”.
- ICC is defined as the initial capital cost of the project.
- NVF_n is defined as the net value flow in period “n” resulting from an investment made in a previous period.
    - NVF will be measured in dollars but will include politically valued benefits (or costs), as well as externalities, beneficial or detrimental. (Feather, et al, 1995; Hanley and Spash, 1993; McDonald and Jones, 1999; Seneca and Taussig, 1984)
    - It is the difference between the periodic benefits and the periodic costs (e.g., periodic revenue from customers minus periodic maintenance and operational costs of a water processing plant) of the project whose capital cost was expended in the initial period. (In finance we use the term “net cash flow” instead of “net value flow”, but see Hanley and Spash, 1993; Dorfman and Dorfman, 1993.)

TABLE 2. IMPACT OF TIMING OF NET VALUE FLOWS ON INTERNAL RATE OF RETURN

Net Value Flows	ICC	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	IRR
Project I	-100	50	25	10	10	10	10	10	10	10	10	14%
Project II	-100	10	10	10	10	10	10	10	10	25	50	7%

Both projects have the same benefit-cost ratio, 1.55 to 1. Which is more valuable?

The Implications of the Discount Rates

We have used two terms to identify discount rates: the "internal rate of return", "k"; and the cost of capital or market rate of interest, "i". The internal rate of return is a discount rate that causes the present value of the expected net benefits to be equal to the initial capital cost of the project. It is a measure of the efficiency with which the initial investment is put to work in the effort to accomplish an investment goal. No investment whose internal rate of return is less than the market rate of interest should be implemented. Even if financing of the project is available at a rate of interest lower than the market rate of interest, the first decision criterion is "k"> "i".

For a number of reasons, policy makers may use a rate of discount that is different from the internal rate of return and from the market rate of interest as a discount rate to determine net present value. Perhaps in recognition of the interests of future generations, a very low discount rate may be used to determine the net present value of a project. This has the effect of giving a greater value to net benefits expected in more distant periods. No project whose internal rate of return is below the market rate of interest should be considered since this does not result in an efficient use of resources. The question of planning far into the future and considering the effects of policy on future generations is an important one that deserves its own discussion.

DETERMINING THE VALUE OF A WATER RESOURCE PROJECT

The "mutually exclusive" Case

Once the water resource problem to be solved has been properly identified, the available solutions need to be evaluated. For each technically viable, mutually exclusive, as well as socially and politically acceptable solution the sponsors will estimate the initial capital cost as well as the net value flows for each of the years of the functional life of the project. With this data, the sponsors can determine the internal rate of return for each solution, (i.e., where the discount rate "k" makes NPV=0), identify those for which k > i, then, using "i" as the discount rate, determine the NPV of those that meet the criteria k > i. For those projects that meet the criteria k > i, rank them according to NPV (using "i" as the discount rate), from largest to smallest. The project with the largest NPV is the most valuable. From an economic valuation point of view, it is the solution that should be implemented

.

The "interdependent" Case

In many cases for which a water resource problem needs to be solved, the policy makers may have an option to implement one solution that then allows the indefinite postponement of one or more other, perhaps more expensive, solutions. That is, a situation may exist in which two or more solutions can be used and used sequentially to solve a water resource problem. This option (to select and schedule) has a value that is related to the opportunity cost involved in the timing and size of the expenditures for the alternate solutions.

As an example, the city of New York was faced with the problem of building a multi-billion dollar filtration system to process water coming down from the upstate Delaware River/Catskill Mountain watershed areas west of the Hudson River. (Water from the Croton River watershed on the east side of the Hudson River is already being filtered.) The city managed to get agreement for, and to implement a watershed management plan that, although expensive, was orders of magnitude less costly than building a filtration system. The city would thus benefit by the amount of the present value of the cost *not incurred* to build, operate, and finance the filtration system over the period during which the filtration system was not required.

The trade-off involves a comparison of the capital and operating costs of the two alternative solutions as well as the evaluation of the loss involved in, for example, cancer deaths related to drinking water quality. (Conrad and Lopez 2001, present a detailed mathematical analysis of this problem.) so long as the watershed management program is able to keep nutrient levels in the surface water below the critical level the city can justify chlorination without filtration. This involves a significant benefit to the city because of the value of the postponement of the initial capital cost as well as the accompanying annual operating costs of the filtration system.

Implications for Policy Makers

Water resource projects require the commitment of scarce resources in their implementation. Over their life they are expected to generate net benefits that may or may not justify the initial capital cost. Policy makers face a difficult task in the decision to commit resources to a project, the results of which cannot be known with certainty.

The implications of the foregoing observations are that projects that have large capital costs will be harder to justify the higher the market interest rate and the farther in the future the time when the benefits to be created by the project are to be received. The higher the cost of capital (market interest rates), the greater the benefit (in the economic sense) from choosing a lower capital cost project with a lower annual debt service but higher annual operating and maintenance costs. Also the degree of uncertainty in the estimates of costs and benefits of any solution needs to be considered explicitly in the decision making process. If there is a less expensive interdependent solution that can be used to solve the problem temporarily, the costs and their timing should be compared to the expected savings (opportunity costs) to be gained from not implementing the more expensive solution until some later time.

If a water supply system is being considered for a region, careful planning is necessary to prevent over building for a consumer demand that may not materialize soon, or ever. On the other hand, regional planners, governments and regulators should be looking ahead to the availability of water resources and their efficient development since the regional water resource is without doubt the limiting constraint on any proposed regional growth plan. Good planning will start with effective watershed management practices.

As between two projects with equal initial capital cost, the one whose net benefit flow is the more certain is the one to be preferred. The project whose net benefits will occur soon after the investment commitment is made is to be preferred over the one whose benefits will be received far in the future.

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COOPERATIVE INFRASTRUCTURES FOR SMALL WATER SYSTEMS: A CASE STUDY

Micki M. Young
Dixie Reaves
Eluned Jones
Agricultural and Applied Economic
Virginia Tech
Dixie@vt.edu

Tamim Younos
Virginia Water Resources Research Center
Virginia Tech
Blacksburg, Virginia

ABSTRACT

Small water systems (SWS) can serve as many as 3,300 people and as few as 25 people, compared to large waterworks that serve thousands of people in metropolitan areas. In Virginia, more than 90% of the water suppliers fall into this category of public "rural" SWS. In 1996, the Safe Drinking Water Act (SDWA) was amended to protect Americans from unsafe drinking water and to prevent contamination of drinking water sources. Specifically, section 1420 of the SDWA focuses on developing the financial, managerial, and technical capacities of SWS where violations of drinking water standards are prevalent. In 1997, 304 Virginia waterworks reported violations of drinking water standards, 53% of which were rural SWS.

The SDWA authorized the United States Environmental Protection Agency (U.S. EPA) to set National Primary Drinking Water Standards (NPDWS). Large water systems, serving over 3,300 people, typically possess the financial resources and technical skills to meet the NPDWS due to economies of scale. However, a large number of small water systems do not meet SDWA standards because they lack the available capital, do not retain a large volume of business, and are limited by their dispersed geographic locations. Often SWS are an auxiliary operation to another business with limited available capital, which results in the operation's inability to comply with the NPDWS.

The overall goal of this study is to analyze the opportunities and potential for a cooperative structure in rural Carroll County, Virginia. It is hypothesized that, by organizing as a cooperative, SWS in Virginia can obtain operational efficiency and meet the NPDWS through economies of scale. Specifically, the research involves a market analysis of the factors which influence costs, operational efficiency, revenue, the exchange of technical information, operational capacities, and, thereby, the number of NPDWS violations in those participating SWS.

The results of this research reveal ways in which a cooperative structure could result in efficiency and compliance gains. Results are used to develop guidelines for a conceptual

cooperative structure that can be applied to SWS across rural Virginia and perhaps may have application on a broader geographic scale.

WINTER MANAGEMENT OF CONSTRUCTED WETLAND TREATMENT SYSTEMS

E. Smith
R. Gordon
A. Madani
G. Stratton
Nova Scotia Agricultural College
Nova Scotia, Canada
mamadani@nsac.ns.ca

KEYWORDS: constructed wetlands, cold climates, first order rate constants, hydraulic loading rate

ABSTRACT

Small-scale constructed wetland systems have been designed to evaluate the wastewater treatment achieved in cold climates. The wetland systems have been found to be effective in treating BOD_5, TSS, TP, SRP, TKN, NO_3-N, NH_3-N, and fecal coliform, with treatment efficiencies > 76% and mass reductions >62%. First-order rate constants were also evaluated for selected wastewater parameters to assess their relationship with water temperature, as well as solar radiation. Parameters measured were not found to be directly related to either water temperature or solar radiation. Results illustrate that there is a strong relationship between hydraulic load (q) and first order rate constants (k), especially for BOD_5.

INTRODUCTION

The number of livestock raised on farms in North America has risen steadily since the 1950s (Merkel 1981). As a result, large amounts of livestock waste is produced in concentrated areas which present a threat to the air, soil and water quality (Merkel 1981). To manage this threat, new methods for handling, storing, treating, utilizing, and disposing of wastes have been developed (Hammer 1992).

Livestock waste is a source of nitrogen (N) and phosphorous (P) pollution, especially when raised in concentrated areas (Merkel 1981). These nutrients can be recycled simply by applying them to cropland as a fertilizer, however the amount of waste produced can often exceed the area of the land the producer has available to reuse the nutrients (Merkel 1981). Pollutants derived from agricultural operations have the potential to cause impairment of both surface and groundwater quality. They often enter surface waters from diffuse or non-point sources associated with runoff. They can also come from point sources which are typically associated with highly concentrated farming activities, such as the production of livestock (Merkel 1981). It is important that recognition of the impacts that may result from the release of concentrated levels of oxygen demanding organic waste and the potential polluting ability of the nutrients contained take place. Fortunately, this recognition is now being made and has lead to the investigation of multiple waste management alternatives (Kadlec and Knight 1996).

One alternative to deal with this problem, that has been receiving increased consideration, is the use of constructed wetlands to intercept and partially remediate wastes before they leave the farm in the form of surface runoff or through groundwater infiltration (Peterson 1998). Constructed wetlands offer a low-cost, low-energy alternative to other waste treatment technologies and are often compatible with typical farming operations (Kadlec and Knight 1996).

Constructed wetlands are gaining increased attention for the treatment of non-point source pollution (Kadlec and Knight 1996). Although they have been used successfully for wastewater treatment in warm climates, less is known about treatment efficiencies in colder climates. Many colder climate systems typically store wastewater during the winter months and then discharge into the wetland during the spring, summer, and fall when the treatment efficiency is thought to be good. The advantage is the availability of warm climate design information and standards; the disadvantage is the cost of the storage lagoons. Therefore, further study of the effects of winter freezing temperatures (<0EC) on treatment efficiencies is warranted. This research is designed to assess wetland effectiveness and observe the impact of winter climatic conditions on their performance.

OBJECTIVES

Constructed wetland treatment systems have been implemented throughout North America and have been used to treat various types of wastewater. These systems have shown promising results and success in warm climates with removal efficiency rates ranging from 70 to 99% (Cronk 1996). This has prompted the agricultural sector to utilize these systems with improving the management of agricultural wastewater. The question remains however, whether these systems have the ability to treat wastes year-round in colder climates. Waste production is a year-round process and, therefore, so should wastewater treatment. For this reason, the goal of this research is to develop winter management techniques that can be implemented to help improve and promote winter treatment performance of constructed wetlands. The specific objectives are to:

- Evaluate the wastewater treatment (by looking at reductions in BOD_5, TSS, TN, ammonia nitrogen (NH_3-N), TP, SRP and fecal coliform) achieved during the cold and warm months in replicated agricultural wetland treatment systems.
- Derive first order rate constants (k) for selected water quality parameters and assess their direct relationship with the prevailing atmospheric conditions.

MATERIALS AND METHODS

Two similar surface flow (SF) wetland systems with an approximate surface area of 100 m^2 were constructed in Bible Hill, Nova Scotia (Figure 1). Both wetlands were lined with a polyethylene liner. Each wetland system was a one-celled system that contained two deep and two shallow zones. The shallow zones were approximately 0.15 m in depth, while the deep zones were 1 m. The shallow zones were covered with 0.30 m of loamy sand topsoil to act as a bed for aquatic vegetation. Each wetland system was then planted with cattails that were gathered from a nearby natural wetland system. Water was added to each wetland system and plants were then given two months to establish themselves before wastewater was introduced.

Dairy wastewater with an approximate BOD_5 of 1000 mg L^{-1} was loaded into the three storage tanks (Figure 1). After the dairy wastewater was tested, it was then loaded into each wetland system at a controlled rate of approximately 291 kg of BOD_5 $ha^{-1}d^{-1}$ (with approximately 200 L of wastewater entering each wetland per daily). The dairy wastewater was then gravity fed from one of the holding tanks into the first sampling station, where inflow was measured using a tipping bucket and recorded using a CR10X data logger. The wastewater was then emptied into a metal collection pan, where the wastewater was equally divided prior to entering the wetlands. This ensured that equal amounts of wastewater flowed to each wetland system. The first wetland system acted as a control, where it remained at a constant water depth, however the water level in the second wetland system was altered during the time of freezing to help achieve an insulating effect and prevent total ice formation.

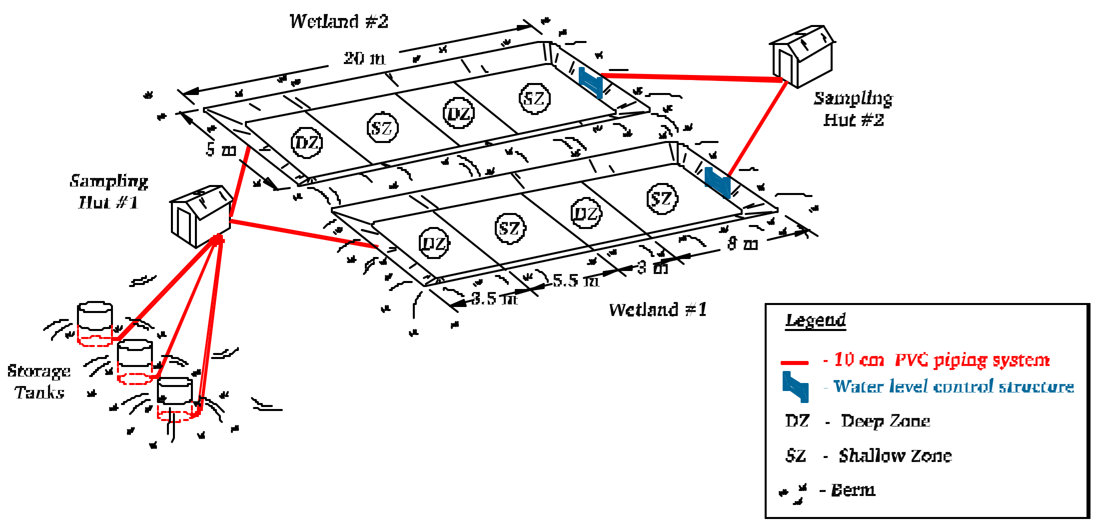


Figure 1: Schematic of SF constructed wetlands located in the Agri-Tech Park in Bible Hill, Nova Scotia

Isco Model 6700 Portable Autosamplers (Isco, 1999) were used to collect multiple wastewater samples for the two-year period of November 2000 through March 2002 at both the inflow and outflow ends. The frequency of sampling depended on the prevailing weather conditions. For example, if the winter was extremely cold for long periods of time there was little to no outflow, therefore fewer samples during this time were collected. However, most times a sample was collected on a weekly basis. Wastewater samples were also manually obtained at various locations throughout the wetlands, including above and below the ice surface and were again analyzed for the following parameters:

- **Nutrient Parameters:** total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate (NO_3), soluble reactive phosphorous (SRP), and total phosphorous (TP).

- **Other Parameters:** total suspended solids (TSS), five-day biochemical oxygen demand (BOD_5), and a fecal coliform (FC).

All samples were analyzed using the procedures outlined in Standard Methods for the Examination of Water and Wastewater (APHA 1998) and Hach Water Analysis Handbook (Hach 1992). By analyzing the samples for the parameters mentioned above, the treatment efficiencies for both of the wetland systems were determined.

The percentage (%) removal was calculated for each of the above mentioned water quality parameters as follows:

$$\% \, Removal = \frac{C_{in} - C_{out}}{C_{out}} \times 100 \tag{1}$$

where:

C_{in} = Inflow concentration (mg L^{-1})
C_{out} = Outflow concentration (mg L^{-1}).

The % mass removal was similarly determined by:

$$\% \, Mass \, Removal = \frac{(\sum C_{in} \times \sum Q_{in}) - (\sum C_{out} \times \sum Q_{out})}{(\sum C_{in} \times \sum Q_{in})} \tag{2}$$

where:

3C_{in} = sum of monthly inflow concentration (mg $L^{-1)}$
3C_{out} = sum of monthly outflow concentration (mg L^{-1})
3 Q_{in} = sum of the monthly flow volume into the wetland (L)
3Q_{out} = sum of the monthly outflow volume out of the wetland (L).

Meteorological conditions have also been monitored at the wetland site to help get a better understanding of the results obtained from sampling. Meteorological conditions have been monitored using a Campbell Scientific CR10X data logger. Measurements taken included, precipitation using a heated rain gauge, solar radiation using a pyranometer, air, and soil and water temperature using temperature referenced copper constantan thermocouples.

Several physical measurements have also been recorded such as, water and ice depth, to determine how or if the ice froze throughout the wetland during the winter months. Water depth has been measured using sonic depth sensors. Ice thickness and water depth has also been measured using an ice auger and a meter stick. To help determine how water level affects efficiency, the water level in wetland 1 has been left at a 0.30 m operating depth. However, in wetland 2 the water level has been raised at the time of freezing, once freezing occurred the water level was then lowered by the use of gate valves. It was anticipated that this would prevent total ice formation and allow for microbial activity to continue, hence aiding in winter time efficiency.

WETLAND DESIGN

Constructed wetlands should only be designed as secondary and tertiary wastewater treatment systems, which from an agricultural perspective means that they are primarily designed to treat runoff from agricultural waste storage facilities and not the raw wastewater itself (Hammer 1992; Kadlec and Knight 1996). The size of the wetland must be based on the estimated volume of wastewater to be treated, the concentration of the wastewater entering the wetland and the desired level of treatment to be achieved (Hammer 1991). The design of animal waste treatment wetlands was originally derived from municipal treatment wetlands (Kadlec and Knight 1996). Their design has typically been approached as a first-order rate equation based on plug flow assumptions. The most popular approach in design has been presented by Kadlec and Knight (1996) as:

$$A = -\frac{Q}{k}\left[\ln\left(\frac{C_{out} - C^*}{C_{in} - C^*}\right)\right] \qquad (3)$$

where:

A = surface area of the wetland (m^2)
Q = average flow in the wetland ($m^3\ y^{-1}$)
C_{in} = influent concentration ($mg\ L^{-1}$)
C_{out} = effluent concentration ($mg\ L^{-1}$)
C* = background concentration ($mg\ L^{-1}$)
k = first-order, area-based rate constant ($m\ y^{-1}$).

The hydraulic loading rate, q ($m\ d^{-1}$) is defined as:

$$q = \frac{Q_{ave}}{A} \qquad (4)$$

where: Q_{ave} is the average flow rate ($m^3\ d^{-1}$) (Reed *et al.*, 1995):

$$Q_{ave} = \frac{Q_{in} + Q_{out}}{2} \qquad (5)$$

and where:

Q_{in} = is the sum of flow into the wetland ($m^3\ d^{-1}$),
Q_{out} = is the sum of flow out of the wetland ($m^3\ d^{-1}$).

In many cases, the application of constructed wetlands to treat agricultural waste has been impeded due to a lack of design criteria and a limited understanding of how these systems can be managed. By quantifying k values for various water quality parameters a wastewater loading rate can be estimated and in turn the proper wetland size can be determined to help improve the overall treatment performance of these systems. For the purpose of this research investigation k values are being used as integrated performance indicators.

Constructed wetlands encounter three main challenges in cold climates: (i) ice formation, (ii) hydrology and hydraulics, and (iii) inadequate treatment processes due to low temperatures (Maehlum and Jenssen 1998). The biological reactions responsible for the decomposition of organic matter (BOD), mineralization, nitrification, denitrification, and the removal of pathogens are, in most cases, known to be temperature dependent in all wastewater treatment processes including constructed wetlands (Reed *et al.* 1995; Kadlec and Reddy 2001). With this in mind, it is always important to assess the role temperature plays on treatment performance and ensure that a temperature effect is not being masked by other environmental factors. This is achieved by rearranging eqn. (1) to calculate a temperature-related rate constant (k) for a particular wastewater parameter measured in a wetland system.

STATISTICAL ANALYSIS

Statistical analysis on the constructed wetland data were performed using the Minitab system (Minitab 2000). Regression analysis was completed to determine if there were any correlations between specific wastewater parameters and atmospheric conditions.

RESULTS

Table 1 indicates the daily loading rates that were used for each wetland system throughout the course of this research investigation. Mean concentration values and standard deviations for each parameter measured at the inlet and outlets can be seen in Table 1. Mass reductions for the most part, for each wetland system, demonstrated that these systems are indeed working; even though the loading rate for BOD_5 (291.5 kg ha^{-1} d^{-1}) was higher than some current wetland systems being monitored in Nova Scotia.

TABLE 1: DAILY LOADING RATES AND MEAN INFLOW AND OUTFLOW CONCENTRATIONS (± STANDARD DEVIATIONS) FOR BOTH WETLAND 1 (W1) AND 2 (W2).

Parameter	Daily Loading Rate (kg ha^{-1} d^{-1})	Inflow (mg L-1)	W1 (mg L-1)	W2 (mg L-1)
BOD_5	291.5	1491 ± 963.1	18.2 ± 20.4	7.6 ± 6.8
TSS	199.1	716.0 ± 600.9	38.6 ± 39.6	20.6 ± 31.1
TP	15.8	44.4 ± 26.2	4.0 ± 4.6	2.2 ± 2.9
SRP	13.7	39.0 ± 22.6	3.4 ± 3.9	1.7 ± 2.1
TKN	60.9	172.9 ± 154.5	11.2 ± 12.9	3.8 ± 3.5
NH_3-N	35.9	147.0 ± 136.9	8.1 ± 11.1	1.6 ± 2.2
NO_3-N	0.82	2.4 ± 4.3	0.566 ± 1.13	0.357 ± 0.424
FC	1.91 × 1010	7438.1 ± 17568.8	20.4 ± 72.7	23.6 ± 71.0

*The daily loading rate for FC is measured in CFU ha^{-1} d^{-1} and concentration values are in CFU 100 mL^{-1}.

TABLE 2: MASS REDUCTIONS (%) FOR WETLAND 1 (W1) AND 2 (W2).

Parameter	Mass reduction for W1 (%)	Mass reduction for W2 (%)
BOD_5	94.0	94.0
TSS	87.9	87.0
TP	76.0	62.0
SRP	75.1	65.1
TKN	80.2	94.8
NH_3-N	81.8	88.0
NO_3-N	82.0	67.5
FC	99.1	96.8

Throughout the course of this research investigation, there was an imposed increased water depth during the winter months in W2 (Fig. 2). Figure 2 indicates the various monthly mean water depths in each wetland system. Wetland 2 for the most part, had a higher water depth, although the volume of each wetland system was similar. During the cold months, the water level in W2 was raised before freezing occurred, allowed to freeze for a short period and then lowered. This management practice was used to ensure that there was an existing air gap between the frozen water on the top and the unfrozen water on the bottom. Results demonstrated that total ice formation was prevented, although neither wetland at any point in time had total ice formation.

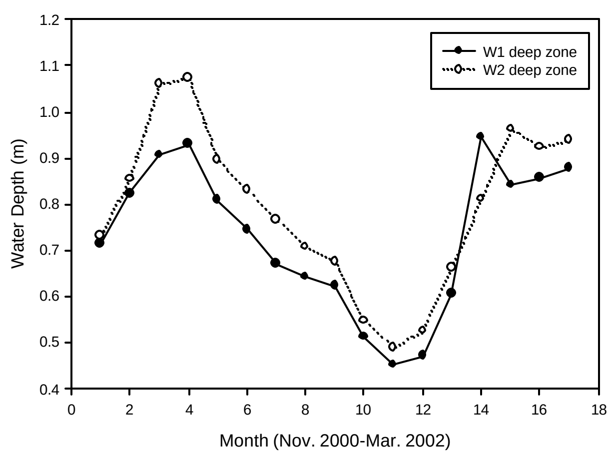


FIGURE 2: AVERAGE MONTHLY WATER DEPTHS IN THE DEEP ZONES OF BOTH WETLAND 1 (W1) AND 2 (W2) (WHERE MONTH 1 IS NOV. 2000).

Throughout the course of this research, cumulated monthly outflows for each wetland system were higher than the inflow into each system (Figure 3). This was mainly due to high precipitation levels; ice and snow melt within each wetland system. Outflows however, were fairly constant during the period of May 2001 to December 2001 (Figure3). Evapotranspiration within the wetland systems accounted for some of this.

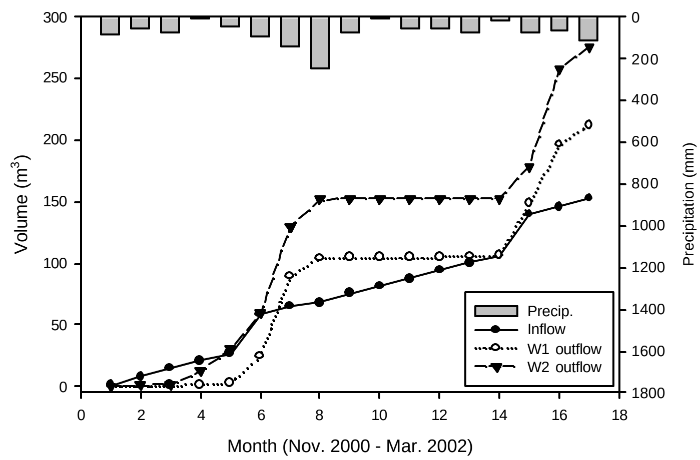


FIGURE 3: CUMULATED MONTHLY FLOWS AND PRECIPITATION FOR BOTH WETLAND SYSTEMS (WHERE MONTH 1 IS NOV. 2000).

The cumulative mass removal for BOD_5 was very good with treatment efficiencies ranging from 89.0 to 99.9%. The mass reductions for both wetland systems were 94.0% (Figure 4).

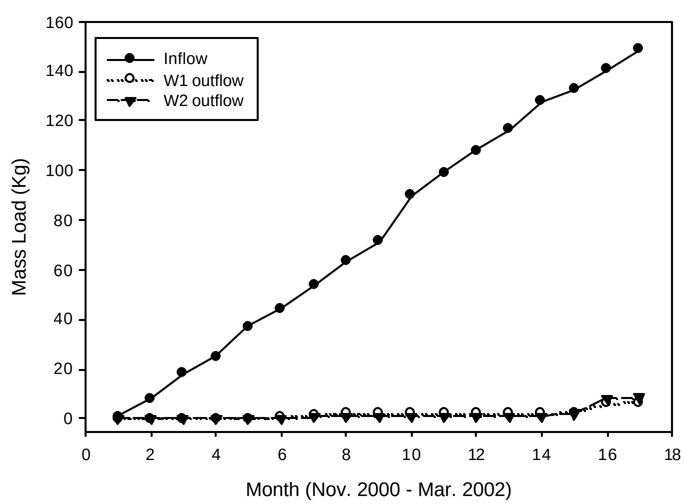


FIGURE 4: CUMULATED MASS LOAD VALUES FOR BOD_5 (WHERE MONTH 1 IS NOV. 2000).

TP demonstrated similar patterns with percent removals ranging from -2.22 to 99.9% and total mass reductions of 76.0 and 62.0% for W1 and W2, respectively (Figure 5 and Table 2).

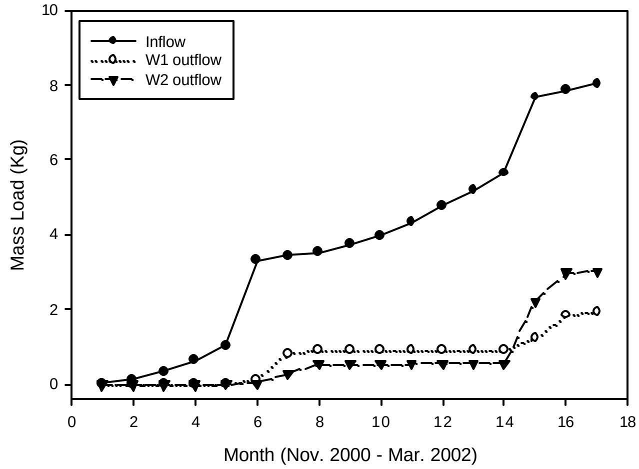


FIGURE 5: CUMULATED MASS LOAD VALUES FOR TP (WHERE MONTH 1 IS NOV. 2000).

TKN demonstrated results with percent removals of -23.5 to 99.9%. Mass reductions of 80.2 and 94.8% were seen for W1 and W2, respectively (Table 2 and Fig. 6).

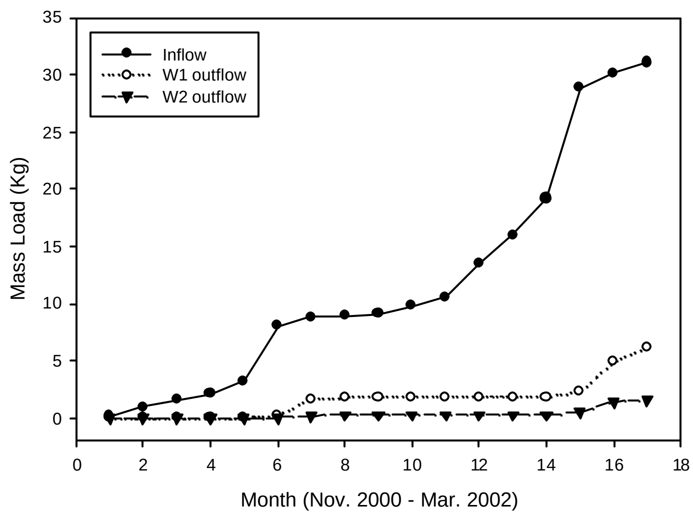
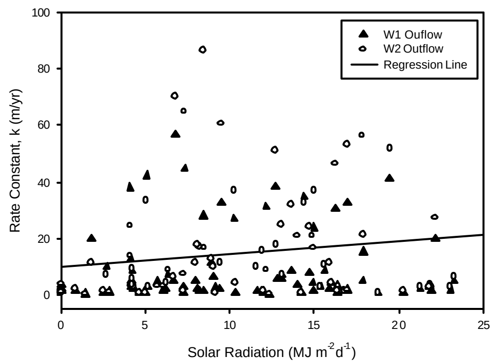


FIGURE 6: CUMULATED MASS LOAD VALUES FOR TKN (WHERE MONTH 1 IS NOV. 2000).

Rate constants (k) for both wetland systems were determined using eqn. 3. Rate constants for BOD_5 ranged from 0.09 to 86.65 with a mean value of 19.8 m y^{-1} (Table 3 and 4). Kadlec and Knight (1996) found a mean k value of 34 m y^{-1} when they examined 20 SF wetland systems, which was higher than the one found in this case. However, the mean value of 19.8 m y^{-1}, was similar to other values found (Kadlec and Reddy 2001).

Rate constants (k) were plotted against both water temperature (EC) and the average daily solar radiation (MJ m^{-2}). Solar radiation is a function of air, as well as water temperature. Both temperature and solar radiation are good performance independent variables. For instance, temperature controls the biological activity that takes place in a wetland, whereas solar radiation controls the level of ultra violet light and influences day length. Solar radiation also influences both air and water temperature, that may in turn have a potential drying effect on a wetland environment. A typical k versus solar radiation plot showed a great deal of scatter and a slight upward trend with increasing solar radiation (Figure 7). R^2 value was found to be 0.034, which was similar to values found by Kadlec and Reddy (2001), which plotted rate constants ($m\ y^{-1}$) against water temperature (EC). When k values were plotted against water temperature there was also a lot of variability and a slight downward trend with increasing water temperature (Figure 8). This trend was also seen in wetlands in Listowel, Ontario (Kadlec and Reddy, 2001), where they also indicated that temperature overall seemed to have a minimal effect on BOD_5 removal.



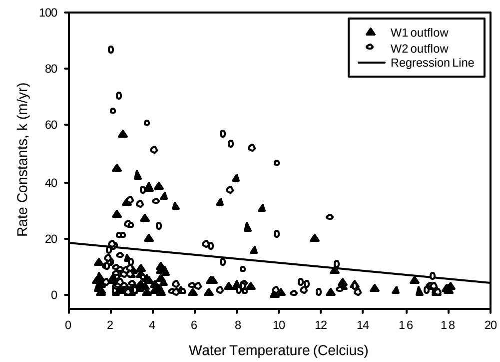
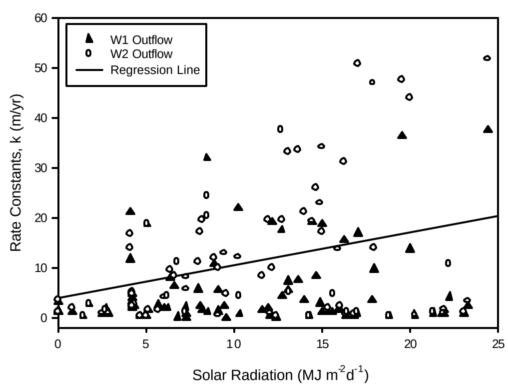


Figure 7: Rate constants (k) for BOD_5 vs. radiation.

Figure 8: Rate constants (k) for BOD_5 vs.solar water temperature.

Rate constant (k) values for TP ranged from -0.32 to 51.7 $m\ y^{-1}$ (Figures 9 and 10). The mean k value found was 9.9 $m\ y^{-1}$, which coincided with a mean value of 12.1 $m\ y^{-1}$ found by Kadlec and Knight (1996) and Reed *et al.* (1995) who examined a number of SF wetland systems throughout North America. Their values also had a much lower loading rate than the ones used in this experiment. Rate constants (Fig. 9) demonstrated strong variability with no real trend and an R^2 of 0.121 for k vs. solar radiation and 0.002 for k vs. water temperature. These findings again were similar to Kadlec and Reddy (2001), where rate constants were plotted against water temperature.



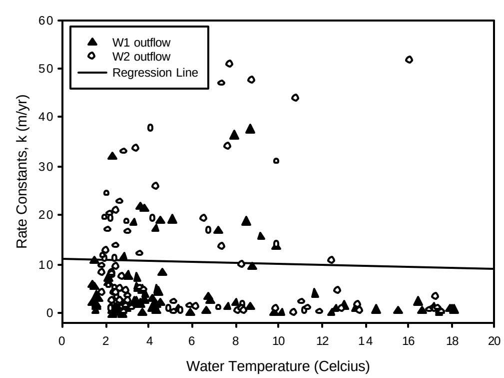


Figure 9: Rate constants (k) for TP vs. radiation.

Figure 10: Rate constants (k) for TP vs.solar water temperature.

Rate constant (k) values for TKN ranged from -11.008 to 72.038 $m\ y^{-1}$ (Fig. 11 and 12). The mean k value found was 9.9 $m\ y^{-1}$ (Table 3 and 4), which was lower than the mean value of 22 $m\ y^{-1}$ found by Kadlec and Knight (1996) who examined a total of 82 wetland systems throughout North America and comparable with values found by Stone *et al.* (2000). Rate constants (Fig.11) demonstrated strong variability with no real trend and an R^2 of 0.074 for k vs. solar radiation and 0.004 for k vs. water temperature. These findings again were similar to Kadlec and Reddy (2001), where rate constants were plotted against water temperature and also comparable with Kadlec and Knight (1996), who also concluded that temperature had little effect on N removal.

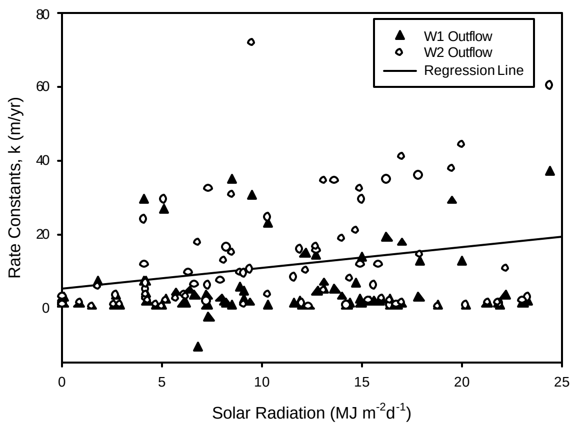


Figure 11: Rate constants (k) for TKN vs. radiation.

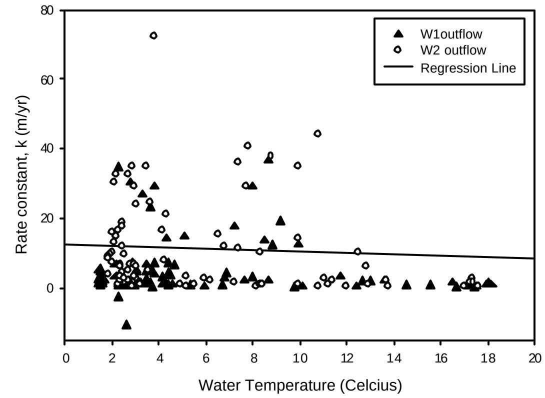


Figure 12: Rate constants (k) for TKN vs. solar water temperature.

When BOD_5 k values were plotted against the hydraulic loading rate (q) regression analysis revealed an R^2 value of 0.95 and slope of 4.53 (Fig. 13). This indicated that BOD_5 was strongly dependent on the q and inlet concentration into the system. This meant that outlet BOD_5 concentration is strongly dependent on inlet concentration, as well as the background concentration in the wetland systems. This was also comparable to results found by Kadlec (2000), where he too found that rate constants and background concentrations were strong functions of hydraulic loading and inlet concentration.

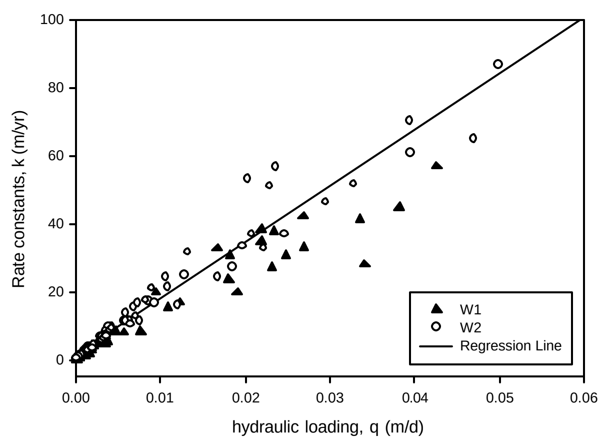


Figure 13: The effect of hydraulic load (q) on the relative removal rate constant (k) for BOD_5

The k vs. q plot for TP demonstrated more scatter and a R^2 value of 0.48 with a slope of 1.70 (Fig. 14). These results suggest that there is not as strong as relationship between inlet and background concentrations when dealing with TP as there is with BOD_5, as indicated by the lower slope value.

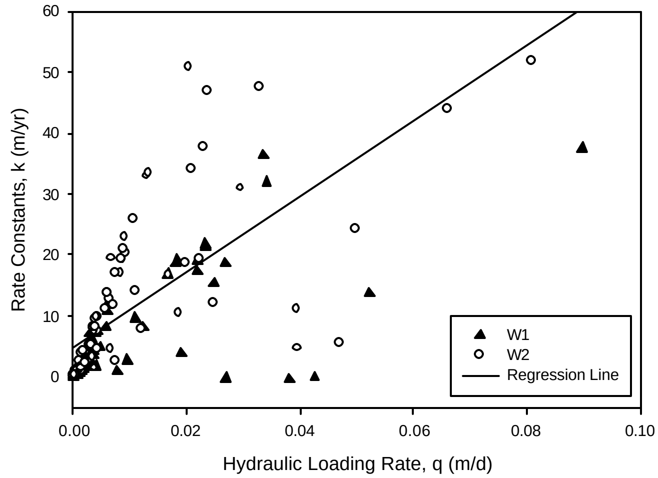


Figure 14: The effect of hydraulic load (q) on the relative removal rate constant (k) for TP

When k values for TKN were plotted against q, similar results were found, with a slightly higher R^2 value of 0.70 and a slope of 2.24 (Fig. 15). It appears that neither TP nor TKN is as strongly dependent on q as compared to BOD_5.

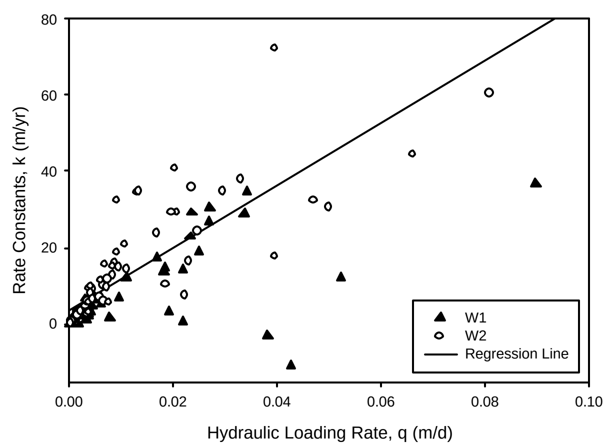


Figure 15: The effect of hydraulic load (q) on the relative removal rate constant (k) for TKN

CONCLUSIONS

To date, the nformation generated from this project has shown promising results for the use of constructed wetlands in cold climates. Data has indicated that these systems do work in cold climates with proper management and design. It has been demonstrated that it is possible to continually load these systems during the winter months and prevent total ice formation. Results do illustrate that there is a strong relationship between hydraulic load (q) and first order rate constants (k), especially for BOD_5. Although it has been demonstrated that temperature has little correlation to removal rates, k values have been developed for these systems and may be incorporated into future wetland system designs.

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WATER QUALITY AND WATER QUANTITY RESEARCH ACTIVITIES IN NOVA SCOTIA CANADA

A. Madani
R. Gordon
G. Stratton
Nova Scotia Agricultural College
Nova Scotia, Canada
mamadani@nsac.ns.ca

KEYWORDS. Environmental management, outreach, adaptive research, water quality, air quality

BACKGROUND

Sustainable farming practices have historically been well understood and demonstrated by a large portion of the Nova Scotia agri-food industry. A need still exists however, to emphasize to all agri-food sectors that environmental management is a vital element of contemporary business. In today's highly competitive global market, an increased worldwide environmental consciousness has created greater opportunities for those who adopt environmental standards and more restrictions for those who do not embrace sustainable business practices.

The inherent goal of the Nova Scotia Department of Agriculture and Fisheries/Nova Scotia Agricultural College Environmental Research Program is to provide the agri-food industry with options to help ensure environmental sustainability. The program has been committed to meeting industry needs in relation to environmental research. However, the program is also in a unique position to provide opportunities for the training of highly qualified personnel. This has been an integral pat of the mandate of our program and to that end, we have been active in providing graduate training for a number of individuals in environmental engineering and science through the Nova Scotia Agricultural College
.

To ensure maximum benefit from our program, we have attempted to create and maintain accountability to all potential stakeholders in the agri-food industry. This has been achieved through the development of formal partnerships with other research institutions and farm associations including the Nova Scotia Federation of Agriculture.

MANDATE OF THE PROGRAM

- A commitment to provide the agri-food industry with innovative solutions to environmental management problems;
- Provide hands on training opportunities for young scientists at the graduate level through the Nova Scotia Agricultural College;
- Work closely and in partnership with the Nova Scotia agri-food industry and its stakeholders.

CURRENT ADAPTIVE RESEARCH PROJECTS

Below is a list of the current research projects being undertaken by the program with the objectives and funding sources for each project:

Surface Energy Balance Characterization of Constructed Treatment Wetlands (Funding sources: AF2000). The objectives of this investigation are to (i) evaluate the extent of evaporation and transpiration from constructed wetland systems; (ii) characterize wetland hydrological processes that affect their performance; and (iii) link constructed wetland hydrologic processes into simple, “rule of thumb” procedures to assist in their design. The project will be completed by 2002.

Nitrate Nitrogen in Domestic Wells in Kings County, Nova Scotia (Funding sources: AF2000, NSDAF, NSDOEL). The objective of this investigation is to develop a better understanding of the extent and persistence of nitrate nitrogen in domestic wells throughout the intensive agricultural regions of Kings County, Nova Scotia. The project will be completed by 2002.

Peat Filter for the Treatment of Milkhouse Wash Water (Funding sources: Nova Scotia Agri-Futures, AF2000, Agriculture and Agri-Food Canada, Nova Scotia Milk Producers Association). The objectives of this project are to test the feasibility of commercially available peat filters for the treatment of dairy farm milkhouse wash water. The project will be completed in 2002.

Evaluation of Alternate Pond Construction Techniques (Funding sources: AWARD). The objective of this project are to evaluate the feasibility of constructing deep ponds (> 15 feet) to provide adequate quantities of water for irrigation purposes throughout a growing season in the Annapolis Valley of Nova Scotia. The project will be completed by 2002.

Impact of Manure Application on Movement and Persistence of E-Coli Bacteria in Soils and Leachate Water (Funding sources: AWARD, NSDAF). The scope of this study is intended to gain an understanding of the transport of *E. coli* bacteria and their ability to survive over extended time periods in agricultural soils. The project will be completed by 2003.

Characterization of Phosphorus Immobilization Mechanisms in Constructed Wetlands Treating Agricultural Wastewater (Funding sources: AF2000). The objectives of this research are to characterize spatial and temporal changes within a constructed treatment wetland systems with respect to P-saturation status. This project will specifically focus on one constructed wetland which has been receiving dairy wastewater for approximately seven years. The project will be completed by 2003.

Disinfection of Microbial Pathogens for Irrigation Water (Funding sources: NSDAF, AF2000). This research will conduct a thorough field-scale testing and optimization of UV and chlorination disinfection systems for reducing microorganisms (eg. fecal coliform) in irrigation water being used for crops which may be consumed raw (eg. strawberries). The project will be completed by 2004.

An Improved Understanding of the Survival and Release of Fecal Bacteria From Rural Stream Sediments (Funding sources: AWARD, Nova Scotia Agri-Futures, Agriculture and Agri-food Canada). The objectives of this study are: (i) to evaluate the growth and decay of fecal bacteria within stream sediment and (ii) to assess the release patterns of fecal bacteria from sediment under both hydrologic and external influences. The project will be completed by 2004.

Managing Ammonia Loss from Surface Applied Manure (Funding sources: AF2000, NSERC). The objective of this research investigation is to precisely identify the relationship between surface soil moisture status and rainfall effects on the ammonia volatilization from surface applied liquid dairy manure. Project results can be utilized to evaluate the benefits (i.e. environmental and nutrient retention) of scheduling manure spreading activities in relation to both prevailing meteorological conditions (i.e. forecast rain) and current soil moisture levels. The project will be completed by 2006.

Performance Modeling of Agricultural Treatment Wetlands (Funding Source: Canadian Water Network - National Centre of Excellence): The objectives are to optimize the treatment efficiencies of constructed wetlands through the identification of design improved criteria and first order rate functions. The project will be completed in 2005.

Soil Water Risk Management (Funding Source: AF2000): The objectives are to evaluate a soil water budget model (Versatile Soil Moisture Budget Model - VSMB) in an attempt to better understand the frequency and risks of threshold deficit and surplus soil water contents in Nova Scotia. The project will be completed in 2003.

Environmental Impacts of Dairy Wastewater Management Alternatives (Funding Sources: NS Agri-Futures, Milk Nova Scotia): The objectives f this study are to assess the impacts of the dairy operations which are typical of this region have on water resources in relation to milkhouse wash water. The project will be completed in 2002.

Farm Irrigation Water Safety Initiative (Funding Sources: Horticulture Nova Scotia, AWARD): The overall goal is to develop a better "farm-level" understanding of the fate and occurrence of fecal bacteria through the irrigation of agricultural crops and identify possible management strategies that can be utilized to minimize their risks. The project will be completed in 2004.

Greenhouse Gas Emissions from Constructed Wetland Treatment Systems (Funding sources: AF2000, Climate Change Funding Initiative for Agriculture): The objectives are to evaluate greenhouse gas emissions (N_2O and CH_4) under a range of meteorological and physical conditions from on-farm constructed wetland treatment systems and identify their source/sink status relative to greenhouse gases. The project will be completed in 2004.

Winter Management of Constructed Wetland Treatment Systems (Funding sources: AF2000, NSERC, Atlantic Land Improvement Contractors Association, Nova Scotia Agric-Futures): The objectives of this investigation are to provide a detailed assessment of the potential of agricultural constructed wetlands to treat wastewater during the cold winter months. This will specifically include: (i) determining the level of wastewater treatment achieved during the winter months; (ii) determining the extent of constructed wetland wastewater flow that occurs over the ice surface compared to beneath the ice; (iii) identifying design criteria to maximize below ice flow; and (iv) developing recommendations for design purposes in relation to full year loading versus loading during the warm growing season months. The project will be completed in 2003.

Hog Mortality Management (Funding sources: AF2000, New Brunswick Agriculture, Nova Scotia Agri-Futures, Atlantic Land Improvement Contractors Association): The objectives of this investigation are to develop a thorough understanding of on-farm hog mortality management in Atlantic Canada. More specifically this will include: (i) evaluating the potential and efficiency of low tech composting practices for the complete and environmentally safe management of hog mortalities; (ii) evaluate the time requirement necessary for complete decomposition of mortalities; (iii) evaluate the potential for cold/wet weather composting of hog mortalities; and (iv) evaluate the potential environmental impacts of composting hog mortalities (i.e. surface and groundwater impacts). The project will be completed in 2003.

Watershed Water Quality Impacts Pilot Project (Funding sources: AWARD 2000, NS Agri-Futures): The purpose of this initiative is to a develop a watershed management strategy for a small, agriculture dominated catchment within the intensively farmed Cornwallis River Watershed region. There are five steps within the watershed assessment process: (i) defining a quantitative water quality objective, (ii) relating the loading of pollutants to the objective (i.e. how much load can the system assimilate), (iii) estimating existing pollution sources (how much load do we have now), (iv) selecting/evaluating load reduction alternatives, and (iv) allocating among sources. The project will be completed in 2004.

Aeration of Treatment Constructed Wetlands and Anaerobic Lagoons (Funding sources: NSDAF, NSERC): The goal of this research is to develop and test low cost and robust aeration technology for use within agricultural treatment wetlands. This will involve implementation of a diffused air-aeration system installed within the shallow zones of a constructed wetlands. The high energy costs associated with operating an aeration system have often precluded the use of conventional aeration technologies. Therefore, a secondary objective will be to develop alternate aeration system energy sources such as wind and solar. The project will be completed in 2004.

Phosphorous Management in Crop Production Systems (Funding sources: AF2000): The objectives of this project are to assess the phosphorous leaching potential from various agricultural soils and the P adsorption capacities in Nova Scotia. The project will be completed in 2004.

Nova Scotia Phosphorous Leaching Baseline Study (Funding sources: Nova Scotia Agri-Futures, Agriculture and Agri-Food Canada, AWARD): The goal of this study will be to perform a detailed monitoring investigation of high risk P leaching areas. The specific objective will be to assess P concentrations in subsurface drainage water from several (approximately 75-100) fields throughout the province that have been soil-tested and rated as high to excessive in order to develop a better understanding of the P risks within the Nova Scotia cropping systems. The project will be completed in 2004.

Application of the Root Zone Water Quality Model for Atlantic Canada (Funding sources: NSAC): The objective of this investigation is to evaluate the application of the Root Zone Water Quality Model for Atlantic Canada and specifically its ability to estimate nitrate leaching from field applied manure. The project will be completed in 2002.

Survivability of E-Coli in Soil Systems (Funding sources: NSDAF, AWARD 2000): The objectives of this investigation are to evaluate the survivability of E-Coli in soil systems proceeding the surface application of either hog or dairy manure. A secondary objective is to evaluate the survivability in relation to tilled or no-tilled systems. The project will be completed in 2003.

Presence of Fecal Coliforms and Nitrate-Nitrogen in Sub-surface Drainage Systems (Funding sources: Agriculture and Agri-food Canada, AF2000, NSERC): The objectives of this research program are to more precisely understand fecal coliforms and nitrate-nitrogen leaching from several cropping and manure spreading strategies. This is a large initiative that includes four research sites across Nova Scotia and a large multi-disciplinary research team. On-going.

Processing Carrot Production Impacts on Water Quality (Funding sources: AAFC MII, NSERC, AF2000): The objectives of this study are to evaluate a number of environmental sustainability issues related to carrot production in Atlantic Canada. These include the following specific objectives. (i) To evaluate the quantity and persistence of nitrates and indicator bacteria (fecal and total coliforms) in the soil and subsurface drainage water under two carrot production systems (i.e. commercial fertilizer and liquid hog manure); (ii) To identify the benefits of liquid hog manure versus commercial fertilizer applications on carrot yield and quality. The project will be completed in 2002.

Hog Manure Solid-Liquid Manure Separation (Funding sources: Pork Nova Scotia, HEMS, Nova Scotia Agri-Futures):The overall objective of this proposed investigation is to perform on-farm evaluations of three solid-liquid hog manure separation systems. This will include the following: (i) evaluate the ease of each separation system on-farm; (ii) evaluate the performance of each system including: labour costs, separation efficiency as well as the solid and liquid fractions in relation to the manure (i.e. nitrogen, phosphorous, pathogens, volume, mass, and moisture content); and (iii) perform an economic assessment of each system. The project will be completed in 2002.

Simultaneous Measurements of Ammonia, Odour and Nitrous Oxide Emissions from Surface Applied Swine Manure (Funding sources: NSERC, AF2000): The objectives of this study are to evaluate the relationship and magnitude of NH_3, N_2O and odour emissions from grass and crop land applied with swine manure in relation to manure dry matter content, incorporation methods, application rate and soil water status under a variety of atmospheric conditions. A longer-term objective is to more clearly define the factors that influence the rate of gaseous emissions from manure spreading activities and develop adaptive farm-level management strategies to minimize their impacts. The project will be completed in 2006.

Manure Stockpiling: Environmental and Nutrient Loss Impacts (Funding sources: NSDAF, Tech Development Program): The objectives of this investigation involve assessing both the environmental (i.e. water quality) and manure nutrient status effects associated with both short and long-term stockpiled manure. The project will be completed in 2004.

Enhanced Wetland Treatment System Design Criteria Through Accurate Hydraulic Retention Assessments (Funding sources: Canadian Water Network, Tech Development Program, NSDAF) The objectives of this investigation include: (i) evaluating the suitability of three ions (Br, F, and Li) as hydrologic tracers in a laboratory scale surface flow wetland; (ii) extending the most favorable tracer to compare the actual and theoretical hydraulic retention times of four operational farm constructed wetlands; and (iii) testing practical design criteria (using pilot scale treatment wetlands) which can be incorporated into the construction of current and future wetlands to optimize their treatment performance. The project will be completed in 2004.

REGIONAL FLUORIDE MITIGATION STRATEGY FOR 57 COMMUNITY WATER SYSTEMS

Scott Emry
Shonia Holloway
Hampton Roads Planning District Commission
723 Woodlake Road
Chesapeake, VA 23320
757-420-8300; Fax 757-523-4881
SHOLLOWA@HRPDC.ORG

KEYWORDS: fluoride, treatment, community, groundwater, PMCL

The Fluoride Mitigation Strategy was developed by the Hampton Roads Planning District Commission (HRPDC) staff in cooperation with the HRPDC Directors of Utilities Committee and the Virginia Department of Health (VDH). The HRPDC Directors of Utilities Committee established a Fluoride Subcommittee in response to the rescinding of exemptions in August 2000. The 1970s exemptions allowed community water systems (CWS) that supplied drinking water with fluoride levels in excess of the Safe Drinking Water Acts (SDWA) Primary Maximum Contaminant Level (PMCL) standard to legally operate the system without treatment.

The subcommittee consisted of representatives from the cities of Chesapeake, Suffolk and Franklin, the county of Isle of Wight, HRPDC staff, and an owner of several local CWS. Staff representatives from the Virginia Department of Health, Department of Environmental Quality and Hampton Roads Sanitation District provided valuable input and guidance to the process. The Subcommittee met on a periodic basis to review and determine the best methods to provide an adequate resource to the CWS owners facing fluoride level compliance for their current drinking water systems.

Unfortunately for many private and publicly owned CWS in Hampton Roads, fluoride is naturally occurring in the ground water at levels that exceed the PMCL of 4.0 milligrams per liter (mg/L) for drinking water. There are over 297 private and publicly owned CWS in the affected area. Of these systems, approximately fifty-seven (57) exceed the fluoride PMCL standard. The CWS that are in violation of the fluoride standard in Hampton Roads are concentrated in the cities of Chesapeake, Franklin and Suffolk and the counties of Isle of Wight and Southampton.

A CWS, by definition, must have at least 15 equivalent residential connections or must serve at least 25 people for more than 60 consecutive days. All CWS are permitted by VDH and are required to meet the Virginia Waterworks Regulations standards.

The privately owned CWS with fluoride levels above the EPA standard vary significantly in size. They serve water to as few as 37 people (17 connections) or as many as 1,100 people (270 connections). Defined by Section 1412 (b) (4) (E) of the 1996 SDWA Amendments, all of the systems are considered small public water systems.

The purpose of this project was to provide resources and guidance to private and publicly owned CWS that have naturally elevated levels of fluoride in their source drinking water. The report provides the CWS owners with sufficient information to evaluate the suitability of the various options available to comply with the fluoride standard and to consider the effects and costs associated with each option.

The most common treatment options suitable for removing fluoride from ground water include reverse osmosis (RO), electrodialysis reversal (EDR), ion exchange, and activated alumina. These treatment options are suitable for central treatment system applications as well as home treatment. Various vendors have developed manufactured off–the-shelf modules and package plant systems. Other options include connecting to a nearby municipal water system, identifying a source of ground water with a fluoride concentration below the EPA regulatory PMCL, or in some cases, modifying the configuration of the existing CWS.

A CWS should identify all of the costs associated with implementing an alternative and the possibility of securing funding to build the treatment option. The document provides a list of variables that should be considered when evaluating the cost of building and operating a treatment option. Although some costs are provided, the document could not possibly provide the cost of all the components that may be needed to implement the treatment option for an individual system. It is highly recommended that the CWS owner secure the engineering expertise to develop a detailed cost estimate for construction, operation and maintenance.

The CWS will be required to secure permits from various state, federal, and local agencies to construct and operate the treatment alternative. The VDH Waterworks Regulations have specific requirements that all permitted CWS must follow in order to modify the existing system. In order to discharge the brine waste generated during treatment to surface water, the DEQ Virginia Pollution Discharge Elimination System permit must be obtained. In some cases, the Hampton Roads Sanitation District may provide services within a close proximity to an affected CWS that is considering installing a treatment option. The HRSD has expressed a willingness to work with the CWS and it has specific requirements and fee schedules that must be followed.

In Virginia, there are several government and non-profit organizations that may provide technical assistance. The Virginia Water Resources Research Center and the National Environmental Service Center (NESC) provide technical resources at an affordable cost that can be useful for small CWS. The NESC administers the National Drinking Water Clearinghouse and the National Small Flows Clearinghouse. The Water Reach Committee, Virginia Section of the American Waterworks Association, may be able to assist in finding pro-bono engineering assistance for qualified CWS. The South Eastern Rural Community Assistance Project (SE-RCAP) can provide technical assistance in assessing treatment options and financial capability.

There are various state and federal low-interest loans and grant funding programs that focus on drinking water quality for rural small CWS. However, a CWS that is an incorporated business or privately owned is not eligible for most of the state and federal funding programs. One exception is the VDH State Drinking Water Revolving Fund, which is a primary program that a CWS should consider. A non-profit, non-government CWS may be eligible for loans or grants from the various rural community assistance programs, such as the U.S. Department of Agricultural, Rural Development Assistance Program, the SE-RCAP and special programs administered by the Virginia Department of Housing and Community Development (DHCD). A privately owned CWS may consider restructuring its ownership to a non-profit status such as a homeowners association or a cooperative. However, prior to restructuring, the CWS owner should weigh the advantages and disadvantages of restructuring and should consult with the various rural assistance programs and the VDH.

n conclusion, numerous options are available to the CWS owner to remediate the fluoride in the drinking water. Although, achieving compliance will be difficult for several of the affected CWS, it should not be considered a daunting task. The biggest obstacle will be the capital cost associated with achieving compliance and the ability of the CWS to carry a loan to cover that cost.

INTRODUCTION

The fluoride issue in the Hampton Roads region initially surfaced following the enactment of the Safe Drinking Water Act (SDWA) of 1974 (Section 1412). The SDWA was the first legislation to require regulations focused on the safety of drinking water. State and local authorities disputed the U.S. Environmental Protection Agency (EPA) on whether or not fluoride posed a health threat at the naturally occurring concentrations in Southeast Virginia. The debate focused on the lack of study data available to support EPA's regulation. Since 1974, numerous studies have been conducted to further determine the health risks associated with fluoride intake.

Early investigations into the physiologic effects of fluoride in drinking water predated the first community field trials. Since 1950, opponents of water fluoridation have claimed it increased the risk for cancer, Down Syndrome, heart disease, osteoporosis and bone fracture, acquired immunodeficiency syndrome, low intelligence, Alzheimer disease, allergic reactions, and other health conditions. According to the Morbidity and Mortality Weekly Report (Volume 48,October 1999), the safety and effectiveness of water fluoridation has been re-evaluated frequently, and no credible evidence supports an association between fluoridation and any of the conditions cited by opponents (CDC 1999).

The EPA recognizes that fluoride in drinking water has some benefits, including the prevention of dental caries (tooth decay) and providing a cost effective and beneficial means for individuals unable to afford preventative tooth care. As well, there are risks associated with excess fluoride, including dental fluorosis (staining or mottling of teeth) and skeletal fluorosis (crippling bone disorder, resembling osteoporosis). At present, the scientific community does not agree on the fluoride concentration for long-term exposure that may result in the more serous health risks. The EPA, however, recommends that CWS provide fluoride in drinking water at a concentration between 0.8 mg/L and 1.0 mg/L to fight tooth decay.

The 1975 Interim Drinking Water Regulations, and the amendments to the SDWA of 1986 and 1996 further supplemented the SDWA of 1974. Original exemptions for fluoride exceedence to the 1974 rule are discussed in Section 1414 of the Act. Exemptions were granted to many local public water systems and were intended to extend until January 1, 1981 or 1983, depending on the qualifications of the exempt system. The EPA required the exempt CWS owners to notify the consumers that the public water system had been issued an exemption for fluoride and to report measured levels to the consumer annually. The exclusions continued from 1983 until the EPA required the VDH to rescind the exemptions in August 2000. Approximately 57 CWS in Hampton Roads have received notices of violation (NOV) from the VDH for exceeding the 4.0 mg/L PMCL for fluoride.

State and local authorities disagreed with the EPA on whether or not fluoride posed a health threat at the naturally occurring concentrations in Southeast Virginia. The debate focused on the lack of study data available to support EPA's regulation. Since 1974, numerous studies have been conducted to further determine the health risks of fluoride intake.

FLUORIDE MITIGATION STRATEGY

The Fluoride Mitigation Strategy project has been designed to provide treatment options and alternatives to a wide variety of CWS. There are common characteristics among the systems that have been used to focus on suitable technological options. For instance, all the CWS are ground water dependent. The Potomac Aquifers of the Virginia Coastal Plain are used as the source of ground water for all of the systems. The major ion of concern for all of the CWS is fluoride. The concentration of fluoride in the affected systems ranges from over 4.0 mg/L to less than 6.0 mg/L. As a result of the commonalities, the technologies selected for discussion are all suitable to treat elevated concentrations of fluoride in ground water systems that range in concentration from 4.0 to 6.0 mg/L fluoride.

The remedy for the fluoride issue will vary. The Fluoride Subcommittee, through experience, research, and discussions has made an initial attempt to outline the remedial options that are available to the CWS. Based on geographical location, available and appropriate technologies, and system configurations, the following options were determined to be potentially viable solutions: reverse osmosis, electrodialysis reversal, ion exchange, activated alumina, connection to a public water system, point of use and point of entry treatment technologies, development of a new source, and system modifications. Depending on the specific configuration and parameters of each system, one or more of these options may be considered feasible. The subcommittee's assessment did not consider the economic ability of each CWS to implement the options. As well, this paper was set-up to offer resources to CWS owners throughout the compliance process.

The VDH compliance process involves the following:

- Receive Notice of Violations (NOV);
- Determine financial capacity;
- Identify/locate technical assistance;
- Identify/locate financial assistance;
- Preliminary Engineering Conference (PEC);
- Preliminary engineering report (PER);
- Submit plans and specifications; and
- Enter consent order.

TREATMENT

Fluoride removal can be successfully achieved through several available technological means including: reverse osmosis, electrodialysis reversal, ion exchange, and filtration containing activated alumina. Fluoride is not removed by boiling, home water softening systems, sediment filters or ultraviolet systems (www.crha-health.ab.ca, 2001). In determining whether a particular treatment process is the best option for a CWS to comply with the SDWA, CWS owners should consider the current source water quality characteristics, desired finished water quality characteristics, current and future water usage needs, current and future financial support and any current and future regulatory requirements that may affect finished water quality.

Centralized treatment refers to the installation of a system that treats water for the entire service area before entering the distribution system. Central treatment can be achieved through full-scale conventional treatment or package plant treatment. Full-scale conventional treatment is most commonly utilized in systems that serve greater than a few thousand persons, and is designed by a consulting engineer who develops original designs of the system and its structures. Package plants are suitable for the smaller systems and are skid mounted factory assembled units that arrive on-site virtually ready to use.

The following sections will focus on the types of package plant systems found most appropriate for the affected CWS. The information for each system includes technology descriptions, performance, concentrate/wastes, and an example of costs. Details pertaining to disposal options of wastewater (concentrate) generated during treatment are provided in the last portion of this section.

Editor's note: Due to the length of this paper, it was not possible to print the entire report. However, the complete report is available from the authors or the editor. Contact jupoff@vt.edu for additional information.

THE EFFECTS OF THE DROUGHT ON SMITH MOUNTAIN LAKE AND CLAYTOR LAKE WATER QUALITY

Carolyn L. Thomas
David M. Johnson,
Ferrum College
Ferrum, VA
540-365-4368; FAX 540-365-4370,
cthomas@ferrum.edu
djohnson@ferrum.edu

KEYWORDS: Water Quality, Fecal coliforms, Chlorophyll A, Smith Mountain Lake

The Smith Mountain Lake Volunteer Water Quality Monitoring Program was initiated in 1987 and has functioned each year since. Smith Mountain Lake is a 25,000-acre pump-storage reservoir located in South Western Virginia. The program monitors the trophic status of Smith Mountain Lake. Beginning in 1996, monitoring of fecal coliform bacteria has been carried out to assess the bacteriological quality of the water as well as the degree of nutrient enrichment.

The Claytor Lake Volunteer Water Quality Monitoring Program was initiated during the spring and summer of 1996. Claytor Lake is a 4500-acre mountain reservoir on the New River, located in Pulaski County, Virginia. The program is designed to monitor the water quality of Claytor Lake and the trophic status. Beginning in 1998, monitoring of fecal coliform bacteria has been carried out to assess the bacteriological quality of the water.

According to the Virginia Climatology Office (April 2002) a deficit of 40 inches of cumulative rainfall goes back to the summer of 1998. Only the 1960's drought approaches the same figure.

The trophic status of Smith Mountain Lake and Claytor Lake was measured by four parameters: total phosphorus, nitrate, chlorophyll A, and the degree of water clarity as determined by Secchi depth measurements. Chlorophyll A measured in Smith Mountain Lake and Claytor Lake indicates a decrease in water quality and an increase in nutrient enrichment, especially in the increase in the algal population. Chlorophyll A exhibited an average concentration in Smith Mountain Lake and in Claytor Lake the summer of 2001, which was double the chlorophyll A in 2000. The lack of rainfall and, therefore, a decrease in sediment entering the water resulted in greater water clarity and thus greater photic zones and higher algal populations.

The fecal coliform populations in Smith Mountain Lake were the lowest they have been in the six years of monitoring, and were also low in Claytor Lake in 2001. Most of the input of fecal coliforms comes from nonpoint source runoff, which did not occur in either watershed during the drought of 2001.

EXAMINING THE POTENTIAL FOR BIOTRANSFORMATION AND SORPTION OF ROXARSONE, AN ORGANOARSENIC ANIMAL FEED ADDITIVE

Brenda L. Brown
Madeline E. Schreiber
Dept. of Geological Sciences
Virginia Tech
Blacksburg, VA 24061
(540) 231-2404; FAX: 540-231-3386
brbrown@vt.edu

KEYWORDS: arsenic, animal waste, sorption, extraction

ABSTRACT

Poultry production, one of the largest and fastest growing industries in the world, has been economically successful. But this success is not reflected in the management of poultry waste. Poultry manure is high in nutrients, and is commonly used as a fertilizer. It also contains pharmaceuticals such as antibiotics, steroids, and organoarsenicals. The organoarsenical Roxarsone is added to poultry feed because it increases weight gain and improves feed efficiency and pigmentation. Studies have shown that organoarsenic compounds do not accumulate in poultry tissue but are rapidly excreted, resulting in elevated concentrations of arsenic (8-40 mg/kg) in poultry litter. However, little work has been done to evaluate the fate of Roxarsone after it has been introduced into agricultural watersheds by poultry litter application. We are investigating the potential for sorption of Roxarsone by the Frederick series, the main soil type present in the Shenandoah Valley of Virginia, using batch experiments (ASTM Method D 4319-93). Results indicate that clay-rich soils strongly adsorb Roxarsone and that organic-rich soils show pH-dependent sorption of Roxarsone, with the greatest sorption occurring at pH 5. Sequential and total extraction techniques, although not completely effective, indicate that the poultry-amended soils have a higher concentration of arsenic than the control (non-amended) soils.

INTRODUCTION

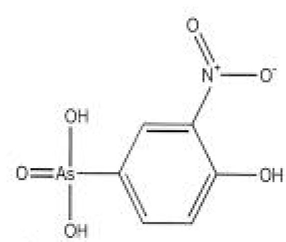

Figure 1. Roxarsone

The organoarsenical Roxarsone (3-nitro-4-hydroxyphenyl-arsonic acid) (Figure 1) is added to poultry feed at a concentration of 22.7 to 45.5 g per ton to improve weight gain, feed utilization, and pigmentation. When combined with anticoccidial drugs, Roxarsone also aids in the control of coccidiosis. In Virginia, poultry production units (one unit represents a broiler complex comprised of a group of farms served by a single feed mill) typically use a combination of Roxarsone, anticoccidials, and antibiotics to optimize growth rate (Chapman and Johnson 2002). Poultry manure is mixed with pine bedding material to make poultry litter, which is often applied to soil as a fertilizer. In 1997, the Virginia Poultry Federation estimated that over 50,000 tons of poultry litter was brokered from poultry growers to other users (VADEQ 1998).
The behavior of arsenic (As) in natural systems is controlled by a variety of biogeochemical reactions, including biotransformation, oxidation-reduction, precipitation-dissolution, complexation, and sorption reactions. These processes affect the form (inorganic vs. organic), the speciation (arsenite, As(III) vs. arsenate As(V)), as well as the concentration of As in natural waters. Understanding the form and speciation of As is important because they both affect toxicity characteristics. Sorption reactions are particularly important in controlling As mobility in the environment due to the high affinity of many minerals for As. Soil texture, soil mineralogy, pH, and the presence of competing ions have been shown

to influence the adsorption process (Smith et al. 1998). As interacts with metal (Fe-, Al-, and Mn-) oxides/hydroxides (e.g., Sadiq 1997; Pierce and Moore 1980; Bowell 1994) as well as clays and carbonates (Xu et al. 1991; Sadiq 1997). The presence of natural organic matter (NOM) also affects As behavior, as NOM has been shown to significantly decrease sorption of As to metal oxides (Redman et al. 2002). Competitive adsorption of As oxyanions on soils occurs in the presence of other oxyanions, such as phosphate and molybdate, which can decrease arsenate sorption, thus increasing mobility (Lin et al. 2002).

Previous studies have demonstrated that organoarsenicals do not accumulate in poultry tissue or feathers (Aschbacher and Feil 1991; Moody and Williams 1964) but instead are rapidly excreted, resulting in elevated concentrations of As (8-40 mg/kg) in poultry litter (Kunkle et al. 1981; Morrison 1969). The fate of this litter-derived As, however, has not been thoroughly studied. Garbarino et al. (2001) suggested that once excreted, Roxarsone is rapidly biotransformed to arsenate. Rutherford et al. (2001) conducted a preliminary evaluation of the sorption characteristics of Roxarsone. They found that, compared to arsenate, Roxarsone has a lower sorption affinity for iron oxides and a higher affinity for organic matter. However, quantitative measures of sorption were not determined.

This research has three objectives. The first objective is to examine the sorption characteristics of Roxarsone on Frederick series soils, common in the Shenandoah Valley, where over 148 million poultry are raised each year (VADEQ 1998). The second objective is to determine the pH-dependence of Roxarsone sorption. Batch sorption experiments are being conducted to evaluate these objectives. The third objective is to determine the partitioning of As to soil compartments through application of a sequential extraction method.

EXPERIMENTAL METHODS

Reagents

Deionized water (Nanopure) was used for preparation of samples and standards. All reagents were of analytical grade or better.

Sample Collection and Preparation

Soils were collected from an agricultural site in the Muddy Creek subcatchment, Rockingham Co., VA. Control soils were collected from a non-agricultural site near Mt. Crawford, also in Rockingham Co. Soils are of the Frederick series, which consist of deep, well-drained soils formed in residuum derived mainly from dolomite limestone with interbeds of sandstone and siltstone. At the Muddy Creek site, poultry litter is applied annually as fertilizer for corn. Poultry litter is applied at a rate of about 4500 kg/ha (Hyer et al. 2001). Two soil samples were collected: well-drained sandy loam (0-6 in. depth), and a clay loam layer (12-18 in. depth). These layers are approximately equivalent to the Ap (control) and Bt1 (control) layers of the Frederick series soils used for comparison. Poultry litter was also collected from the site. The Muddy Creek soils were excavated with a shovel and placed in plastic bags. Soils and poultry litter were transported in an ice cooler to the lab, where they were refrigerated until analysis. The Frederick series control soils (Ap, Bt1, and Bt2) were obtained by Greg Mullins of the Crop and Soil Environmental Sciences Department at Virginia Tech. These soils were collected in 5-gallon buckets and were refrigerated until analysis. Chemical characteristics of the soils are presented in Table 1.

Table 1. Physical and Chemical Characteristics of Muddy Creek (MC) and Control Soils. Concentrations in mg/kg.

Treatment	pH	%OM	P	K	Ca	Mg	Zn	Mn	Cu	Fe	Textural Class
Ap-control	6.1	1.4	9	71	418	53	1.7	7.7	1.0	4.6	silt loam
Ap-MC	**6.8**	**2.8**	**298**	**152**	**1283**	**179**	**14.4**	**8.9**	**3.8**	**15.3**	**sandy loam**
Bt1-control	5.9	0.7	1	20	336	92	0.4	2.2	0.2	4.2	silty clay loam
Bt1-MC	**6.3**	**0.9**	**30**	**109**	**494**	**150**	**1.4**	**3.8**	**0.9**	**6.5**	**clay loam**
Bt2-control	5.5	0.6	1	22	416	109	0.3	1.3	0.2	3.2	silty clay

Determination of Total Arsenic

EPA Method 3052 (*Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices*) was used to determine the total As concentration in the soil samples and poultry litter. Homogenization of the sample was achieved by oven-drying (at 95ºC) the soils and poultry litter, and then crushing the samples with an agate pestle and mortar and mixing with a spoon. The sample (0.5 g) was digested in 9 mL of concentrated nitric acid for 20 minutes using an ETHOS PLUS Microwave (Milestone Laboratory System). The temperature was ramped to 180 ± 5ºC in ~ 10 minutes and maintained at this temperature for 10 minutes. After cooling, samples were filtered, diluted to volume, and analyzed by inductively coupled plasma atomic emission spectrometry (ICP-AES) or graphite furnace atomic absorption spectrometry (GFAAS) with Zeeman background correction.

Determination of Roxarsone Adsorption by Soils

ASTM Method D 4319 – 93 (Re-approved 2001) (*Standard Test Method for Distribution Ratios by the Short-Term Batch Method*) was used for the sorption tests. Two sets of sorption experiments were conducted. The first set, designed to construct an adsorption isotherm, was performed on the Muddy Creek and control soils by varying the amount of Roxarsone (0, 100, 200, 500, and 1000 µg/L). The second set, designed to construct an adsorption edge, was conducted on the Muddy Creek and control soils with 200 µg/L Roxarsone and varying values of pH (3, 5, 7, 9, and 11). Samples were run in triplicate. A 6.25 g of homogenized soil sample was placed into an acid-washed centrifuge tube. Twenty-five mL of 0.01 M NaCl solution was added to the tube. The pH was adjusted by addition of NaOH or HCl. After spiking with Roxarsone, the sample was mixed and placed on a wrist shaker for 24 hours of the 3-d period. During the latter two days of the contact period, the mixture was allowed to stand and settle. The sample was centrifuged for 20 minutes (3500 x g) at 25ºC. The supernatant was filtered with a 0.45 µm filter followed by a 0.2 µm filter and then preserved with HNO_3 (pH<2). The sample was analyzed by GFAAS.

Extraction Procedure for Defining the Partitioning of Arsenic to Soil Fractions

The modified Tessier extraction procedure, developed by Turpeinen et al. (1999), was used to delineate the As sequentially as exchangeable, bound to easily-reducible metal oxides, bound to organic matter, bound to Fe- and Al-oxides, and residual (Table 2). Homogenized soil (2.5 g) and the appropriate solutions were added to a 50-mL centrifuge tube. After each extraction, the sample was centrifuged for 30 minutes (3500 x g) at 25ºC. The supernatant was removed and diluted with Nanopure water to give a final HNO_3 concentration of 5%. The residual of the extracted soil was washed with 8 mL of Nanopure water, centrifuged, and the supernatant was discarded. The residual solid was then used for the next extraction. Concentrations were determined by ICP-AES or GFAAS.

Table 2: The Modified Tessier Extraction Procedure (Turpeinen et al. 1991); further modified by Brown (2002)

Target Phase	Extraction procedure
Exchangeable	1 M $MgCl_2$ (25 mL, pH 7); 4 h (25°C); shaker
Easily reducible metal-oxides	0.1 M $NH_2OH{\cdot}HCl$ (10 mL) + 0.01 M HNO_3 (15 mL); 30 min (25°C); shaker
Bound to organic matter	0.02 M HNO_3 (22.5 mL) + 30% H_2O_2 (2.5 mL); 2 h (85°C), 3.0 M NH_4Ac (3.5 mL) + 25% HNO_3 (1.5 mL; pH 2.5); 5 h (85°C) + 30 min (25°C)
Method II - Bound to organic matter	To 0.5 g of soil, add 0.5 g $KclO_4$ and 10 mL of concentrated HCl; 45 min (25°C) intermittent shaking
Bound to Fe- and Al-oxides	0.175 M $(NH_4)_2C_2O_4$ (12.5 mL) + 0.1 M $C_2H_2O_4$ (12.5 mL); pH 3.25; 30 min (95°C)
Method II – Bound to Fe-oxides	To 0.5 g of soil, add 0.11 M $(NH_4)_2C_2O_4$ (10 mL) + 0.09 M $C_2H_2O_4$ (10 mL); 45 min (80°C), add 0.4 g $Na_2S_2O_4$; 45 min (80°C), cool, rotate overnight, centrifuge
Residual	32.5% HNO_3 (10 mL); autoclave 30 min (120°C, 1 atm)

Two alternate methods of analyzing the amount of As partitioned onto organic matter and iron oxide soil fractions were employed (Table 2). For the alternate organic matter extraction, a step from the sequential extraction procedure by Breit et al. (2001) was implemented. To 0.5 g of soil, 0.5 g $KClO_4$ and 10 mL of concentrated HCl were added into a glass tube. The mixture was shaken by hand, allowed to settle for 10 minutes, and then placed on the wrist shaker for 30 minutes. After 5 minutes (equivalent to a total time of 45 minutes of intermittent shaking), the sample was centrifuged (3500 x g) for 5 minutes. The supernatant was analyzed by GFAAS. For the alternate iron oxide extraction, an oxalic-dithionite extraction procedure (Rutherford et al. 2001) was used. In an acid-washed centrifuge tube, 0.5 g of soil, 10 mL of ammonium oxalate (0.11 M) and 10 mL of oxalic acid (0.09 M) were added. The mixture was heated at 80ºC for 45 minutes. Next, 0.4 g of sodium dithionite was added, and the mixture was again heated at 80ºC for 45 minutes. The sample was allowed to cool, then placed on the wrist shaker overnight. The mixture was centrifuged, and the supernatant was analyzed by GFAAS.

RESULTS

Roxarsone adsorption

Results of the first sorption experiment were used to construct an adsorption isotherm (Figure 2). Roxarsone sorbed most strongly to the clay-rich soils (Bt2-control > Bt1-control > Bt1-MC) and least strongly to the Ap soils. There appears to be a direct, linear relationship between the amount of the solute sorbed onto the solid (soil), C*, and the concentration of the solute, C. The resulting linear sorption isotherm is described by the equation $C^* = K_dC$, where K_d is the distribution coefficient. The K_d is equal to the slope of the linear sorption isotherm (Fetter, 1999). Values of K_d for the different soils are shown in Table 3.

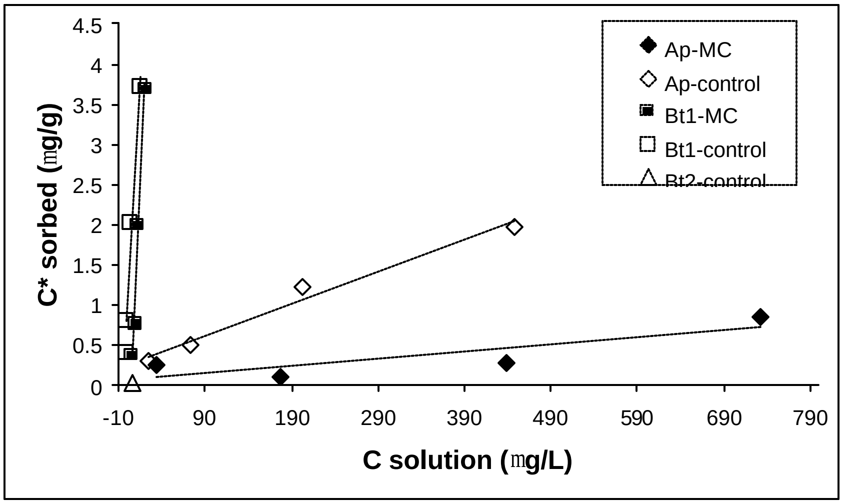

Table 3 – Values of K_d

Soil Type	K_d (L/µg)
Ap-control	0.005
Ap-MC	**0.001**
Bt1-control	0.259
Bt1-MC	**0.165**
Bt2-control	0.252

Figure 2. Linear Isotherm of Roxarsone Adsorption

In the second sorption experiment, the pH was manipulated to determine the adsorption edge for Roxarsone. C*sorbed was plotted against the pH to generate the adsorption edge (Figure 3). Adsorption of Roxarsone to the clay-rich soils (Bt2-control, Bt1-control, and Bt1-MC) is only weakly pH-dependent. Adsorption of Roxarsone to the Ap soils is strongly pH-dependent, with the Ap-MC showing the most influence of pH. Peak adsorption in the Ap-control occurred at low pH (3 and 5) and decreased with increasing pH. The Ap-MC showed no significant adsorption at the low and high pH levels (3, 9, and 11), and peaked at pH 5.

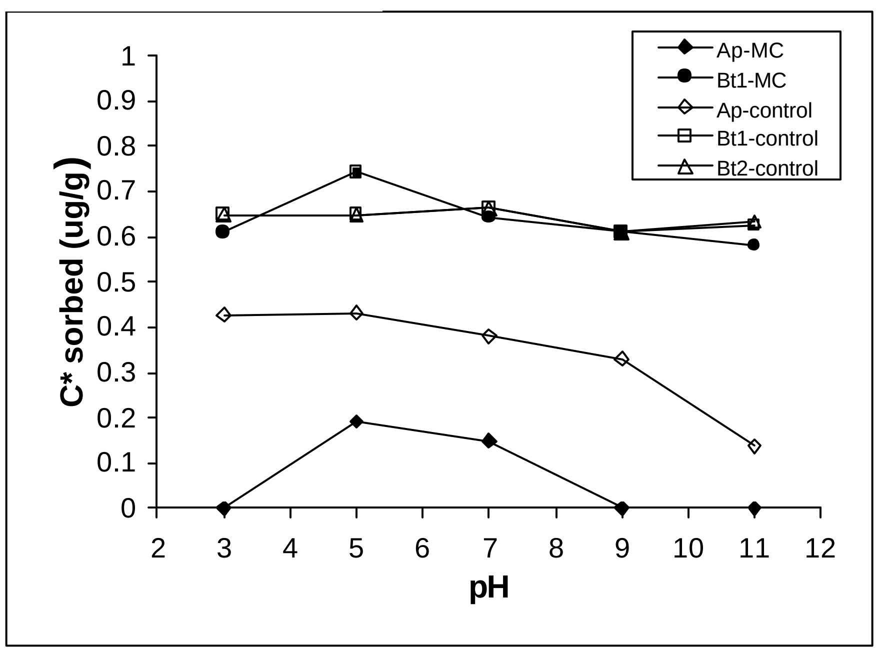

Figure 3. pH dependence of Roxarsone sorption

Sequential Extraction of Arsenic

Results of the sequential extraction procedures are shown in Table 4. The initial sequential extraction procedure (Turpeinen et al. 1999) showed the highest As concentration in the residual extraction step. In comparing the total As extracted from the soils using the microwave digestion procedure (EPA Method 3052) and the total amount extracted during the sequential extraction procedure (Table 4), the sequential extraction procedure appears to be incomplete. This technique most noticeably failed to extract As from the clay-rich soils (Bt2-control, Bt1-control and Bt1-MC). For example, the Bt2-control showed the highest amount of As from the total digestion yet no As was extracted during the sequential extraction procedure. Consequently, two additional methods of extraction were performed (labeled Method II in Table 4). The two alternative methods were able to extract As much more efficiently. These results indicate that the majority of As is being bound to organic matter, followed by iron oxides.

Table 4. Comparison of Extracted Arsenic Concentrations

As total conc. (mg/kg)	**Ap-control**	**Ap-MC**	**Bt1-control**	**Bt1-MC**	**Bt2-control**
Sequential Extraction					
Exchangeable	bdl	0.067	bdl	bdl	bdl
Easily reducible metal-oxides	bdl	0.086	bdl	bdl	bdl
Bound to organic matter	0.0156	0.511	bdl	bdl	bdl
Method II – OM bound	5.642	7.242	NA	NA	NA
Bound to Fe- and Al-oxides	0.0224	0.407	bdl	bdl	bdl
Method II – Fe-oxide bound	0.256	0.212	0.50	0.052	0.258
Residual	0.110	3.625	bdl	bdl	bdl
Sequential Extraction TOTAL	1.340	4.696	bdl	bdl	bdl
Seq. Ext.with Method II TOTAL	*6.008*	*12.303*	*0.50*	*0.052*	*0.258*
Total Digestion Extraction	**6.58**	**7.03**	**5.10**	**10.58**	**14.82**

Notes: NA = not available, bdl = below detection limit of 0.0056 mg/kg

DISCUSSION

The slightly higher pH of the MC soils in comparison with the control soils can be attributed to the addition of lime to the field, and the increase in %OM in amended soils is typical of treated fields (Kingery et al. 1994) (see Table 1). The nutrient concentrations were also higher (in the case of phosphorus, 30 to 130 times more) in the amended MC soils. The Ap-MC and the Bt1-MC soils contain more As than the Ap-control and Bt1-control soils. The Bt2-control soil had the highest amount of total extractable As, as determined by microwave-assisted acid digestion, yet the sequential extraction procedure failed to extract detectable amounts of As. The problem may be due to using an inappropriate technique to extract the As from the clays. A method specifically aimed at As extraction from clays will be attempted in further work.

The linear sorption isotherm (Figure 2), generated by varying the concentration of Roxarsone added to the soils, indicates that Bt2-control, Bt1-control, and Bt1-MC soils adsorb the Roxarsone very effectively (Table 3). These soils have high clay content and low (less than 1%) organic matter content. The clays in the MC soils are primarily kaolinite and illite (Hyer et al. 2001), which, according to the literature (Manning and Goldberg, 1997), show strong affinity for As. The Ap-control soil (1.4% OM) displayed moderate sorption capacity, while the Ap-MC soil shows the weakest adsorption of Roxarsone (Table 3).

The Ap-MC has the highest percentage of organic matter (2.8%), which may be blocking the adsorption of Roxarsone. These results are in agreement with the findings of Redman et al. (2002) and Xu et al. (1991) that organic matter interferes with the adsorption of As. However, it is interesting to note that the greatest amount of As was extracted from the organic matter by the alternative (Method II) extraction procedure, yet these soils, with the highest percent of organic matter, showed the lowest adsorption capacities.

The adsorption edge (Figure 3) shows similar trends as seen in the isotherm data. The Bt2-control, Bt1-control, and Bt1-MC soils continue to adsorb a high percentage of Roxarsone over the pH range of 3 to 11 (C* sorbed = 0.6 to 0.75 µg/g). The Ap-control soil shows moderate adsorption (C* sorbed = 0.3 to 0.5 µg/g) of Roxarsone from pH 3 to 8 and sharply decreases from pH 8 to 11. The Ap-MC is only able to weakly adsorb (C* sorbed = 0.1 to 0.2 µg/g) Roxarsone from pH 4 to 8, and no significant adsorption at pH 3, 9, and 11. This pattern may be related to the amount of organic matter in the soils and the changes that may be occurring to the organic matter at pH values outside of the range of pH 4-8. Further work on evaluating the causes of pH-dependent sorption of Roxarsone is underway.

CONCLUSIONS

Sorption experiments were conducted to evaluate the adsorption characteristics of Roxarsone, an organoarsenic poultry feed additive. Results indicate that clay-rich soils (Bt1 and Bt2 soils of the Frederick series) from a field site where poultry litter has been applied and from a control site strongly adsorb Roxarsone (K_d values 0.16-0.26 L/µg). Ap soils from both sites displayed lower sorption capacity (K_d values 0.001-0.005 L/µg). Results of experiments in which pH was varied shows pH-dependent sorption of Roxarsone to organic-rich (Ap) soils, with the greatest sorption occurring at pH 5. The causes of this pH dependence are currently being evaluated.

Sequential extraction techniques, utilized to determine As partitioning in soils (e.g., easily exchangeable, bound to organic matter, bound to iron oxides), were not fully effective at extracting As. Despite these difficulties, the methods were useful in documenting that soils collected from an agricultural site where poultry litter has been applied have overall higher concentrations of As than do comparable control soils. Current work is aimed at developing alternate methods for extracting As from iron oxides and clay minerals.

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EVERYDAY DECISIONS AFFECT GROUNDWATER QUALITY: A MULTIMEDIA TEACHING TOOL

Phyllis Leary Newbill
Radford University Geology Department
Box 6939
Radford, VA 24142
(540) 831-6387; Fax (540) 831-5732
pnewbill@radford.edu

Parvinder S. Sethi
Radford University Geology Department
(540) 831-5619; Fax (540) 831-5732
psethi@radford.edu

KEYWORDS: Groundwater pollution, education, multimedia

ABSTRACT

Introductory college-level science classes are often the last formal opportunity for non-science majors to learn about environmental issues such as groundwater pollution. Introductory college-level geology textbooks typically devote from a few pages to a full chapter on groundwater. From studying this kind of work, students learn about groundwater movement, permeability, porosity, and perched water tables. Unfortunately, students often miss how these topics are relevant to their lives and how their own decisions affect groundwater. We have developed an interactive, multimedia instructional tool designed to help citizens understand how their everyday decisions affect groundwater quality. Our teaching tool is based on educational theories, including multiple intelligences theory and Gagne's nine events of instruction. We focus on groundwater basics, reading lab reports, septic systems, landfills, underground storage tanks, agricultural chemicals, and karst topography. In each section, learners receive instruction on how groundwater is polluted and how their own decisions can affect groundwater quality. The instruction is organized by three to five relevant, common sense questions, such as, "How might my septic system pollute the groundwater?" or "What can I do to protect the groundwater from pollution from landfills?" Each section also includes a clear statement of objectives, the opportunity to practice new knowledge, and a "Coffee Break" designed to encourage learners to review and transfer the information presented in the section to new situations. A fictional groundwater consultant, Jamie, leads the "conversation" and answers questions about the different groundwater quality issues. The program is designed for one-on-one or small group work at the college freshman level, but is appropriate for general public use as well. It includes text, drawings, photographs, animations, and videos, as well as narrations, all of which were produced in-house at the Radford University Geology Department Multimedia Lab.

INTRODUCTION

Groundwater pollution is expensive and sometimes impossible to clean up, so prevention is the key to clean groundwater. Public education is of critical importance for prevention of groundwater pollution. Many well-known researchers in groundwater pollution have established the need for additional educational materials. Fairchild (1987) notes, "There is a lack of publicly available data on agricultural chemical contamination of groundwater health effects." Kastning and Kastning (1990) assert, "There is a general lack of public understanding of groundwater behavior, particularly in karst." The Environmental Protection Agency has established an entire office dedicated to environmental education (www.epa.gov/enviroed).

Introductory college-level science classes are often the last formal opportunity for non-science majors to learn about environmental issues such as groundwater pollution. Typically, introductory-level college physical geology students are exposed to one chapter on groundwater systems with, at most, a few pages on groundwater pollution (for example, Thompson and Turk 1993, Hamblin and Christiansen 1998, Tarbuck and Lutgens 1999, Press and Siever 2000). From these textbooks, students learn about groundwater movement, permeability, porosity, and perched water tables. Unfortunately, students often miss how these topics are relevant to their lives and how their own decisions affect groundwater.

People who make decisions that affect groundwater quality must understand, through education, the threats and mechanisms of pollution. Decision-makers include homeowners, business owners, business managers, policymakers, and voters, to name a few. Many of these future decision-makers can be reached in introductory-level college geology or environmental science courses.

To address this problem, we have developed an interactive, multimedia instructional tool designed to help citizens understand how their everyday decisions affect groundwater quality. Our teaching tool is based on educational theories, including multiple intelligences theory (Gardner 1993) and Gagne's nine events of instruction (1965).

PROGRAM DESCRIPTION

The instruction contains seven sections that cover groundwater basics, lab reports, septic systems, landfills, underground storage tanks, agricultural chemicals, and karst topography. In each section, learners receive instruction on how groundwater is polluted and how their own decisions can affect groundwater quality. The program is designed for one-on-one or small group work at the college freshman level, but is appropriate for general public use as well. It includes text, drawings, photographs, animations, videos, and narrations, all of which were produced in-house at the Radford University Geology Department Multimedia Lab (Figure 1).

The instruction in each section is organized by three to five relevant, common sense questions (Figure 2), such as, "How might my septic system pollute the groundwater?" or "What can I do to protect the groundwater from pollution from landfills?" Each section also includes a clear statement of objectives; the opportunity to practice new knowledge, and a "Coffee Break" designed to encourage learners to review and to transfer the information presented in the section to new situations (Figure 3). A fictional groundwater consultant, Jamie, leads the "conversation" and answers questions about the different groundwater quality issues.

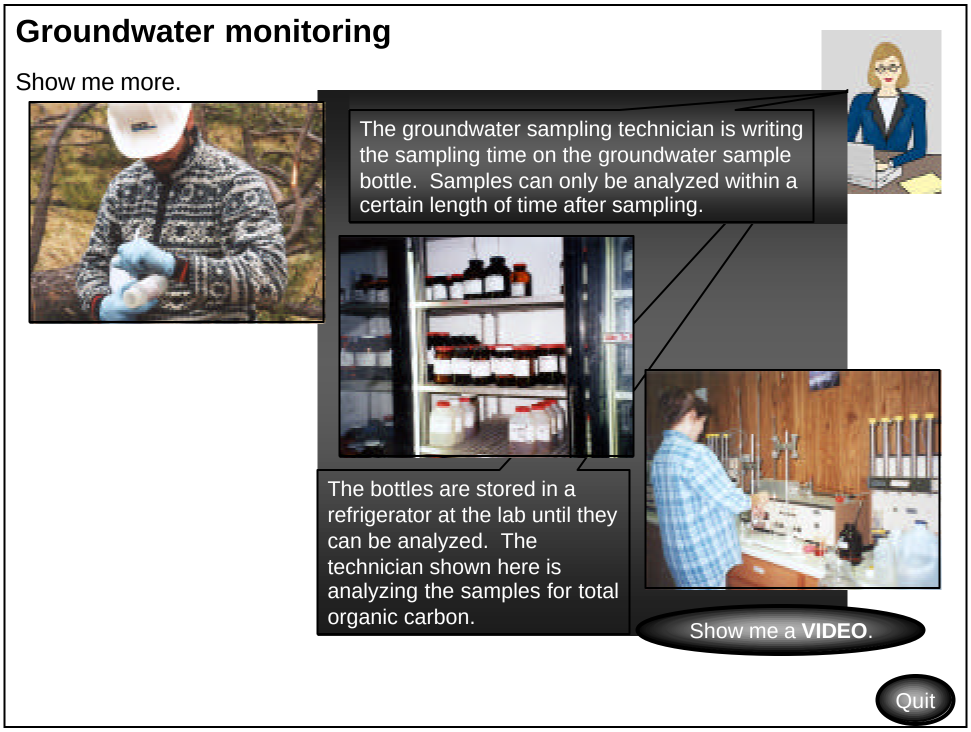

FIGURE 1. SAMPLE SCREEN SHOWING PHOTOGRAPHS, TEXT, DRAWING, AND LINK TO VIDEO.

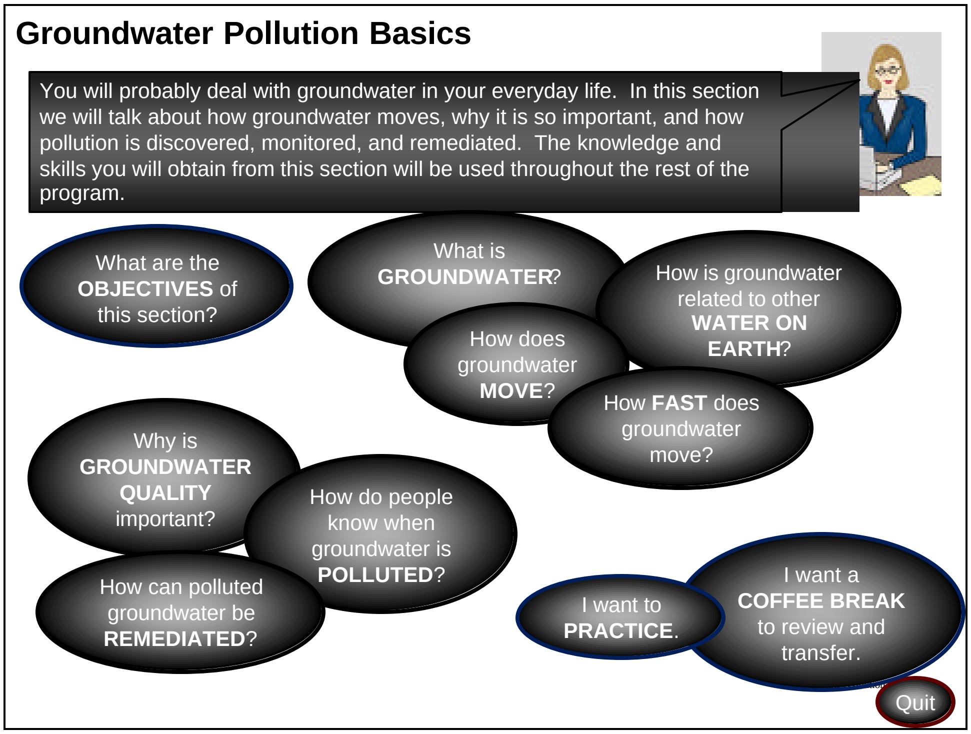

FIGURE 2. SECTION START SCREEN FOR GROUNDWATER POLLUTION BASICS

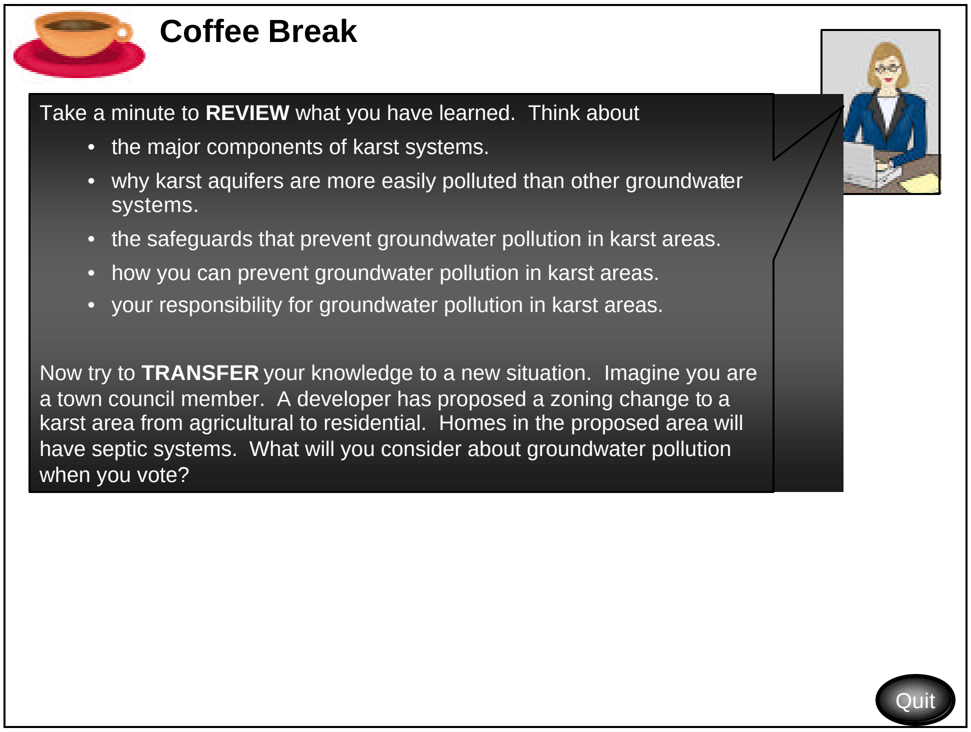

FIGURE 3. COFFEE BREAK SCREEN FROM KARST AQUIFERS SECTION

CD-ROM OUTLINE

The outline below shows the structure of the entire program. As described above, the instruction is set up as a conversation between the student and a groundwater expert. Therefore, the program is organized by questions asked from the student's point of view. Questions were designed to be easily understood.

- I. Introduction
  - a. What are the objectives of this program?
  - b. How do I use the program?
  - c. Why is this relevant to me?
- II. What is groundwater and how does it get polluted?
  - a. What are the objectives of this section?
  - b. What is groundwater?
  - c. How is groundwater related to other water on earth?
  - d. How does groundwater move?
  - e. How fast does groundwater move?
  - f. Why is groundwater quality important?
  - g. How do people know when groundwater is polluted?
    - i. How is groundwater monitoring done?
  - h. How can polluted groundwater be remediated?
    - i. What is risk assessment?
    - ii. What are some methods of groundwater remediation?
  - i. I want to practice.
  - j. I want a coffee break to review and transfer.
- III. How do I read lab reports?
  - a. What are the objectives of this section?

b. How are lab reports organized?
    i. Show me a chain of custody form.
    ii. What is quality control data?
c. How do I know what the samples were tested for?
d. What do the abbreviations on lab reports mean?
e. Show me a sample lab report.
f. I want to practice.
g. I want a coffee break to review and transfer.

IV. I have a new septic system. What should I know about it and groundwater pollution from it?
a. What are the objectives of this section?
b. What is a septic system?
c. What prevents groundwater pollution from septic systems?
d. What groundwater pollutants come from septic systems and what are their health effects?
e. What can I do to prevent groundwater pollution from my septic system?
f. What is my responsibility for septic system pollution?
g. I want to practice.
h. I want a coffee break to review and transfer.

V. A landfill is proposed near my home. How might it affect my water?
a. What are the objectives of this section?
b. What is a landfill?
c. What prevents groundwater pollution from landfills?
    i. How does a landfill liner system work?
    ii. How does a leachate collection system work?
    iii. How does a groundwater monitoring system work?
d. What groundwater pollutants come from landfills and what are their health effects?
e. What can I do to prevent groundwater pollution from landfills?
f. What is my responsibility for pollution from landfills?
g. I want to practice.
h. I want a coffee break to review and transfer.

VI. A gas station is on the hill near my home. How might its underground storage tanks affect my water?
a. What are the objectives of this section?
b. What is an UST?
c. What prevents groundwater pollution from USTs?
d. What groundwater pollutants come from USTs and what are their health effects?
e. What can I do to prevent groundwater pollution from USTs?
f. What is my responsibility for pollution from USTs?
g. I want to practice.
h. I want a coffee break to review and transfer.

VII. I want a beautiful lawn and a termite-free house. How might fertilizers and pesticides that I apply affect my water?
a. What are the objectives of this section?
b. What are pesticides and fertilizers?
c. What prevents groundwater pollution from pesticides and fertilizers?
d. What are the health effects of groundwater pollution from pesticides and fertilizers?
e. What can I do to prevent groundwater pollution from pesticides and fertilizers?
f. What is my responsibility for pollution from pesticides and fertilizers?
g. I want to practice.
h. I want a coffee break to review and transfer.

VIII. My home is near sinkholes. How might they affect my water?

a. What are the objectives of this section?
b. What are karst aquifers and how do I tell if I live near them?
c. What prevents groundwater pollution in karst aquifers?
d. What can I do to prevent groundwater pollution in karst aquifers?
e. What is my responsibility for pollution in karst aquifers?
f. I want to practice.
g. I want a coffee break to review and transfer.

CONCLUSION

Preliminary testing shows the program to be useful and enjoyable for introductory-level geology students. At present, the CD-ROM described here has not been published, and is therefore not available for sale. However, the idea shows promise, and could be expanded upon or used as a template for other environmental education applications.

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DESIGN CRITERIA FOR FISH SCREENS IN VIRGINIA: RECOMMENDATIONS BASED ON A REVIEW OF THE LITERATURE

Charles Gowan
Randolph-Macon College
Department of Biology
Ashland, VA 23005
804-752-7293
cgowan@rmc.edu

Greg Garman
Center for Environmental Studies
Virginia Commonwealth University
Richmond, Virginia

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ABSTRACT

Water withdrawals from rivers and lakes for municipal and other uses can pose a major threat to juvenile fish, and these withdrawals are becoming more common in Virginia. Numerous types of screens have been designed to prevent fish from being drawn into the water intake system (entrainment), but improperly designed screens can allow fish to be drawn against the screen surface and killed (impingement). Reducing the rate of entrainment and impingement to acceptably low levels requires a combination of engineering technology and an understanding of the life history characteristics and swimming capabilities of the fish being protected. This report reviews the literature on swimming capabilities and life-history characteristics of Virginia's important fish species and makes recommendations regarding appropriate engineering design criteria for protecting fish at water withdrawals in the Commonwealth. Available data indicate that a screen mesh size of 1 mm or smaller is required to prevent entrainment of larval lifestages of important species, and that water velocities through the screen should not exceed 0.25 ft/s.

INTRODUCTION

Water withdrawals from rivers and lakes can pose a major threat to juvenile fish (Versar 1986; Van Winkle et al. 1980; Boreman and Goodyear 1988), and these withdrawals are becoming more numerous as Virginia's human population grows, demanding more water for power production, municipal and industrial uses, and irrigation. The potential for harm to fish has long been recognized, and engineering solutions, variously successful, have been developed. Numerous types of screens have been designed to prevent fish from being drawn into the water intake system, a process known as entrainment. However, preventing entrainment with screens can cause impingement, whereby fish are drawn against the screen surface and killed. Reducing the rate of entrainment and impingement to acceptably low levels requires a combination of engineering technology and understanding of the life-history characteristics and swimming capabilities of the fish being protected. This report reviews the literature on screen design, including swimming capabilities and the life-history characteristics of Virginia's important fish species, and makes recommendations regarding appropriate engineering design criteria.

GENERAL CONCEPTS IN FACILITY DESIGN

Fish protection devices must achieve three goals: prevent entrainment, prevent impingement, and guide fish away from the facility. Minimizing entrainment and impingement and maximizing guidance requires an: 1) understanding the life-history and behavioral traits of the species of interest so that diversion structures are not located near critical fish habitat and water withdrawals are minimized when vulnerable lifestages are present; 2) knowing the swimming capabilities of vulnerable lifestages so that water velocities through the screen are set below the sustained swimming speed of the target species; and 3) knowing the sizes of vulnerable lifestages so that screen mesh size is correctly chosen to prevent entrainment.

Facility Siting and Operation

Fish lifestages most vulnerable to water withdrawals are eggs, larvae, and juveniles. Because the presence of these lifestages is limited to specific seasons and habitats, the first consideration is to separate fish spatially and temporally from the intake (Zeitoun et al. 1981; Travnichek et al. 1993). Thus, siting a diversion requires delineation of the seasonal and diel patterns of fish abundance, and the vertical and horizontal distribution of fish in the water column. For example, vulnerable lifestages are often found in shallow water habitats, and a common recommendation is to locate intakes offshore in deep water where exposure of juveniles is minimized (e.g., Washington Department of Fish and Wildlife 1995; National Marine Fisheries Service 1995; California Department of Fish and Game 1993). If intakes cannot be located away from habitats supporting vulnerable lifestages, reducing or eliminating water withdrawals during the period these lifestages are present (i.e., seasonal or time-of-day restriction) can be an effective protection strategy (Dempsey 1988).

Once a location and withdrawal schedule are selected, it is important to design the overall facility in a way that allows vulnerable fish quick egress away from the site because the longer a fish is exposed to the facility the higher the probability of death (Fletcher 1985). In flowing water, the intake should be constructed within the stream channel and parallel to stream flow. For example, if cylinder screens are used, they should be placed in the stream channel, not in a diversion structure set into the stream bank.

Setting Appropriate Water Velocities and Screen Surface Area

Water velocity through the screen surface ("approach velocity") is the single most important consideration in preventing impingement. When juvenile fish encounter the screen surface, they tend to align themselves parallel to the flow through the screen, swimming against it (Schuler 1973; Stone and Webster 1976; Fletcher 1985). If velocity through the screen exceeds the sustained swimming speed of the fish, impingement results and death from abrasion or asphyxiation ensues. When screens are set at an angle to the approach flow (often to help guide fish away from the facility), the velocity (V) can be broken into two vector components. The first component is the approach velocity, V_n (perpendicular to the screen surface, sometimes called the normal velocity), and the second component is the sweeping velocity, V_s (parallel to the screen surface). The optimum screen configuration results in the lowest possible approach velocity and highest possible sweeping velocity, hence the general recommendation to set the screen parallel to stream flow whenever possible.

Low approach velocities are important because this component of the flow is responsible for impingement. Approach velocities must be set lower than the sustained swimming speed of the target lifestages. High sweeping velocities are important because this component of the flow may help guide fish away from the intake facility. Thus, sweeping velocities must be set high enough so that fish are moved past the facility before they fatigue and become impinged.

Providing Fish Bypass

Providing fish ready egress from the facility is important because without it fish will eventually fatigue and become impinged. Intakes placed in open water, especially if natural currents create a sweeping velocity, are the preferred configuration because an engineered bypass is not required. However, whenever intake structures are set into the stream or lake bank, a bypass system is necessary. The need is especially high for protection of downstream juvenile migrants (either resident or anadromous) encountering gravity-fed intakes because these fish tend to move with the flow and may never escape from the intake structure. The entrance to the bypass should be at the downstream end of the screen and velocities at the entrance should be high enough to provide efficient guidance for outmigrating fish.

MESH-SIZE AND VELOCITY CRITERIA FOR FISH SCREENS IN VIRGINIA

Screen Mesh Size

A number of studies examined the empirical relationship between fish size and mesh size needed to prevent entrainment. One of the most comprehensive was by Turnpenny (1981), who took morphometrical measurements, including standard length (L_s), maximum body depth (D_{max}), and maximum body width (W_{max}), on 24 marine and freshwater fish species and quantified the relationship between these variables and mesh size required to prevent entrainment. From this, he developed a general formula to relate morphological measurements from any fish species to mesh size requirements:

$$M = \frac{L_s * D}{0.0209 L_s * D + 0.6564 D + 1.199 L_s}$$

Where: M = maximum mesh size that prevents entrainment (mm)

L_s = fish standard length (mm from tip of nose to last caudal vertebra)

D = maximum body depth or width (mm), whichever is greater (to account for laterally compressed [$D_{max} > W_{max}$], round [$D_{max} = W_{max}$], or dorsoventrally compressed [$D_{max} < W_{max}$] species which are assumed to be excluded by the largest dimension).

Many researchers have noted that the ratio of fish length to body depth (L_s/D; often referred to as the "fineness ratio", FR; Webb 1975) expresses the degree of streamlining a fish exhibits. Optimum FR is about 4.5, which gives minimum drag for maximum body volume, and many freshwater fish families common to Virginia have FRs in the range 4 to 7 (Scarnecchia 1988). The ratio is important in terms of entrainment because it provides a good index of body shape and thus susceptibility to entrainment. For example, fish with high FRs tend to be long, slender, and round in cross-section (an extreme example are eels), meaning that even a large individual, in terms of standard length, can be entrained through a small-sized mesh. Conversely, fish with low FRs tend to be compressed (laterally such as sunfish or dorsally such as flounder), and so a small individual can be excluded by a relatively large mesh size. To illustrate the point, Turnpenny's (1981) equation was used to predict the maximum mesh size sufficient to exclude fish of a given standard length, over a range of FRs from 3 to 10 (Fig. 1).

Turnpenny (1981) reported that his equation was very reliable for predicting required mesh sizes, with an average of 7.3% error (across the 24 species) between the mesh size determined empirically to prevent entrainment and the mesh size predicted by his equation. Even so, Turnpenny's (1981) work illustrates that very small mesh sizes are required to prevent entrainment, a conclusion supported by many other studies involving a variety of fish species and screen types (Dames and Moore 1979; Delmarva Ecological Laboratory 1980; Browne et al. 1981; Hanson 1981; Otto et al. 1981; Schneeberger and Jude 1981; Cada and Loar 1982; Tomljanovich and Heuer 1986; Weisberg et al. 1987).

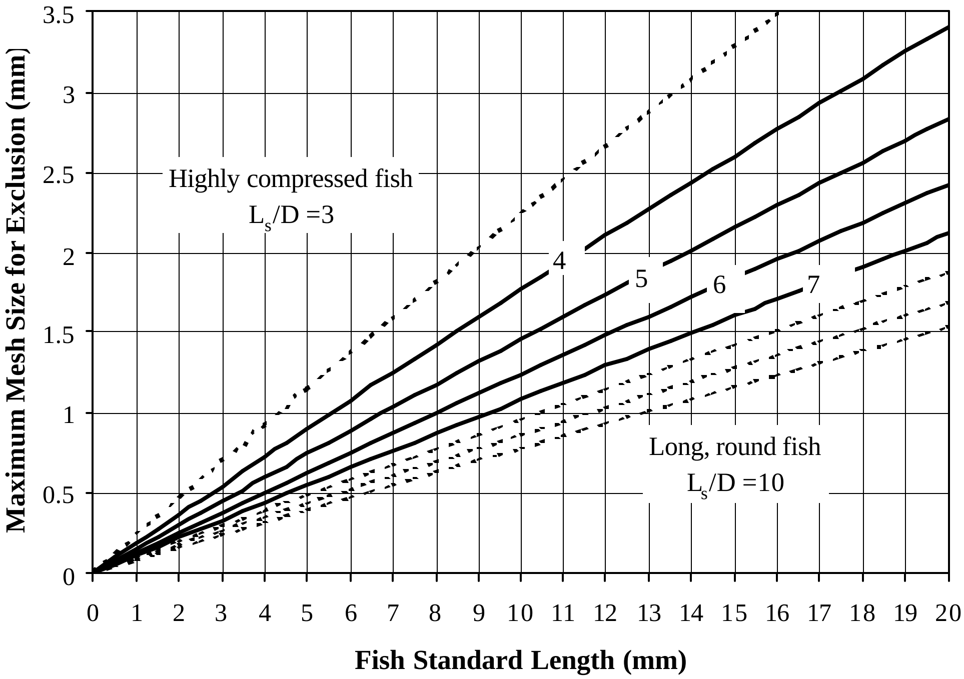

FIGURE 1. RELATIONSHIP OF FISH STANDARD LENGTH (L_S, MM) TO MAXIMUM MESH SIZE CAPABLE OF PREVENTING ENTRAINMENT (M), AS A FUNCTION OF THE RATIO OF STANDARD LENGTH TO MAXIMUM BODY DEPTH (D). BOLD LINES CORRESPOND TO L_S/D RATIOS (FINENESS RATIOS) COMMON FOR FRESHWATER FISH (RATIOS 4 THROUGH 7), AND DASHED LINES FOR FISH EITHER HIGHLY COMPRESSED (EITHER DORSALLY OR VENTRALLY; L_S/D < 4) OR VERY LONG RELATIVE TO BODY DEPTH (L_S/D > 7).

To determine appropriate mesh sizes for Virginia, we reviewed size data for eggs, pro-larvae, post-larvae, and juveniles of every freshwater fish species found in Virginia for which we could obtain data. This totaled 104 species for eggs, 58 for pro-larvae, 51 for post-larvae, and 56 for juveniles. Although we had difficulty obtaining fineness ratio data for most Virginia fish, it is reasonable to expect fineness ratios in the range of 4 – 7. Given that newly-hatched larvae of important Virginia fish (shad, for example) are typically <6 mm, Turnpenny's (1981) work shows that mesh sizes < 1 mm are required to prevent entrainment. In light of these data, and on results of the empirical studies evaluating entrainment as a function of fish size, it is recommended that statewide criteria of 1 mm mesh size be established. Unfortunately, the 1-mm criteria will not be sufficient to protect smaller life-stages of most freshwater fish. For example, assuming a 2-mm-diameter egg can be entrained through a 1-mm mesh (William Miller, personal communication, Miller Ecological Consultants, Inc. Fort Collins, Colorado), eggs of 74 of the 104 species (71%) for which data were available could be entrained, including representatives of important families such as clupeids, cyprinids, centrachids, and percids. Similarly, pro-larvae of 52 of 58 species (90%), post-larvae of 20 of 51 species (39%), and juveniles of 13 of 56 species (23%) would be subject to entrainment under the proposed guidelines. Moreover, these values may underestimate actual entrainment because where a range of sizes was reported for a particular lifestage; we used the largest value in the analysis.

Approach Velocity

Approach velocity criteria are based on fish swimming capability, with criteria set at a value just below the swimming speed of the species and lifestages to be protected. A complicating factor is the issue of endurance, i.e., the duration of time the fish can swim at a given speed. For our purposes, we will use the term critical swimming speed (U_{crit}), defined as the maximum sustained speed that can be maintained for a prescribed period of time (Brett 1964). Still, research we reviewed reported critical swimming speeds for times ranging from 15 minutes to 6 hours. In addition to the variation among studies in endurance time, it is well established that swimming speed is greatly influenced by fish species (see Bell 1986 for a summary), size of the individual (Heap and Goldspink 1986; Smith and Carpenter 1987), and water temperature (Smith and Carpenter 1987).

The primary difficulty in developing approach velocity criteria for Virginia is that very few data exist for swimming performance of non-salmonids. Therefore, in developing criteria, we focused on larval lifestages of the handful of species for which data on critical swimming speed were available (Table 1). Available studies were inconsistent in the duration of the time fish swam, in temperature, and in fish size. We selected a time interval of at least 1 hour to be conservative (studies that defined critical swimming speed as that sustained for something less than 1 hour were not included in the analysis), and simply report fish size and temperature. Despite the limited data, it is clear that, in order to protect larval lifestages of species of most concern in Virginia, very low approach velocity criteria are required. Notice that available data were for relatively large larvae. In particular, data for the major game species in Virginia were for individuals ≥ 9 mm, about double the size at hatching for these species.

The available data indicate that, in order to prevent impingement of major game species, approach velocity criteria in the range of 0.05 to 0.1 ft/s would be required. Unfortunately, approach velocities low enough to afford full protection to Virginia's important species are probably not practical given current technology because extremely large screens would be required to accommodate withdrawal volumes typical of municipal, industrial and agricultural intakes. Therefore, we recommend an approach velocity criterion for Virginia of 0.25 ft/s, the lowest practical velocity achievable with existing technology. Given that existing technology is not adequate to provide full protection for Virginia's fishes, monitoring of impingement and quantification of impacts should be mandatory for every intake.

Sweeping Velocity

Sweeping velocity criteria are designed to move fish past the screen surface, either into a bypass system or past the intake facility altogether, before fatigue and impingement result. Sweeping velocity criteria are often expressed relative to approach velocities. For example, the Washington Department of Fish and Wildlife (WDFW 1995) and the National Marine Fisheries Service (NMFS 1995) specify that sweeping velocity must be greater than the approach velocity, and the California Department of Fish and Game (CDFG 1993) requires sweeping velocity to be twice the approach velocity. We recommend sweeping velocity criteria for Virginia be set at a value equal or greater than the approach velocity. Moreover, screen surfaces must be placed flush with any adjacent footers, piers, walls, or other structures such that an unimpeded flow of water parallel to the screen surface occurs along the entire surface of the screen.

Table 1. Critical swimming velocities (U_{crit}) for selected fish species, as a function of fish total length and trial temperature. Critical is defined as sustained performance ≥1 hour (but see footnote for salmon species). If a study reported a range of values, the mean is shown.

Species	Total length (mm)	Temperature (°C)	U_{crit} ft/s	Primary Reference
3-spined stickleback	6	10	0.098	Taylor and McPhail 1986
Yellow perch	9	13	0.085	Sandstrom 1993
Striped bass	10	17	0.039	Meng 1993
Largemouth bass	10	25	0.131	Beamish 1970
Walleye	10	13	0.049	Nelson 1989
Blueback herring	10	10	0.026	Zittle 1978
American shad	55	Not reported	0.800	Fisher 1981
Rainbow trout	40	10	0.361	Wilson and Egginton 1994
Chinook salmon	40	3	0.380*	Smith and Carpenter 1987
Coho salmon	34	3	0.350*	Smith and Carpenter 1987
Pink salmon	32	3	0.410*	Smith and Carpenter 1987
Chum salmon	38	3	0.400*	Smith and Carpenter 1987

- 15 minute critical swimming speeds; 1 hour speeds would be lower.

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CORROSION: CHEMICAL CAUSES: ECONOMIC, AESTHETIC AND HEALTH EFFECTS – SPONSORED BY THE NATIONAL SCIENCE FOUNDATION – PANEL PRESENTATION

Panel Members: Andrea M. Dietrich, Civil and Environmental Engineering, Virginia Tech (moderator); Marc Edwards, Civil and Environmental Engineering, Virginia Tech;
Sharon Dwyer, Co-Director, Institute for Community Health School of Public and International Affairs; Susan Duncan, Faculty, Food Science and Technology, Virginia Tech; G.V. Loganathan, Faculty, Civil and Environmental Engineering, Virginia Tech

Sponsored by the National Science Foundation, the panel of experts will discuss important issues pertaining to the corrosion of copper in household plumbing. Specific topics to be presented include: EPA's Safe Drinking Water Act copper regulation, an overview of how chemical and biological factors cause corrosion, aesthetic and health effects of copper, and the economic impacts of corrosion to consumers. The key point of the panel is that a team of experts from different disciplines needs to work together to solve a complex problem like corrosion.

Topics presented:

Solutions: Andrea M. Dietrich, Civil and Environmental Engineering, Virginia Tech

Chemical Causes of Corrosion: Marc Edwards, Civil and Environmental Engineering, Virginia Tech

Health Issues of Copper in Drinking Water: Sharon Dwyer, Institute for Community Health School of Public and International Affairs

Aesthetic Issues and Consumer Concerns with Water Pipes: Susan Duncan, Food Science and Technology
Economic Impacts of Corroding Pipes: G. V. Loganathan, Civil Engineering, Virginia Tech