Linking water quality to watershed management and education

James Curatolo and Weixing Zhu

When a huge river in an industrialized country drains into a partly enclosed bay, the challenge of improving the water quality in the bay is a big one. In order to reduce the nutrient loading of Chesapeake Bay, USA, by 40 per cent, farmers and local communities in the upper reaches of the catchment are involved in implementing a 'multi-barrier approach'. Education and community involvement play a major part in meeting this challenge

Watersheds (or 'catchments') are the basic units of land and water that integrate water flow, its quantity and quality, and natural ecosystem processes. Many pollutants also enter watersheds through atmospheric deposition (e.g. acid rain), thus watersheds can act as a sink for air pollution but simultaneously watershed processes are affected by air pollution. Watersheds (referred to as catchments in Europe and Africa) vary in size, from those that cover large drainage basins to those affecting local streams. In watersheds dominated by agricultural activity, nutrient runoff to surface water leads to high nitrogen (N) and phosphorus (P) concentrations, excessive algal growth, depletion of oxygen in the water column, and fish death, in a process collectively called eutrophication. In urban watersheds in developed countries like the US, pollutants from car exhausts, factory waste and even private lawns find their way into local streams.[1]

Groundwater can be contaminated by surface water pollution through complicated hydrological connections. In areas where intensive agriculture is practised, groundwater is often polluted with nitrate, which at high concentration is toxic to humans and livestock. Thus watershed processes are affected by numerous human activities, such as land development, pollutant release, deforestation, river canalization, and agricultural use, and these directly affect water quality and water use by humans.

In the United States, watershed management is the cornerstone of many environmental protection programmes. The Chesapeake Bay is North America's largest and most biologically diverse estuary, with its watershed more than 165 000 square kilometres in size and covering six upland states and the District of Columbia. In 2001, 124.8 million kg N, 8.52 million kg P, and 9.5 million tonnes of sediment were flushed into the bay from watershed states. The nutrient pollution has caused part of the bay and its tidal rivers to be listed as 'impaired' by USEPA (US Environmental Protection Agency) under the Clean Water Act (Chesapeake Bay Program: www.chesapeakebay.net, see Map 1).

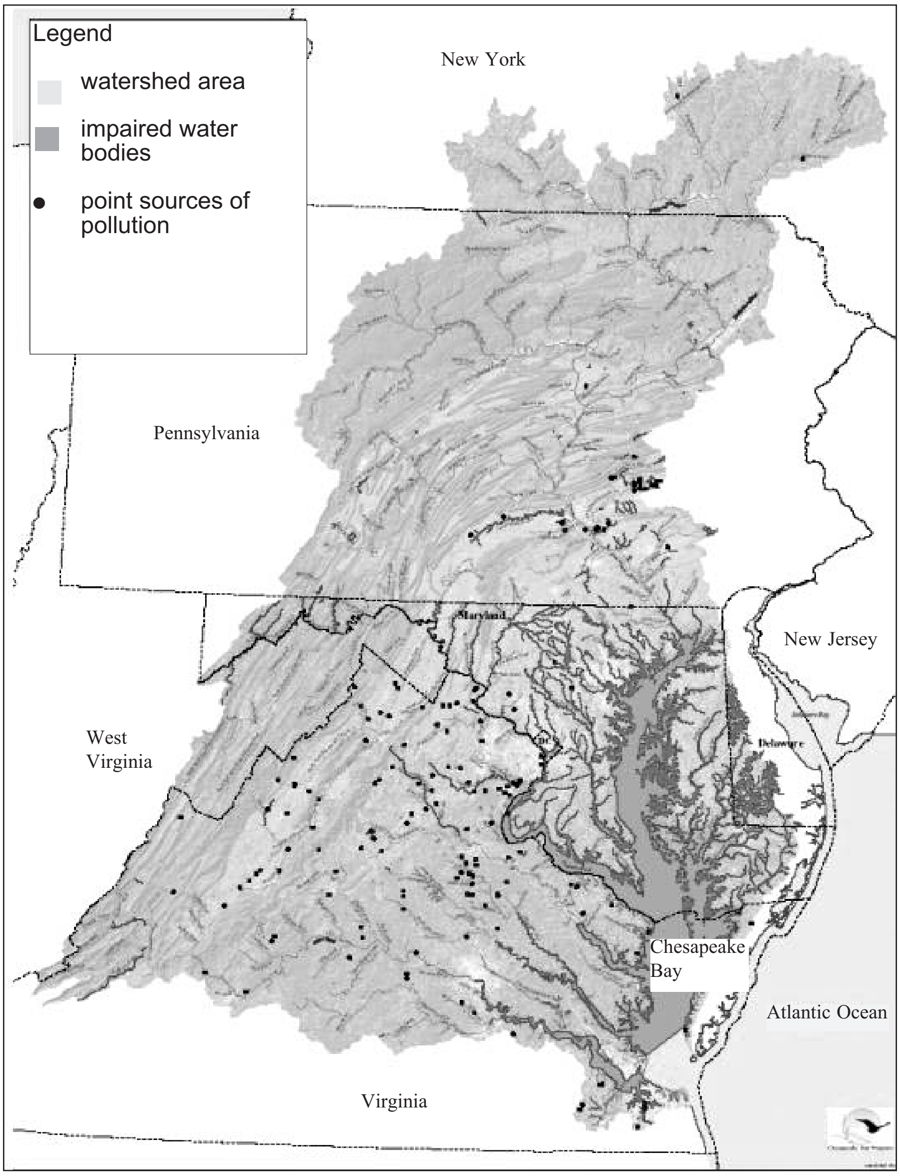
In order to restore the health of the bay ecosystem and maintain its long-term sustainability, the bay states and federal government in June 2000 signed a 'Chesapeake 2000' agreement to take a 'watershed approach' to reduce the nutrient and sediment pollution load by 40 per cent by 2010. The Susquehanna River, the United State's sixteenth largest river, provides half of the freshwater to the Chesapeake Bay. The Upper Susquehanna River headwaters are located in southern New York state and northern Pennsylvania. Surface runoff from low rolling hills and steep-walled valleys feed the main river flows. Steep gradients in the tributaries, combined with glacial till that covers the solid geology of the region, result in stream erosion, gravel deposition and flooding that have important local and regional water-quality consequences. In this basin we take a community-based watershed management approach and, in alliance with universities, promote watershed-based research and education.

Watershed management is still in its early stages in most developing countries. In economically fast-growing countries such as India and China, discharge of untreated industrial and domestic wastes into public water bodies is still common. Large amounts of money have to be spent on water treatment and water-related public health issues. We hope the community-based watershed management and university-affiliated research and education approaches described here provide some insights to achieve both economic development and maintain long-term ecological sustainability.

Community-based watershed management

The Upper Susquehanna Coalition (USC, see website: www.u-s-c.org), established in 1992, is a network of county natural-resource professionals (12 counties in New York State and three in Pennsylvania) who develop strategies, partnerships and projects to protect the headwaters of the Susquehanna River and Chesapeake Bay watershed. The USC is organized under a memorandum of understanding that each county signed, which provides a mechanism to work on joint multi-county watershed projects.

Because the USC is composed of professionals who live in the



Map 1 Chesapeake Bay Ecosystem and its watershed. Credit: Chesapeake Bay Program: www.chesapeakebay.net.

watershed, they are able to work with landowners and other municipal officials as fellow community members. This networking strength provides an important 'liaison' between the local resident and regional, state, federal, academic and non-governmental organizations to help conduct non-point source implementation projects at various watershed scales. The USC is helping New York State develop strategies to address nutrient and sediment load allocations that the state must not exceed to help reduce water impairments in the Chesapeake Bay. We will review several activities that exemplify the USC's low-cost, small-project, multiple-barrier approach to address water-quality issues.

Multi-barrier approach

We use a 'multiple-barrier approach' to address issues of water quality and water quantity. This approach addresses the issue (such as flooding, streambank erosion or degraded fish habitat) at the source (e.g. headwaters), across the landscape, and in the stream corridor, as well as programmatically (e.g. regulations, training). By developing multiple and possibly smaller projects to address problems, progress can continue and tangible results can be achieved over a wide range of funding levels. A multiple-barrier approach can increase the probability of success, be tailored to the critical issues within a basin, and help capture stakeholder interest by demonstrating progress through implementation.

Working with farmers

Agricultural land is an important nutrient and sediment source in the region. USC members follow the New York State Agricultural Environmental Programme that supports voluntary farm assessments to determine water-quality impairments and cost-shares implementation of best management practices. One important practice is rotational grazing for dairy and beef cattle, sheep and goats. The concept is to maximize the availability of high-quality pasture forage to reduce imported feed or row crops. The benefits include lower costs for animal production and less erosion due to permanent pasture. In addition, animals are excluded from the stream. Stream fencing also reduces direct nutrient loading from manure, and studies indicate a 32 per cent reduction in phosphorus from cattle after stream fencing.[2]

USC also supports precision feed and forage management. The dairy producers benefit by reducing the quantity of feed purchased; this is achieved through changes in ration formulation, feeding management and forage production practices. These practices permit balancing the ration closer to the requirements and decreasing nutrient loading to the environment, while maintaining milk production. Targeting the sources of pollution in this way is the most effective step of the multiple-barrier approach in solving water-quality problems.

Other measures

The USC has also developed a wetland programme that helps address local community issues, including flooding and streambank erosion. The focus of the programme is to construct wetlands on hydric soils (soils that are subject to periods of water saturation which result in anaerobic conditions) located in headwater areas, thus capturing precipitation before it enters a defined watercourse. Wetlands, especially in tributaries, tend to desynchronize flood peaks through their water-holding capabilities and their vegetation that retards surface flow.[3] For example, watersheds with 4 to 5 per cent wetlands can have a 50 per cent reduction in peak-flood flows compared to a watershed with no wetlands.[4] We use wetland development as an outreach tool to communities because it can demonstrate how a watershed functions and how capturing or slowing water movement is a good way to reduce flood damage. Wetland projects are one of our first suggestions to community groups who have flooding or stream-bank erosion problems, and they are important components of the multiple-barrier approach.

We also map road ditches, categorizing them according to their severity of erosion and their connections to a stream. Stream banks are similarly mapped. Our watershed contains approximately 21 000 km of streams and 27 400 km of roads. The road ditches form an entire drainage system that overlay the natural watercourses. The runoff from roads into streams, coupled with the disruption by highway culvert- and bridge-maintenance appear to be major causes of stream destabilization in the region. For this reason, we link our stream restoration efforts with highway maintenance training to encourage those who work near streams to understand basic concepts of fluvial geomorphology.

We show highway personnel how to stabilize road ditches, thus reducing maintenance and sediment loading to adjacent streams. Also of great importance is not creating a large shallow streambed, which causes upstream bank erosion and unwanted gravel deposition. Our stream restoration work focuses on natural stream design, which tries to re-establish the streams' physical characteristics based on nearby unaffected reference reaches.

The multiple-barrier approach has also been used in the New York City's drinking water supply watersheds, located just 100 km east of the Upper Susquehanna River basin, and been found highly effective in meeting the phosphorus restriction goals (see website: www.nycwatershed.org). A multiple-level stream and river monitoring programme, carried out by USC, state and federal agents, and university scientists, is currently being developed for the Upper Susquehanna River basin, which will be used to examine the effectiveness of the MBA.

University-based research and education

Binghamton University is located in the Susquehanna River watershed. In 2003, faculty and students from the Departments of Biological Sciences, Geology and Environmental Studies, and Geography formed the Center for Integrated Watershed Studies (CIWS, website: ciws.binghamton.edu). CIWS is a multi-disciplinary study of watersheds, through the integration of research, education and management. In 2002, we started a headwater-stream sampling programme on 22 local streams in the Upper Susquehanna River basin, with a particular emphasis on N species, a major non-point source pollutant that affects the Chesapeake Bay ecosystem as well as local streams, and local drinking-water quality. Three species of N – ammonium (NH_4^+), nitrate (NO_3^-), and dissolved organic N (DON) – were examined. High nitrate concentration in the north-eastern USA is often associated with human pollution, including atmospheric deposition, while ammonium pollution is usually from local agricultural runoff.[5]

Our results showed that nitrate was the dominant form in these headwater streams, suggesting broad human impact in rural New York State (see Figure 1). We found urban streams had significantly higher nitrate concentrations but, surprisingly, streams draining agricultural watersheds had water quality similar to those from rural, mostly forested watersheds. It is likely that broad applications of watershed management practices may have reduced the pollution export from these agricultural watersheds. On the other hand, the management practices of urban streams often alter hydrological flowpaths, reduce natural riparian zones, and cause higher water pollution.[6]

In 2004, Binghamton University was awarded a National Science Foundation grant to integrate watershed-based environmental education on campus. Students from ecology, hydrology and geochemistry classes collect atmospheric deposition and stream-water samples. They found that nitrate concentrations in two tributaries draining the campus portion of the watershed were orders of magnitude higher than those from the nature reserve part of the watershed. Students also found water draining the campus (containing large areas for car parking) had much higher conductivity (due both to its higher nitrate concentration and possibly cation leaching from the paved surface), and a campus storm-water retention facility dramatically reduced nitrate pollution. Students are therefore able to link their daily activities (driving, fertilizer application) to environmental conservation, and learn how to use watershed management practices (such as constructing storm-water retention facilities) to combat urban pollution.

Summary

Watersheds have long been recognized as natural units of water and land

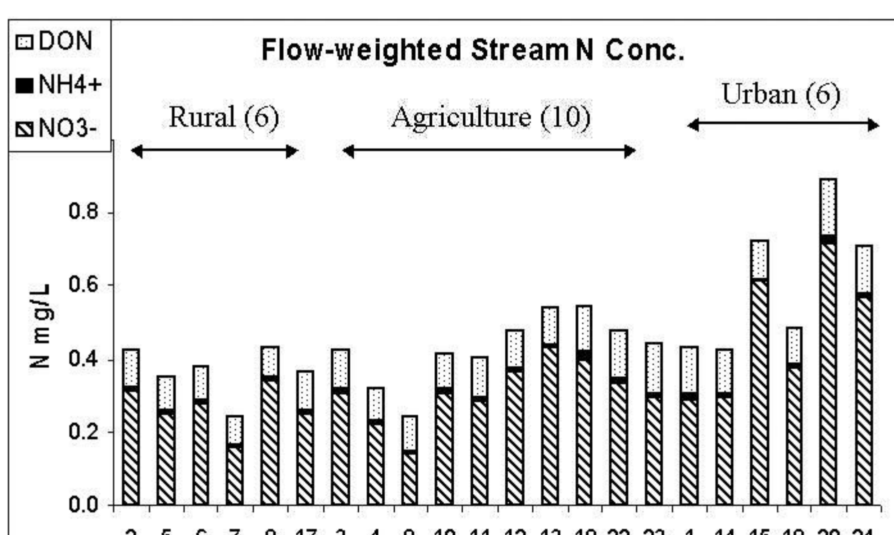


Figure 1 Flow-weighted mean N concentrations in 22 streams collected from autumn 2002 to spring 2003 in the Upper Susquehanna River Basin

integration, and now they should be seen as integrating air pollution (the term 'air-shed' has started to be used). They are also ideal management units to integrate land-use policy, conservation practices, water-quality control, and environmental research and education. Best management practices within local watersheds can benefit local communities and local environmental conservation, and at the same time protect ecosystems hundreds of kilometres away.

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Catchment management

- **The challenges of integrated river basin management in India**
  This questions the idea of transferring 'ready-made' integrated river basin management solutions from Australia, North America and Europe to India, arguing that effective solutions need to be tailored to fit local realities and community-based approaches.
  http://www.iwmi.cgiar.org/waterpolicybriefing/files/wpb03.pdf
- **Integrated Water Resource Management in Water and Sanitation Projects – Lessons from 11 Projects in Africa, Asia and South America**
  Vissher, Jan Teun, Peter Bury, Toby Gould and Patrick Moriarty (1999), Occasional paper No. 31-E. IRC.
  This report of a participatory review examines successes and failures and lessons for the implementation of IWRM strategies. It highlights the role of local communities in monitoring and regulation and the importance of traditional beliefs and customs in catchment protection.
  http://www.irc.nl/content/view/full/1861
- **Protecting groundwater for health: managing the quality of drinking water sources**
  This is a draft for the ongoing revision of the WHO guidelines. It describes a tool for intersectoral development of strategies to protect groundwater for health by managing the quality of drinking water sources. Conceptual guidance is given on prioritizing both hazards and management responses. It is important to consider the socio-economic context in choosing feasible options for protection, control and remediation.
  http://www.who.int/water_sanitation_health/resourcesquality/groundwater2004/en
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  http://gwpforum.netmasters05.netmasters.nl/en/index.html
- **Institute of Water and Environment, Cranfield University**
  The Institute of Water and Environment, in association with other schools in Cranfield University (National Soil Resources Institute NSRI and School of Water Sciences SWS) focuses on the key subjects in Catchment Management, including social perceptions and public participation.
  http://www.silsoe.cranfield.ac.uk/iwe/expertise/catman.htm
- **WHiRL Water Households and Rural Livelihoods**
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  http://www.nri.org/WSS-IWRM/proj_outline.htm
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  http://www.nri.org/WSS-IWRM/Reports/SavetheSandUnit8.pdf.
  http://www.sphereproject.org/handbook/html/4_ch2.htm

Compiled by Julie Fisher, Water, Engineering and Development Centre, UK for WELL. WELL is a resource centre and network providing access to information and support in water, sanitation and environmental health for the Department for International Development (DFID) of the British Government