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River Voices

What Lies Beneath?

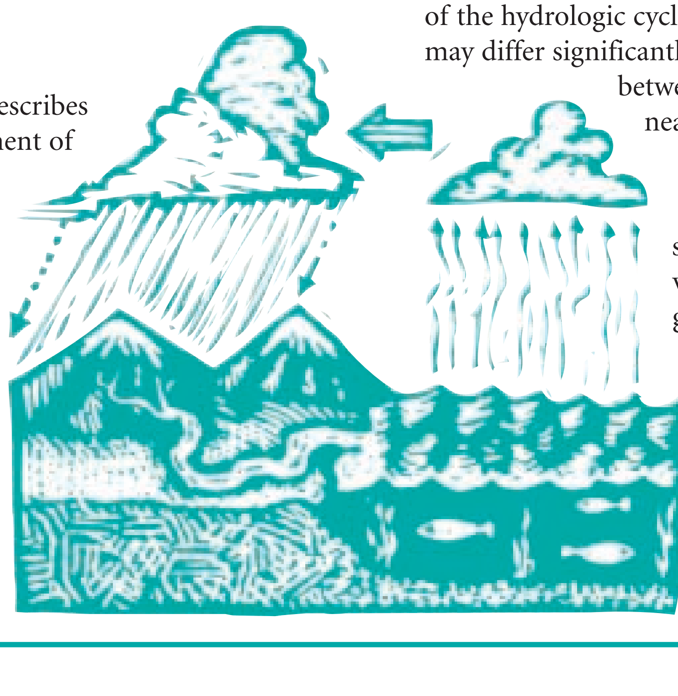
Protecting Our Rivers from the Groundwater Up

by Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley, USGS www.usgs.gov

As the Nation's concerns over water resources and the environment increase, the importance of considering groundwater and surface water as a single resource has become increasingly evident. Issues related to water supply, water quality and degradation of aquatic environments are reported on frequently. The interaction of groundwater and surface water has been shown to be a significant concern in many of these issues. For example, contaminated aquifers that discharge to streams can result in long-term contamination of surface water; conversely, streams can be a major source of contamination to aquifers. Surface water commonly is hydraulically connected to groundwater, but the interactions are difficult to observe and measure and commonly have been ignored in water-management considerations and policies. Many natural processes and human activities affect the interactions of groundwater and surface water.

Hydrologic Cycle

The hydrologic cycle describes the continuous movement of water above, on and below the surface of the Earth. The water on the Earth's surface—surface water—occurs as streams, lakes and wetlands, as well as bays and oceans. Surface water also includes solid forms of water—snow and ice. The water below the surface of the Earth primarily is groundwater, but it also includes soil water.



The hydrologic cycle commonly is portrayed by a very simplified diagram that shows only major transfers of water between continents and oceans. However, for understanding hydrologic processes and managing water resources, the hydrologic cycle needs to be viewed at a wide range of scales and as having a great deal of variability in time and space. Precipitation, which is the source of virtually all freshwater in the hydrologic cycle, falls nearly everywhere, but its distribution is highly variable. Similarly, evaporation and transpiration return water to the atmosphere nearly everywhere, but evaporation and transpiration rates vary considerably according to climatic conditions. As a result, much of the precipitation never reaches the oceans as surface and subsurface runoff before the water is returned to the atmosphere. The relative magnitudes of the individual components of the hydrologic cycle, such as evapotranspiration, may differ significantly even at small scales, as between an agricultural field and a nearby woodland.

Movement of water in the atmosphere and on the land surface is relatively easy to visualize, but the movement of groundwater is not.

The Groundwater Component of Streamflow

The amount of water that groundwater contributes to streams can be estimated by analyzing streamflow

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River Network

Connecting People, Saving Rivers

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River Network is a national, nonprofit organization whose mission is to help people understand, protect and restore rivers and their watersheds.

From The President


credit: © River Network Collection

Out of sight, out of mind. That's groundwater's story.

Even in the vast areas of the country that are completely dependent on it for drinking water, few people give much thought to groundwater. Even fewer give much thought to how their actions affect it. And fewer still appreciate the connections between groundwater and the quality and quantity of water in their rivers, streams, lakes and wetlands.

The result? Land and surface water are managed in ways that reduce groundwater recharge, and groundwater is used unsustainably. Water tables fall, lake levels and base flows of rivers and streams drop, pollution concentrations in surface water during dry weather increase and public water supplies (from both surface and groundwater sources) become less reliable.

Many observers believe that as population increases these problems can only get worse. I am not among them. I firmly believe it is possible to meet the water needs of people and the ecosystems upon which we depend. But we cannot do so by continuing the practices that have created today's large and growing problems. *The key is to manage land, surface water and groundwater in an integrated fashion at the basin and watershed scales.*

Today, water management is not just divided between surface water and groundwater. Surface water management itself is divided into many categories, including drinking water supply; wastewater transport, treatment and disposal; flood control; and stormwater quality improvement. We build new reservoirs to replace the water supplies we have polluted. We use high-quality drinking water for purposes that don't require it. We dispose of treated wastewater that could be used and re-used. We pave groundwater recharge areas and then pave streams to get rid of the higher storm flows that result. The list goes on and on. Water isn't the only thing being wasted. The public and private costs of piecemeal water and land management are astronomical.

By integrating land, surface water and groundwater planning and management, we can do much better. We can achieve sustainable use, even in populous areas. Watershed groups are better positioned than anyone to lead the needed change. The information and ideas in this issue of *River Voices* can help us get started.

Don Elder

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science for a changing world

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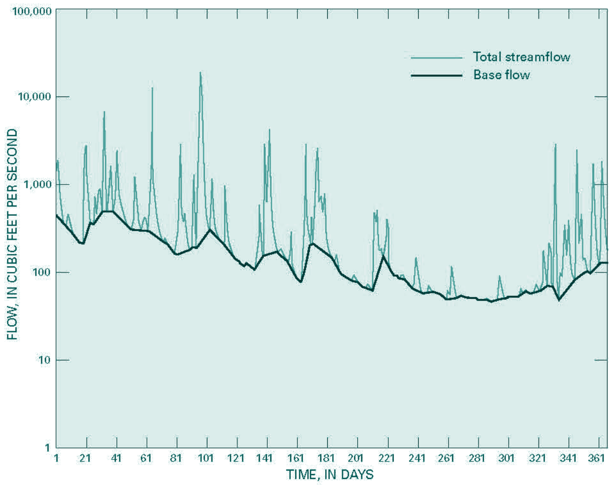
hydrographs to determine the groundwater component, or the "base flow."



Streams interact with groundwater in all types of landscapes (i.e., mountainous, riverine, coastal, glacial, karst, etc.). The interaction of groundwater with surface water depends on the physiographic and climatic setting of the landscape. The interaction takes place in three basic ways:

1. ***Streams gain water*** from inflow of groundwater through the streambed. For groundwater to discharge into a stream channel, the altitude of the water table in the vicinity of the stream must be higher than the altitude of the stream-water surface.

2. ***Streams lose water*** to groundwater by outflow through the streambed. For surface water to seep into the ground, the altitude of the water table in the vicinity of the stream must be lower than the altitude of the stream-water surface.

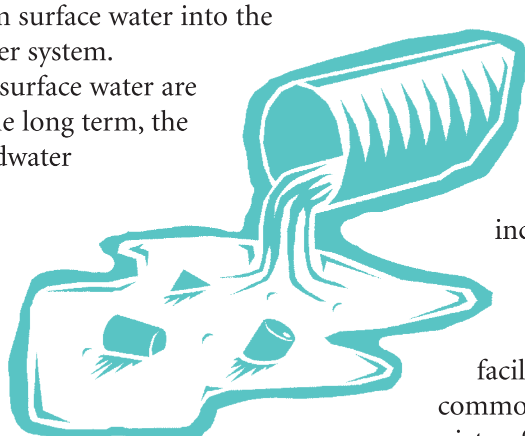
3. ***Streams do both***, gaining in some reaches and losing in other reaches. Even in settings where streams are primarily losing water to groundwater, certain reaches may receive groundwater inflow during some seasons. Flow direction can change in very short timeframes as a result of individual storms causing focused recharge near the streambank, temporary flood peaks moving down the channel or transpiration of groundwater by streamside vegetation.

A type of interaction between groundwater and streams that takes place in nearly all streams at one time or another is a rapid rise in stream stage that causes water to move from the stream into the streambanks. The process, termed bank storage, usually is caused by storm precipitation, rapid snowmelt or release of water from a reservoir upstream. As long as the rise in stage does not overtop the streambanks, most of the volume of stream water that enters the streambanks returns to the stream within a few days or weeks. The loss of stream water to bank storage and return of this water to the stream in a period of days or weeks tends to reduce flood peaks and later supplement streamflows. If the rise in stream stage is sufficient to overtop the banks and flood large areas of the land surface, widespread recharge to the water table can take place throughout the flooded area. In this case, the time it takes for the recharged floodwater to return to the stream by groundwater flow may be weeks, months or even years. Depending on the frequency, magnitude and intensity of storms and on the related magnitude of increases in stream stage, some streams and adjacent shallow aquifers may be in continuous readjustment from interactions related to bank storage and overbank flooding.

The Effects of Groundwater Withdrawals on Surface Water

Withdrawing water from shallow aquifers that are directly connected to surface-water bodies can have a significant effect on the movement of water between these two water bodies. The effects of pumping a single well or a small group of wells on the hydrologic regime are local in scale. However, the effects of many wells withdrawing water from an aquifer over large areas may be regional in scale.

Withdrawing water from shallow aquifers for public and domestic water supply, irrigation and industrial uses is widespread. Withdrawing water from shallow aquifers near surface-water bodies can diminish the available surface-water supply by capturing some of the groundwater flow that otherwise would have discharged to surface water or by inducing flow from surface water into the surrounding aquifer system. Groundwater and surface water are one resource; in the long term, the quantity of groundwater withdrawn is approximately equal to the reduction in streamflow that is potentially available to downstream users. Furthermore, changes in direction of the flow between ground and surface water can affect transport of contaminants associated with the moving water.



Effects of Human Activities on the Interaction of Groundwater and Surface Water

Human activities commonly affect the distribution, quantity and chemical quality of water resources. The range in human activities that affect the interaction of groundwater and surface water is broad.

- **Agricultural Development** Agriculture has been the cause of significant modification of landscapes throughout the world. Tillage of land changes the infiltration and runoff characteristics of the land surface, which affects recharge to groundwater, delivery of water and sediment to surface-water bodies and evapotranspiration. All these processes either directly or indirectly affect the interaction of groundwater and surface water. Two activities related to agriculture that are particularly relevant to the ground-surface water interaction are irrigation and the application of chemicals to cropland.

- **Urban and Industrial Development** Point sources of contamination to surface water bodies are an expected side effect of urban development. Examples of point sources include direct discharges from sewage-treatment plants, industrial facilities and stormwater drains. These facilities and structures commonly add sufficient load of a variety of contaminants to streams to strongly affect the quality of the stream for long distances downstream. Contaminants in streams can easily affect groundwater quality, especially where streams normally seep to groundwater, where groundwater withdrawals induce seepage from the stream and where floods cause stream water to become bank storage.

Point sources of contamination to groundwater can include septic tanks, fluid storage tanks, landfills and industrial lagoons. If a contaminant is soluble in water and reaches the water table, the contaminant will be transported by the slowly moving groundwater. If the source continues to supply the contaminant over a period

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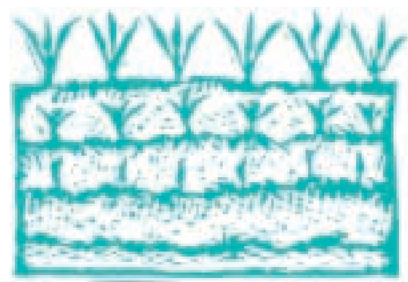
of time, the distribution of the dissolved contaminant will take a characteristic "plumelike" shape; contaminant plumes often discharge into a nearby surface water.

◆ Drainage of the Land Surface

In landscapes that are relatively flat, have water ponded on the land surface or have a shallow water table, drainage of land is a common practice preceding agricultural and urban development. Drainage can be accomplished by constructing open ditches or by burying tile drains beneath the land surface. Drainage can ultimately affect the base flow to streams; alter the water-holding capacity of topographic depressions as well as the surface runoff rates from land having very low slopes and can result in significant changes in the biota that are present and in the chemical and biological processes that take place in wetlands.



Drainage of the land surface is common in regions having extensive wetlands, such as coastal, riverine and some glacial-lake landscapes. In the most extensive artificially drained part of the Nation, the glacial terrain of the upper Midwest, it is estimated that more than 50 percent of the original wetland areas have been destroyed.

◆ Modification to River Valleys

Levees are built along riverbanks to protect adjacent lands from flooding. During flooding, recharge to groundwater is continuous; given sufficient time, the water table may rise to the land surface and completely saturate the shallow aquifer. Under these conditions, an extended period of drainage from the shallow aquifer takes places after the floodwaters recede. The irony of levees as flood protection is that if levees fail during a major flood, the area, depth and duration of flooding in some areas may be greater than if levees were not present.

The primary purpose of *reservoirs* is to store water for uses such as public water supply, irrigation, flood attenuation and generation of electrical power. The effects of reservoirs on the interaction of groundwater and surface water are greatest near the reservoir and directly downstream from it. Reservoirs can cause a permanent rise in the water table that may extend a considerable distance from the reservoir, because the base level of the stream, to which the groundwater gradient had adjusted, is raised to the higher reservoir levels. Near the dam, reservoirs commonly lose water to shallow groundwater, but this water commonly returns to the river as base flow directly downstream of the dam.

Human-controlled reservoir releases and accumulation of water in storage may cause high flows and low flows to differ considerably in magnitude and timing compared to natural flows. As a result, the environmental conditions in river valleys downstream from a dam may be altered as organisms try to adjust to the modified flow conditions.

To make land available for agriculture and urban growth, development sometimes involves cutting of forests and

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Chemical Interactions of Groundwater and Surface Water

Two of the fundamental controls on water chemistry in drainage basins are the type of geologic materials that are present and the length of time that water is in contact with those materials. Chemical reactions that affect the biological and geochemical characteristics of a basin include:

1. **Acid-base reactions** involve the transfer of hydrogen ions among solutes dissolved in water, and they affect the effective concentrations of dissolved chemicals through changes in the hydrogen ions concentration in water.

2. **Precipitation and dissolution of minerals** result in minerals being formed (precipitated) from ions that are dissolved in water.

3. **Sorption and ion exchange.** Sorption is a process in which ions or molecules dissolved in water (solutes) become attached to the surfaces (or near-surface parts) of solid materials, either temporarily or permanently. Thus, solutes in groundwater and surface water can be sorbed either to solid materials that comprise an aquifer or stream or to particles suspended in groundwater or surface water. The attachment of positively charged ions to clays and of pesticides to solid surfaces are examples of sorption.

   When ions attached to the surface of a solid are replace by ions that were in the water, the process is known as ion exchange. Ion exchange is the process that takes place in water softeners; ions that contribute to water hardness—calcium and magnesium—are exchanged for sodium on the surface of the solid. The result of this process is that the amount of calcium and magnesium in the water declines and the amount of sodium increases.

4. **Oxidation-reduction reactions** take place when electrons are exchanged among solutes. In these reactions, oxidation (loss of electrons) of certain elements is accompanied by the reduction (gain of electrons) of other elements.

5. **Biodegradation** is the decomposition of organic chemicals by living organisms using enzymes. Enzymes are specialized organic compounds made by living organisms that speed up reactions with other organic compounds. Microorganisms degrade (transform) organic chemicals as a source of energy and carbon for growth. Microbial processes are important in the fate and transport of many organic compounds.

6. **Dissolution and exsolution of gases** are common geochemical reactions. One of the more common gases is carbon dioxide (CO_2). For example, stalactites can form in caves when dissolved CO_2 exsolves (degasses) from dripping groundwater, causing pH to rise and calcium carbonate to precipitate. Other gases commonly involved in chemical reactions include oxygen, nitrogen, hydrogen sulfide and methane.

Groundwater chemistry and surface water chemistry cannot be dealt with separately where surface and subsurface flow systems interact. The movement of water between groundwater and surface water provides a major pathway for chemical transfer between terrestrial and aquatic systems. This transfer of chemicals affects the supply of carbon, oxygen, nutrients such as nitrogen and phosphorus and other chemical constituents that enhance biogeochemical processes on both sides of the interface. This transfer can ultimately affect the biological and chemical characteristics of aquatic systems downstream.

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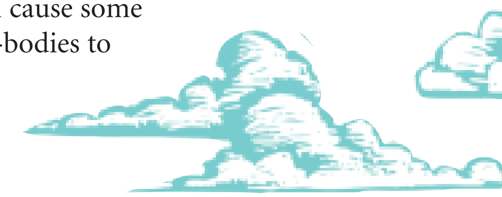
Photo credit: Charles Carroll

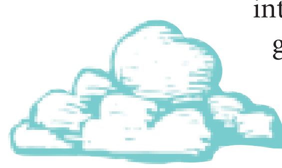
The Metolius River (OR) is one of the largest spring-fed rivers in the United States.

removal of riparian vegetation and wetlands. Deforestation tends to decrease evapotranspiration, increase storm runoff and soil erosion and decrease infiltration to groundwater and base flow of streams. Some of the important functions of riparian vegetation and riparian wetlands include preservation of aquatic habitat, protection of the land from erosion, flood mitigation and maintenance of water quality. Destruction of riparian vegetation and wetlands removes the benefits of erosion control and flood mitigation, while altering aquatic habitat and chemical processes that maintain water quality.

- **Modifications to the Atmosphere** Atmospheric deposition of chemicals can cause some surface water-bodies to become acidic. Concern about the effects of acidic precipitation on aquatic ecosystems has led to research on the interaction of groundwater and surface water, especially in small watersheds.



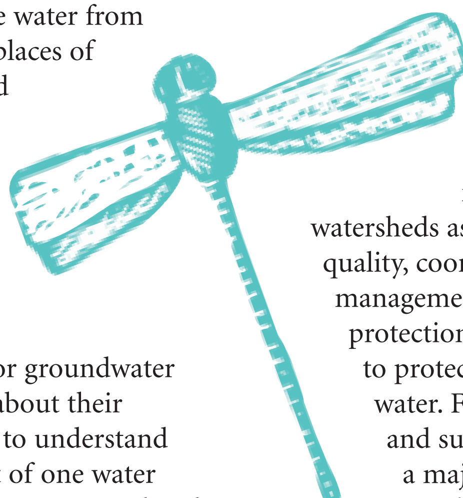
Additionally, the concentration of gases in the atmosphere has a significant effect on the heat budget of the Earth's surface and the lower atmosphere. At present, the analysis and prediction of "global warming" and its possible effects on the hydrologic cycle can be described only with great uncertainty. Although the physical behavior of carbon dioxide and other greenhouse gases is well understood, climate systems are exceedingly complex, and long-term changes in climate are embedded in the natural variability of the present global climate regime. Surficial aquifers, which supply much of the streamflow nationwide and which contribute flow to lakes, wetlands and estuaries, are the aquifers most sensitive to seasonal and longer term climatic variation. As a result, the interaction of groundwater and surface water will be sensitive to variability of climate or to changes in climate.



Challenges and Opportunities

The interaction of groundwater and surface water involves many physical, chemical and biological processes that take place in a variety of physiographic and climatic settings. Interest in the relation of groundwater to surface water has increased in recent years as a result of widespread concerns related to water supply; contamination of groundwater, lakes and streams by toxic substances; acidification of surface waters caused by atmospheric deposition of sulfate and nitrate; eutrophication of lakes; loss of wetlands due to development; and other changes in aquatic environments.

Water Supply: Water commonly is not present at the locations and times where and when it is most needed. As a result, engineering works of all sizes have been constructed to distribute water from places of abundance to places of need. Much research and engineering has been devoted to the development of water resources for water supply. However, most past work has concentrated on either surface water or groundwater without much concern about their interrelations. The need to understand better how development of one water resource affects the other is universal and will surely increase as development intensifies.



Water Quality: For nearly every type of water use, whether municipal, industrial or agricultural, water has increased concentrations of dissolved constituents or increased temperature following its use. Therefore, the water quality of the water bodies that receive the discharge or return flow are affected by that use. In addition, as the water moves downstream, additional water use can further degrade the water quality. If irrigation return flow, or discharge from a municipal or industrial plant, moves downstream and is drawn back into an aquifer because of groundwater withdrawals, the groundwater system also will be affected by the quality of that surface water.

Water scientists and water managers need to design data-collection programs that examine the effects of biogeochemical processes on water quality at the interface between surface water and near-surface sediments. These processes can have a profound effect on the chemistry of groundwater recharging surface water and on the chemistry of surface water recharging groundwater.

The tendency for chemical contaminants to move between groundwater and surface water is a key consideration in managing water resources. With an increasing emphasis on watersheds as a focus for managing water quality, coordination between watershed management and groundwater protection programs will be essential to protect the quality of drinking water. Furthermore, groundwater and surface water interactions have a major role in affecting chemical and biological processes in lakes, wetlands and streams, which in turn affect water quality throughout the hydrologic system. Improved scientific understanding of the interconnections between hydrological and biogeochemical processes will be needed to remediate contaminated sites, to evaluate applications for waste-discharge permits and to protect or restore biological resources.

Condensed from *Ground Water and Surface Water: A Single Resource,* USGS Circular 1139

To view the publication in its entirety, please visit: water.usgs.gov/pubs/circ/circ1139/

Working with the U.S. Geological Survey

Groundwater Information and Partnership Opportunities

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and

by G.V. Steele
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This article is intended to provide river conservationists with information describing how to better use the groundwater resources available through USGS. You may view this article online at http://pubs.usgs.gov/article/rivervoices/2005/vol15.html*, where all of the referenced webpages are actively linked to the appropriate words or phrases in the text.*

Overview of USGS Organization and Water Programs

The U.S. Geological Survey (USGS) is a multi-disciplinary science organization that focuses on biology, geology, geography and water. It is dedicated to the timely, relevant and impartial study of the landscape, our natural resources and the natural hazards that threaten us. The 9,000 scientists, technicians and support staff of the USGS are located in nearly 400 offices in every state and in several foreign countries. The USGS leverages its resources and expertise in partnership with more than 2,000 agencies of Federal, State, local and Tribal governments; the academic community; non-governmental organizations; and the private sector. Although water-related work is conducted in offices throughout the USGS, the focus of this article will be the organization, activities, products and partnership opportunities associated with the Water Resources Discipline[1] (WRD). Descriptions of activities and products are tailored primarily to the topic of groundwater.

The main operating units of the WRD are the Water Science Centers[2] (WSCs), each with program responsibilities in its host state. Because nearly every WSC has multiple offices, WRD staff are located in about 180 cities throughout the U.S. The WRD receives about one half of its funding from Congressional appropriations for the USGS's water-resources programs and the other half through reimbursable agreements with other governmental organizations. The reimbursable program allows the WRD to formally partner with those organizations to accomplish USGS mission-relevant work that contributes directly to the science-information needs of the partner organizations. The WSCs receive USGS program funding and direction from headquarters. Guidance for meeting the science goals and quality-assurance requirements of the WRD is provided by the technical Offices of Ground Water, Surface Water and Water Quality. The WRD Regional Offices also provide technical support for the WSCs through the Regional Specialists for Ground Water, Surface Water, Water Quality and Reports. Additional USGS national capabilities that help the WSCs with their program responsibilities include the National Research Program[3], the National Water Quality Laboratory[4] in Denver and the Hydrologic Instrumentation Facility[5] at the Stennis Space Center in Mississippi.

The primary activities of a WSC include long-term data collection, assessments of water resources, topical or problem-focused investigations and applied research. In fiscal year 2005, for example, the WSCs collected data on water quantity and quality at about 10,000 surface water sites and more than 16,000 groundwater sites and were engaged in over 700 investigative studies of water resources. Products from WSC activities include data, formal reports, technical and general purpose information posted on websites and enhanced scientific expertise that regularly is called upon by others to help make water management decisions.

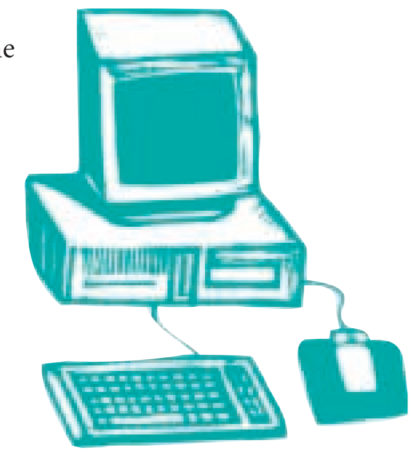
[1] http://water.usgs.gov/about_WRD.html
[2] http://water.usgs.gov/local_offices.html
[3] http://water.usgs.gov/nrp/
[4] http://nwql.usgs.gov/
[5] http://wwwhif.er.usgs.gov/public/

Products and Information available from USGS

Data

The USGS has been collecting water resource data for more than 125 years. Each year, every WSC produces a report, *Water Resources Data*, [State], Water Year [YYYY], that is a compilation of the quality-assured and "approved final" data collected by the WSCs on the quantity and quality of water resources in each state. Recently, these annual data reports[6] have become available online. The USGS also maintains a nationally distributed network of computers and file servers to store, retrieve and permanently archive water data (National Water Information System or NWIS[7]). The NWIS includes data collected at more than 1.5 million sites throughout the U.S. Of those, nearly 1.4 million are groundwater sites—for which 8 million water level measurements and nearly a million water quality analyses are stored. The majority of the data in the NWIS now are available for public viewing and retrieval through an internet interface called NWISWeb[8]. Descriptive site information is available for all data. For groundwater sites, the database includes information such as latitude/longitude, well depth, altitude of land surface, aquifer name and the begin date and end date for the types of data available (water levels and water quality analyses, for example). The actual data may be retrieved in various graphical and tabular formats.

The USGS annually monitors groundwater levels in thousands of wells in the U.S. This data is collected and stored as either discrete measurements or as continuous record. Data from more than 800 of the continuous record sites are relayed electronically and are available online as real-time groundwater data[9]. Nearly every WSC operates at least a few real-time groundwater sites. The USGS Ground-Water Climate Response Network[10] has been established to present data that can be used to monitor the effects of droughts and other climate variability on groundwater levels in the U.S. This web site serves not only real-time water level plots, but also statistical summaries of the water level data for the period of record. Selected USGS WSC web sites also serve derivatives of basic groundwater level data. The Pennsylvania WSC, for example, serves groundwater level 30-day duration graphs for more than 60 observation wells.



Reports

Comprehensive information is available online about all USGS publication products[11] and, specifically, about water resources reports. Most recent USGS water resources publications are available online and older reports are being scanned to facilitate online distribution. The USGS online Publications Warehouse[12] currently lists bibliographic citations to about 70,000 report and map products and provides online access to the full content of many of the products. The Publications Warehouse may be searched by subject, author, date and USGS publication series.

The USGS Library[13], the largest library for earth sciences in the world, offers another option for access to USGS publications. Besides the four libraries of the central

[6] http://water.usgs.gov/pubs/wdr/
[7] http://pubs.usgs.gov/fs/FS-027-98/
[8] http://waterdata.usgs.gov/nwis
[9] http://waterdata.usgs.gov/nwis/current/?type=gw
[10] http://groundwaterwatch.usgs.gov/
[11] http://www.usgs.gov/pubprod/
[12] http://infotrek.er.usgs.gov/pubs/
[13] http://library.usgs.gov/

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library system, the USGS has many specialized libraries located in science centers across the Nation. The public is welcome to visit the USGS libraries and use the collections on the premises or request items owned by the libraries on interlibrary loan. The online catalogue[14] includes all USGS reports published since 1975, as well as the majority of reports dating back to 1879.

Information Available from the USGS Office of Ground Water

The USGS Water Discipline's Office of Ground Water[15] (OGW) webpages include many informational resources that could be helpful to watershed organizations. The OGW website includes a link to a page referencing over 70 "Selected USGS Ground Water Publications," including introductory primers on *Ground Water, Aquifer Basics, Ground Water and the Rural Homeowner* and *The Water Cycle*. It references many online USGS circulars that provide in-depth coverage of various groundwater topics, such as *The Importance of Long-Term Water-Level Data*, *Sustainability of Ground-Water Resources*, *Ground Water and Surface Water—A Single Resource* and *The Role of Science in Managing Ground-Water Resources*. The page includes a web link to some of the USGS's primary training documents, *USGS Techniques of Water-Resources Investigations Reports* (TWRI). The TWRI series includes chapters on aquifer-test design, introduction to ground-water hydraulics and several chapters on instruments for measurement of water levels (A1, A3) and groundwater modeling techniques (see Book 6: Section A; Chapters A1-A7). The OGW page "Selected … Publications" also provides links to online USGS publications dealing with documentation of groundwater models, groundwater data collection protocols and procedures, and water use. The document, *A Quality-Assurance Plan for District Ground-Water Activities of the U.S. Geological Survey*, is a plan that is implemented in every WSC to help ensure that all scientific work done by or for the WRD is conducted in accordance with a quality-assurance program. The OGW site links to an online version of the *Ground Water Atlas of the United States*, an extensive presentation of text and illustrations on the nation's groundwater resources. Finally, the OGW site identifies "Selected Ground Water Issues" and provides references to publications and other USGS websites with detailed information relevant to each "Issue" (examples are "Ground-Water and Surface-Water Interactions" and "Ground-Water Networks").

Information Available at the Water Science Centers

The best source of USGS information specific to the groundwater resources in a given State or watershed is the USGS WSC. Each WSC maintains a website[16] that includes information about the data collection and investigative project activities of the WSC and references to data and interpretive reports produced by the WSC. Virtually all such reports published in recent years are available online. Some of the WSCs also maintain special-purpose databases of hydrologic and water quality information in addition to NWIS, but serve the information online (examples: Blue River Watershed, CO and High Plains Aquifer).

Although most of this article relates to USGS products and information that are available electronically, individuals and organizations having water interests and responsibilities always are encouraged to talk personally with the staff of the WSCs.

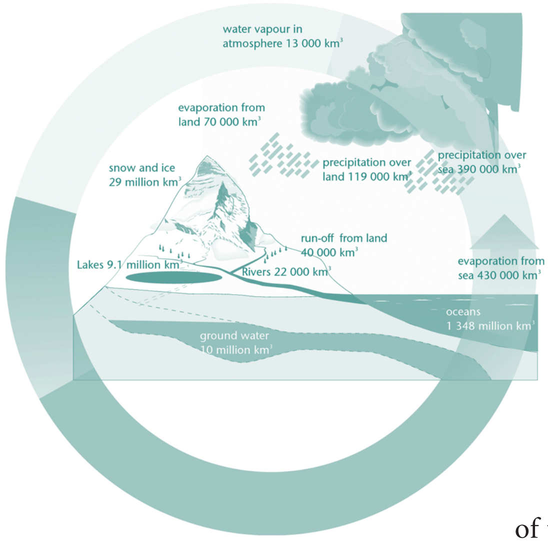
[14] http://igsrglib03.er.usgs.gov:8080/#focus
[15] http://water.usgs.gov/ogw/
[16] http://water.usgs.gov/local_offices.html

The WSC staff need and seek opportunities to learn about the water information needs of others within the state water community, share insight about current USGS water resources activities and the vision for future science activities, and discuss with other water-related organizations shared science interests that potentially could lead to productive partnerships. The WSC Director always is a good point of contact for initiating discussions with a WSC.

Partnership Opportunities and the Cooperative Water Program

The USGS conducts water resources activities through formal partnerships with watershed organizations throughout the country. Funding of those activities is made possible through the WRD's Cooperative Water Program[17] (CWP). By law, these partnerships must be with State, local or tribal governmental entities. The CWP allows the USGS to provide up to one-half the cost of a data-collection activity or interpretive study (or both) conducted by the USGS to address the informational needs of the cooperator and the CWP priorities issued annually by the USGS. The CWP now funds about 65 percent of the WRD's long-term data-collection activities and more than half of the WRD's interpretive studies (see selected Recent Accomplishments[18]). In situations where the cooperating organization has the technical capacity and interest to do some part of the project activity, their project contributions may lessen the overall cost of the work. If that activity involves data collection, the USGS and cooperative participants normally must develop and implement data-quality measures (see, for example, Greve, 2002) to help ensure the overall integrity of the data produced. Direct participation of cooperator personnel in a USGS water resources project, as with any WRD activity, would involve quality assurance provided through various means. Examples include technical training; blind-sample testing; laboratory certification; reviews of proposals, project work plans and reports; and use of quality-assurance plans. Some of the USGS technical training courses, offered both at the USGS National Training Center and in USGS WSCs, are open on a space-available basis to employees of USGS formal cooperator organizations.

The 'Big' Water Cycle



Source: Water Facts & Trends, WBCSD, 2005

Case History of a Formal Partnership between a Watershed Organization and the USGS

In 1969, the Nebraska legislature created a system of 23 Natural Resource Districts (NRDs), based on the boundaries of river basins, to deal with natural resources issues in each district. This unique system of

[17] http://water.usgs.gov/coop/
[18] http://water.usgs.gov/coop/accomplishments.html

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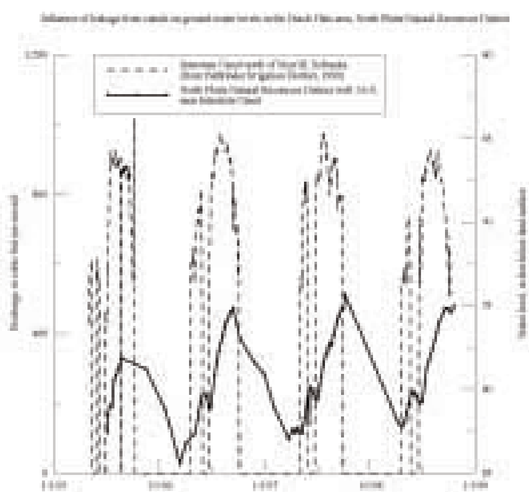
locally-controlled, tax-funded, watershed-based conservation organizations are charged with 12 areas of responsibility including, but not limited to, the management of groundwater and surface water. Accordingly, each NRD is required by the State to have a plan to protect groundwater from overuse and pollution.

The North Platte NRD, one of three NRDs in the western Nebraska panhandle, manages the water resources associated with about three million acres of the North Platte River Basin and its tributaries. Important concerns of the North Platte NRD include the availability of ground-water supplies to producers and municipalities and the development of options for managing impairments to groundwater quality due to elevated concentrations of nitrates. To help address some of these concerns, the North Platte NRD and the USGS Nebraska Water Science Center have worked cooperatively since 1990 on many data-collection efforts and interpretive studies having varying purposes, scopes and funding levels.

A groundwater quality reconnaissance study was done in 1990-91 to help the North Platte NRD establish a baseline for water quality conditions in their District. Since then, several additional cooperative studies have been completed, including three large-scale, multi-year studies during the mid-1990s. These three studies used (1) radiological isotopes and groundwater age-dating techniques to identify sources of uranium and the effects of the interaction of surface water in the North Platte River and seasonal irrigation canals with the shallow alluvial aquifers *(figure 1)*.

Figure 1



(2) surface-geophysical techniques to identify bedrock surfaces and to delineate areas of canal leakage (an important source of good-quality groundwater recharge for much of the northwestern part of the North Platte NRD) or (3) nitrogen isotopes to identify the possible source of large nitrate concentrations in groundwater. In addition, a regional groundwater flow model of western Nebraska is being developed by the USGS, in cooperation with the North Platte NRD, to simulate the effects of using canals and laterals in the North Platte NRD to enhance groundwater recharge.

Along with the interpretive projects, an integral part of the cooperative work has been monitoring the quantity and availability of groundwater in the North Platte NRD. In the mid-1990s, the USGS and North Platte NRD began establishing a network of groundwater observation wells, now including 15 real-time sites in Banner, Garden, Morrill, Scotts Bluff and southern Sioux Counties. In addition, the USGS and the North Platte NRD are using hand-held computer technology, including bar coding, to facilitate the rapid collection and storage of groundwater data from many other monitoring wells.

Several of the cooperative studies and data-collection activities have involved training of NRD personnel both on-the-job and in the classroom (at the USGS National Training Center in Denver, Colorado). This training includes coverage of quality assurance (QA) and quality control (QC) processes established to ensure consistency of data-collection efforts. Training and oversight of field operations by USGS personnel have enabled North Platte NRD personnel to collect groundwater level data without USGS personnel on-site or to assist USGS personnel in collection of ground-water quality samples using USGS protocols. Additional QA and QC efforts involve USGS personnel independently visiting some North Platte NRD ground-water recorder wells on a quarterly basis to inspect the equipment and evaluate the data record.

The findings of the cooperative studies have been published in a series of USGS reports[19], scientific journal articles and abstracts authored by the USGS and North Platte NRD personnel. All data, including the water quality data collected during the studies and the basic groundwater data collected by North Platte NRD personnel, are stored in the NWIS.

The cooperative relationship between the USGS and the North Platte NRD has demonstrated the benefits of pooling Federal and local resources to achieve water-management objectives. By sharing responsibilities for financing and conducting groundwater data collection and studies activities, the two agencies have amassed more technical information and understanding than otherwise would have been possible. The partnership has resulted in an impressive array of USGS products (data and interpretive reports) and the North Platte NRD has been an active participant in collecting groundwater quantity and quality data that are technically sound and defensible.

[19] http://ne.water.usgs.gov/html/projects/NPNRD_pubs.htm

CASE STUDY

The Importance of Long-term Flow Monitoring in the Pomperaug River Watershed

by Marc J. Taylor
Chair, Pomperaug River Watershed Coalition
www.pomperaug.org

The U.S. Geological Survey (USGS) gaging station on the Pomperaug River has been recording flows (discharge) on the river continuously since 1932. The Pomperaug River Watershed Coalition (PRWC) and our scientific collaborators depend on real-time and historical discharge measurements from this station for many purposes, including the creation of a watershed management plan based on computer models.

The Watershed. The Pomperaug is a 90 square mile sub-basin of the Housatonic River in western Connecticut. Tributaries arising in the surrounding uplands join an eight mile-long main stem that traverses the length of the Pomperaug Valley to join the Housatonic River on its way to Long Island Sound. The Pomperaug is a beautiful natural resource with undeveloped flood plains, a well-preserved riparian corridor and a long tradition of exceptional recreational fishing. There is a small impoundment in a headwater tributary, and there are four wastewater treatment plants that discharge to the river.

The Aquifer. The Pomperaug aquifer, formed by the deposition of porous sediments dating to the melting of the last glacier, underlies the river at the valley's base. Groundwater from the aquifer is the source of the river's flow when rainfall is at low levels. As explored earlier in this issue, the river and the aquifer are dynamically connected. Three public water systems draw water from wells sunk into the aquifer very near the river. Two of these systems send quantities of water out of the basin.

Land Use. Over the past 70 years farms (and irrigation) have given way to forests and low-density housing. Now the region is becoming suburbanized. More impervious surface is impacting areas that used to allow precipitation to recharge the groundwater, and surface runoff is increasing. Demand for public water supplied by the aquifer has accelerated.

To deal with these threats, the PRWC initiated a group of computer modeling studies using discharge information from the gaging station and other inputs. The projects are intended to provide quantitative information to assist decision makers in their land use and water resource determinations.

Hydrologic Modeling. The models employed by the USGS (PRMS and MODFLOW) provide a quantitative understanding of how water enters, moves through and leaves the basin under varying conditions of weather, land use and pumping from the aquifer or river. Multiple simulations can be run. The model can predict consequences of various types of development at different locations in the watershed. One scenario, for example, predicts how discharge would change under drought conditions when water is pumped maximally to out-of-basin towns.

Flow Habitat Model. The Northeast Instream Habitat Program MesoHABSIM model (University of Massachusetts, Principal Investigator Dr. Piotr Parasiewicz) quantifies habitat availability in the Pomperaug River system for a target fish population under different flow conditions measured at the gaging station. (The suitability of habitat for the target fish community is used as a surrogate for the river's overall environmental health.) This model will be used to generate ideal flow regimens that would sustain fish habitat at desirable levels through the seasons. Our management plan will combine information from both models.

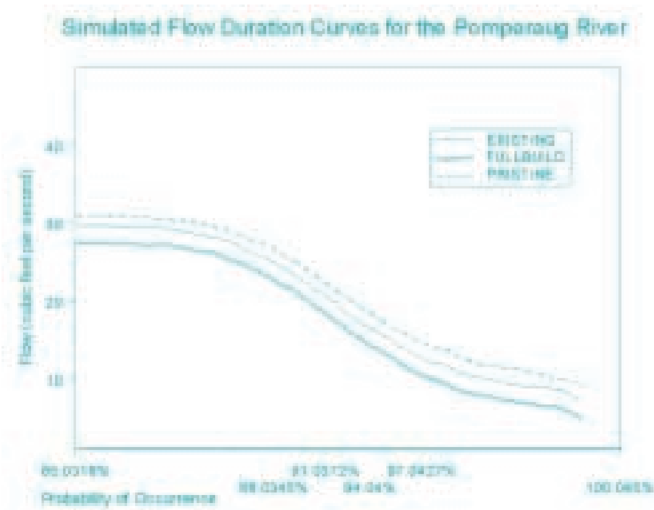
Other Studies. The PRWC is looking at water quality, transport of sediments, dilution of treated wastewater, chemical contamination and the fate of drug

ACKNOWLEDGMENTS
David Bjerklie, Virginia de Lima, Jeff Starn and Elizabeth Ahearn of the USGS Connecticut Water Science Center http://ct.water.usgs.gov/ provided provisional data, figures used in this article and/or helpful advice in preparing it. More information about the MesoHABSIM model can be found at www.neihp.org.

Details concerning the Pomperaug Watershed Management Plan and a link to the USGS gage on the Pomperaug are available at www.pomperaug.org.

metabolites reaching the environment. Reliable discharge data play an important role in all these undertakings.

Figure 2

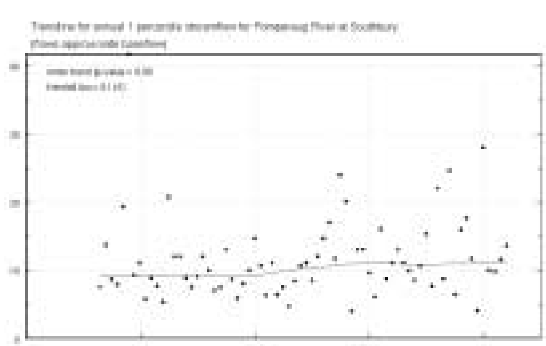


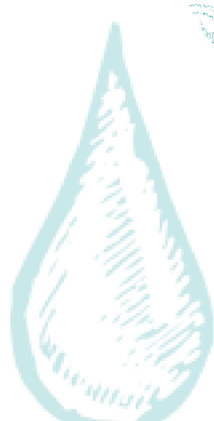
Groundwater. By the time flows decrease to about 10 cubic feet per second (cfs) at the gaging station, many of the upland tributaries have run dry. At about 6 cfs, as occurs during the growing season without rain, all flow arises from the aquifer (base flow). These lowest flow times pose the greatest threat to fish and other species. The rates, timing and locations of pumping and where that water goes (especially whether in or out of basin) become crucial variables determining groundwater availability and base flow. Luckily, it may be possible to control these variables.

Long-term Data. Having long-term measurements of these lowest flows permits analysis of base flow trends over the period of record. Figure 1 represents base flow discharge values over 72 years. (Base flow is approximated by the flows that are equaled or exceeded 99% of the time.) The PRWC will continue to monitor these very low flows as important indicators of groundwater management in the watershed. The simulation in Figure 2 demonstrates that lower flows are more likely to occur with increasing land development. In this simulation water use was held constant; increased pumping would have further decreased the aquifer's contribution to base flow.

Figure 1

PROVISIONAL DATA





Lessons We Are Learning.

1) Long-term gaging station information is essential to understanding water issues and land use trends in our watershed.

2) The lowest flows (base flows) are particularly useful reflections of overall land use and water management practices.

3) Quantitative models can assist decision-making.

4) Ecologically desirable flow regimens can be developed and can be used for allocation decisions.

5) Testing our predictions against actual data over time will establish the validity and utility of our models.

6) Advocacy and relationship building are as important as ever.

7) While models are helpful, they are not for everyone. They are resource intensive.

8) The USGS and our academic collaborators are indispensable partners for this kind of work.

Linking Groundwater to Aquatic Biodiversity:

Developing Methods for Freshwater Conservationists

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The Nature Conservancy in Oregon

When you think of biodiversity and water, remember to think deep.

Most of us who work in the world of freshwater conservation think about water all the time. When a big storm brings heavy rains, we wonder whether it will be enough to fill a nearby river and push the water out of its banks onto the floodplain. We think about whether the winter snow pack is thick enough to sustain the streams, wetlands and lakes through the summer. During prolonged drought, we worry about the survival of fish, mussels and amphibians that rely on a constant source of clean water. But we probably rarely remember that much of the snowmelt and rain travels underground before reaching those rivers, lakes and wetlands.

How Much Water is Below the Surface?

It is estimated that groundwater represents about 21% of the world's freshwater and 97% of all the unfrozen freshwater on earth (Dunne and Leopold, 1978). Next to glaciers and ice caps, that makes groundwater reservoirs the largest holding basins for fresh water in the world's hydrologic cycle.

The World's Thirst for Groundwater

Groundwater accounts for a large proportion of the world's freshwater supply. In many regions, water demand exceeds surface water supply, so water management agencies and water users are increasingly turning to groundwater to meet the growing need. For example, groundwater is used extensively to supply drinking water to a growing global population (Table 1).

Table 1

Estimated percentage of drinking water supply obtained from groundwater

REGION	PERCENT	POPULATION SERVED (millions)
Asia-pacific	32	1000-2000
Europe	75	200-500
Central and South America	29	150
USA	51	135
Canada	30	8.9
Australia	15	3
Africa	NA	NA
World	—	1500-2750

Source: Sampat 2000 after UNEP, OECD, FAO, US-EPA, Australia EPA, Environment Canada

Why Does Groundwater Matter to Biodiversity?

Groundwater is critical to biodiversity because it helps to provide the hydrologic regimes, chemical and temperature conditions, and water quality upon which many aquatic ecosystems and species depend.

Hydrologic regime: For many aquatic ecosystems and communities, groundwater is a significant component of the total available water. Because it flows year round, groundwater is critical during times of low flow, for example, in late summer.

- **Rivers and streams:** Discharge of groundwater into streams sustains the flow during periods of little precipitation. The portion of the flow regime provided by groundwater is referred to as base flow. The amount of base flow determines the water depth and velocity during the dry season, which are two important habitat characteristics for fish and other aquatic species. Sustained base flows are particularly critical for freshwater mussels and other species with limited ability to move in response to streams drying up.

  In arid environments, groundwater may be the primary source of streamflow. Riparian plant species in these settings are tightly coupled to groundwater depth and water table fluctuations in the floodplain.

◆ **Springs and Seeps:** Springs and seeps are unique locations in the landscape where groundwater emerges to the surface. Springs have a relatively constant water temperature, and are often the only source of cold water in streams during the dry season. Springs and seeps provide habitat and food sources for numerous aquatic and terrestrial species including fish, mollusks, amphibians and birds. In the Great Basin, approximately 158 of the 199 endemic aquatic vertebrate and invertebrate species occur primarily in low to mid-elevation springs (Sada et al. 2001).

◆ **Wetlands:** In many hydrogeologic settings, including topographic depressions and areas where a hillside meets a plateau or basin, wetlands receive some of their water from groundwater.

In these settings, if the landscape slope allows the emerging groundwater to pool, a type of wetland called a *fen* will form. Because groundwater flow tends to be slow but constant, fens are wet year-round, with little water table fluctuation. This produces unique physicochemical characteristics. A diverse suite of plants and animals are specifically adapted to these conditions, and while fens represent only a small proportion of overall surface area in most watersheds, they harbour a disproportionate number of rare and endemic species.

Fens receive most or all of their water from groundwater; however, wetlands that receive most of their water from surface water inputs also can receive groundwater inflow. Here, the water table generally fluctuates in response to streamflows, but similar to base flow in streams, the wetlands never go completely dry because of the constant supply of groundwater.

◆ **Lakes:** Groundwater seepage into lakes is an important water source in some landscape settings. Groundwater is most likely to be important in mid- or lower catchment lakes that have overly deep, permeable soils or highly fractured bedrock. Groundwater seepage has been shown to correlate with the diversity, abundance and distribution of species such as aquatic macrophytes, epibenthic algae, diatoms and cyanobacteria (Hagerthey 1996; Lodge et al. 1989).

Water chemistry: As groundwater travels through rocks and soils, it can pick up various soluble minerals and so the emerging water can have a very different chemistry from its original state. For example, where groundwater emerges that has moved through calcium-rich limestone, calcareous fens will form. These rare fens are home to a unique suite of species specifically adapted to alkaline, mineral-rich waters (Table 2). In addition, groundwater is often quite clean, and it can serve to dilute more contaminated surface water.

Temperature: Groundwater movement from floodplains into streams provides cool, clear water that functions as refugia for cold water species. For example, the

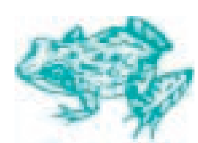

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Table 2

Species that occur in ecosystems that can depend on groundwater

ECOSYSTEM	SPECIES
Cool Streams	Bull trout - *Salvelinus confluentus* Salmonidae Oregon tailed frog - *Ascaphus truei*
Groundwater fed wetlands	Mosses - *Bryum paliescens, Philonotis fontana, Tomenthypnum nitens, Campylium stellatum, Sphagnum warnstorfii* Hine's emerald green dragonfly - *Somatochlora hineana Williamson* Owens Valley checkerbloom - *Sidalcea covillei*[1] Cottongrass - *Eriophorum spp.*
Hot Springs	Microbial flora tolerant of high temperatures and low ph[1] *Chloroflexus* species (photosynthetic bacteria[1])
Cold Springs	Columbia spring snail - *Pyrgulopsis spp.* Riffle beetles - *Elmidae* Killfish - *Cyprinodontidae*, poolfish - *Goodeidae*, minnow - *Cyprinidae* and livebearer families - *Poecillidae*[1]

[1] Sada et al., 2001

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tailed frog (*Ascaphus truei*) of the western U.S. requires a narrow range of cool water temperatures for all of its life stages. Conversely, hot springs are places where groundwater emerges at the surface after gathering heat from rocks deep below the surface. They support microbial flora and fauna tolerant of temperatures above 100°C and pH less than 3.

No News Isn't Always Good News:

We cannot see groundwater until it emerges at the surface, so it may be tempting to think it's in good condition and not threatened. This may not be true. Groundwater extraction and contamination are growing threats (Morris et al. 2003). In a survey of approximately 40 different locations across the United States, altered flow regimes due to groundwater pumping was identified as the largest threat to aquatic ecosystems (*Figure 1*). Withdrawing groundwater near aquatic ecosystems can alter the amount of water available to discharge at the surface. Studies in Arizona showed that water table declines of 1-2 meters will result in loss of perennial flow and compositional shifts in riparian vegetation, thus changing the amount and composition of available habitat (*Stromberg et al., 1996*). Additionally, groundwater-fed wetlands are sensitive to changes in water quantity that result from groundwater pumping. Groundwater withdrawals for agriculture or municipal uses can lower subsurface flow, which can lead to wetland drying, increased peat decomposition and stress to the associated biota.

Groundwater contamination from agricultural, industrial or urban sources changes the wetland water chemistry, which often eliminates the species specifically adapted to those particular chemical conditions.

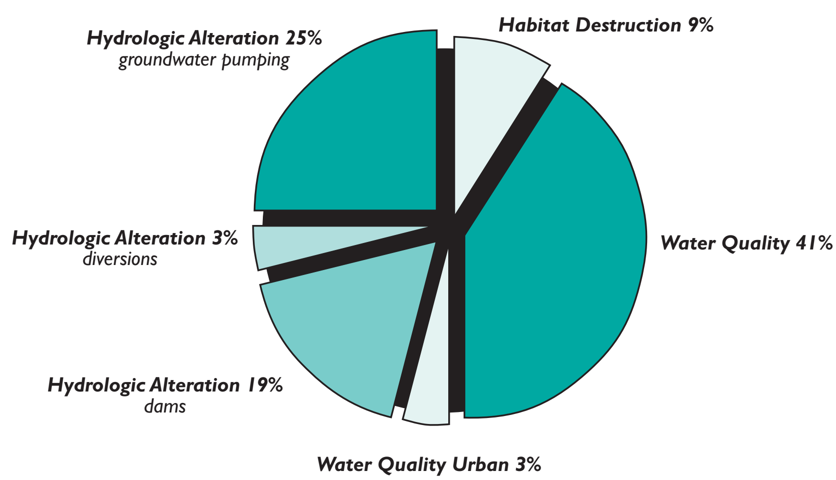
What Can You Do?

To date, most government agencies have focused on protecting groundwater for human consumption. Virtually no attention has been directed towards either evaluating the significance of groundwater to biodiversity or protecting groundwater specifically for biodiversity conservation. While many conservation groups working on local issues have expressed concern, there has been limited information generated to help resource managers and conservation groups understand the implications of groundwater management to native species and ecosystems.How do you know if groundwater is important to your site, and if so, how do you figure out what actions to take? The Nature Conservancy has faced those same questions, so the Oregon chapter is

Figure 1

Summary of Killer Threats

Source: *Freshwater Initiative*, The Nature Conservancy

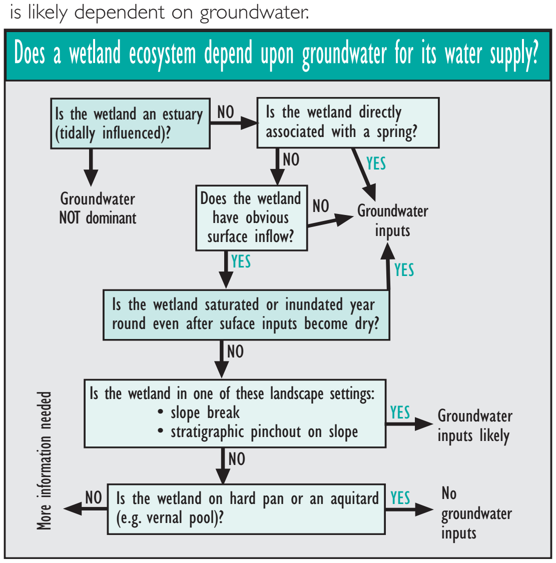


developing guidance for resource managers to integrate groundwater issues into their conservation plans and actions. Our goal is to develop and test methods to: 1) determine the importance of groundwater to biodiversity at a site and 2) assess the effects of groundwater extraction on the integrity of this biodiversity. Armed with this understanding, we will then 3) test a suite of strategies directed at managing groundwater to meet the needs of both the human and natural communities.

Groundwater is so Complicated

It is complicated, but not impossible! The first question that arises at a conservation site is almost always: is groundwater an important contributor to the aquatic resources here? We've put together a series of decision trees that will help managers make a quick assessment of the likelihood that groundwater needs to be considered (*Figure 2*). It is intended to identify those situations in which it is very likely that groundwater is important to consider. However, there always will be some gray areas requiring further assessment.

Figure 2: Draft decision tree for evaluating when a wetland is likely dependent on groundwater.



For sites where groundwater may be important, our methodology will guide managers through the development of a conceptual model of groundwater movement at the site. The initial analysis uses readily available GIS data layers such as surficial geology, topography and hydrography to construct a 3-dimensional model of groundwater movement within the watershed in the proximity of the target site. We then offer some suggestions on how to use locally available data or review by local experts to refine this model.

If the model shows that groundwater is important, the next step is to identify the relationship between groundwater and specific ecosystems or species. As described earlier, there are a number of reasons that biodiversity can depend upon groundwater (*Table 2*). Over the course of this project, we will develop examples of how to identify the key ecological attributes, including ecosystem structure, biotic and abiotic processes, and species composition associated with groundwater that maintain the integrity of the ecosystems and species at a site. Finally, we'll identify potential management objectives and strategies for each of these attributes.

Moving On

Armed with this critical information about groundwater-associated biodiversity, those of you working as natural resource managers and conservationists, as well as those working within regulatory agencies, can increase the protection of these diverse and unique aquatic ecosystems and species. You not only will be able to say if groundwater is important at a site, but also how it is important and what conditions are necessary to support the groundwater-dependent ecosystems and species. The next step will be to understand the threats to groundwater that are likely to impair the ecosystems and then to identify management strategies that can address these threats.

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VOICES FROM THE FIELD

You can't paddle directly on it, walk alongside it or even swim in it. Yet, without groundwater's constant feeding of our surface waters, many of our rivers, lakes and wetlands would run dry. In most first-aid classes, you are taught that it is the silent patients who often are the ones most in need of attention. Similarly, river conservationists need not only concern themselves with the health of our babbling brooks and roaring rivers, but also with that of the oft unseen and unheard groundwater. Below are a few examples of how River Network Partners are addressing groundwater issues within their watershed.

We're working intensively on the groundwater/surface water connection in the Prettyboy Watershed. The Prettyboy Reservoir is one of Baltimore's three drinking water reservoirs; much of our work is watershed management to keep the water quality high. However, those who live in the Prettyboy watershed don't drink from its reservoir and, quite frankly, don't really care about the drinking water quality in Baltimore's system. A good percentage of these residents live in another county—Carroll County—and they resent that past commissioners "sold their streams" to the Baltimore system.

We've learned that we need to find the "hooks" to engage these local watershed residents by encouraging them to protect their drinking water source: groundwater. We've done a septics workshop, organized tree plantings and working to draw residents in by focusing on all the water resources—surface and groundwater in the region. We'll be also doing some stormdrain stenciling in two small municipalities in Carroll County starting this winter.

Prettyboy Watershed Alliance (MD)
www.prettyboywatershed.org

Due to sandy soils and an underground rift valley, drinking water aquifers in the eastern (and downstream) portion of Dakota County (the area just south of the city of St. Paul) have become contaminated with nitrates and agricultural pesticides. Studies have shown a direct connection between surface water, surface land use and groundwater aquifers for this area. Friends of the Mississippi River (FMR) has worked closely with Dakota County to pass a land protection referendum and establish a septic system compliance and inspection program in order to protect surface water and underground drinking water supplies. FMR is continuing to work with the county and local communities to establish protective stormwater management policies and water friendly agricultural practices.

Friends of the Mississippi River (MN)
www.fmr.org

North Jersey Resource Conservation & Development Council has been working in our six county area for over ten years on the issue of limestone geology and the link to groundwater contamination in these sinkhole prone areas. Our Council's Limestone Committee has developed a model ordinance for towns to use when faced with development in limestone areas. The ordinance requires developers to conduct thorough investigations which are then reviewed by a geologist that the town hires. Among other things, the ordinance also requires that any corrective measures taken to fill sinkholes on a site must be recorded in the deed for the property. By doing this, all future property owners will be aware of the limestone issues. Approximately 15 towns in our service area have adopted a limestone ordinance.

North Jersey Resource Conservation & Development Council (NJ)
www.northjerseyrcd.org

VOICES FROM THE FIELD

An aquifer supplies drinking water for the city of Springfield. Danis-Clarkco wanted to place a landfill above the aquifer. A citizens' group sued and after many years and about $300,000 won. By digging a treach and examining the sides for cracks, the group was able to demonstrate that the supposedly impervious terrain was actually quite pervious. Despite the densly compacted material, numerous cracks were visible. This leachate would get to the aquifer in perhaps one year, rather than the 100 or more as originally stated.

Rivers Unlimited (OH)
www.riversunlimited.org

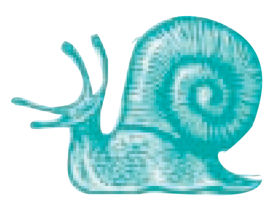
Three years we had three major studies undertaken: 1. Open Space, 2. Watershed Management and 3. Growth Management.

After the first two were complete, it dawned on our policy makers that perhaps we should do a groundwater study. We did and the results were quite staggering. The number of private wells has grown exponentially, the best groundwater recharged areas were being paved over, and the rate of recharge was around 8.25" per year even though we receive around 45 inches of rain.

Therefore, we have a policy of buying open space that preserves/protects riparian corridors and also groundwater recharge areas. In fact, having that information allows us to push open space acquisitions projects through with relative ease. People here in the moist southeast are starting to understand that water is a finite resource. Also, people are starting to understand the relationship between groundwater recharge, streamflow volume, etc. Having solid data and good maps have really helped.

Wake County Parks, Recreation and Open Space (NC)
www.wakegov.com/county/parks

In the Millstone Watershed of Central New Jersey, groundwater provides more than 50% of the water used for drinking water. The Stony Brook-Millstone Watershed Association developed a set of maps for six municipalities in the watershed that lie above important aquifers for groundwater recharge. The maps are one aspect of the document, *Water Resources Protection in Your Municipality*, and portray areas in need of groundwater protection, critical areas protection and areas where threatened and endangered species are located. For more information about this report go to: www.thewatershed.org/wm_supporting_muni.php and select "For Municipal Officials."



Stony Brook-Millstone Watershed Association (NJ)
www.thewatershed.org

Chesapeake Environmental Protection Agency (CEPA) is concerned about our aquifers being continuously depleted over a period of at least 30 years. Especially disturbing is the fact that no government agency is actively managing the use of our water resources. Even though the aquifers cover more than one county, and sometimes more than one state, there is no coordination between the jurisdictions. In 2001, CEPA drafted a proposal which would establish a statewide Water Resources Commission to study the depletion of the aquifers and to make recommendations regarding the management of our water resources. At that time, it appeared that the legislative process would take a long time, and Governor Glendening was asked to issue an executive order establishing the commission, even though his order would only be effective for one year. He did so in April of 2002, but didn't appoint anybody until January 2003, and that commission never even met. CEPA then worked with State legislators to pass a bill establishing such a commission for 3 years with members appointed by the legislature, as well as the Governor. CEPA members testified in both the Senate and House of Delegates; the bill was passed unanimously in both houses during the 2003 legislative session, but Governor Ehrlich vetoed it and reappointed a new commission himself. They met several times and, recognizing the complexity of the task, recommended, among other things, the continuation of the advisory board with subcommittees for water demand and water supply, increased state staffing and funding and increased monitoring of aquifers.

Chesapeake Environmental Protection Agency (MD)

A few years back, a large corporation in our watershed applied to the state for permission to substantially increase its groundwater withdrawals for use in chip processing. Organization for the Assabet River (OAR) worked with them to establish a $1.5 million fund for water recharge projects to replace the lost groundwater. It helped both that the corporation, Intel Massachusetts, is environmentally-minded, and that they were extremely anxious to get their water withdrawal permit. For the last few years, OAR has been working with Intel to award grants to municipalities and NGOs for water recharge.

Organization for the Assabet River (MA)

www.assabetriver.org

Our parent organization, Conservation Council of New Brunswick (Canada), launched a major campaign in the late 1980s to protect groundwater in our province. The result was the removal of all unused underground gasoline storage tanks, new regulations requiring double-walled tanks and new legislation that protects wellfields from certain types of development that have the potential to pollute groundwater. It is the first, and still I believe, the best groundwater protection legislation in Canada, although the regulations to "activate" it took a long time to put in place. We also produced some public education material, such as a groundwater "primer" and a booklet on leaking underground storage tanks.

Fundy Baykeeper (NB)

www.fundybaykeeper.org

The Tri-State Water Quality Council is publishing a review paper called *Septic System Impact on Surface Waters*, to help people understand how sub-surface waste discharge can affect both groundwater and surface water. The report documents research in the inland Northwest and elsewhere which explains how soluble nitrates and other constituents of septic system discharge are passed into groundwater and then into nearby surface waters—both lakes and rivers—potentially contributing to nutrient/algae/eutrophication problems. The report seeks to educate local policymakers, especially county governments, on this issue because septic systems are booming in numbers in small communities in Montana, Idaho, Washington and Oregon. Both policy and technical alternatives for addressing the problems are discussed. The report will be available on our webpage.

Tri-State Water Quality Council (ID)
www.tristatecouncil.org

The Rock River Coalition's Groundwater Issue Team is taking steps toward creating a process-based framework synthesizing what is known about the hydrology by assisting the U.S. Geological Survey (USGS) in implementing a basin-wide groundwater flow (GFLOW) computer model. The GFLOW model creates a combined simulation of groundwater and surface water systems and how they interact, providing information necessary to understand the hydrologic system of the Basin. A GFLOW model describes sources and sinks of water, general directions of groundwater flow and estimated travel times. Such information is critical for understanding the fate and transport of contaminants within the watershed. The model outputs, in turn, can be used to quantify groundwater movement throughout the basin and form the foundation for utilizing quantity and quality groundwater information during planning. The GFLOW model also provides a regional framework for more site-specific studies in the future. This project is the first step to understanding the groundwater/surface water interaction, and the first step to ensuring the quantity and quality of the water that citizens of the Basin enjoy.

Additionally, since 2003, the Rock River Coalition has worked with seven communities in four Wisconsin counties to design, install and hold workshops about rain gardens and their benefits. We have worked with a youth organization, a church, a senior center, schools, parks departments, city and county governments, the Wisconsin Department of Natural Resources, Master Gardeners and the University of Wisconsin-Extension.

Rock River Coalition (WI)
www.rockrivercoalition.org

Groundwater Pumping:
A Pernicious Threat

by Robert Glennon

From Arizona to Massachusetts, rivers have recently dried up. The cause is not any of the usual culprits: diversions, dams, or drought. Instead, American rivers face an unseen and largely unknown but profoundly pernicious threat: groundwater pumping.

Groundwater comes from underground aquifers—large repositories of water once thought to be as ubiquitous and plentiful as the air we breathe. We now know better. The science of hydrology teaches that groundwater is part of a hydrologic cycle that provides freshwater to lakes, rivers, creeks, springs and wetlands. If this seems surprising, consider the following riddle: where does water in a river come from if it hasn't rained recently? The answer is it comes from the ground. When the water table surrounding a river is higher than the river, groundwater flows subsurface toward the river to provide "base flow"—flows even in the absence of rain.

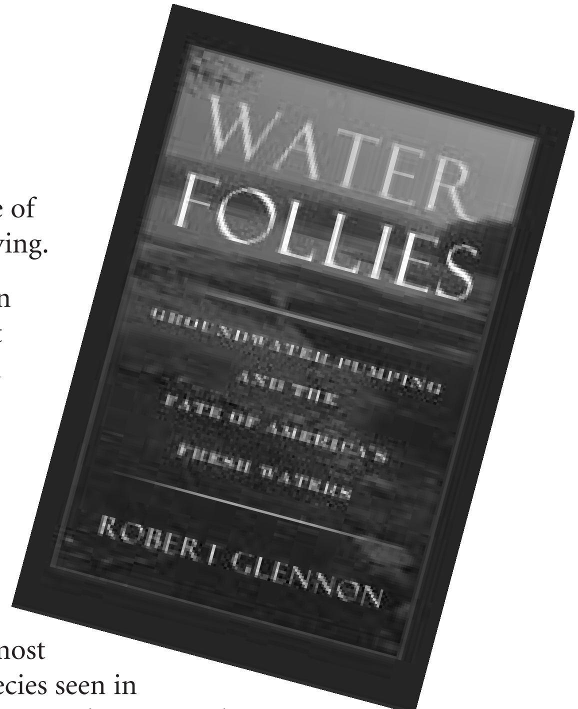
Groundwater pumping disrupts this cycle: it steals water from our rivers. Because groundwater moves slowly, the impact may occur imperceptibly over years or even decades. Eventually, stark consequences—rivers that dry up—are apparent. Pumping that gradually reduces flows and causes a decline in the number of birds, butterflies, fish or trees, incrementally diminishes our enjoyment of the resource. As a consequence, we may not notice the effects until they are disastrous.

In the United States in 2000, we pumped a staggering 30 *trillion* gallons of groundwater. Over half of us rely on groundwater as our drinking water source. And we are dramatically increasing the amount of groundwater pumped. During the recent drought, farms, cities, mines and even individual homeowners desperately searched for new water supplies. The usual solution was to drill new wells because groundwater pumping is largely unregulated. Think of an aquifer as a giant milkshake glass and think of each well as a straw in the glass. The legal rules in most states allow anyone to insert a new straw into the glass. The legal rules permit limitless access to a finite resource, a phenomenon known as the tragedy of the commons. Such unrestricted and unsustainable access will eventually deplete the supply, cause land subsidence, create water quality problems and induce salt water intrusion. But for those of us who care about our rivers, the most horrifying prospect is the drying up of rivers, creeks, springs and wetlands.

This increase in groundwater pumping often comes from quite innocent human activities, such as the country's new-found fascination with bottled water. Sixty percent of us drink the stuff, which has made bottled water the fastest growing product among supermarket categories. Consumption has risen 1,300 percent in the last 15 years. Consider Nestlé Waters North America, the largest bottler of water in the United States whose brand names include Arrowhead, Calistoga, Poland Spring, Ice Mountain, Zephyrhill and Osarka. Nestlé's marketing strategy has generated protests from citizens' groups in Michigan, Wisconsin, Maine, Texas and California. Nestlé sells "spring" water because the company thinks that American consumers find greater cachet with bottled "spring" water than with "artesian," "natural," "flavored" or "mineral" water, which are other U.S. Food and Drug Administration approved categories. But to market "spring" water, the company's wells must be adjacent to the springs. Those wells pump water that would discharge to the springs and provide cold, renewable supplies of water to downstream rivers, often creating just the right habitat for trout reproduction. Diminishing the flow of a spring may increase the ambient temperature of the river and impair trout reproduction. It's a water folly because if Nestlé moved its wells away from the springs, the water would have the same chemical corporation and the springs would be protected. A marketing strategy drives this water use.

For another new use of groundwater with ominous implications for rivers, consider McDonald's french fries. Until recently, farms in the Midwest, the East and the Southeast were "dry-land" farmed, meaning that the farmers had no irrigation systems. However, our love affair with french fries (the average American consumes 30 pounds a year) has caused some potato farmers to shift from dry land to irrigation farming. The size, shape, and texture of dry-land potatoes depends heavily on seasonal weather patterns. During the growing season, potatoes need constant moisture or they will have knobs and odd shapes. A misshapen or knobby potato is perfectly edible, but it is not acceptable to McDonald's. In 1988, McDonald's began to offer consumers "super-sized" meals with larger portions of french fries served in rectangular boxes with flat bottoms. Since then, McDonald's will only accept potatoes from farmers who irrigate. Irrigation produces fries with a uniform length—just long enough to jut out of the super-sized box to allow the consumer to grasp the fry between index finger and thumb and dip it in ketchup. In Minnesota, this change in potato-farming practices threatens rivers, such as the Straight River, a blue-ribbon trout stream. This water use is a folly because the insistence on an "industrial" potato (as the trade calls it) has consequences for our rivers.

In *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters*, I tell these stories and a dozen others from around the country. My stories illustrate human foibles including greed, stubbornness and especially, the unlimited human capacity to ignore reality. A recent development in one of my stories is horrifying.



In a striking collection of short stories that brings to life the human and natural consequences of our growing national thirst, Glennon provides an occasionally wry and always fascinating account of groundwater pumping and the environmental problems it causes. Water Follies *brings this widespread but underappreciated problem to the attention of citizens and communities across America.*

You can order online at www.islandpress.org

In July 2005, the San Pedro River, the last free flowing river in southern Arizona, went dry for the first time in recorded history. The San Pedro supports an estimated 390 species of birds (almost two-thirds of all species seen in North America). The river has received special designations from the Birder's Digest, the Nature Conservancy, the American Bird Conservancy and the National Audubon Society. However, population growth in the nearby city of Sierra Vista and surrounding Cochise County is exploding and this growth is entirely dependent on groundwater. The issue of fostering sprawl versus protecting the river is well framed. But not surprisingly, local developers claim that groundwater pumping has not caused water levels in the river to decline. Scientific uncertainty attends many disputes over the impact of pumping on a particular river or spring. Some of this debate is in good faith, an honest disagreement about what the evidence suggests and the computer models predict. Other positions seem animated by gross self-interest. With so much money at stake, developers pay consultants handsome fees to help obtain lucrative permits to pump. My hydrologist friend, Tom Maddock, dismisses such hydrologists as "hydrostitutes."

Golly, you (readers) must be thinking, this is a cheery, uplifting article. Is it all doom-and-gloom or does he offer some solutions? Indeed I do. To begin, we must recognize the urgency of the problem. It may take

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years or even decades before the effect of pumping on the environment becomes apparent. The irremediable fact is that groundwater pumping that has already occurred will cause environmental damage in the future. Those consequences are spilt milk. Our focus should be on reforming the system to control pumping by restricting new wells. Although the cure will not be easy or quick, there is great incentive because Mother Nature has enormous regenerative capacity. If we change direction and chart a new course for the future based on wise policies, then there is reason to be hopeful for the future of our rivers.

We should combine a command-and-control model of government rules and regulations with the market forces of transferable rights and price incentives. Any meaningful reform should do two things. First, it should protect the rights of existing users by creating quantified water rights that are transferable (and therefore valuable), and second, it should halt the tragedy of the commons by placing restrictions on drilling new wells.

States should require new users, developers who wish to place additional straws in the milkshake glass, to pinch someone else's straw. States should foster a market in water rights by allowing the easy transferability of rights from existing users to newcomers. We use an enormous quantity of groundwater for extremely low-value economic activities. For example, in California, an acre-foot of water (325,000 gallons) used to grow alfalfa generates $60 in revenue. That same acre-foot used in California's Silicon Valley generates $980,000 in revenue. State law should facilitate the reallocation of water to higher-value uses by encouraging water markets.

But water markets alone are not a sufficient response because markets are notoriously incapable of internalizing environmental harms. Companies such as Nestlé do not absorb the environmental costs of habitat that is degraded by their pumping. To correct for this market malfunction, we need governmental rules and regulations. Water conservation regulations make a great deal of sense, as do rules that set minimum flow levels in rivers. But most importantly, rules should protect rivers by prohibiting the drilling of new wells in areas that are hydrologically connected to surface flows.

There is another solution that has received scant attention. We need to price water appropriately. In the United States, most of us pay more for our cell phones and cable television than for water. In fact, most of us pay nothing for water. When we receive a monthly water bill from a public utility or the public water department, that bill usually includes only the extraction cost of drilling the wells, the energy costs of pumping the water, the infrastructure costs of distribution and storage system, and the administrative costs of the water department or company. With rare exceptions, water rates do not include a commodity charge for the water itself. The water is free!

Our habits as consumers will change only *if and when* the cost of water rises sufficiently to get our full attention. We should adopt inverted block rates that raise the price of water as the volume used increases. Such rates would protect persons of modest means and discourage discretionary water uses, such as outdoor landscaping and swimming pools.

In the end, I am optimistic. Now that we understand the connection between groundwater pumping and rivers, it is time to act. If we have the political will, our springs will bubble and our rivers flow.

Robert Glennon specializes in constitutional law, American legal history and water law at the University of Arizona. In 1997, he was named the Morris K. Udall Professor of Law and Public Policy. In 2002, his book, Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters, *was published by Island Press.*

Groundwater – Surface Water Interactions:

No Shortage of Policy Challenges

by Dennis Wichelns
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Population growth and economic development generate increasing demands on natural resources. When demand exceeds supply, policy interventions often are required to slow the rate of resource depletion, protect resource quality, maintain equitable access or enhance the benefits society derives from limited resources. Optimal policy programs change over time with changes in public preferences regarding productive outputs and environmental amenities. Advances in technology and scientific understanding also create the need for new policies and institutions that influence resource allocation.

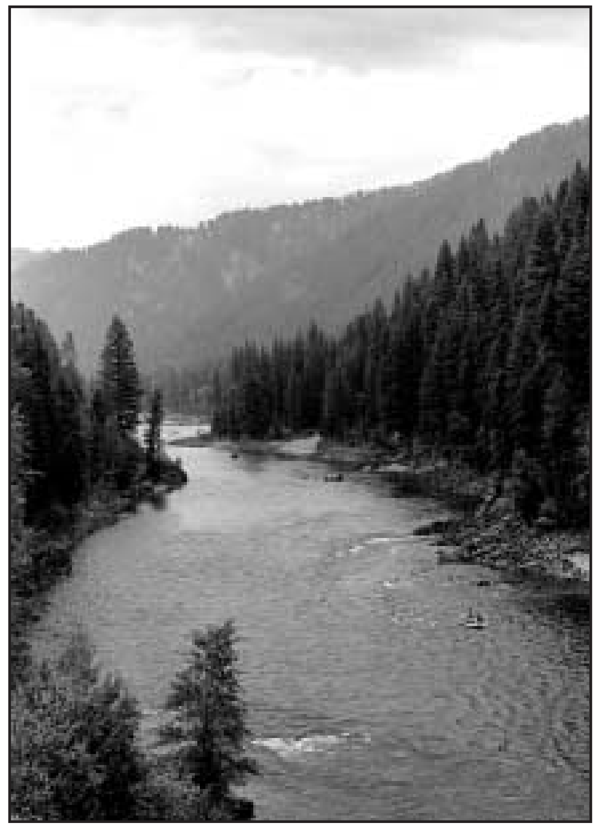
Changes in demand, technology and scientific understanding create new challenges in river systems in arid areas. Often the first response to increasing demand is to allocate surface water through a state-sanctioned system of water rights. Withdrawals are monitored and allocations are enforced. Surface water rights work well in areas with little interaction between river flows and groundwater pumping.

Advances in groundwater pumping methods in the 1940s and 1950s enabled some farmers to obtain irrigation water without a surface water right or allocation. In many areas groundwater pumping reduced the flow of water in nearby rivers, but the linkage was not immediately understood. Scientific understanding of the linkage between groundwater pumping and surface water flows increased more slowly than the adoption of groundwater pumping. As a result, existing systems of surface water rights became inadequate to ensure equitable or efficient water use.

Public officials and legal scholars have been called upon in recent years to modify water policies and allocations to account for groundwater—surface water interactions. The challenges they face are substantial in many areas where the demand for water exceeds the available supply. Two examples illustrate the challenges of redefining water rights and motivating reductions in water use.

The Snake River Basin, Idaho, USA

Many rivers in the western United States have been developed to provide water for hydropower, agriculture and recreation. The Snake River, which flows from the Grand Teton Mountains in Wyoming, through Southern Idaho, to the Columbia River in Washington is a good example. There are 25 large dams on the mainstem of the Snake and its tributaries. In 1990 farmers diverted 8.4 million acre-feet to irrigate 4 million acres of land (Shallat, 2000). Idaho ranks second to California in the number of irrigated acres and leads the nation in water withdrawals per capita, at 19,000 gallons per day (Palmer, 1991; Raines, 1996).



© Tim Palmer

The competition for water in southern Idaho is substantial, given that much of the Snake River Plain receives less than 10 inches of rain per year. Increasing, demand alone would have placed substantial

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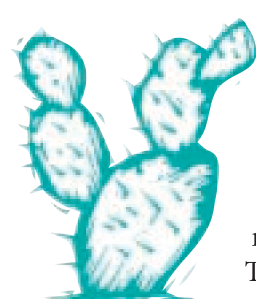
pressure on surface water supplies and the historical system of water rights. Groundwater pumping has made the problem much more challenging. The Snake River and its tributaries are linked hydrologically with the Snake River Aquifer, which underlies about 10,000 square miles of central and eastern Idaho (Raines, 1996).

Idaho farmers began pumping groundwater in the 1940s. Competition between surface water diverters and groundwater pumpers increased over time. The state began requiring permits to pump groundwater in 1963, but officials lacked authority to disable unauthorized wells until 1986 (Raines, 1996). In 1994, the Idaho Legislature approved a complete moratorium on water development in the Snake River Plain and began requiring all groundwater users to install meters and record water use. The state began a comprehensive adjudication process in 1987 to determine the volume, priority date and source of every water right in the Snake River Basin in Idaho (Raines, 1996). That process has taken nearly 20 years to complete (*Idaho Statesman*, 2005).

The San Pedro River, Sonora, Mexico and Arizona, USA

The San Pedro is one of the few remaining perennial rivers in the southwestern United States. Although the river receives seasonal flow from precipitation and snowmelt, base flow is comprised primarily of groundwater (Luster, 2002). As groundwater pumping has increased over time, base flow has been reduced and concern has arisen regarding water supply and environmental amenities.



The Upper San Pedro River Basin supports an ecosystem rich in biodiversity. The watershed, which is a transition area between the Sonoran and Chihuahuan Deserts (Stromberg et al., 1996; Steiner et al., 2000), is home to numerous land mammals and provides habitat for more than 300 species of birds (Luster, 2002). More than 100 species breed each spring and summer, and another 250 species of migrant and overwintering birds use the river's corridor for feeding and shelter (Hanson, 2001).

Increases in groundwater pumping and surface diversions for municipal, industrial and agricultural uses have lowered water tables and reduced base flows along the San Pedro River (Lite and Stromberg, 2005). Efforts to improve the situation are challenging, in part, because the region's residents rely entirely on groundwater. The transboundary nature of the river complicates the policy process. International cooperation is required to select and implement policies that will achieve the optimal allocation of water among competing uses.

Looking Ahead

Competition involving groundwater and surface water interactions will increase with increasing population and rising income levels. Increasing water demands and shifts in public preferences regarding productive outputs and environmental amenities will generate the need for new policies to reallocate limited water supplies. Combinations of regulatory measures and market-based incentives will be required. The public costs of determining optimal policies and implementing new programs will be substantial in many areas. Improvements in scientific understanding and consideration of the wide range of benefits provided by water resources will be helpful in guiding public officials toward optimal policy decisions.

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CASE STUDY

Ground Truthing Groundwater:
Local Citizens Unite to Prevent Withdrawals

by Melissa Scanlan
Midwest Environmental Advocates
www.midwestadvocates.org

In early 2000, the people of Wisconsin found new hope that their water resources would not be put up for sale to the highest bidder. This is due in part to the dedication of a small grassroots group in central Wisconsin that fought to protect their spring waters from exploitation by a multinational corporate water bottling company, Perrier, Inc. and Great Spring Waters of America.

The story began in February of 1999, when officials with the Wisconsin Department of Commerce invited Perrier to locate in Wisconsin and establish high capacity wells for its planned water bottling plant and pipeline.

In June of 2000, Perrier filed an application for a high capacity well permit under Wisconsin law to establish high capacity wells in the Big Springs area of Columbia and Adams Counties near the peaceful town of New Haven, Wisconsin. Perrier wanted to operate the wells 24 hours per day every day of the year, pumping up to 500 gallons per minute. The proposed bottling plant would have had a footprint of some 80 acres, with up to seven miles of pipeline to move water from the source to the bottle.

The project details were fleshed out in a private agreement between the Department of Natural Resources (DNR) and Perrier, without any knowledge by the public until August of 2000.

However, the DNR did not conduct a thorough analysis of how the high capacity wells would deplete the precious and pure spring waters in the area. Moreover, the analysis did not carefully consider how the pumping would affect nearby trout streams fed by the spring waters. In fact, the DNR did not even know the exact locations of the high capacity wells when it conducted its environmental review. Despite this, the DNR concluded that it would conduct no further review of Perrier's proposed high capacity well permits.

The citizens in the town of Newport and other areas that would have been affected by water withdrawls decided to fight the issuance of the permit; the steps they took to protect water may be useful for other communities. The everyday people involved in this effort became incredible activists. They used all of the tools available to them, from organizing public meetings and passing local referenda, to getting their message out to the media and going to court.

Step One:* *Gain access to information

a. Attend public meetings.

b. Use the open records laws to access information from the government.

c. Hold public meetings and invite public officials to attend.

Step Two:* *Use information to wage an effective media campaign

a. Raise funds to purchase advertising space in local newspapers.

b. Consistently write letters to the editor raising questions about the project.

c. Distribute yard signs to build grassroots opposition to the project.

d. Develop relationships with the press so they cover the story.

Step Three:* *Develop a political strategy to build opposition to the project among elected officials.

a. Attend and speak at government meetings.

b. Meet with elected officials to discuss the group's position on the issue.

c. Participate in local elections to make the project a campaign issue.

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Groundwater Legislation in Wisconsin – One Man's Story

Scott Froehlke is a former board member of the River Alliance of Wisconsin and was an important actor in events that led up to the call for groundwater regulation in Wisconsin, and the passage of the legislation itself. In his own words….

It all started with Perrier and their proposal to take groundwater out of central Wisconsin and bottle it (*in 2001*). That got stopped cold by all the locals coming together. Their role ended at the Coloma High School gym, when hundreds of people turned out to corner two Perrier guys. They finally left the state, but with the tacit understanding they would come back when there was a law that might get at groundwater permitting.

The Perrier situation led to the River Alliance of Wisconsin, in the person of Todd Ambs (*former executive director of the River Alliance*), starting talks with a group of people who'd be seriously affected by groundwater removal and regulation—the potato and vegetable growers. From those conservations came a statement of principles about groundwater withdrawals, which we then took to legislators. At this point, I jumped in deep, because of my work as a lobbyist and connections to legislators.

We got Rep. Dwayne Johnsrud's attention (*at that time chair of the Assembly Natural Resources Committee*) because of the unusual alliance of farmers and an environmental group. Johnsrud really wanted something to come of this, got his Senate colleague Neal Kedzie involved, and then things got complicated. The legislators wanted "a big tent," and industry people, municipalities and well-drillers got in the mix. The potato and vegetable growers' lobbyist got involved because he didn't like what the farmers he represents had started.

The big moment in all this, though, was turning it over to the lawmakers and trusting the process—believing that something good would come out the other end. Johnsrud was determined to pass something and even though he worked off our original outline, the greens were very skeptical. What brought them along was the entry of Steve Born (*University of Wisconsin planning professor and long-time conservation activist*). Born scolded the greens to keep them from being an obstacle. In the middle of it all was Todd Ambs (*now water division administrator for WI DNR*), who'd gone from advocate to regulator on the same issue.

In the end, a backroom deal was struck that delivered a very flawed product. The bill passed with only one vote against it in both houses of the legislature. Though flawed, what's important is what the law got started, not what it accomplished per se. What got started is the groundwater advisory committee to study the big issues and make recommendations and to define the vague term "deleterious impact" from groundwater withdrawals that the legislation didn't define. The law gave two thirsty regions of the state—Brown County and southeastern Wisconsin—license for local governments to cooperate on groundwater withdrawals and conservation measures.

The story's just begun with this law.

Step Four: ***Use the law and litigation as a last resort to protect your environment and quality of life***

a. Bring legal action to defend the public's rights to clean water and a clean government.

b. Remember that a lawsuit is a supplement to and not a replacement for the educating and organizing work of the grassroots group.

The community formed a group and called themselves the Concerned Citizens of Newport. They retained the help of Midwest Environmental Advocates, Inc. and Garvey and Stoddard, PC to go to court, a decision that complimented their multi-level organizing and local activism.

In *Concerned Citizens of Newport v. Department of Natural Resources*, the Concerned Citizens of Newport alleged that the DNR had violated the Wisconsin Environmental Policy Act (WEPA) by failing to conduct a sufficient environmental review of the high capacity wells and by failing to include the public in the environmental review. The Concerned Citizens of Newport also alleged that the DNR violated the Public Trust Doctrine by essentially giving Wisconsin's precious water to a private, multinational corporation.

In summary, the court granted Concerned Citizens of Newport's petition on the claim that the DNR had failed to adequately examine the environmental effects of the high capacity wells. Specifically, the court stated that "the DNR's record…is not adequate nor is the environmental impact statement decision on that record reasonable…" Moreover, "[t]he modeling and the data are insufficient to make a reasonable assessment of the potential impact on groundwater, impact on the marsh levels, the creek flow and so forth." The Court required the DNR to reconsider the high capacity well permits, and conduct a more thorough environmental review of the surface water impacts caused by the wells.

Further, the Court ruled that the closed-door process set up by the DNR to conduct its environmental review of the high capacity wells also violated Wisconsin law. Specifically, the Court called the process "impermissible" and that the DNR and Perrier effectively cut the public out of environmental decision-making—the very public that would be hurt the most by Perrier's high capacity wells. When the DNR re-examined the high capacity well permits, the Court held that it must do so by providing the public with the full opportunity to participate.

The court gave the DNR the task of creating a new Environmental Assessment that would have more fully shown the public the environmental impacts of Perrier's proposal. Faced with their inability to accomplish this, Perrier announced on September 17, 2002, that it would let its permits expire and leave Wisconsin.

CASE STUDY

Columbia River Slough: Aquifer Adventure

by Eric Kellon
Outreach Programs Coordinator
Columbia Slough Watershed Council
www.columbiaslough.org

How deep is the brine
Down near Davy Jones' Locker?
And how frothy the foam
By the fishermen's dock, arr?

How clean is the drink
In a Slough pirate's cabin?
Head to the trees
And the answer be grabbin'!

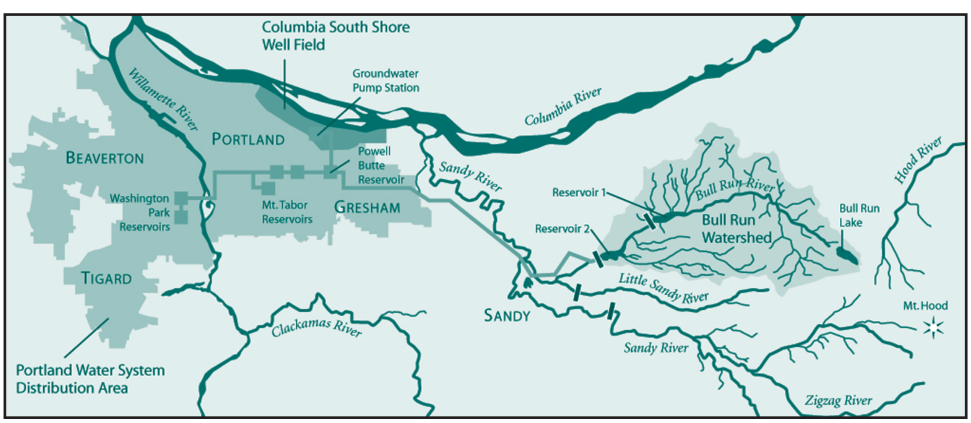
— Ethan Chessin

What does a pirate's riddle, a 30-foot long Chinook salmon named Claudia and groundwater have in common? They are all part of the third annual groundwater protection event "Aquifer Adventure," sponsored by the City of Portland's (OR) Water Bureau and the Columbia Slough Watershed Council. This year over 200 seadogs and landlubbers gathered along the banks of the Columbia Slough for a day of adventure including canoe rides guided by slough pirates, a treasure hunt and groundwater inspired games. The treasure hunters searched the woods and trails along the Slough for clues that lead them to hidden "treasure." The treasure they sought was not gold or silver but a vital resource that flowed under their feet…groundwater.

At its core, Aquifer Adventure is a treasure hunt that focuses on groundwater principles, water conservation and groundwater protection actions that kids and their parents can take at home. Games and activities teach kids and adults how to protect this important groundwater resource. The games make a difficult and hard-to-see subject fun to learn about. Activities like the groundwater model illustrate how contaminates, that spill on the ground or leak from underground tanks, move through the ground into aquifers.

Portland, Oregon is in the fortunate position of having two distinct drinking water sources. Since 1895, the Bull Run River has been the primary source of drinking water for Portland Water Bureau customers. The Columbia South Shore Well Field is the Water Bureau's supplemental and emergency source. The Well Field draws water from 25 wells in four aquifers spread over an eleven square mile area that includes lands in three different cities.

In 1987, the City adopted a Wellhead Protection Program in response to concerns about potential contamination in the well field from industrial and residential pollutants. This program was one of the first of its kind in the U.S. In 2003, the City of Portland and the neighboring cities of Gresham and Fairview adopted the current Wellhead Protection Program which regulates businesses in the wellhead protection area that use or store chemicals, focusing on containment and spill prevention. The Wellhead Protection Program also encourages residents to use safe practices when handling household and yard chemicals. Although residential use of chemicals in the well field involves smaller amounts, the need



for spill prevention is clear. It takes only one gallon of TCE (trichloroethylene—a solvent used to clean metal parts) to contaminate 292 million gallons of water.

And how is a 30-foot Chinook related to groundwater and well field protection? Simple…kinda. The Portland Water Bureau is working to improve conditions for threatened fish in the Bull Run watershed by improving water temperature, habitat and river flows. By using groundwater to supplement our primary water supply from the Bull Run, the Portland Water Bureau has the flexibility to increase flows for fish in the Bull Run River.

The message of Aquifer Adventure was summed up best by the Aquifer Adventure's Chief Pirate, a.k.a. David Shaff, Interim Water Bureau Administrator. "The City of Portland is fortunate to have a secondary water supply, and it is in the best interest of us all to protect it. We all depend on drinking water, but aren't always aware of choices we can make to protect it."

Here are some of the many simple ways to help protect groundwater:

- ◆ Consider safe alternatives to hazardous products.
- ◆ Use household, yard and automotive chemicals safely.
- ◆ Check vehicles for leaks and clean-up spills with absorbent materials
- ◆ Test soil to determine fertilizer needs— avoid over-treating.
- ◆ Use native plants. They require less fertilizer and pesticides.
- ◆ Properly recycle hazardous chemicals—do not pour them down the drain.
- ◆ Clean up pet waste, bag it and put it in the garbage.

Put it in our Backyard:

Water, Science and Sustainable Development

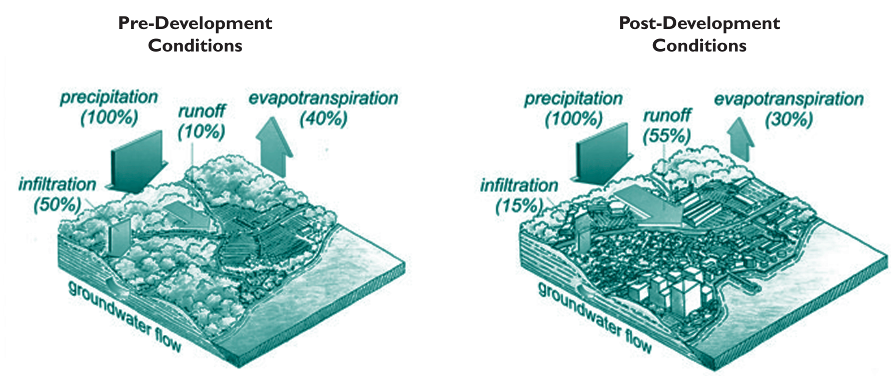
by Robert Zimmerman Jr.
Executive Director
Charles River Watershed Association
www.crwa.org

There is a general notion floating around in essays by economists and environmentalists that the world is running out of fresh water. We hear much of the "commodification" of water, and large corporations like Seagrams and Coca-Cola buying up water rights for some future catastrophic shortage. We also hear of the pending construction of new desalination plants all over the United States, where we would burn fossil fuels to take salt out of seawater, and then pump that water uphill to replenish our parched cities and towns. It all sounds pretty dire. The consequences to the natural world of such an engineered series of events would likely be beyond calculation.

This view of water and our water future is, however, fundamentally flawed. It assumes that when we use water, we use it up, in much the same way that when we burn gasoline we use it up by changing it chemically. Fortunately, that is simply not true. The same amount of water has been on the face of the Earth for about 4.5 billion years. When we use water, we make it dirty, but the water is still water.

The flawed view of water and human use is the direct result of two centuries of water infrastructure engineering. Our cities reach out to get water from the ground and from reservoirs and rivers, transport that water some distance where it is treated and distributed for use, and then collect the dirty water for treatment and discharge someplace else. Over time, as cities grow, such systems are not sustainable and they have significant impacts on surface waters by 1) drawing them down, particularly in the summer months, 2) raising surface water temperatures, 3) concentrating pollutants that remain and 4) allowing sunlight to penetrate to sediments promoting weed growth.

The proliferation of paved and constructed land surfaces further complicates the situation by preventing rainwater from infiltrating into the ground, exacerbating the impact of water use and surface water drawdown by reducing the amount of water stored in the ground. The effects of groundwater storage are also seen mostly in the summer months. The net result of our water/wastewater engineering and our paved and constructed surfaces on the water environment is growing more dire every year, and it is this that has given rise to the notion that we are running out of water.



Source: Massachusetts Smart Growth Toolkit

In addition to the dramatic changes in water hydrology illustrated here, impacts associated with water withdrawl and wastewater discharge have rendered our current water engineering not sustainable. We are throwing water away in extraordinary volumes.

In addition to the dramatic changes in water hydrology illustrated here, impacts associated with water withdrawal and wastewater discharge have rendered our current water engineering not sustainable. We are throwing water away in extraordinary volumes.

We are not, however. We are simply throwing tremendous volumes of water away because that is the way we are accustomed to engineering things.

The Charles River Watershed Association (CRWA) has been working on this problem for 12 years using all the science, engineering and legal tools at our disposal. It turns out there are fairly straightforward solutions to this mess.

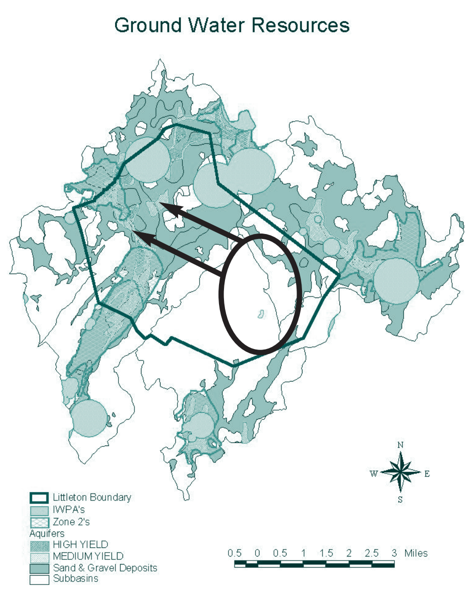
A Bend in the River

The first thing to recognize is that water, once dirty, can be made clean again. How many towns along the Chattahoochee, Mississippi or Missouri withdraw water from the river, treat it for use, and then discharge it back to the river downstream, only to have it withdrawn farther downstream, treated and used and discharged once again. The point is that wastewater is only wastewater if we waste it.

Instead of throwing the water away, we need to think of human use as a "bend" in the river, and we need to return the water we use very near the place we get it from. If we get it from groundwater through wells, we need to clean the water to drinking water standards and return it to the ground near the wells. If we get it from a reservoir, we need to return it to the ground near the tributaries that supply the reservoir. To the extent possible, we need to keep water local. Beyond that, in cities and towns we need to work to re-engineer paved and constructed surfaces to allow rainwater to behave as if we had never built our cities and towns. The key is to get water and land to work together in something approximating the way it would have worked had the land remained in a natural state.

Recharge, Recycle, Restore

Low impact development (LID), the landscaping methods for capturing rainwater in built environments and infiltrating it to the ground, thereby preventing it from being collected and



Source: Charles River Watershed Association

Spot-sewered density zone in Littleton, MA, an ex-urban Massachusetts town facing serious growth pressure, showing where treated wastewater should be returned to the ground. Note that the discharge areas are removed from well locations.

cont. on page 38

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thrown away through stormdrains, is a very good start. LID is gaining converts in cities around the nation, notably around the Chesapeake Bay, in the Pacific Northwest and in New England. It is based on a number of solid principles: reducing paved surfaces, reducing or eliminating curbs to allow water to run into vegetated swales, and creating rain gardens that trap runoff, clean it and infiltrate it.

In suburban and ex-urban communities, water supply withdrawal and wastewater discharge need to be viewed as two ends of the same process. Using a technique called "spot-sewering," distributed public water supply can be collected and returned to municipally managed decentralized wastewater treatment plants where it is treated to high standards and returned to the ground near where the water came from. Spot-sewering has a number of important benefits. First, it uses water infrastructure to promote smart growth and density zones. Second, it returns water to the locality it was taken from and recharges the groundwater stores on which we and the natural environment depend. Third, by recharging groundwater day-in and day-out year around, it returns surface water flow, especially in the summertime, to something beginning to approximate natural norms. Fourth, water quality in the surface water body resulting from this sort of groundwater recharge is dramatically enhanced. Between the treatment plant and the filtration and dilution of the water in the ground, nutrient loading is all but eliminated, as are suspended solids.

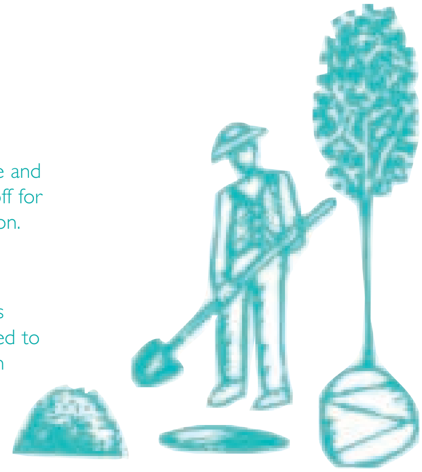
Think of it this way. If average per capita water use on a daily basis is 100 gallons, but 95 of those gallons are returned to the environment they came from, the net impact on that environment is negligible. This process breaks the cycle of getting water from one place, using it in a second and throwing it away in a third, and brings human water demand into balance with the natural world. Further, it is sustainable virtually forever.

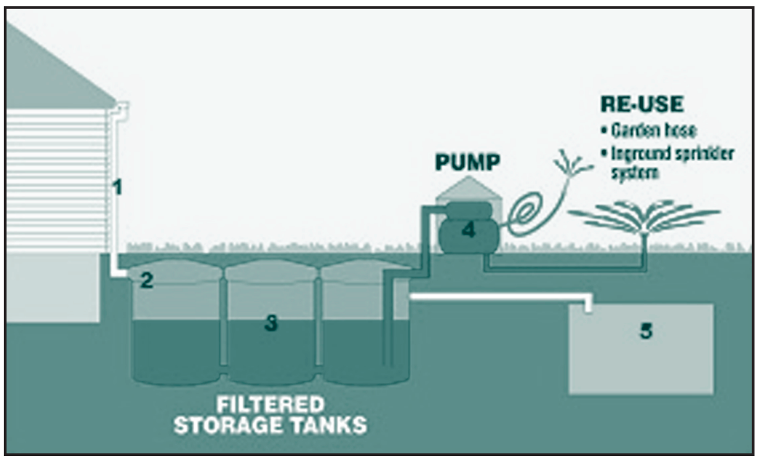
Finally, summertime potable water demand nearly doubles over wintertime use due to residential and commercial irrigation. Such demand occurs at exactly the wrong time, when groundwater storage is finite because recharge from rainwater is lost to plantlife and impervious surface runoff. Thirty-six states in the union, however, get three feet of rain or more each year, and if buildings simply captured and stored roof runoff to use as irrigation, demand on potable water supplies would be dramatically reduced. This is a straightforward engineering fix. Additionally, using stored roof runoff for irrigation actually mimics the way the environment uses rainfall during the summer months.


Source: Charles River Watershed Association

LEFT: Cistern/drywell systems capture and store roof runoff for reuse in irrigation.

BELOW: Excess runoff is diverted to a drywell, which recharges groundwater year around.





Source: Rainwater Recovery

The elements, then, of getting water use right are these:

1. Spot-sewering and the centralized management of decentralized wastewater treatment systems that return water to its source.

2. Low impact development that captures rainwater and prevents runoff to reduce or eliminate the effects of paved and constructed surfaces on the dynamics of land and water working together.

3. The use of cistern/drywell systems to capture roof runoff and store it for discretionary landscape irrigation, reducing or eliminating the surge in use of public potable water supplies during the summer months for landscape irrigation.

There is a fourth element, particularly in urban and suburban landscapes, of getting the science of groundwater/surface water interactions to better mimic historic norms. That is an investigation too detailed for this discussion and will have to be taken up in a later article.

Bottom line? We are not running out of water. We are simply misusing it. By putting a stake in the ground now, and basing all of our water infrastructure investments now and into the future on the principles and elements outlined here, we will sustain our water supplies and restore the natural water environment. With either the old throw-it-away approach, or the new recharge, recycle, restore approach, we will continue to spend public funds on water infrastructure. The new approach promises to be dramatically cheaper over the middle and longer terms, and will bring our water use into balance with natural supply.

CASE STUDY

The Appalachian Coal Country Watershed Team: Building Partnerships to Combat Groundwater Contamination

by Dana M. Zufall
Outreach Coordinator, OSM/VISTA

Appalachian Coal Country is a region of the United States east of the Mississippi and stretches from southwestern Pennsylvania down into Alabama. It is an area most remembered for its coal production, but perhaps most recognized by its orange streams polluted by acid mine drainage (AMD). Appalachia is mainly comprised of small rural communities whose environmental degradation is compounded by the problems of economic depression. Rising to this challenge, the Office of Surface Mining Clean Streams Program (OSM) partnered with

AmeriCorps/VISTA (Volunteers In Service To America) in 2001. In just three short years, the Appalachian Coal Country Watershed Team (ACCWT) has expanded to 30 full-time OSM/VISTAs serving in eight states across the Appalachian Coal Country region. Members of the ACCWT are OSM/VISTAs dedicating a year as community service volunteers in exchange for experience, a modest living stipend and an educational award. The ACCWT has core goals of watershed group capacity building, watershed research and project development/implementation, watershed education and outreach, and community revitalization. OSM/VISTAs diligently work to combat water quality issues while upholding the core goals of the team, and they are succeeding.

Septic Systems

The amount of pollutants contaminating groundwater via septic systems is a problem throughout Appalachia. Team member, Martha Podren, OSM/VISTA for Hands Across the Mountain in Virginia, is attempting to start a water monitoring group in Big Stone Gap, Virginia. Water monitoring is an active approach to educate citizens of the need to improve water quality. She has been working to build relationships between her organization and the Department of Conservation and Recreation, the Tennessee Valley Authority, the Upper Tennessee River Roundtable and the Canaan Valley Institute—all organizations with a similar mission to educate the community and improve water quality. These partners are working together to conduct an environmental inventory of Upper Powell River sub-watershed. The plan will locate the main sources of bacteria impairment and assess the number of inadequate or failing septic systems.

This study will hopefully produce a GIS layer containing bacteria counts for the Upper Powell. It will serve as a valuable resource in the future for finding "hot-spots" of bacteria within the watershed. Podren has been working with the rural communities of Lower and Upper Exeter and the Wise County Health Department to identify what needs to be done to install an alternative wastewater treatment system there. An alternative sewer system will minimize river contamination and watershed pollution. Developing a sewer system and alternative wastewater treatment plan will be a step towards preventing groundwater and surface water contamination within these communities.

Septic Pump Out Program

The Cawaco RC&D Council of Birmingham Alabama is using education as a preventative measure to reduce groundwater contamination. Supported through an educational grant, OSM/VISTA's Hilary Aten is organizing the Septic Pump Out Program. The program is a partnership between the Cawaco RC&D Council and local septic system companies. Participants of the program attend a 45 minute workshop that educates citizens on the maintenance and workings of a septic system, they then receive a $75 voucher to have their system pumped. The benefits of this program are a reduction of nonpoint source pollution and reduction in pathogens in the groundwater and eventually the watershed. By using education as a preventative measure to reduce possible groundwater contamination, the Cawaco RC&D Council hopes that those involved with the program will continue to pump their systems in the years to come, giving the program long term benefits.

Acid Mine Drainage

Josh Pittman, OSM/VISTA for Six Mile Run Area Watershed Committee (SMRAWC), Defiance, Pennsylvania, has begun a community volunteer AMD discharge monitoring team. The volunteers report to SMRAWC on a monthly basis and collect water samples, temperature and pH readings. There are about 75 seeps that are currently being monitored quarterly and semi-annually by this team of community volunteers. These AMD discharges of contaminated groundwater are so severe that the drinking water is unsafe. Pittman notes that this civic engagement of volunteer monitoring has sparked a sense of fellowship among community members. Part of the job of an OSM/VISTA is to help the community sustain themselves for the future. The data collected at these discharges can then be analyzed, and the appropriate type of treatment system can be installed in the years to come.

Stormwater

In Tazewell County, Virginia, the Upper River Tennessee River Roundtable is working with county representatives, private developers, local municipality officials, Virginia Department of Transportation, the Tennessee Valley Authority and the Southeast Watershed Forum to implement a stormwater plan. OSM/VISTA Shane Barton organizes meetings and planning sessions to educate the community about the differences between pervious and impervious surfaces, noting the benefits to groundwater provided through pervious surfaces. By incorporating pervious surfaces into future community development, groundwater levels are able to recharge, assisting in the prevention of avoiding drought conditions. By monitoring infrastructure growth, Barton is working with local partners to develop a 20-year development plan that includes stormwater ordinances.

These are just four examples of sites working to address the issues of groundwater quality in rural communities across Appalachia, but the ACCWT works to address all issues facing the Appalachian region. Each OSM/VISTA is responsible for water monitoring, writing reports, press releases, preparing grant proposals, recruiting volunteers, producing educational materials, community development and other capacity-building tasks. By building partnerships and combining science with civic engagement necessary for sustainable programs, the ACCWT is strengthening communities through watershed development.

To learn more about the ACCWT

Visit www.osmre.gov/vista/vistahome.htm

Email: osm-team-leader@wv-esec.org

Phone: 304/345-7663

Resources & References

ORGANIZATIONS

The American Water Works Association (AWWA) is an international nonprofit scientific and educational society founded in 1881, dedicated to the improvement of drinking water quality and supply. AWWA is an authoritative resource for knowledge, information and advocacy to improve the quality and supply of water in North America and beyond. AWWA is the largest organization of water professionals in the world. AWWA advances public health, safety and welfare by uniting the efforts of the full spectrum of the entire water community. www.awwa.org

The Groundwater Foundation was founded on the principle that education is a powerful motivator for change and that factually informed people who understand the value and vulnerability of groundwater will act responsibly and responsively on its behalf. The Groundwater Foundation works to engage interest in, and inspire action on behalf of, groundwater protection and conservation through on the ground programs serving people. They base their programs on sound science and incorporate current research, technology and practices into its publications and public information events. www.groundwater.org

The National Agriculture Compliance Assistance Center is the "first stop" for information about environmental requirements that affect the agricultural community. The Ag Center was created by the U.S. Environmental Protection Agency (EPA) with the support of the U.S. Department of Agriculture (USDA). This Ag Center home page is your gateway to a large library of compliance information, as well as up-to-date news about related EPA programs and proposals. On most topics, the Ag Center offers publications that you can read online, download or order by fax or mail. You will find resources for both surface water and groundwater through the center's site. www.epa.gov/agriculture/water.html

The National Groundwater Association is a nonprofit organization founded in 1948. The organization serves as a hallmark for anyone associated with the groundwater industry. Headquartered in Ohio, their purpose is to provide guidance to members, government representatives and the public for sound scientific, economic and beneficial development, protection and management of the world's groundwater resources. www.ngwa.org

The U.S. Geological Survey (USGS) is an unbiased, multidisciplinary science organization that focuses on biology, geography, geology, geospatial information and water. They are dedicated to the timely, relevant and impartial study of the landscape, natural resources and natural hazards that threaten communities. USGS is designed to provide hydrologic information and understanding to achieve the best use and management of the Nation's water resources. USGS has compiled a significant amount of data on groundwater and surface water and the connection between the two. water.usgs.gov

The University of Wisconsin Water Resource Institute coordinates research programs which are applicable to the solution of present and emerging water resource problems. In carrying out this mission, the Institute has developed a broadly based research, training, information transfer and public service program involving personnel from many academic disciplines in the University of Wisconsin System. The Wisconsin Institute is one of 54 Water Resources Research Institutes nationwide authorized by the federal Water Resources Research Act. The state-based Water Resources Research Institutes are located at land grant universities and promote research, training and information dissemination on the nation's water resources problems. www.wri.wisc.edu

DOCUMENTS/LINKS

Basic ground-water hydrology
This USGS report gives you the basic run down of the various aspects of groundwater hydrology. From rocks and water to hydraulic conductivity and groundwater movement and topography, the document provides a good foundation on groundwater. water.usgs.gov/pubs/wsp/wsp2220

EnviroTools Fact Sheets
Provided by EnviroTools, the fact sheets provide a basic guide to groundwater with easy to follow illustrations. This link is particularly helpful for making the groundwater/surface water connection and is written in layperson's terms to facilitate understanding for people not working with groundwater issues. www.envirotools.org/factsheets/groundwater.shtml

EPA's Know Your Watershed Groundwater & Surface Water: Understanding the Interaction
This guide designed for watershed partnerships provides insight into how groundwater and surface water interact. It provides information on pollution, management approaches, issues relating to groundwater and provides a test to determine your groups' groundwater IQ. www.ctic.purdue.edu/kyw/brochures/groundsurface.html

Understanding Groundwater
The University of Nebraska has a series of 'NebGuides' which focus on different issues. This particular guide provides information on how groundwater exists, where it exists and how it moves. ianrpubs.unl.edu/water/g1128.htm

USGS Ground Water and Surface Water: A Single Resource (Circular 1139)
This USGS resource takes a closer look at the specific connection between groundwater and surface water. It discusses natural processes, chemical interactions, variables posed by different landscapes, the impact of humans and more. water.usgs.gov/pubs/circ/circ1139

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Nomination packets must be postmarked by February 10, 2006.