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**NDWC Offers FREE Sanitary Survey Course Prep CD**

Once again, the Montana Water Center (MWC) gives water system personnel a fun and informative training CD—the Sanitary Survey Fundamentals Prep Course—and the National Drinking Water Clearinghouse (NDWC) is a primary distributor.

Sanitary Sam, the CD's host, leads field staff through the procedures of inspecting and evaluating small water systems through interactive animation, games, narration, and video.

Course basics take about two hours to complete, preparing inspectors-to-be for the fast-paced sanitary survey workshops.

Call the NDWC at (800) 624-8301 and ask for item **#DWCDTR19**. Maximum orders of 20 CDs can be requested by those who provide the 2-day or 3.5-day sanitary survey workshops.

**The NDWC is a program within the National Environmental Services Center.**
Nearly 80 percent of communities rely on groundwater as their primary drinking water source. Wells extract groundwater for use in homes and businesses. Preventing groundwater contamination is of utmost importance, especially since a number of factors can contribute to groundwater contamination.
We’ve all been saying it would happen for years, and it finally did. The lights went out on August 14, 2003—and along with them the water supplies failed in many towns and cities across the northeast.

Large cities, such as Detroit and Cleveland, issued boil water warnings to their residents. The stress of bringing water systems back online caused distribution line failures in a number of cities and towns, as well.

America’s infrastructure needs some upgrades. In 2001, the American Society of Civil Engineers (ASCE) released the Report Card for America’s Infrastructure, grading 12 infrastructure categories, including roadways, bridges, drinking water, and energy, at a discouraging D+ overall and estimating the need for a $1.3 trillion investment to bring conditions to acceptable levels.

The report blamed the deteriorating infrastructure on a weak economy, limited federal programs, population growth, and the threat of terrorism, which diverted money to security.

Thomas Jackson, ASCE’s president, said that our concerns about security are real, but that it really doesn’t matter if a dam fails because the cracks in it have never been repaired or if it fails because a terrorist blew it up. The towns below the dam will still be just as flooded.

But if we do something now, we won’t have to worry about when distribution lines will collapse. There is at least one remedy to this predicament: develop a rate structure that is on par with the real cost of water. If we don’t, the consequences in terms of public health threats could be tremendous. Let’s not let it get that far.

Aside from the nation’s crumbling infrastructure, I need to convey some more sad news. One of the National Drinking Water Clearinghouse’s best writers has moved on to a new career, and we would like to say good-bye to him.

Jamie Knotts began teaching special needs students this fall. He loves his new job. Like all of us in the service industries, such as environmental health and education, Jamie’s wish is to make a difference. We know he will succeed. We are happy for him and wish him the very best.

Jamie did leave us one article to remember him by. It will be published in the Winter On Tap. The article is about water theft, and it is a good one. Be sure to keep an eye out for it.

As always, we’re looking for your comments. If you have story ideas, photos, or concerns you’d like to share with us, please know that we are interested. E-mail any suggestions to kjespers@wvu.edu or mkemp@wvu.edu. We look forward to hearing from you.

Kathy Jesperson
On Tap Editor
The National Drinking Water Clearinghouse (NDWC) is a nonprofit organization funded through the U.S. Department of Agriculture’s Rural Utility Service. Our mission is to help small towns and rural areas have the best drinking water possible. We have information available to make it easier for you to achieve that goal.

We maintain a toll-free technical assistance hotline, produce On Tap magazine, and distribute many other free educational materials. We also sponsor conferences, workshops, and seminars.

The NDWC houses several databases, including a comprehensive small system treatment technologies database called RESULTS, which can be searched by request at no charge.

To learn more about the NDWC, you can order an information package or speak with a member of our staff by calling (800) 624-8301. Or, you can visit our Web site at: www.ndwc.wvu.edu.
**DECEMBER 2003**

**Maine Rural Water Association**
**MRWA 23rd Annual Water & Wastewater Technical Conference & Exhibition**
December 2–3, 2003
Freeport, ME
Phone: (207) 729-6569
Fax: (207) 725-1497
www.mainerwa.org

**National Groundwater Association**
**Annual Conference**
December 9–12, 2003
Orlando, FL
Contact: Kathy Butcher
Phone: (800) 551-7379
Fax: (614) 898-7786
www.ngwa.org

**JANUARY 2004**

**Water Sources Conference & Exposition**
**American Water Works Association and Water Environment Federation**
January 11–15, 2004
Hilton Austin Hotel
Austin, TX
Phone: (800) 926-7337
Fax: (303) 347-0804
www.awwa.org/conferences

**South Dakota Association of Rural Water Systems Annual Conference**
**Rural Water: Liquid Gold**
January 13–15, 2004
Ramkota Inn
Pierre, SD
Contact: Kristie Johanson
Phone: (605) 336-7219
Fax: (605) 836-1491
www.sdawrs.com

**4th National Conference on Science, Policy and the Environment “Water for a Sustainable and Secure Future”**
January 29–30, 2004
Ronald Reagan Building and International Trade Center
Washington, DC
Contact: Theresa Cluck
Phone: (202) 530-5810
Fax: (202) 628-4311
www.ncseonline.org

**FEBRUARY**

**Delaware Rural Water Association**
**Annual Conference**
February 25–26, 2004
Delaware State Fair Grounds
Harrington, DE
Contact: Pat Kucek
Phone: (302) 424-3792
Fax: (302) 424-3790
www.dwra.org

**MARCH**

**WEF/ AWWA Joint Management Conference**
March 14–17, 2004
Sheraton San Marcos Resort and Conference Center
Phoenix (Chandler), AZ
Phone: (800) 666-0206
Fax: (303) 347-0804
www.wef.org/conferences

**Virginia Rural Water Association’s 16th Annual Conference and Exposition**
March 15–17, 2004
Holiday Inn Select-Koger Center
Richmond, Virginia
Contact: Myrica Keiser
Phone: (800) 582-7476 or (540) 261-7178
Fax: (540) 261-2465
www.vrwa.org

**Pennsylvania Rural Water Association**
**2004 Annual Conference**
March 23–26, 2004
The Penn Stater Conference Center and Hotel
State College, PA
Contact: Sharon Birchard
Phone: (814) 353-9302
Fax: (814) 353-9341
www.prwa.org

**Michigan Rural Water Association**
**2004 Annual Management & Technical Conference**
March 30–April 1, 2004
Grand Rapids, MI
Contact: Tim Neumann
Phone: (989) 539-4111
Fax: (989) 539-4055
E-mail: mrwa@chartermi.net

For a complete calendar listing go to www.nesc.wvu.edu/ndwc/ndwc_calendar.htm.
**Think Before You Flush That Pill**

We used to think the best way to dispose of old or leftover medicine was to flush it down the toilet. That way kids and animals wouldn’t come in contact with it and inadvertently become poisoned. But that’s not true anymore, and environmental scientists are warning people, “Do not flush.”

Antibiotics, hormones, painkillers, antidepressants, and an array of other medications are now finding their way into the nation’s waterways—raising disturbing questions about potential health and environmental effects, according to the *Associated Press* article, “Flushing Expired Drugs No Longer Recommended.”

Besides individuals who flush prescriptions, nursing homes dispose of anywhere between $73 million and $378 million worth of drugs each year. Some are incinerated, but many are just flushed.

The U.S. Environmental Protection Agency (EPA) is studying whether to develop formal recommendations for what to do with old or leftover drugs. “The age-old wisdom of flushing medication down the toilet is probably the least desirable of the alternatives,” says Christian Daughton of EPA’s Las Vegas laboratory.

Long-term effects of these drugs aren’t known, but environmental scientists worry that exposure to even tiny amounts might cause harm, at least to the ecology.

Studies have linked hormone exposure to reproductive side effects in fish (see the article in *On Tap*, Winter 2003, “They’re in the water. They make fish change sex. Endocrine Disruptors. What are they doing to you?”) Scientists also worry about environmental exposure to antibiotics because they fear microbes may become drug resistant and eventually become “super germs.”

The Food and Drug Administration (FDA) is reevaluating its policy about labeling drugs with instructions for disposal. In addition, some states are working to allow nursing homes to donate medications to indigent patients, as long they weren’t opened or tampered with in any way. Until there’s labeling, though, environmental experts offer this advice:

- Take all of a prescribed medication unless there’s a good reason not to, such as a bad side effect.
- Trash is better than the toilet. Take proper precautions against children or pets accidentally ingesting them, such as breaking up capsules and crushing tablets and then putting the remains back in the original container. Tape the container, and then double bag it before tossing.
- Check to see if there’s a local household hazardous waste collection site that will take old prescription drugs.
- The FDA suggests asking pharmacies to take old medication back.

**RUS Loans: Poverty Rate Unchanged; Others Up**

The Rural Utilities Service (RUS) announced interest rates for water and wastewater loans. RUS interest rates are issued quarterly at three different levels: the poverty line rate, the intermediate rate, and the market rate.

The rates, which apply to all loans issued from October 1 through December 31, 2003, are:

- **Poverty line** 4.5 percent (unchanged from the previous quarter);
- **Intermediate** 4.75 percent (up 0.375 percent from the previous quarter); and
- **Market** 5.0 percent (up 0.75 percent from the previous quarter).

RUS loans are administered through state Rural Development offices, which can provide specific information concerning RUS loan requirements and applications procedures.

For the phone number of your state Rural Development office, contact the National Drinking Water Clearinghouse at (800) 624-8301 or (304) 293-4191. The list is also available on the RUS Web site at www.usda.gov/rus/water/states/usamap.htm.
Nitrate in drinking water is associated with an increased risk for bladder cancer, according to a University of Iowa (UI) study that looked at cancer incidence among nearly 22,000 Iowa women.

The study results suggest that even low-level exposure to nitrates over many years could cause increases in certain types of cancer, said Peter Weyer, Ph.D., associate director of the UI Center for Health Effects of Environmental Contamination (CHEEC) and one of the study’s lead authors. The study was published in the May 2001 issue of the journal *Epidemiology*.

“The positive association we found between nitrate contamination in drinking water and bladder cancer is consistent with some previous data. However, this is something that warrants follow-up research,” said Weyer, who co-authored the article with James R. Cerhan, M.D., Ph.D., an investigator with the department of health sciences research at the Mayo Clinic in Rochester, Minnesota.

The researchers assessed nitrate exposure from drinking water in 21,977 women who were participants in the Iowa Women’s Health Study. The women, who were between 55 and 69 years old in 1986 (at the start of the study) resided in a total of 400 Iowa communities and had used the same drinking water supply for more than 10 years. Approximately 16,500 of the women received their water from municipal water supplies; the remaining women used private wells.

Because no individual water consumption data were available, the researchers assigned each woman an average level of exposure to nitrate based on data collected between 1955 to 1988 on nitrate levels in her community’s water supply. No nitrate data were available about women using private wells.

Using cancer incidence data from the Iowa Cancer Registry for 1986 to 1998, and after adjusting for factors such as smoking and nitrate in the diet, the researchers found a greater risk for bladder cancer as the nitrate levels in the community’s water supplies increased. Women whose average drinking water nitrate exposure level was greater than 2.46 milligrams (mg) per liter (nitrate-nitrogen) were 2.83 times more likely to develop bladder cancer than women in the lowest nitrate exposure level (less than 0.36 mg per liter).

Nitrate is produced naturally within the body, environmental sources include food (including many vegetables), contaminated drinking water, cigarette smoking, and certain medications. Drinking water can account for a substantial proportion of the total nitrate intake. Up to 20 percent of ingested nitrate is transformed in the body to nitrite, which can then undergo transformation in the stomach, colon and bladder to form N-nitroso compounds. These compounds are known to cause cancer in a variety of organs in more than 40 animal species, including higher primates.

“The U.S. Environmental Protection Agency drinking water standard is 10 mg per liter nitrate-nitrogen. Our study suggests that nitrate levels much less than that could be a serious health concern,” Weyer said.

Weyer emphasized that additional studies are needed to look at possible links between nitrate levels in drinking water and cancer, particularly with respect to refining exposure assessments.

“From a public health perspective, source water protection is a main concern. Sources of nitrate which can impact water supplies include fertilizers, human waste, and animal waste,” he said. “All of us, rural and urban residents alike, need to be more aware of how what we do as individuals can impact our water sources and, potentially, our health.”

For more information about this study, e-mail ellenr@nitrate.com or call (888) NITRATE (1-888-648-7283).

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**Need answers to your drinking water questions?**

The National Drinking Water Clearinghouse’s (NDWC) technical assistance specialists are available to answer questions about drinking water issues such as regulatory requirements, water quality problems, funding sources, and water system troubleshooting.

If you have a drinking water-related question and don’t know where to turn, call the NDWC at (800) 624-8301 or (304) 293-4191 and select option “4” to speak with a drinking water technical specialist.
**Water Peace or Water War**

After seven years of negotiations, tentative pacts, broken deals, bitter denunciations and a federal water cutback, four giant Southern California water agencies finally have a plan that can lead to peace on the Colorado River, protect the Salton Sea and give San Diego a measure of water independence.

The California and federal governments support the agreement. So do the other six Colorado River Basin states. The California Legislature has passed the implementing bills with rare unanimity and dispatch.

All that remains is formal approval by the water district boards: the Imperial Irrigation District, a giant farming area in Imperial County; the San Diego County Water Authority, the wholesaler to districts throughout its county; the Metropolitan Water District of Southern California, wholesaler to six area counties; and the Coachella Valley Water District, serving Riverside County farms and cities. They should seal the deal quickly.

The plan allows California to continue to take surplus water from the Colorado River, when it is available, for the next 12 years. This would enable the state to gradually wean itself from the water it has been taking in excess of its legal entitlement, 4.4 million acre-feet a year. One acre-foot provides the annual needs of two households.

Finally settled is how California’s Colorado River allotment would be divided among Imperial, Coachella and Metropolitan. This has been an unsettled and disrupting issue since the 1930s. Metropolitan would gain access to some Imperial water, thus reducing its need to seek additional supplies from Northern California.

San Diego would receive up to 200,000 acre-feet a year from Imperial in the largest farm-to-city water trade ever. Currently, San Diego is all but totally reliant on Metropolitan. In a severe drought, San Diego’s portion could be cut back to preserve supplies for other, more senior Metropolitan customers.

The new plan ingeniously provides environmental protection for the Salton Sea, which relies on Imperial Valley irrigation runoff to prevent a fatal buildup of salt. The cost of Salton Sea restoration, to both the state and the agencies, killed an earlier agreement. The new plan provides for Imperial to sell an additional block of conserved farm water to the state, which would then resell the water at a profit to Metropolitan. The estimated $300 million would go to the Salton Sea rescue program.

Davis and his chief negotiator, Richard Katz, should get credit for insisting for months that talks continue until agreement was reached. The four agencies have agreed to act by October 12th. Metropolitan ratified the pact Tuesday. The only question mark is Imperial, set to vote on the plan October 7th.

This deal is as good as it’s going to get for all the parties and for the state as a whole. With it comes water peace. Without it, endless water war — in the courts and elsewhere.

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**New Jersey DHSS Releases Radium Report**

The New Jersey Department of Health and Senior Services (DHSS) conducted a study that shows an association between elevated levels of radium in drinking water and a rare type of bone cancer. Previous studies in Ontario, Illinois, Iowa, and Wisconsin also found a connection between osteosarcoma and radium in drinking water.

Radium is a naturally occurring radioactive element found in groundwater throughout the U.S., including New Jersey. The federal government has established maximum contamination levels for radiological contamination. New Jersey has been monitoring and testing water supplies for many years, requiring water systems to undertake remediation efforts if they exceed the standards.

The body absorbs radium and deposits it in bones, where it can cause osteosarcoma if a person is exposed over a long period of time. Osteosarcoma occurs in an average of three people per million annually in New Jersey.

The study showed that males in parts of central and southern New Jersey, where radium concentrations exceeded federal standards, had a three-fold higher risk of developing osteosarcoma. The risk was highest in men age 25 and over. Researchers did not find an increased risk among females. (Genetic susceptibility may contribute to up to half of all osteosarcomas, and exposure to certain medical treatments also may cause the cancer.)

New Jersey’s study, based on the nation’s most complete measurement of all types of radium contributing to an individual’s overall natural exposure, reviewed 75 cases of osteosarcoma diagnosed from 1979–1998 and water test results from 1997–2000. Researchers used data from community water system surveys conducted by the New Jersey Department of Environmental Protection and the U.S. Geological Survey. They examined 117 community water systems and subsystems serving 1.4 million people in 10 counties, where they found that 17 of the systems exceeded drinking water standards for radiological contamination.

To view a copy of the report, please visit the department Web site at www.nj.gov/health/ eoh/radium.pdf.
The condition of our nation’s roads, bridges, drinking water systems, and other public works have shown little improvement since they received a D+ in 2001, and some areas are sliding toward failing grades, concluded the American Society of Civil Engineers (ASCE) in their 2003 Progress Report for America’s Infrastructure.

The report examines trends and assesses progress and decline of America’s infrastructure, including roads, bridges, mass transit, aviation, schools, drinking water, wastewater, dams, solid waste, hazardous waste, navigable waterways, and energy. In 2001, ASCE engineers released the Report Card for America’s Infrastructure, grading the same 12 infrastructure categories at a discouraging D+ overall and estimating the need for a $1.3 trillion investment to bring conditions to acceptable levels.

“Time is working against our nation’s infrastructure,” said ASCE President Thomas L. Jackson, P.E. “Since we graded the infrastructure in 2001, our roads are more congested than ever, the number of unsafe and hazardous dams has increased, and our schools are unable to accommodate the mandated reductions in class size.

“While millions of Americans struggled to live without electricity for three days, millions more are still in the dark about the shaky state of our nation’s infrastructure. Our transportation, water, and energy systems haven’t been maintained, let alone updated, to supply our every-increasing demands,” said Jackson.

“Americans’ concerns about security threats are real, but so are the threats posed by crumbling infrastructure,” he continued. “It doesn’t matter if the dam fails because cracks have never been repaired or if it fails at the hands of a terrorist. The towns below the dam will still be devastated.”

In 2001, the estimated cost for infrastructure renewal was $1.3 trillion over a five-year period. Today, that cost has risen to $1.6 trillion over a five-year period. The forecast for the trends detailed in the 2003 Progress Report was based on condition and performance of each infrastructure category as reported by federal sources, capacity of infrastructure versus need, and current and pending investment of state, local, and federal funding for infrastructure versus need.

For more information, including local infrastructure conditions and state infrastructure statistics, visit ASCE’s Web site at www.asce.org/reportcard.

Federal Funding Sources Catalog Available

The Catalog of Federal Funding Sources for Watershed Protection Web site is a searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund watershed protection projects. To select funding programs for particular requirements, use either of two searches: One is based on subject matter criteria, and the other is based on words in the title of the funding program.

Criteria searches include the type of organization (e.g., non-profit groups, private landowners, states, businesses), type of assistance sought (grants or loans), and keywords (e.g., agriculture, wildlife habitat).

Searches result in a listing of programs by name. Click on each program name to review detailed information on the funding source.

For more information about this catalog, visit the Web site at cfpub.epa.gov/fedfund.

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(Please note that this message must be in the body of the e-mail and not in the subject line or the server won’t recognize it.)
World Bank: Water Is the New Middle East Crisis

The water shortage problem is close to crisis levels in most countries of the Middle East and North Africa (MENA) region, a senior World Bank official warned in a Yahoo News article (Yahoo News is an Internet news service.)

“Fresh water availability is falling to crisis levels in MENA countries,” said Jean-Louis Sarbib, senior vice president of the World Bank, speaking at a conference at the annual World Bank and International Monetary Fund meetings in Dubai.

Annual per capita fresh water availability in MENA countries is about 1,200 cubic meters compared with a world average of about 7,000 to 7,500 cubic meters, according to Sarbib.

He said the figure for Yemen is about 500 cubic meters, almost half the water poverty line of 1,000 cubic meters.

Sarbib said nearly 70 percent of municipal water in cities like Amman goes unaccounted for, while Egypt recovers only two percent of its irrigation costs.

Hazim el-Naser, Jordan’s minister of water and irrigation, said the problem lies in the fact that many countries in the region have “no long-term vision” regarding the water issue.

Although the MENA region accounts for five percent of the world population, it has only one percent of accessible fresh water worldwide, according to the World Bank.

They’ve made the politically charged issue of scarce water resources one of its “millennium development goals.”

Newly Discovered Bacteria Eats Arsenic

Some newly discovered Australian bacteria have a strange appetite: They like arsenic. An Australian research group led by Joanne Santini of La Trobe University is working on how to use bacteria that eat arsenic to clean up contaminated wastewater in Australia, overseas mining environments, and drinking water wells in Bangladesh and West Bengal in India.

Santini presented her research at Fresh Science, a British Council-sponsored program that highlights the achievements of Australian scientists who are beginning their careers.

“If the iron guts of bacteria that can eat arsenic without dying could be harnessed to process this waste, less damage would be done to the environment and hopefully, one day, fewer people on the subcontinent will get sick,” Santini said.

Arsenic occurs naturally in rocks and, in this form, is harmless. But when exposed to air and water, it becomes soluble and toxic to plants, animals, and humans. Mining and boring rock for drinking wells can expose the arsenic and turn it into two toxic forms: arsenate and arsenite.

Arsenate is easy and safe to get rid of. But arsenite is not. Santini hopes arsenite can be removed by the use of arsenite-eating bacteria on a mass scale.

Santini and her students are studying 13 rare bacteria that were isolated from gold mines in the Northern Territory and Bendigo, Victoria. One bacterium, NT-26, is an arsenite-munching champion. It eats arsenite and excretes arsenate, which is a form of arsenic that’s easy to treat.

Theoretically, she says, it is cheaper and safer to use bacteria to clean up the environmental mess than chemical methods using chlorine or hydrogen peroxide.

Santini’s group has found the enzyme directly responsible for converting arsenite to arsenate. The group is now working to identify the same enzyme in other microbes and hunting for other proteins and genes involved in eating arsenite.

Santini, however, reminds us that to understand how these microbes work, they must be closely scrutinized. “We can’t just plonk them into a biological reactor and hope for the best,” she said.

For more information about this research, contact Santini at 03-9479 2206, or email her at j.santini@latrobe.edu.au.
**Ground Water Protection Council**  
www.gwpc.org

The Ground Water Protection Council (GWPC) is a national association of state groundwater and underground injection control agencies whose mission is to promote groundwater protection and conservation. Further, the council recognizes groundwater as a critical component of the ecosystem. GWPC provides a forum for stakeholder communication and research to improve governments’ role in groundwater protection and conservation.

For more information, visit their Web site at www.gwpc.org. You also may write to them at Ground Water Protection Council, 13308 N. MacArthur, Oklahoma City, OK 73142. Or call (405) 516-4972. E-mail them at dan@gwpc.org.

**Karst Waters Institute**  
www.karstwaters.org

The Karst Waters Institute (KWI) is a 501 (c)(3) nonprofit institution whose mission is to improve the fundamental understanding of karst water systems through scientific research and the education of professionals and the public. Institute activities include initiating, coordinating, and conducting research, sponsoring conferences and workshops, and occasionally publishing scientific works. By acting as a coordinating agency for funding and personnel, KWI supports these activities but does not supply direct funding or grants to individual researchers.

For more information, visit the KWI’s Web site at www.karstwaters.org. You also may write to them at Karst Waters Institute, P.O. Box 537, Charles Town, WV 25414, or call (304) 725-1211.

**Groundwater Foundation Informs the Public**  
www.groundwater.org

The Groundwater Foundation is a nonprofit organization that is dedicated to informing the public about one of our greatest hidden resources, groundwater. Since 1985, the foundation’s programs and publications present the benefits everyone receives from groundwater and the risks that threaten groundwater quality. The foundation makes learning about groundwater fun and understandable for kids and adults alike.

For more information about the Groundwater Foundation, visit their Web site at www.groundwater.org. You also may write to them at The Groundwater Foundation, P.O. Box 22558, Lincoln, NE 68542-22558. Or call them at (800) 858-4844. E-mail them at info@groundwater.org.

**NGWA Delivers Groundwater Information**  
www.ngwa.org

The National Ground Water Association (NGWA) is headquartered in Westerville, Ohio, and has groundwater experts from a variety of fields, such as geologists and hydrologists, engineers, groundwater contractors, manufacturers, and suppliers of groundwater-related products and services.

The organization’s purpose is to provide guidance to members, government representatives, and the public for scientific, economic, and beneficial development, protection, and management of the world’s groundwater resources.

NGWA hosts educational courses and conferences on cutting-edge technology throughout the U.S. They also publish three national publications, Water Well Journal, Ground Water Monitoring & Remediation, and Ground Water.

They also conduct two annual series of lectures: the Darcy Hydrogeology Lecture Series and the McEllhiney Distinguished Lecture Series in Water Well Technology. NGWA also maintains Ground Water On-Line, a database containing more than 87,000 groundwater literature citations.

For more information, visit NGWA’s Web site at www.ngwa.org. You also may write to them at NGWA, 601 Dempsey Road, Westerville, OH 43081-8978. Or call them at (800) 551-7379 or (614) 898-7791. E-mail them at ngwa@ngwa.org.
National Council for Science and the Environment
NCSEonline.org

The National Council for Science and the Environment (NCSE) has been working since 1990 to improve the scientific basis for environmental decision making. More than 500 academic, scientific, environmental, and business organizations, as well as federal, state, and local governments support the council. To achieve its goals, the council works closely with many communities that create and use environmental knowledge to make and shape environmental decisions. The council focuses on the role of science but does not take positions on environmental issues themselves.

The council:
• promotes science for the environment;
• enhances programs at academic institutions;
• catalyzes and advances science-based ideas from diverse communities;
• communicates science-based information to society; and
• develops science solutions for environmental challenges.

For more information about the council, visit their Web site at NCSEonline.org. You also may write to them at National Council for Science and the Environment, 1707 H Street N.W., Suite 200, Washington, DC 20006-3918 or call 202-530-5810. E-mail also is available at info@NCSEonline.org.

Groundwater Central©
www.groundwatercentral.info

Groundwater Central© is a free portal for Internet-based groundwater information. The search engine provides a one-stop shop to browse a wide variety of information from online publications and bibliographies, to case studies, data repositories, vendors, and announcements for events. Links send users to pages and/or downloadable files from a variety of relevant Web sites.

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  2. Groundwater Central© News e-mail notices
• Ask An Expert
• Profile Registration

For more information about the center, visit their Web site at www.groundwatercentral.info. You also may e-mail them at admin@groundwatercentral.info.

There’s always room for improvement.

Do you have a suggestion for improving this magazine or an idea for an article? Do you have a question for our “Ask the Experts” column or a Web site that you find helpful? The On Tap editors are always eager to learn something new from you. Here’s how to get a hold of us:

Mark Kemp-Rye, e-mail: mkemp@wvu.edu
phone: (800) 624-8301 ext. 5523

Kathy Jesperson, e-mail: kjespers@wvu.edu
phone: (800) 624-8301 ext. 5533

Or write to us at:
National Drinking Water Clearinghouse
West Virginia University
P.O. Box 6064
Morgantown WV 26506-6064
What groundwater contaminants or other groundwater problems does your community or system encounter? What are the solutions?

Handle Each Situation Differently

Peninsula Light Company owns or manages more than 90 very small water systems. In our service area, we have not experienced primary groundwater contamination, although other areas of the state have experienced nitrate, arsenic, and radionuclides that exceed the maximum contaminant levels. Our primary water quality concerns are:

1. iron and/or manganese exceeding the secondary contaminant standard,
2. hydrogen sulfide odor complaints,
3. potential risk for salt water intrusion, and
4. sanding or sediment problems from wells not being properly developed or pumping capacities being overstated.

We have handled each of these situations differently depending upon customer desires, resources available, and/or degree of the problem.

For iron and manganese, we may or may not provide treatment. If we are fortunate enough to have more than one source, we can blend or set pumping schedules to provide the best water quality possible. Treatment can be provided, but due to resource limitations, as a policy it is only provided to systems that are willing to pay for the true cost of operation and maintenance, not just capital investment costs. Our policy is consistent with the state's.

Hydrogen sulfide can be handled by proper aeration at a storage facility. Unfortunately, many of our systems do not have adequate storage. Chlorination is used with a slight benefit. When we get calls in the winter we can flush lines with some improvement. When we get calls in the summer on one of our systems with storage, it's because there is less retention time and flushing only exacerbates the problem.

There are systems in our area that have salt-water intrusion problems. We have a few systems more at risk that we have an increased monitoring requirement for chlorides. The system with the most at-risk well has two wells, so pumping at the one has been restricted to only what is needed for system capacity, and chlorides are checked on a quarterly basis.

Sanding problems, which not only result in complaints from customers, but can affect the pump's useful life, affect a couple of the systems we have acquired. One new system we elected not to acquire because they would not install storage and reduce pump capacity. Another new system agreed to the added cost of storage and reduced pump capacity. And another small system we own said we could reduce the pump capacity because of storage that we added. We've also installed sand filters. It’s much more expensive to go back and retrofit or redevelop wells.

The later two problems (salt water and sanding) are also more manageable when customers are metered and conservation is encouraged.

A Different Twist on Groundwater

I would like to propose a different twist on this question. I am guessing that most will respond in the area of contaminants, treatment, and such. That is great, and they certainly deserves discussing.

I might suggest that we look into the issue of the actual availability of water. Having just moved to Colorado, I am finding out that this is becoming a very serious issue for the western states and possibly all across the country. The big issues are:

1. Water rights
2. Water augmentation
3. Who owns “what you can’t see,” i.e., groundwater?
Conduct a Detailed Study

Wellhead protection (source water protection) is an attempt to prevent contamination by controlling land uses in the general area above the well. Imposing wellhead protection after the well has become contaminated is not a viable solution.

If the well already is contaminated, you need to conduct a fairly detailed hydrogeologic and hydrochemical investigation. The objectives of the study would be to:

1. develop a conceptual model of the subsurface geology that includes identifying the aquifers, confining layers, direction of groundwater flow, and likely recharge areas;
2. gain a detailed understanding of the contaminant found in the well including the time it was detected and concentration levels over time;
3. use knowledge of the contaminant with knowledge of the aquifer to identify potential contaminant sources and flow patterns and long-term fate of the well/aquifer system; and
4. develop a plan for remediation of the well and aquifer or abandonment of the well and development of an alternative water supply source.

4. Is groundwater really a renewable resource?
5. And if so, is it being used faster than it is being renewed?

In the old days in this country, they used to hang people for stealing horses and cattle. The attitude these days seems to be: “I’m not worried about my horses or my cattle, but if you take my water—get a rope!”

The availability of water may be the real demise of the small system. In theory, there is a treatment technology available for any contaminant; it may be expensive but the problem can be treated. However, if the groundwater is just not available, you have no option but to close your doors.

Another area is to delve into things like global warming and changing weather patterns and how that may be impacting aquifer recharge areas.

I hope I have given you a flavor for what the issues might be. And as I said, I am just beginning to learn about this.

Rod Coker
Tribal Utility Consultant (retired)
Indian Health Service

On Tap

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Ike Dixon and Junior Dilsworth who work for Three-D Drilling Company of Kingwood, West Virginia, drill a well in Albright, West Virginia.

By Kathy Jesperson • On Tap Editor
One of our most valuable resources is right beneath our feet, and we can’t even see it. The old adage “out of sight, out of mind” certainly applies to groundwater.

Despite its being buried beneath the ground, people have known about groundwater since ancient times. In the Bible, for example, “Exodus,” refers to water and wells several times and specifically discusses “water under the Earth.”

Other historic scripts also reveal that ancient humans had knowledge of groundwater, and they knew they had to dig wells to be able to use it. But even though we know it’s there, it has only been within recent times that scientists have learned to estimate how much groundwater there is.

It’s All in Storage

“An estimated one million cubic miles of the world’s groundwater is stored within one-half mile of land surface,” says the U.S. Geological Survey (USGS). “Only a fraction of this groundwater reservoir, however, can be practically tapped and made available on a perennial basis through wells and springs. The amount of groundwater in storage is more than 30 times greater than the nearly 30,000 cubic miles in volume in all the fresh water lakes and more than the 300 cubic miles of water in all the world’s streams at any given time.”

Groundwater is stored in geological formations called aquifers. Aquifer means “water bearer.” It refers to “saturated permeable rocks of a geologic formation, group of formations, or part of a formation that is water bearing,” notes the Texas Natural Resources Conservation Commission (TNRCC). The commission also says that, “to be an aquifer, the water-bearing formation should yield water in sufficient quantities to provide a usable supply; otherwise the formation will have a different name.”

While aquifers are typically classified as confined and unconfined, they can be broken down into even smaller group types. According to USGS, “the principal water-yielding aquifers in North America can be grouped into six types:

- unconsolidated sand and gravel,
- semi-consolidated sand,
- sandstone,
- carbonate-rock,
- interbedded sandstone and carbonate-rock, and
- basalt and other types of volcanic rocks.”

Gravity Makes It Move

When people attempt to visualize groundwater, most of the time they picture it flowing in large underground rivers or lakes. But that’s not quite true. While it’s hard to imagine exactly what it looks like “down there,” groundwater is simply water that’s underground, saturating the pores or cracks in soil and rocks.

Groundwater normally flows in the direction of the general topography of the land surface because gravity is the main force acting on it. So, groundwater typically flows downhill toward rivers and lakes at the bottom of valleys. In addition, groundwater must make its way through small spaces between rocks. Therefore, groundwater moves very slowly.

How slowly does it go? Groundwater usually moves inches per day, whereas rivers move more swiftly—feet per second (ft/sec). In sandy soils, however, groundwater moves a bit more quickly, between one to five feet per day. Even at this rate, groundwater and substances dissolved in it may take five years to travel about one mile. In comparison, a small twig moving downstream in a river at one to two ft/sec would only take an hour to travel one mile.

Why do small systems rely on groundwater?

Perhaps groundwater’s availability is why the lion’s share of small drinking water systems obtain their water from wells. According to the U.S. Environmental Protection Agency (EPA), approximately 80 percent of all community water systems are groundwater systems. The agency also notes that “Larger systems are more likely than smaller systems to use surface water as their primary source; most small systems use groundwater.”

Community Well Funding

Does your community need a new well? Are you looking for a way to finance the project?

As with most drinking water projects, the primary funding sources for community wells are Rural Utilities Services (RUS) loans and grants and the U.S. Environmental Protection Agency’s (EPA) drinking water state revolving loan fund (DWSRF). Other sources, such as community development block grant money and state programs, may be available, too. (See “Besides SRF and RUS funding, what are some alternatives?” in the Winter 2003 On Tap for more information about water infrastructure financing.)

Community wells may also be funded from two programs not typically used in drinking water projects: the clean water state revolving loan fund (CWSRF), most often used for wastewater treatment, and the Superfund program, both overseen by EPA.

Although primarily used for wellhead protection, the CWSRF is sometimes used for community wells and drinking water protection. If your community’s wells have been contaminated by industrial waste, the Superfund offers a potential way to pay for new ones.

Call the National Drinking Water Clearinghouse at (800) 624-8301 or e-mail ndwc_contact@mail.nesc.wvu.edu to obtain contact information about your state’s RUS, DWSRF, CWSRF, Wellhead Protection, or Superfund coordinator.

www.ndwc.wvu.edu
Precipitation replenishes groundwater. Depending upon the local climate and geology, groundwater also is unevenly distributed in quantity and quality. When rain falls or snow melts, not all of the water flows into streams or filters through the ground. Plants use some of that water, and some of it evaporates before it makes its way into streams or the ground. Because of this and how slowly groundwater moves, it can literally take years to replenish depleted reserves.

**Confined and Unconfined Aquifers**

A confined aquifer (sometimes called an artesian aquifer) is the saturated formation between low permeability layers, such as bedrock, that restrict movement of water vertically (meaning it cannot seep through the ground) into or out of the saturated formation. In other words, this area is drenched, contained, and pressurized.

Drilling a well into this type of aquifer is analogous to puncturing a pressurized pipeline. In some areas, confined aquifers produce water without pumps and are commonly known as flowing artesian wells. When pumping from confined aquifers, water levels often change rapidly over large areas. However, water levels will generally recover to normal when pumping ceases.

An unconfined aquifer (also called a water-table aquifer) is the saturated formation in which the upper surface fluctuates by adding or subtracting water. The upper surface of an unconfined aquifer is called the water table. Water held in an unconfined aquifer is free to move laterally in response to differences in the water table elevations.

**Other Groundwater Basics**

Between the land surface and the aquifer is a zone that hydrologists call the unsaturated zone. In this zone, a little water exists, but it’s mostly in the smaller openings of soil and rocks. Larger openings usually contain air. Molecular attraction holds some water in the unsaturated zone, but it will not flow toward or enter a well. Any excess water will enter the water table.

Below the water table, all of the openings in rocks are full of water that moves through the aquifer to streams, springs, or wells. Natural refilling of an aquifer is a slow process. For example, geologists have estimated that if the aquifer that underlies the High Plains of Texas and New Mexico were drained completely dry, it would take thousands of years to replenish. (See the article “When Enough is Enough: Sustainable Development” in the Summer 2003 On Tap.)

**What is not an aquifer?**

If a water-bearing formation is not an aquifer, what is it? These formations are called aquitards or aquicludes. While they may contain water, they are not aquifers, says USGS.

An aquitard hinders groundwater flow. “Aquitards are semi-permeable, semi-confining geologic formations adjacent to or between aquifers that partially restrict the movement of groundwater,” says the TNRCC.

For example, clay deposits generally tend to be confining layers. But, if that clay layer contains sand, it may distinguish it as a leaky aquitard. This means that aquitards not only restrict groundwater movement, they also can leak.

An aquiclude prohibits groundwater flow. In vicinities where clay is thick, widespread, and unfractured, it is called an aquiclude. Aquicludes are also known as confining or impermeable layers. They are generally an impervious barrier to groundwater movement and act as a confining layer to the aquifer. However, clay layers can store a considerable quantity of groundwater; it’s just very difficult to retrieve.

Groundwater is everywhere. It may be only a few feet down or buried several hundred feet below ground, but it’s there. And, by a number of accounts, we’ve known of its existence for a long time. Since we know it’s there, we should take care of it.

For more information about groundwater, visit the U.S. Geological Survey’s Web site at www.usgs.gov. Additional information also may be found on the University of Kansas’ Web site www.kgs.ukans.edu/HighPlains/atlas/apdrdwn.htm. The National Ground Water Association has a wealth of information about groundwater on their Web site as well at www.ngwa.org.

On Tap Editor Kathy Jesperson has begun to work toward a masters in public health. She hopes to finish the degree in the next three years.
No one questions whether surface water sources are contaminated. We wouldn’t go down to the local waterway, dip our cups in, and take a big drink—there’s no telling what’s in there, right? But we will drink water that comes directly from a well. Why is that? Largely because we think that groundwater that has been filtered through the soil has become safe to drink, and we don’t give it much more thought than that.

Until recently, this view may have been mostly true. But now groundwater investigators have found contaminants in groundwater supplies, such as industrial and municipal wastes; leaking sewer or septic tank effluent; animal feedlot runoff; and lawn and crop fertilizers, pesticides, and herbicides.

A well can be contaminated easily if it is not properly constructed or if toxic materials are released into the well. Toxic material spilled or dumped near a well can leach into the aquifer and contaminate the groundwater drawn from that well. Contaminated wells used for drinking water are especially dangerous. Wells can be tested to see what chemicals may be in the well and if they are present in dangerous quantities.
These are some nasty contaminants that can have some equally nasty health effects. The health effects of microbial contaminants are generally immediate, leading to diarrhea, nausea, and vomiting. But the health effects of some chemical contaminants won't be apparent for a long time and could lead to cancer.

**Health Relies on Clean Sources**

We depend upon environmental engineers, public health officials, and regulators to figure out how to remove contaminants from groundwater. But removing contaminants from groundwater is a bit trickier than removing them from surface water. Surface water is pumped from the source, such as a river, lake, or stream, to a treatment plant, where it's made safe to drink.

And, yes, we probably could build treatment plants to treat groundwater sources, and many are likely already in place. But this solution only solves part of the problem. It still leaves pollutants in the ground and the groundwater that may compromise the ecosystem.

**Remediation Can Improve Quality**

Remediation techniques can improve the quality of groundwater, and many approaches already exist or are being developed.

For years, groundwater remediation usually meant the pump and treat method. This approach applies well-established wastewater treatment to groundwater remediation.

Using the pump and treat method, contaminated groundwater is pumped from the ground to a treatment plant on the surface. This method has the advantage of using proven techniques and is easy to control. The treated groundwater can be reinjected into the ground or discharged into rivers or lakes.

The main disadvantages are that it disturbs the routine way that groundwater flows, and it requires steady energy and other inputs. In addition, it doesn't work so well with some slowly secreted contaminants, such as polyaromatic hydrocarbons (PAHs).

In recent years, groundwater remediation techniques have improved. According to the Ground Water Remediation Technologies Analysis Center, a nonprofit organization that evaluates novel remediation technologies, there are a number of innovative ways to rehabilitate your well.

**Innovative Methods Can Rehabilitate Wells**

**Air sparging** involves injecting gas (usually air or oxygen) that's under pressure into well(s) installed within the saturated zone to volatilize (break apart) contaminants dissolved in groundwater.

**Blast-enhanced fracturing** creates “fracture trenches” or highly fractured areas through detonation of explosives in boreholes (shotheoles). This technique is used at sites with fractured bedrock formations to improve the recovery rate and predictability of contaminated groundwater.

**Directional wells** are especially useful when a contaminant plume covers a large area and has linear geometry, or when surface obstructions are present. This technology uses horizontal wells. Trenched or directly drilled wells also are installed to use for groundwater monitoring or remediation.

**Groundwater recirculation wells** involve creating a groundwater circulation “cell.” Injecting air or inert gas into a zone of contaminated groundwater creates an airlift pumping system that causes groundwater to rise and break up volatile contaminants. Groundwater is recirculated through a stripping well until remediation goals are met. This application works best for volatile organic contaminants, but modifying the basic process could make the application acceptable for semi-volatile organic compounds, pesticides, and inorganics.
Hydraulic and pneumatic fracturing techniques create enhanced fracture networks to increase soil permeability to liquids and vapors and accelerate contaminant removal. The techniques are especially useful for vapor extraction, biodegradation, and thermal treatments and work best in unconsolidated sediments or bedrock.

**In Situ flushing** is also known as injection/recirculation or *in situ* (in place) soil washing. This method requires injecting or infiltrating a remediation solution into contaminated soil/groundwater. The solution is then extracted below the area where the solution was injected. The groundwater may be further treated and possibly reinjected back into the aquifer. This flushing method works best in moderate to high permeability soils. It may be used for a variety of organic contaminants, including nonaqueous phase liquid and inorganic contaminants.

**In Situ stabilization/solidification** is also known as *in situ* fixation or immobilization. It involves injecting or infiltrating stabilizing agents into contaminated soil or groundwater. The process changes organic or inorganic contaminants to a harmless or immobile state. Contaminants are physically bound or enclosed within a stabilized mass or their mobility is reduced through chemical reaction. This process works best for moderate to high permeability soils and may be used for a variety of organic and inorganic contaminants.

**Permeable reactive barriers** include passive barriers, passive treatment walls, treatment walls, or trenches. An in-ground trench is backfilled with reactive media to provide passive treatment of contaminated soil or groundwater. The trench is placed at a strategic location to intercept the contaminant plume and backfilled with media, such as zero-valent iron, microorganisms, zeolite, activated carbon, peat, bentonite, limestone, saw dust, or other material. This application can work for a wide range of organic and inorganic contaminants.

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**Biological Treatment**

**Bioslurping** uses vacuum-enhanced pumping to recover light, nonaqueous phase liquid. This process promotes biodegradation of organic compounds.

**Intrinsic bioremediation** is a natural, non-enhanced process that uses microbials to degrade organic constituents. Contaminants are broken down to simpler, often less toxic, compounds through aerobic or anaerobic processes.

**Monitored natural attenuation** includes intrinsic bioremediation. It relies on a variety of physical, chemical, or biological processes (within the context of a carefully controlled and monitored site cleanup approach) that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater.

**Phytoremediation** uses plants to remediate environmental media in situ. This technique includes:

- rhizofiltration in which plant roots absorb, concentrate, and precipitate heavy metals,
- phytoextraction in which plant roots and shoots can be harvested and contaminates can be extracted,
- phytotransformation in which plant tissues degrade complex organic molecules to simple molecules,
- phytostimulation or plant-assisted bioremediation in which the release of exudates/enzymes into the root zone stimulates microbial and fungal degradation, and
- phytostabilization in which plants absorb and precipitate contaminants, principally metals.

These processes may or may not involve periodically harvesting plants. These processes may be applied to a wide range of organic and inorganic contaminants, but they are most appropriate for sites where large volumes of groundwater have been contaminated by relatively low concentrations of pollutants but must be remediated to strict standards. They are most effective where groundwater is within ten feet of the ground surface and soil contamination is within three feet of the ground surface.

**Electrokinetics**

**Electrokinetics** is an *in situ* process that involves applying low intensity direct electrical current across electrode pairs implanted in the ground on each side of a contaminated area, causing electro-osmosis and ion migration. The process separates and extracts heavy metals, radionuclides, and organic contaminants from saturated or unsaturated soils, sludges, and sediments. Especially unique due to ability to work in low permeability soils as well as high permeability soils. The process works for a broad range of organic and inorganic contaminants.

For more information about groundwater remediation, contact the Ground-Water Remediation Technologies Analysis Center, Concurrent Technologies Corporation, 28th Floor, Regional Enterprise Tower, 425 Sixth Avenue, Pittsburgh, PA 15219. You may e-mail them at gwrtac@gwrtac.org, or call (800) 373-1973. Their Web site is located at www.gwrtac.org.
When it comes to well water, most folks think their water comes from the ground pure and pristine. But those of us who have operated groundwater treatment plants with any or all of the following contaminants—iron, manganese, carbon dioxide, arsenic, radon, iron and sulphur bacteria—tell a different story.

**Do I have carbon dioxide?**

Carbon dioxide (CO$_2$) may seem to be an odd place to start an article on groundwater treatment, but, in my area at least, it contributes to more treatment problems than any other contaminant. CO$_2$ reduces pH, which, in turn, contributes to a wide range of treatment difficulties.

Throughout the Lead and Copper Rule, we learned that decreased pH contributes to corrosion problems and the leaching of lead and copper into customers’ water. Also, the lower the pH, the more time it takes to oxidize metals, like iron, in the treatment process.

Carbon dioxide tends to be most prevalent in areas with large underground deposits of carbon, such as coal, petroleum, or brine. Companies, including Hach and LaMotte, sell CO$_2$ test kits that are quick and accurate for onsite testing, or an operator may choose to use an approved lab. Using a pH meter, you can detect carbon dioxide’s presence, if not the concentration.

To check for CO$_2$, grab a sample of raw water and quickly check the pH. Then pour the sample back and forth between two beakers several times and check the pH again. If the pH has gone up, the chances are that your water is the proud owner of CO$_2$.

**The treatment for CO$_2$?**

Think a bit about pouring the raw water sample back and forth between the two beakers: what were you doing? Aerating. CO$_2$ vaporizes easily when aerated. This is a lesson that those working in West Virginia learned early on. A pH level in the fours is not uncommon here. Consequently, almost all groundwater treatment plants in this state come equipped with an aerator. It may be as simple as coke trays or as state of the art as vortex aerators, but they are there releasing the CO$_2$, hydrogen sulfide (H$_2$S), radon, and other contaminants, making the water safer and easier to treat.

There are states that have decided aerating water turns it into surface water, therefore, requiring full treatment. These same states allow chemical treatment using soda ash up to 300 milligrams per liter (mg/L). Using that much soda ash is expensive, and it’s not even very effective.

Another design requirement often used as an argument against aeration is “double pumping.” Aeration usually requires a basin or tank following the aerator to allow oxygen to release prior to filtration or pumping into the distribution system. A double-pumping design requires a second pump to move the aerated water through the filter and into the distribution system.

There are degassing units, which allow CO$_2$ removal without the need for double pumping. However, the head loss through the unit makes single stage pumping practical in limited situations only.

A perfect example of the effectiveness of aeration is the water treatment facility in Mt. Hope, West Virginia. The Mt. Hope plant was built just as the Lead and Copper Rule was getting into full swing. The raw water source was an artesian spring emanating from an abandoned coalmine. The Mt. Hope’s water system operator decided the raw pH (6.3) needed to be raised to 7.5 to make the water non-corrosive.
Iron is the most common mineral in the Earth’s crust and, therefore, the most common contaminant found in well water. Although iron is a secondary contaminant, its secondary maximum contaminant level is 0.3 mg/L. Together with manganese, they make up the terrible twins of groundwater treatment. Customers can drink water containing any number of harmful contaminants without notice, but one washer load of white clothes covered with brown iron stains will cause most operators to lock the doors and take the phone off the hook.

Considering the problems iron can cause, it is actually very easy to control—just oxidize, then filter. Iron is fairly easy to oxidize, changing ferrous (soluble) iron into the ferric state, which are particles of rust. If you have an aerator, it will introduce oxygen and possibly raise the pH that begins the process. Chlorine or potassium permanganate can then be applied to finish turning soluble manganese into a properly operated and maintained greensand filter or one of the many look-alike manganese oxide coated media. If iron is present, and it usually is, the filter should be capped with anthracite, chlorine applied to oxidize the iron that will be trapped in the anthracite, and then allow the greensand to remove the manganese. Soluble manganese may be sequestered in small concentrations; insoluble manganese cannot be sequestered. (For more in-depth answers concerning iron and manganese removal, see “How to Operate and Maintain Manganese Greensand Treatment Units,” in the *On Tap* Winter 2003.)

### Iron’s Terrible Twin

Manganese is the terrible twin of groundwater treatment and usually is found keeping company with its sibling, iron. The secondary maximum contaminant level for manganese is 0.05 mg/L, six times less than iron. Several years ago a popular hair tonic for men advertised “A little dab will do ya,” and so it is with manganese. Even in concentrations less than 0.05, you can have a cumulative effect on the insides of pipes and fittings that will show up in customers’ homes following line breaks, use of fire hydrants, or any other time the line flow has been drastically altered. It reaches the customers’ homes either as black particles or block staining.

Although more difficult than iron to oxidize, in my opinion, the best treatment is to bring the soluble manganese into a properly operated and maintained greensand filter or one of the many look-alike manganese oxide coated media. If iron is present, and it usually is, the filter should be capped with anthracite, chlorine applied to oxidize the iron that will be trapped in the anthracite, and then allow the greensand to remove the manganese. Soluble manganese may be sequestered in small concentrations; insoluble manganese cannot be sequestered. (For more in-depth answers concerning iron and manganese removal, see “How to Operate and Maintain Manganese Greensand Treatment Units,” in the *On Tap* Winter 2003.)

### Radon Can Be Aerated

Radon is a naturally occurring radioactive gas formed when uranium breaks down in the soil. Breathing air that contains radon can cause radioactive particles to become trapped in your lungs.

### Table 1

<table>
<thead>
<tr>
<th>Well Diameter</th>
<th>Ounces of 65 percent Hypochlorite</th>
<th>Pints of 5 percent Bleach</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–8 feet</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10–14 feet</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>16–20 feet</td>
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<td>7</td>
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<tr>
<td>22–26 feet</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>28–30 feet</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>36 feet</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

Pour the chlorine solution directly into the well, splashing the casing, hose, and other components as much as possible. Using a hose attached to a potable water supply, thoroughly wash down the interior of the well. If at all possible recirculate the chlorinated water for at least one hour using a plumbing system that allows water to be pumped out of then back into the well. Afterward, allow it to stand as long as possible—up to 24 hours.

The chlorinated water should then be pumped from the well using whatever method your state requires for handling chlorinated water. You might want to consider an in-line tablet de-chlorinator if approved by your state regulations. When chlorine is no longer detected in the well effluent, the well may be put back in to service.

*Source: Larry Rader*
and lead to lung cancer. Radon is the second leading cause of lung cancer in the U.S. each year, second only to cigarette smoking. Most radon enters the home, and therefore your lungs, by seeping from the soil under and around your house. However, groundwater can also contain radon and contribute to the problem.

Although there are health issues from drinking water containing radon, most concerns center on radon in the air. Radon is released into the air in the customer’s home from the shower and other sources of running water. What action is taking place when you turn on the shower and radon is released into the air? That’s right, aeration! According to the Federal Register Vol. 64, No. 211, the best available technology for the removal of radon in groundwater is “high-performance” aeration.

For individual home wells, granular activated carbon (GAC) filters are effective providing all water used in the home passes through the GAC.

What do iron and sulphur bacteria do to a well?

Although neither iron bacteria nor sulphur bacteria pose a particular health hazard, they can, in fact, render a well field useless. Iron bacteria are generally the more common of the two simply because of the abundance of iron in groundwater. They are usually discovered when a well begins to lose efficiency. The well pump is pulled only to find the screen is covered with a foul smelling brown slime. By the time they are discovered, you are quite likely in big trouble.

Iron bacteria can grow extremely fast by combining iron in groundwater with oxygen. Iron bacteria cannot only reduce a good-producing well to a trickle, but the biofilm can also mask the presence of other more harmful bacteria, such as fecal coliforms. They are usually found in more shallow aquifers and the best protection is to make certain the well is properly cased and employs approved wellhead protection.

Sulphur bacteria are divided into two basic categories: 1) Sulfur-oxidizing bacteria convert sulfide into sulfate and produces a dark brown slime that plugs well screens, plumbing, and pumps, similar to iron bacteria; 2) Sulfur-reducing bacteria (SRBs) on the other hand, live in oxygen-deficient environments. SRBs produce hydrogen sulfide gas during the process of breaking down sulfur compounds. SRBs are the more common of the two sulfur bacteria, and the hydrogen sulfide gas they produce is extremely corrosive.

Do I have iron or sulphur bacteria?

A series of tests called BART (Biological Activity Reaction Tests) are available. BART kits are easy to use and simple to understand. They consist of a plastic vial containing a ball coated with appropriate chemicals. A sample of raw water is poured into the vial, which is then tightly capped.

Color changes will begin to appear that correspond to a color chart provided with each test. Extremely or very aggressive levels of the appropriate bacteria will provide color changes within 12 to 24 hours. Moderately aggressive to background levels may take from two to 32 days to reach the correct color change. The charts provided with each test also show various other color changes along with the explanation. I have used BARTS almost from the time they became available. They can be found in most any water treatment supply catalog and cover a wide range of different bacteria.

The method I used before BARTS was also simple. The test was only for iron-related bacteria and consisted of the following equipment: One small jar that can be tightly sealed (my preference was a baby food jar) and a bright new nail that would easily fit into the jar. The jar and cap I sterilized with boiling water, were placed upside down on a clean paper towel, and allowed to cool. The shiny nail is cleaned with alcohol to remove any traces of oil. The nail was placed in the baby food jar, which was then filled with raw water and tightly capped.

I put the jar was on a shelf and checked for brown hair every few days, which indicates the presence of iron bacteria. If the raw water did contain iron bacteria, it immediately began looking for a food source and discovered the nail. In a few weeks, if the sample contained iron bacteria, strings of brown hair (slimy by-product) could be detected rising from the nail. You won’t find this in the American Water Works Association’s “Standard Methods,” but it was all I had available.
If I have iron or sulphur bacteria, what can I do?

Because these bacteria are extremely difficult to completely destroy, the best defense is a proactive offense. Wells should be monitored frequently, in my opinion every six months, using something like the BART tests.

The other part of that offense is also extremely important. Anything—and I do mean anything—that goes into the well must be disinfected with a 250 mg/L solution of chlorine. This includes pumps, electric cables, pipe or hose, portable water level indicators, or anything else that enters the well. If you discover bacteria early, shock chlorination may work. (See the water well disinfection table on page 23). If the bacteria are advanced, ask your well driller about other options. But remember, it is best to catch the problem early, or better yet, prevent it from happening at all.

Hydrogen Sulfide Is an SRB Byproduct

Hydrogen sulfide (H2S) is not only a byproduct of SRB; it can also exist naturally in the ground. A rotten egg odor that becomes stronger as the levels increase announces its presence. Although H2S can be toxic, the odor at those levels should prevent anyone from drinking the water. The major concern with H2S is its corrosiveness to metals such as copper, iron, brass, and steel. There are kits available to check H2S concentrations; however, testing must be performed onsite because it vaporizes very quickly. If samples are sent to a laboratory, ask for directions to stabilize the sample.

What’s the treatment for H2S?

Because it readily vaporizes, aeration can remove high levels of H2S. Other methods of oxidation such as chlorination, ozonation, and potassium permanganate treatment also are effective if there is at least twenty minutes of contact time. Manganese greensand filters can remove H2S up to 6 mg/L, and activated carbon filters work well through the process of adsorption. If your system contains H2S, it may be necessary to retrofit hot water heaters by replacing the magnesium corrosion control rods with rods made of aluminum.

Although I am a believer in aeration for most, if not all, groundwater systems, there are cautions. H2S, for instance, can be flammable when vaporized. It can also be toxic when high levels of the vaporized gas are breathed. Other volatiles such as radon would be hazardous if contained inside a building, for instance, following aeration. Make certain the vaporized gases are vented to the outside air, and you have checked with the agency that regulates air quality in your state.

References:


Larry Rader has more than 25 years experience in the water industry. If you have a question for Rader, he can be reached by e-mail at lrader@meer.net.
“Show me the money,” athlete Rod Tidwell (as played by Cuba Gooding, Jr.) said over and over in the movie Jerry Maguire. It was a phrase that caught on with the public and could be heard frequently in the late 1990s. Utilities—while rarely as crass as Tidwell—probably have been tempted to echo his refrain at one time or another. Whether it’s securing funds for major infrastructure projects or seeking better ways to keep a system solvent, money is at the heart of many small water system concerns.

For utilities and communities interested in better financial management, there’s help available through the U.S. Environmental Protection Agency’s (EPA) Environmental Finance Network. Established in 1992, the network consists of nine Environmental Finance Centers (EFCs) located at universities scattered around the country. Each center has experts who provide training and assistance to state and local governments so that they can find ways to finance environmental compliance and sustainable development.

“We help state and local governments figure out how to pay for environmental programs,” says Jeff Hughes, associate director of the EFC at the University of North Carolina at Chapel Hill. “We’ve found that great ideas that are not grounded with some type of sustainable financing system rarely lead to long lasting environmental improvements. We use different approaches for different types of programs. We work a lot with utilities and try to institutionalize financial planning within their organizations by working on things like capital planning and cash flow analysis.”
EFCs Provide Different Expertise

While the Environmental Finance Centers (EFCs) offer some of the same activities, each specializes in a particular area. “The EFCs do have commonalities, but each center has a slightly different focus or specialization,” says Heather Himmelberger, director of the EFC at the New Mexico Institute of Mining and Technology. “These differences are intentional for several reasons:

1. The EFCs were set up to service the EPA regions and there are definitely different needs depending on the region;
2. The intent was not to recreate the same center several different times, but rather to increase the power of the network by having different centers provide different types of services. In this way, the network as a whole is truly greater than the sum of its parts;
3. The areas of focus also may stem somewhat from the expertise of the particular university or part of the university where the EFC is located; and
4. The directors of the centers represent many different technical disciplines (e.g., business, public administration, engineering, science) and each center’s specialization in some way reflects the experience and expertise of the director.

“Although the centers certainly have different areas of focus depending on the regions, the issue of water and wastewater is so large and important that many centers do get involved with activities in this area,” says Himmelberger.

Each EFC must also narrow its activities as a matter of practicality. “The potential scope of our work is so great that it’s impossible to cover it all,” says Hughes.

Water Is a Prime Consideration

As Himmelberger notes, water infrastructure financing is a big issue throughout the country. It’s not surprising, then, that most of the EFCs have done work in this area. Here are four that are especially involved in water and wastewater finances:

University of Maryland

Over the last several years, the EFC at the University of Maryland has been involved in a number of water-related projects, including source water protection planning, capacity development, equitable utility rate structures, and capital improvement planning.

Environmental Finance Information Online

The Environmental Finance Information Network (EFIN) Web site (www.epa.gov/efinpage/efin.htm) provides a central source for information about funding alternatives for state and local environmental programs and projects.

Developed by the U.S. Environmental Protection Agency (EPA), the site contains abstracts of reports, articles, and publications about environmental finance, plus case studies that demonstrate successful uses of funding methods. Most EFIN listings include names and contact information.

According to a 2001 annual report, they accomplish much of their work using charrettes (special focus groups lead by experts) and roundtable discussions, in addition to more traditional methods, such as training workshops and conferences.

Recent work at this EFC has focused on watershed protection initiatives. In 2002, they conducted a series of workshops about financing watershed strategies in collaboration with the Maryland Department of Natural Resources.

University of North Carolina at Chapel Hill

The EFC@UNC, as it is affectionately known, recently completed a comprehensive environmental finance course for professionals involved in the planning, delivery, regulation, or financing of environmental infrastructure services. Other projects involve using distance learning to provide training about environmental finance and a database of low-cost loan and grant sources for environmental projects in the Southeast.

“We are within the University of North Carolina Institute of Government,” Hughes explains, “the country’s largest university-based, local government consulting and training program. As a result, we are able to integrate our work into many existing local government-training programs in North Carolina. This environmental finance work is done by a range of professions, including engineers and public finance folks.”

New Mexico Institute of Mining and Technology

The EFC in New Mexico was actually the first center in the network to be established.
To learn more about the Environmental Finance Center in your area or about one dealing with a topic that interests you, see the following:

**Region 1**

Environmental Finance Center
University of Southern Maine
96 Falmouth St.
PO Box 9300
Portland, ME 04104-9300

Phone: (207) 780-4418
E-mail: barringr@usm.maine.edu
Web: efc.muskie.usm.maine.edu

Specialization—This EFC investigates emerging approaches and techniques of land conservation and creates education and training programs for their use and development.

**Region 2**

Environmental Finance Center
Syracuse University
219 Maxwell Hall
Syracuse, NY 13244-1090

Phone: (315) 443-9438
E-mail: farrell@maxwell.syr.edu
Web: www.maxwell.syr.edu/efc/

Specialization—This EFC explores the issues of full-cost pricing of environmental services, the value of intergovernmental cooperation (both nationally and internationally) in addressing environmental improvement projects, collaborative planning among public and private environmental service providers, and the coordination of technical assistance services available to rural communities.

**Region 3**

Environmental Finance Center
University of Maryland
0112 Skinner Hall
College Park, MD 20742

Phone: (301) 403-4220 ext. 26
E-mail: greer@mdsg.umd.edu
Web: www.efc.umd.edu

Specialization—This EFC at Maryland uses charrettes (special focus groups lead by experts) as a technique to help communities in Region 3 obtain information on the nature of finance issues facing them.

**Region 4**

Environmental Finance Center
University of North Carolina at Chapel Hill
CB #3330 Knapp Building
Chapel Hill, NC 27599-3330

Phone: (919) 966-5381
E-mail: richard_whisnant@unc.edu
Web: www.efc.unc.edu/index.html

Specialization—The EFC@UNC’s core mission focuses on the environmental financing needs of underserved populations in small- to medium-sized communities, particularly those that are considering interlocal or regional arrangements for environmental infrastructure.

**Region 5**

Environmental Finance Center
University of Louisville
426 W. Bloom Street
Louisville, KY 40208

Phone: (502) 852-8032
E-mail: pbmeyer@louisville.edu
Web: cepm.louisville.edu/organization/SEFC/seefc.htm

Specialization—This center draws on experts in pollution prevention, environmental and civil engineering, environmental education, law, and the health and biological sciences in pursuing economically efficient sustainable development and environmental protection.

**Region 6**

Environmental Finance Center
New Mexico Institute of Mining and Technology
The Institute for Engineering Research and Applications (IERA)
901 University Blvd., SE
Albuquerque, NM 87106-4339

Phone: (505) 272-7357
E-mail: efc@efc.nmt.edu
Web: efc.unm.edu

Specialization—The New Mexico EFC provides technical assistance to federal, state, and local governments and public and private entities, specifically in capacity development for small water systems. They have a commitment to identifying financing options and promoting low-cost, alternative, and appropriate technologies for projects that will encourage sustainable development, pollution prevention, and source reduction—at affordable and viable levels.

**Region 7**

Environmental Finance Center IX
851 West Midway Avenue
Alameda, CA 94501

Phone: (510) 749-6867
E-mail: efc9@greenstart.org
Web: www.greenstart.org/efc9

Specialization—The Region 9 center explores development of successful models for public-private partnerships financing environmental systems, emphasizing greater participation of small- and medium-sized businesses.

**Region 8**

Environmental Finance Center
University of North Carolina at Chapel Hill
CB #3330 Knapp Building
Chapel Hill, NC 27599-3330

Specialization—The Great Lakes EFC focuses on brownfield site redevelopment and industrial pollution financing, especially financial issues affecting the availability of credit and financial tools and incentives to spur investment in abandoned commercial and industrial sites.

**Region 9**

Environmental Finance Center
New Mexico Institute of Mining and Technology
The Institute for Engineering Research and Applications (IERA)
901 University Blvd., SE
Albuquerque, NM 87106-4339

Phone: (505) 272-7357
E-mail: efc@efc.nmt.edu
Web: efc.unm.edu

Specialization—The New Mexico EFC provides technical assistance to federal, state, and local governments and public and private entities, specifically in capacity development for small water systems. They have a commitment to identifying financing options and promoting low-cost, alternative, and appropriate technologies for projects that will encourage sustainable development, pollution prevention, and source reduction—at affordable and viable levels.

**Region 10**

Environmental Finance Center
Boise State University
1910 University Drive
Boise, Idaho 83725

Phone: (208) 426-4293
E-mail: bjarock@boisestate.edu
Web: www.boisestate.edu/eafc

Specialization—This center coordinates analysis training and outreach activities about the viability assessment of drinking water systems.
This EFC has concentrated on capacity development strategies and helping small communities and Indian tribes use EPA’s state revolving loan fund for water and wastewater projects. They also spearheaded the effort—with several of the other EFCs—to create a national source water protection pilot project.

**Boise State University**

Boise State is perhaps best known for their software programs: CapFinance™, a capital improvement planning and financing tool; RATECheckUp™, designed to help utilities with rate setting; Ratio8™, a guidebook and spreadsheet program to help local decision makers evaluate their water utility’s financial condition; and Plan2Fund™, a watershed planning tool. They conduct utility rate design workshops and presentations throughout EPA Region 10.

**Service Is Available to All**

Suppose your community is interested in a financial topic. What requirements would you need to meet in order to get help from an EFC? What if the EFC in your region doesn’t specialize in the problem you have?

“In general, there are no particular requirements,” says Himmelberger. “However, the big issue is funding. In some cases, a particular center may be able to address the community’s needs on a free basis if that activity fits within the scope of services offered by the EFC and the available funding. In other cases, the request may fall outside of these boundaries, and it may be necessary for the center to either pass on the contact to another EFC, who may be able to help, or to try to seek funding for that project. In other cases, it may be necessary to refer

Financial issues can be a big challenge for small communities. The 10 centers that make up the Environmental Finance Network are home to experts who help local officials understand and implement proper financial management techniques.
Remember when your grandpa told you “An ounce of prevention is worth a pound of cure”?
That’s how Brendan Murphy, project manager at the National Rural Water Association (NRWA), describes the value of wellhead protection. The cost of developing and implementing a wellhead protection program is considerably less than the cost of restoring water quality after the supply has been contaminated.

Protection Is Important
The 1996 Safe Drinking Water Act (SDWA) Amendments required states to develop wellhead protection programs to prevent contamination of public groundwater supplies. The U.S. Environmental Protection Agency (EPA) must approve state programs. Today, 49 states—plus the territories of Guam and Puerto Rico and a number of Indian tribes—have EPA-approved wellhead protection programs in place.

Unlike state programs, local wellhead protection programs are voluntary. This means that water systems sometimes wait until they face a specific water quality threat to pass a wellhead protection ordinance or begin developing a program. But waiting until a problem occurs is not the best approach. “Having a full-fledged wellhead protection program in place gives a system more standing” in its attempts to protect its supply, says Kathleen Reilly, a watershed coordinator with the Colorado Department of Public Health and Environment. “When a system has already defined the area to be protected and has notified the county, then the county knows this is a sensitive area when it makes land-use decisions,” Reilly says.

The key steps in developing a wellhead protection program are:
- delineate the land area to be protected,
- inventory potential sources of contamination,
- implement strategies to manage these contaminant sources (these strategies often focus on public awareness and education programs), and
- develop contingency plans for emergencies.

Start a Protection Program
If your utility has a safe water supply, developing a wellhead protection program can be a relatively simple, inexpensive process that merely requires state approval. Systems dealing with more complicated challenges may have to resort to mandatory approaches such as zoning ordinances or land-use restrictions. Depending on its situation, a system might begin by partnering with its state NRWA affiliate, asking the appropriate division of state
government for help, or hiring a consulting engineer to conduct a needs assessment.

In each of the lower 48 states, NRWA has at least one staff person who can help small systems develop wellhead protection programs on site. According to Murphy, these specialists can educate system operators, boards and councils, and the public about the benefits of wellhead protection; guide systems through the steps required to establish a program; and advise systems about available financial resources. (To get in touch with your state NRWA affiliate, visit the organization’s Web site at www.nrwa.org, click on the link to “state associations” for a map of state affiliates, and then click on your state.)

The Northern Colorado Water Association, which serves the 1,300 people of Wellington, developed its wellhead protection program with the help of Shauna Wooten, a groundwater specialist with NRWA’s Colorado affiliate. System manager JoAnn Jordan says Wooten determined their protection zone and identified potential contamination sources almost single-handedly. Without Wooten, she says, “Our program would never have gotten done.”

The more complex experience of Pleasant Valley Public Water District (PVPWD) in Peoria County, Illinois, demonstrates the value of cooperating with state agencies. PVPWD, which serves about 6,200 people, won an Illinois Shining Star Groundwater Protection Award last year for being the state’s first water system to designate a regulated recharge area.

First, says system manager Joe Loftus, the utility contracted an engineer to conduct a needs assessment. Although the utility had established a maximum wellhead setback zone in 1988, groundwater modeling showed that the recharge area for the wells was larger than the area protected by the setback zone. The needs assessment also identified potential threats from current land uses in the area.

Next, PVPWD hired an intern, paid by the Illinois EPA (IEPA), to visit 34 businesses within the recharge area to increase awareness of the importance of wellhead protection. Eventually, the employees of 14 of these businesses were required to attend a training session on managing chemical substances. Loftus says the meeting’s success was bolstered by the fact that IEPA made attendance mandatory, but added that “the training helped business owners realize it was their own water supply they were helping to protect.”

When the county was unwilling to adopt additional land-use regulations to help PVPWD protect its wells, the utility enlisted the aid of IEPA and the Illinois Pollution Control Board. After seven years of research and public hearings, the Pollution Control Board issued the final order designating the regulated recharge area in September 2001.

**How Much Will it Cost?**

The costs of wellhead protection programs vary, depending on the methods used to determine the protection area and the amount of staff time required to administer the program. Expenses can be divided into development costs and annual implementation costs. Delineating the protection area usually accounts for the largest portion of development costs because of the need for groundwater modeling. You can get a rough idea of potential costs by examining the costs incurred by other small groundwater systems.

According to an EPA study published in 1996, the cost of developing a basic wellhead protection plan at a Louisiana system serving 700 people was $5,487, whereas the cost of a basic plan for a system serving 4,000 people in Maine was $101,014. Charles Job, the EPA staff member responsible for the study, says the more complex geology of the system in Maine caused the difference in these costs. A full report of the study gives a breakdown of program development costs at these two systems.

A more recent study, to be published by the AWWA Research Foundation (AWWARF) next year, reports the costs of wellhead protection programs developed by four small systems in various regions of the
country. In this study, the program at Black Mountain, North Carolina, was the least expensive at $44,500. The program at Torrington, Wyoming, was the most expensive at more than $1 million. Mark Williams, the study’s principal investigator, explained that the Wyoming system used a significant portion of its expenditures to implement improved management practices on adjacent farmland in order to reduce high nitrate concentrations in four of its six wells. The programs in Nantucket, Massachusetts, and Atlantic, Iowa, cost approximately $145,800 and $241,000, respectively.

The AWWARF study also calculated annual per capita costs based on total program costs (development costs, plus the 20-year present value of annual costs beginning with the year the plan went into effect). Estimated annual per capita costs were $1.33 at the North Carolina system, $1.44 at the Massachusetts system, $3.94 at the Iowa system, $5.00 at the Wyoming system (though some of the Wyoming funds came from the 20-year present value of annual development costs, plus the plan went into effect). Estimated annual per capita costs at the Iowa system were $10.97 at the Massachusetts system, $3.94 at the North Carolina system, $1.44 at the Iowa system, $5.00 at the Wyoming system (though some of the Wyoming funds came from the 20-year present value of annual development costs, plus the plan went into effect).

**Can our system get funding?**

Many small utilities have acquired some of the funding to develop their wellhead protection plans from outside sources. Roy Simon, acting chief of the Prevention Branch of EPA’s Office of Ground Water and Drinking Water, says that in 1997, federal funds were made available through the Drinking Water State Revolving Fund (DWSRF) to help states conduct source water assessments. Though these funds ran out in 2003, states can continue to use money from their ongoing annual DWSRF allotments to help local communities complete source water assessments for wells and set up wellhead protection programs. State contributions accounted for 50 percent of program development costs at the Iowa system included in the AWWARF study and 75 percent at the Wyoming system (though some of the Wyoming funds came from the 20-year present value of annual development costs, plus the plan went into effect). Estimated annual per capita costs at the Iowa system were $10.97 at the Massachusetts system, $3.94 at the North Carolina system, $1.44 at the Iowa system, $5.00 at the Wyoming system (though some of the Wyoming funds came from the 20-year present value of annual development costs, plus the plan went into effect).

**Agricultural**

- Animal burial areas
- Animal feedlots
- Fertilizer storage/use
- Irrigation sites
- Manure spreading areas/pits
- Pesticide storage/use

**Commercial**

- Airports
- Auto repair shops
  - waste oils, solvents, acids, paint, waste hydraulic fluids, cutting oils
- Boatyards
- Construction areas
  - asbestos, solvents, paints, glues, adhesives, lacquers, tars, sealants, epoxy
- Car washes
  - soap, detergents, waxes
- Cemeteries
- Dry cleaners
  - perchloroethylene, petroleum solvents, trichloroethane, methylchloroform, ammonia, peroxides, hydrochloric acid, rust removers, amyl acetate
- Gas stations
  - oil, solvents, wastes
- Golf courses
- Jewelry/metal plating
- Laundromats
- Medical institutions
  - x-ray developers and fixers (fixers and x-ray film contain reclaimable silver)
  - Developer contains glutaraldehyde, hydroquinone, phenol, potassium bromide, sodium sulfite, sodium carbonate. Fixer has thiosulfates and potassium allum. Infectious wastes, radiological wastes, biological wastes, miscellaneous chemicals, disinfectants, asbestos, beryllium, acids
- Paint shops
- Photography establishments
  - biosludges, silver sludges, cyanides, miscellaneous sludges
- Railroad tracks and yards
- Research laboratories
- Scrap and junkyards
- Storage tanks

**Industrial**

- Asphalt plants
- Chemical manufacture/ storage
  - cyanides, metal sludges, caustics (chromic acid), solvents, oils, alkalis, acids, paints, calcium fluoride sludges, methylene chloride, perchloroethylene, trichloroethane, acetone, methanol, tolulene, PCBs, paint sludge
- Electroplaters
- Foundries/ metal fabricators
  - paint wastes, acids, heavy metals, metal sludges, plating wastes, oils, solvents, explosive wastes
- Machine/ metalworking shops
  - oils, solvents, metals, organics, sludges, oily metal shavings. Tool and die shops:
  - lubricant and cutting oils, degreasers (TCE), metal marking fluids (“blueing”), mold release agents
  - Mining and mine drainage
  - Petroleum production/ storage
  - Pipelines
  - Septage lagoons and sludge
  - Storage tanks
  - Toxic and hazardous spills
  - Wells (operating/ abandoned)
- Wood preserving facilities
  - treated wood residue and containers (use copper quinolate, mercury, sodium bazide to control stains and fungus and use taner gas to prevent lines from freezing), paint sludge, solvents, creosote, coating, and gluing wastes

**Other**

- Hazardous waste landfills
- Municipal incinerators
- Municipal landfills
- Municipal sewer lines
- Open burning sites
- Recycling/ reduction facilities
- Road deicing operations
- Road maintenance depots
- Storm water drains/ basins
- Transfer stations
- Fuel oil
- Furniture stripping/ refinishing
  - paints, sludges, solvents, empty containers, degreasers sludges, solvent recovery sludges
- Household hazardous products
- Household lawns
- Septic systems, cesspools
- Sewer lines
- Swimming pools (chemicals)

**Residential**

- Septic systems, cesspools
- Sewer lines
- Swimming pools (chemicals)

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**Common Sources of Ground Water Contamination**

**Agricultural**

- Animal burial areas
- Animal feedlots
- Fertilizer storage/use

**Commercial**

- Airports
- Auto repair shops
  - waste oils, solvents, acids, paint, waste hydraulic fluids, cutting oils
- Boatyards
- Construction areas
  - asbestos, solvents, paints, glues, adhesives, lacquers, tars, sealants, epoxy
- Car washes
  - soap, detergents, waxes
- Cemeteries
- Dry cleaners
  - perchloroethylene, petroleum solvents, trichloroethane, methylchloroform, ammonia, peroxides, hydrochloric acid, rust removers, amyl acetate
- Gas stations
  - oil, solvents, wastes
- Golf courses
- Jewelry/metal plating
- Laundromats
- Medical institutions
  - x-ray developers and fixers (fixers and x-ray film contain reclaimable silver)
  - Developer contains glutaraldehyde, hydroquinone, phenol, potassium bromide, sodium sulfite, sodium carbonate. Fixer has thiosulfates and potassium allum. Infectious wastes, radiological wastes, biological wastes, miscellaneous chemicals, disinfectants, asbestos, beryllium, acids
- Paint shops
- Photography establishments
  - biosludges, silver sludges, cyanides, miscellaneous sludges
- Railroad tracks and yards
- Research laboratories
- Scrap and junkyards
- Storage tanks

**Industrial**

- Asphalt plants
- Chemical manufacture/ storage
  - cyanides, metal sludges, caustics (chromic acid), solvents, oils, alkalis, acids, paints, calcium fluoride sludges, methylene chloride, perchloroethylene, trichloroethane, acetone, methanol, tolulene, PCBs, paint sludge
- Electroplaters
- Foundries/ metal fabricators
  - paint wastes, acids, heavy metals, metal sludges, plating wastes, oils, solvents, explosive wastes
- Machine/ metalworking shops
  - oils, solvents, metals, organics, sludges, oily metal shavings. Tool and die shops:
  - lubricant and cutting oils, degreasers (TCE), metal marking fluids (“blueing”), mold release agents
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  - Petroleum production/ storage
  - Pipelines
  - Septage lagoons and sludge
  - Storage tanks
  - Toxic and hazardous spills
  - Wells (operating/ abandoned)
- Wood preserving facilities
  - treated wood residue and containers (use copper quinolate, mercury, sodium bazide to control stains and fungus and use taner gas to prevent lines from freezing), paint sludge, solvents, creosote, coating, and gluing wastes

**Other**

- Hazardous waste landfills
- Municipal incinerators
- Municipal landfills
- Municipal sewer lines
- Open burning sites
- Recycling/ reduction facilities
- Road deicing operations
- Road maintenance depots
- Storm water drains/ basins
- Transfer stations
- Fuel oil
- Furniture stripping/ refinishing
  - paints, sludges, solvents, empty containers, degreasers sludges, solvent recovery sludges
- Household hazardous products
- Household lawns
- Septic systems, cesspools
- Sewer lines
- Swimming pools (chemicals)

**Residential**

- Septic systems, cesspools
- Sewer lines
- Swimming pools (chemicals)
U.S. Department of Agriculture). Utilities generally bear the cost of implementation themselves. (For more information about federal funds that are available to help states and tribes protect source water supplies, see www.epa.gov/safewater/protect/pdfs/guide_sup_sup_funding_matrix.pdf)

Is it worth the cost?

The primary benefit of wellhead protection is the preservation of source water integrity. Other benefits, though real, are difficult to measure. Monetary benefits must be estimated on the basis of avoided costs—money saved by avoiding the cost of remediation, continuing treatment, or replacement of wells or well fields. Wellhead protection programs can also yield nonmonetary benefits such as improved groundwater quality, fewer customer complaints about water quality, increased public awareness of the importance of source water protection, lowered risks associated with land uses or other activities that could contaminate supplies, increased collection of household hazardous waste, improved wildlife or plant habitats, and better working relationships among governmental agencies and water suppliers.

Both the EPA and AWWARF studies calculated “avoided cost–benefit” ratios for the wellhead protection programs they showcased. The EPA study assigned an avoided cost-benefit ratio of 5 to 1 to the system in Maine and a ratio of 200 to 1 to the Louisiana system. But regardless of the ratio of benefits to avoided costs, the study concluded that “If groundwater is the only reliable, high-quality drinking water source, expenditures for special protection are probably warranted.” The authors of the AWWARF study concur. Furthermore, they contend that “wellhead protection is generally well received by the public and does not impede economic development within a community.”

PUPWD’s Loftus and NRWA’s Murphy agree about the importance of protecting source water integrity. “What goes into your well, you’re eventually going to consume yourself,” Loftus says. “If you don’t protect it, you’re taking a chance on damaging your health.” Recalling the adage about an ounce of prevention, Murphy reflected, “It’s always cheaper to protect your source than to clean it up.”

References


Nancy M. Zeilig, an independent writer and editor based in Denver, was editor of Journal AWWA for 19 years.
It takes a lot of energy to get water out of the ground and into cities, homes, and farms. Before a groundwater source can be developed into a community supply, well performance and aquifer capabilities must be adequately assessed. That means studying an area’s geology, drilling test wells, and possibly even performing computer modeling, to name just a few things that must be done.

Wells come in different shapes and sizes, depending upon the type of material the well is drilled into and how much water is being pumped out. For example, some people want to drill a municipal well that can pump thousands of gallons per minute (gpm). Other people want a domestic well that only pumps 10 gpm. How much water a well yields is associated with the size and kind of aquifer you drill into.

Before beginning any well drilling project, it’s important to understand some well terminology, such as well yield, specific capacity, zone of influence, static water level, pumping water level, drawdown, and cone of depression.

**Well yield** is a measure of how quickly and how much water can be withdrawn from the well over a period of time. For instance, a small well’s yield is typically measured in gpm or gallons per hour (gph). For large wells, yield may be measured in cubic feet per second (cfs).

**Specific capacity** is an important term, referring to whether the well will provide an adequate water supply. Specific capacity is calculated by dividing how much water has been taken out of the well—or the well’s drawdown—by well yield. A sudden drop in specific capacity indicates that there may be trouble brewing, such as pump problems, screen plugging, or other possible serious problems.

The **zone of influence** is the area affected by the drawdown and extends out from the well a distance that depends upon porosity—the empty space between soil particles—and other factors.

The **static water level** is the level of water in the well when no water is being taken out. Pumping water level, on the other hand, is the level when water is being drawn from the well.
The **cone of depression** occurs during pumping when water flows from all directions toward the pump. The water’s surface takes on an inverted cone shape.

Once the terms begin to make sense, it makes the job of figuring out where to drill a new high yield well a little easier. From that point, it’s a matter of collecting information before beginning the job.

“The most important key to locating and designing high yield wells is understanding the subsurface geology,” says Dale Ralston, president of Ralston Consulting Services. “You need to develop a conceptual model of the geologic conditions with a special emphasis on controls for groundwater flow.”

Ralston says that the following steps can help maximize results:

1. Assemble available geologic information, such as published maps and reports and use the available information to identify potential aquifers and confining layers.
2. Develop a general understanding of where and how recharge occurs in these aquifers as well as aquifer discharge.
3. Use well logs (generally available from the state water resource agency) to get more site-specific information on subsurface conditions in your area of interest.
4. Use all of this information to write a brief analysis of well development potential, including potential well drilling sites.

### Use Existing Data

State and federal geological and water resource agencies are the first places to look for information about where to drill a new well. In most states, data from previous well logs have been used to draw maps of an area’s geology and water-bearing layers. The agencies also can help identify how productive an aquifer can be and which one is capable of providing the amount of water that the community needs.

Besides helping detect a well’s productivity, these agencies have information about an aquifer’s water quality, such as whether it contains iron and manganese, sulfur, nitrates, or radionuclides. They also may have information about chemical contaminants.

Public and private well owners who surround the area of interest are another source of information. There’s likely a wealth of information from these existing wells. Data collected during the drilling operations can give the community a good idea of what a new well will produce. Beware, however, to only use data from the wells drilled into the aquifer that the community is considering for the new well. Data from other area aquifers will not provide any usable information.

And don’t forget about the people who drilled those wells. Local well-drilling contractors can provide practical information about where wells can be developed along with the quantity and quality of the water.

Hydrogeologists also are a good source and can provide information about where to locate a well. This is especially true in areas where water is scarce or no large aquifers exist.

“Surface geophysical techniques can be used to supplement this approach in some environments,” Ralston explains. “However, the expense associated with geophysical analysis limits its application to probably less than 10 to 20 percent of all locations.

“In most areas, an experienced hydrogeologist can give the probability of obtaining target yields from a production well at a specific location (i.e., 50 percent probability of getting 1,000 gpm but 80 percent probability of getting at least 500 gpm),” he says. “This allows the owner to make rational decisions relative to well construction.”

Geophysical exploration means exploring what’s underground, such as water-bearing faults and fracture zones in the bedrock. Several common methods can be used for geophysical exploration, such as seismic and resistivity methods.

Seismic methods measure the speed at which a sound wave travels through the earth. This measurement can then be correlated to geologic formations that may contain groundwater.

Resistivity methods measure the ground’s electrical resistance with depth into the ground. In general, the lower the resistance, the greater the probability that water is present.

“The methods used are highly dependant on the hydrogeologic setting in the area of the water system,” says David Terry, Ph.D., hydrogeologist with Leggette, Brashears, and Graham, Inc. “You might be able to generalize this by the physiographic setting of the system (e.g., Coastal Plain, Piedmont, Highlands).

“In areas where unconsolidated sediments predominantly underlay the surface (e.g., broad valley floors or Coastal Plain areas), the objective is to find the thickest and coarsest water-bearing sedimentary unit available. This can be done using available literature, geophysical testing, or through test drilling. Knowledge of what information is available is especially useful, along with an understanding of what site-specific investigative approach will work best.

“In areas where fractured rock or karst (limestone) predominantly underlay the surface, generalized studies are less useful,” says Terry. “In those areas, geologists generally obtain an understanding of the location and pattern of bedrock fractures and fracture systems because most of the water flows through cracks rather than the matrix of the
Finding the Water

Groundwater is most likely found under valleys. Valleys that contain permeable soil that has washed down from the mountains usually have productive aquifers. In some areas of the country, only groundwater found in river valleys is of usable quality. Also, bedrock that lies beneath valleys is often fractured and water bearing. Coastal terraces as well as coastal and river plains may have good aquifers.

Any evidence of surface water, such as streams, lakes, springs, or swamps, is a good indication that groundwater is present—although not necessarily in usable quantities. Sometimes vegetation is a good indicator of the presence of groundwater. A thick overgrowth may mean shallow groundwater.

Drilling a Test Well

A test well is another way to explore the area. Test wells can provide abundant information about the most likely place to drill the production well.

“Hopefully, by the time you are drilling a test well, you have already considered where the best locations might be,” says Terry. “In that case, you are trying to confirm the depth and the character of the aquifer materials, but you are first interested in well yield.

“Test wells also can identify the presence/absence of confining layers, and the depth, location, and orientation of bedrock fractures,” he explains. “You can sample water in the test well for water quality parameters to ensure that water in this zone will be of potable quality. You can conduct aquifer testing (pumping tests) to establish quantitative information about the yield potential of the aquifer and potential effects of pumping the well on other users or the environment.”

Computer modeling allows hydrogeologists to evaluate many complex stresses and effects on an aquifer, such as areas where several wells are drilled into the same aquifer. Computer modeling also allows for gaining information about rapid recharge and withdrawal. Then forecasts can be made about the most appropriate location for additional wells.

Terry adds that it’s also important to use a drilling method appropriate to the formation being drilled and to use the most experienced driller that you can find in the area.

Drilling methods are as varied as site locations. “Drilling high yield wells is somewhat different from drilling ordinary domestic wells,” says Terry. “The techniques used to drill these wells are often different, and experience and procedure often influence the final result. It is important to use a driller and consultant familiar with high yield wells when conducting this work.”

Drilling methods include:

- cable tool—a percussion drilling method that has been used for years to drill wells of various sizes;
- rotary hydraulic—a process that uses a variable speed, spinning, cylinder-shaped bit;
- reverse-circulation—a method that differs from rotary hydraulic in that the drilling fluid, typically water, is circulated in the opposite direction;
- California—an approach sometimes called the stovepipe method that is similar to cable tool except a bucket is used as both bit and bailer;
- rotary air—a technique similar to rotary hydraulic except the drilling fluid is air, and
- down-the-hole hammer—a method that uses a pneumatic hammer unit attached to the end of the drill pipe.

Another good way to estimate well yield is drill cuttings. “Drill cuttings are the subsurface material that comes to the surface while drilling a well, says Terry. “They can tell you the type of material through which you are drilling and whether that material is saturated or unsaturated.

“By looking at the cuttings, you may be able to tell whether productive material is being encountered, how thick it is, and when to stop drilling. You may also be able to tell how deep a surface casing should be set to prevent surface contamination from entering the well.

In addition, any cuttings can be fully analyzed. “Sand samples are analyzed to determine the grain size distribution for screen selection,” says Ralston. “Cuttings from fractured rock wells allow stratigraphic identification.”
Hydrofracture techniques have been used for years in the oil drilling industry to overcome well-bore damage. In recent years, researchers have found that this method can be used to increase the production of low-yield wells. Hydrofracturing uses high-pressure pumps to overcome the pressure of overlying rocks and to inject fluids into newly opened fractures.

“In other cases, the nature of the formation is such that there is not an adequate supply of water in the aquifer, or the aquifer is too fine-grained to transmit usable quantities of water to a well,” he continues. “In these cases, it is more difficult to rectify the dry well problem. The best insurance is to understand what you are drilling into then the odds of drilling a successful well will increase before you start.”

Find the Reasons for the Absence of Water

If this is a newly drilled well, reasons for the lack of water may include:

- No aquifer is present (only aquicludes or aquitards).
- The well borehole is not intercepting the water that is present, either through plugging or inadequate fracture apertures (openings, slits, holes) at the well.
- You did not drill the hole deep enough.
- The well borehole was poorly drilled, or the driller used an inappropriate drilling technique.
- You drilled too deep and encountered a zone through which water can exit the well at a faster rate than it flows in.

Many productive wells also fail or decline substantially in yield. This can be caused by other factors, such as:

- biofouling of the well intake area or formation,
- mineral encrustation at the well borehole,
- drought—long or short-term overdrafting,
- someone else has drilled a well that interferes with the well, and
- the well is not really deep enough to sustain yield.

Wells decrease in yield over time for a range of reasons. In many cases, well rehabilitation efforts can restore nearly the original well yield. Aquifers can be recharged artificially in a couple of ways, including:

1. Spreading water over the land in pits, furrows, or ditches or erecting small dams in stream channels to detain and deflect surface runoff, allowing it to infiltrate to the aquifer, or
2. Constructing recharge wells and injecting water directly into the aquifer.

Some recharge projects have been successful, but others haven’t worked out as intended. The lesson is that researchers still have much to learn about how to recharge groundwater supplies.

For more information about groundwater recharge, write to the U.S. Geological Survey, Regional Hydrologist, Southeast Regional Office, 3850 Holcomb Bridge Road, Suite 160, Norcross, GA 30092 or go to www.usgs.gov.
How porous is it?
Within an aquifer, water is stored between grains of sand, rock, or soil. It fully saturates pores and cracks. The amount of open space between pores and cracks in an aquifer refers to its porosity. Because some areas are likely to be more porous than other areas, groundwater is generally unevenly distributed in quantity and quality.

Porosity or pore space refers to the amount of empty space between soil particles. The shape and arrangement of soil particles determine porosity. Infiltration, groundwater movement, and storage occur in these void spaces. The porosity of soil or geologic materials is the ratio of the volume of pore space in a unit of material to the total volume of material.

The arrangement or packing of the soil particles plays a role in porosity. Not all particles are spheres or round. Particles exist in many shapes and these shapes pack in a natural process that can be developed through practice. Although some dowsers claim they have a special ability to detect electrostatic fields associated with groundwater, skeptics say that without scientific instruments (such as a magnetometer) it is impossible for a person to detect minute differences in magnetic or electric fields that may be associated with groundwater.

But the lack of scientific evidence doesn’t hold water with those who believe in this ancient divining technique.

Einstein Was a Believer
Even Albert Einstein believed in dowsing. He also believed that it could be explained. He said, “I know very well that many scientists consider dowsing as they do astrology, as a type of ancient superstition. According to my conviction this is, however, unjustified. The dowsing rod is a simple instrument, which shows the reaction of the human nervous system to certain factors that are unknown to us at this time.”

Whether you believe it works or not, dowsing is still practiced. And, like many other beliefs, it probably will be for quite a while.


Searching For Groundwater with a Stick
Have you heard of dowsing? Maybe you’ve heard it called water witching, divining, or doodlebugging? Whatever the term, this practice is the ancient “gift” of finding water, metal, or other objects underground.

Dowsing, common since European medieval times, is still practiced the same as it was 1,000 years ago. While there’s some confusion about how long ago dowsing was first practiced, some say that the first evidence of dowsing was discovered on African cave walls that were more than 6,000 years old.

How does dowsing work?
Many dowsers use tools such as divining rods and pendulums. Other dowsers say the tool is only an “interface” or “communication device” that acts as a link between water and the subconscious. Therefore, the choice of dowsing tool doesn’t really matter, and some dowsers operate totally free of a dowsing rod or other tool.

Supposedly, when the dowser nears water, the tools move—indicating to the dowser that they’ve found water. Skeptics, however, think that dowsers involuntarily move the tools themselves.

Dowsers believe that objects, including water, possess a natural magnetic, electromagnetic, or other unknown “energy” that their senses can detect. To a dowser, sensing energy is a natural process that can be developed through practice. Although some dowsers claim they have a special ability to detect electrostatic fields associated with groundwater, skeptics say that without scientific instruments (such as a magnetometer) it is impossible for a person to detect minute differences in magnetic or electric fields that may be associated with groundwater.

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Secondary porosity is formed by cracks, which form in the rock, such as faults or joints in the rock. Secondary porosity is generally the more important factor in most types of bedrock, such as shale or granite, while primary porosity may dominate in sandstone,” he says.

“It is important to understand which type of porosity dominates in a particular area, because it will dictate where the highest-yielding well zones are located, and therefore direct you as to how best to locate them.”

For more information about locating high yield wells, contact Dale Ralston at ralston@moscow.com or David Terry at dterry@lbgnj.com.

Other good sources of information are the University of Kansas at www.kgs.ukans.edu/HighPlains/atlas/apdrdwn.htm; the University of Nebraska at www.ianr.unl.edu/pubs/irrigation/g358.htm; the National Ground Water Association at www.ngwa.org; and the American Water Works Association at www.awwa.org.

References:
On January 1, 2004, the Stage 1 Disinfection Byproduct Rule (DBPR) will finally filter down to the small drinking water systems. It will apply to systems that use a surface supply for raw water and serve a population of less than 10,000 people and all groundwater systems under the direct influence of surface water.

A total organic carbon (TOC) concentration greater than 2.0 micrograms per liter (mg/L) in the system’s raw water is the trigger that sets matters in motion. A few basic treatment changes can help you through this rule and on to the next. In most cases, complying with this rule can be as simple as moving the point of chlorination.

**NOM-DOM-POC-TOC**

Although NOM-DOM-POC-TOC may sound like selection number three in a Thai restaurant, they are actually different forms of organics found in surface water sources. And when organics combine with chlorine, a reaction takes place that forms disinfection byproducts.

Natural organic material (NOM) is just what the name implies and is found in all surface water sources. NOM is divided into two forms: particulate organic carbon (POC) and dissolved organic matter (DOM). For the purpose of differentiating between the two, DOM will pass through a 0.45-micron filter and POC will not. The Stage 1 DBPR lumps both forms together by measuring TOC.

If your plant uses conventional coagulation, flocculation, and sedimentation, and if you are bringing good quality water in the range of 1.0 to 2.0 NTU to the top of the filter, the particulate organics should be removed.

Unfortunately, dissolved organics make up approximately 90 percent of the TOC in most surface water sources. Although DOMs can be removed through conventional coagulation, flocculation, and sedimentation, changing their form using a pre-oxidant prior to coagulation can improve results.

In the past, chlorine was the pre-oxidant of choice. Although chlorine oxidizes organics and some inorganics and is a good disinfectant and cheap to use, chlorine and organics react to form disinfection byproducts. While you can rely on coagulation, flocculation, and sedimentation alone for TOC removal, the addition of a pre-oxidant prior to coagulation, in my opinion, gives you a tremendous advantage.
Pre-oxidation Provides Advantages

In my area of the country, the two most common pre-oxidants are potassium permanganate and chlorine dioxide. Both have operational concerns, such as pink water (potassium permanganate) and carrying a residual into the finished water (chlorine dioxide), but these are operational issues and easily controlled with proper plant operation.

Potassium permanganate requires a longer contact time and must be applied at least 15 minutes prior to the addition of a coagulant and preferably at the intake. Although chlorine dioxide can be applied at almost any point in the pre-treatment process, care must be taken to keep any residual from entering the distribution system. However, both oxidize organic material without contributing to the formation of DBPs. Once the dissolved organics are oxidized, an operator can use coagulation, flocculation, and sedimentation to easily remove them.

After the organics have been oxidized and removed in pre-treatment, chlorine can then be applied. Many systems are moving chlorine to the top of the filter when contact time calculations allow it. Again, remove the organics, then add chlorine.

Enhanced Coagulation Reduces TOCs

Enhanced coagulation is a stand-alone treatment for TOC reduction and becomes required treatment if the percent of removal is not achieved through other means. The treatment technique requires dropping the pH in the coagulation process to a specific target number, depending on the alkalinity of the raw water. Organics are removed more completely at a lowered pH.

The U.S. Environmental Protection Agency (EPA) requires bench testing with either alum or ferric to ascertain their removal potential before trying other coagulants. The bench tests identify how much of either coagulant is required to drop the pH into the target zone and which provides the optimum percentage of removal. Ferric, either sulfate or chloride, usually does best because of the free acid it contains and the amount of metal (iron) in the product. Alum contains less metal and less free acid, thus requiring more chemical. Although either alum or ferric may be overfed to achieve the proper pH and better removal, there are downsides.

Over-feeding any coagulant tends to increase carryover to the filter that can cause increased aluminum in the finished water (alum) or increased iron (ferric). Also, operators know that chemical floc does not settle well and tends to go through the filter and into the clear well where it forms pin floc, causing an increase in turbidity. And, of course, overfeeding any coagulant creates more sludge.

I have had some personal experience using sulfuric acid to drop the pH prior to coagulation. In my experience, alum doesn’t coagulate well in the high dosages needed for many low alkalinity waters. First, consider that each part per million (ppm) of alum reduces natural alkalinity by slightly less than 0.5 ppm. In one source that I experimented with, the raw alkalinity was 39 ppm, and I had to apply 80 ppm of alum to reach the target pH of 5.5; there was no alkalinity remaining to support coagulation, and floc never formed. Ferric on the other hand does work well in combination with acid or by itself.

The source water that required 80 ppm alum only required 55 ppm ferric sulfate to reach the same target pH. Floc formed and settled very well leaving a lot of sludge. Using acid is much cheaper than coagulants and could allow lower coagulant dosages, which, in turn, would produce less sludge. Keep in mind, the metal in either alum or ferric assists in the removal of TOCs and reducing the feed rate can reduce the removal rate.

Using sulfuric acid also gives the option of using one of the new poly aluminum chlorides (PACL). Although PACL does not provide as good percent removal as ferric, it does floc well at the lower pH and creates much less sludge. If sludge removal is a concern and you can get by with a slightly lower removal rate, sulfuric acid and PACL could also be an option.

All of these options require bench testing, but for the operator interested in staying ahead of the game, the time is well spent.

For more information about the Stage 1 Disinfection Byproduct Rule, visit EPA’s Web site at www.epa.gov.
Reducing the Risk of Groundwater Contamination by Improving Wellhead Management and Conditions
The condition of your well and its proximity to contamination sources determine the risk it poses to your groundwater. This booklet discusses wells and practices to reduce the risk of groundwater contamination including well construction and maintenance; age, type, and depth of the well; well testing; and unused or abandoned wells. Item #DWBLPE165

Safe Drinking Water How can we provide it in our community?
Important issues come up when discussing community drinking water provision, like water contamination, upgrading current treatment facilities, keeping customers informed, and responsible system management. This booklet of 13 worksheets is intended to be used as a group decision-making tool in a workshop setting. Item #DWBLMG48

Homeowner’s Septic Tank Information Package
The National Small Flows Clearinghouse (NSFC), Penn State College of Agriculture, and Florida Septic Tank Association partnered to create a homeowner’s septic tank information package.

This package includes:
• a recordkeeping folder for storing documents, such as the septic system permit, site drawings, and maintenance and repair information;
• six brochures about septic system maintenance that describe how to recognize potential problems and offer advice on landscaping;
• three issues of the NSFC’s Pipeline newsletter that focus on septic system management and inspections; and
• a fact sheet about various household cleaning solutions that offer safe alternatives to chemical cleansers.

This package will be useful for contractors, developers, the general public, local and state officials, and public health officials.

NSFC also offers the brochures and Pipeline issues included in the package separately. To order, call the NSFC at (800) 624-8301 and request item# WWPKPE28. The cost is $2.25.

To learn more about NSFC’s products and services, visit their Web site at www.nsfc.wvu.edu. Orders also may be faxed to (304) 293-3161 or sent via e-mail to nsfc_orders@mail.nesc.wvu.edu.
All of the products listed are free!

Quantities are limited to one each per order. If bulk copies are needed, please call for availability.

To order these free products, please use the product order form on page 48 or call the National Drinking Water Clearinghouse at (800) 624-8301 or (304) 293-4191. You also may send an e-mail to ndwc_orders@mail.nesc.wvu.edu.

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## Design

- DWBKDM16 Improved Protection of Water Resources from Long-Term and Cumulative Pollution
- DWBKDM06 Manual of Individual and Non-Public Water Supply Systems
- DWBKDM05 Manual of Small Public Water Supply Systems
- DWBKDM01 Manual of Water Well Construction Practices
- DWBKDM12 Radionuclide Removal for Small Public Water Systems
- DWBLDM02 Rainwater Cisterns: Design, Construction, and Water Treatment
- DWBKDM08 Regionalization Options for Small Water Systems

## Finance

- DWBLFN12 Action Guide for Source Water Funding: Small Town and Rural County Strategies for Protecting Critical Water Supplies
- FDBKFN12 Alternative Financing Mechanisms for Environmental Programs
- DWBKFN08 Alternative Funding Study: Water Quality Fees and Debt Financing Issues
- FDVTFN18 Building Support for Increasing User Fees
- DWBKFN30 Catalog of Federal Funding Sources for Watershed Protection
- DWBKFN15 Catalog of Financial Support Sources for U.S.-Mexico Border Water Infrastructure
- DWBKFN09 Drinking Water Infrastructure Needs Survey: First Report to Congress
- DWBKFN33 Drinking Water Infrastructure Needs Survey: Second Report to Congress
- FDBKFN34 The Drinking Water State Revolving Fund: Financing America's Drinking Water—A Report of Progress
- DWBKFN31 Drinking Water State Revolving Fund Program Guidelines
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**DWQUNL09** OnTap, Volume 3, Issue 1; Spring 2003

**Operation and Maintenance**

**DWBKDM23** Alternative Disinfectants and Oxidants Guidance Manual
**DWBKOM17** Arsenic Removal from Drinking Water by Coagulation/Filtration and Lime Softening Plants
**DWBKOM12** Arsenic Removal from Drinking Water by Ion Exchange and Activated Alumina Plants
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- **DWBKPE95** | How to Conduct an Inventory in Your Wellhead Protection Area |
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**NDWC’s Web Site**

Log on to the National Drinking Water Clearinghouse Web site at [www.ndwc.wvu.edu](http://www.ndwc.wvu.edu)

**Organization/Affiliation**

- Consultant/Engineer
- Contractor/Developer
- Educational Institution
- Federal Agency
- Indian Tribe
- International Agency
- Local Government
- Manufacturer
- National Organization
- Regional Organization

**Your Interest/Expertise**

- Conservation
- Design
- Enforcement/Compliance
- Finance
- Health
- Operation and Maintenance
- Outreach
- Planning/Management
- Public Education
- Regulations
- Research
- Technology
- Training
Dear Mr. Kemp-Rye,

Sometimes I’m absolutely amazed at life’s coincidences. Recently, I attended a demonstration on the use of the Internet as a means of transmitting videoconferences at our local community college. By the end of the demonstration, I was so evangelized on how this technology could seriously expand and enrich training opportunities to my fellow wastewater operators that I began making inquiries on what it would take to deliver this technology.

As a result of these inquiries, I have been able to make contact with a number of people who also have expressed an interest in this project. These people have been added to a distribution list titled the Wastewater Distance Learning Working Group.

As I was the one making the inquiries, many of the people in the working group had no knowledge of each another, as well as only a brief sketch of the project. As a means of introduction, I was putting the final touches on a message to the group. When taking a break I opened the summer edition of *On Tap* that had just arrived and discovered the story on how videoconferences provided a solution to the training challenge in rural Nevada. Amazingly, every paragraph mirrored a point I was trying to describe to the working group.

My gratitude cannot be expressed enough for this exceptionally timely article. Please rest assured, due acknowledgment to *On Tap* will be made if an excerpt of the article ever becomes published. I will also send a copy of the publication to your attention.

Again thank you and your staff for this article,

Mark S. Bowman
Gogebic-Iron Wastewater Treatment Facility,
Ironwood, MI
ACROSS

1. Device for moving 70 across
2. Sounds of disgust
3. Flesh
4. Unit of pressure
5. Large in scope
6. Matures
7. Stumble
8. Against
9. Be in debt
10. H2O beneath the earth's surface
11. Cure
12. Nobleman
13. Other
14. Clarified butter
15. Relative by marriage
16. Actual
17. Retailer with many locations
18. Luck of experience (var.)
19. Rowboat needs
20. D.C. time
21. Digression
22. Fine net
23. Smack
24. _____-Kettering Hospital
25. Horse treat
27. Pseudo
28. Take apart
29. Decay
30. Sailboat part
31. Negatively-charged atom
32. Inflexible
33. Repasts
34. Matures
35. Cure
36. Hawaiian necklace
37. Resident (slang)
38. Taxi charges
39. Sleep loudly
40. Golf peg
41. Santa's helper
42. Northern forests
43. Those living on the largest continent
44. _____ Lanka
45. Not well
46. Work hard
47. Italian man
48. Frayed rope end
49. Cattle roper
50. Put in a well
51. Formal address for a man
52. Put a well
53. Legitimate
54. Cure
55. Quick run
56. Miscellany
57. Tattered
58. Poisonous vapor
59. British behind
60. Hee ___
61. Lotion ingredient
62. Singer's need
63. Water shaft
64. Hole
65. Cow's dinner
66. Beget
67. Come up
68. Cain's victim
69. Toot
70. Necessity for life on Earth
71. Caterwaul

Solution on page 49

DOWN

1. Stride
2. Fortune telling cards
3. Child's game
5. Horse treat
6. Negatively-charged atom
7. Inflexible
8. Hawaiian necklace
9. Sleep loudly
10. Santa's helper
11. Cure
12. Nobleman
13. Other
14. Lack of experience (var.)
15. Fortune telling cards
16. Child's game
17. North African grasses
18. Take apart
19. Decay
20. Hawaiian necklace
21. Sleep loudly
22. Santa's helper
23. Cure
24. Nobleman
25. Other
26. Lack of experience (var.)
27. Fortune telling cards
28. Child's game
29. North African grasses
30. Horse treat
31. Negatively-charged atom
32. Inflexible
33. Hawaiian necklace
34. Sleep loudly
35. Santa's helper
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58. Inflexible
59. Hawaiian necklace
60. Sleep loudly
61. Santa's helper
62. Cure
63. Nobleman
64. Other
65. Lack of experience (var.)
66. Fortune telling cards
67. Child's game
68. North African grasses
69. Horse treat
70. Negatively-charged atom
71. Inflexible

Solution on page 49
Ancient Egyptians treated water by siphoning water out of the top of huge jars after allowing the muddy water from the Nile River to settle.

Hippocrates, known as the father of medicine, directed people in Greece to boil and strain water before drinking it.

Sources: New Jersey American Water Works
www.njawwa.org

**WATER TRIVIA Q & A**

Q: How much of the earth’s water is suitable for drinking?

A: 1 percent

Source: City of Albuquerque Public Works Department, www.cabq.gov/water/trivia.html

“Yesterday I changed everyone’s password to ‘password’. I sent it to everyone in a memo, put it on a big sign on the wall and printed it on all of the coffee cups. Guess how many people called me this morning because they forgot the password.”

© 2003 Randy Glasbergen. www.glasbergen.com
Many of us who thumb through the pages of On Tap magazine depend upon water, but not just for the sake of actually “needing” water to stay alive. Water is what pays the bills. It is our life in many ways.

Some of us work in water plants providing safe drinking water for small towns, while other folks sit at a desk and write about how to get water out of the ground or how to go about finding other sources. Then there are people who strap on their waders, grab some empty baby food jars, and wallow through the muck of a semi-polluted stream collecting water samples. There’s no denying the fact that we all need water to survive—but how many of us actually take the time to really think about it?

Does anyone have the foggiest idea of how many gallons of water they use per day?

Conserving water is a foggy idea for many people because, frankly, most of us don’t know where to begin. People may question every little thing such as, “Should we flush every third time or every fourth?” or “How much are we really wasting when we leave the water running while we brush our teeth?”

It may sound ridiculous, but to actually see the numbers from the U.S. Environmental Protection Agency (EPA), Office of Water, April 1995, Water Trivia Facts, the totals for personal water consumption is mind-boggling. According to EPA, in 1995 the average household used 107,000 gallons of water per year and your average Joe used 50 gallons of water per day. And how many gallons of water do you use to brush your teeth anyway? Try two gallons.

Who knows how much water each person will use on a daily basis in 2004 or even 2010?

In an article by Harriet Emerson, from the National Drinking Water Clearinghouse (NDWC) Web site titled, “Conservation: It’s the Future of Water,” she writes, “We can estimate, according to former U.S. Senator Paul Simon’s Tapped Out, the world’s population of 5.9 billion will double in the next 40 to 90 years.

“At least 300 million people live in regions of severe water shortages. By the year 2025, it will be three billion. Compounding these grim realities is the fact that per capita world water consumption is rising twice as fast as the world’s population.” (Read more of this article online at www.nesc.wvu.edu/ndwc/ndwc_conservation.htm about water conservation and how to develop your own water-saving strategies. This is an excellent place to start your conservation education. They offer a variety of water conservation materials for adults, children, and educators. Many of the products provided are free. There’s even a great list of water conservation links.

We all have to start somewhere and, after all, water is life. Without it none of us could survive, and some of us would even be out of a job.

Julie Black has been the graphic designer of On Tap for more than three years. She also moonlights as a writer/photo journalist for www.iPlayOutside.com.
Folks here at the National Drinking Water Clearinghouse (NDWC) want to make sure people in small towns and rural areas have the best drinking water possible, and we have information to help your community achieve that goal.

If you have questions about drinking water issues, look to us for answers. We provide a variety of free services, including a toll-free technical assistance hotline, more than 300 educational products, and On Tap magazine, available at your request. The NDWC also sponsors conferences, workshops, and seminars to bring our services to you in person.

Our staff is made up of engineering scientists, researchers, technical writers, and editors who locate and distribute information on subjects such as:

- water treatment technologies,
- source water conservation issues,
- operation and management strategies,
- regulation updates, and
- funding sources for community water treatment infrastructure.

The NDWC Website located at www.ndwc.wvu.edu is packed with information and links to other organizations that focus on drinking water. Online databases are accessible to the public also.

An organizational database with over 300 drinking-water related groups is listed, and a general water information database offers nearly 2,000 water-related article topics.

Our RESULTS 3.0 database [Registry of Equipment Suppliers of Treatment Technologies for Small Systems] can be accessed by calling us and asking for technical assistance to help you locate water treatment technologies and systems that use them.

The technical assistance hotline can be reached Monday through Friday from 8:00 a.m.–5:00 p.m. Eastern Time.

Contact the NDWC today for a free information packet, to subscribe to On Tap, or to order any of our educational products.

We’re eager to hear from you!
The National Environmental Services Center (NESC)—pronounced “nessie”—specializes in providing technical assistance and information about drinking water, wastewater, and environmental training to communities with fewer than 10,000 residents. You may be familiar with our individual programs, each well established as a national leader in its areas of expertise.

National Drinking Water Clearinghouse (NDWC)
Helping small communities by collecting, developing, and providing timely information relevant to drinking water issues.

National Small Flows Clearinghouse (NSFC)
Helping America's small communities solve their wastewater problems.

National Environmental Training Center for Small Communities (NETCSC)
Assists small communities by providing training and training-related information and referral services in the areas of wastewater, drinking water, and solid waste.

National Onsite Demonstration Program, (NODP)
Demonstrating integrated onsite wastewater management and technology solutions.

Located in Morgantown, West Virginia, NESC is based at West Virginia University, one of the nation’s major doctoral-granting research institutions.

(800) 624-8301  (304) 293-4191
www.nesc.wvu.edu

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