COMPASS

perspectives & tools to benefit southern forest resources

issue 5

FROM MOUNTAIN HEADWATERS TO THE SEA

Forests Clean Our Water

Southern Research Station

USDA Forest Service

inside... the science

DEPARTMENTS

Cover Photo: A surrealistic depiction of clean water flowing from Southern Appalachian forests by Asheville artist, Paul Olszewski.

COMPASS
Science You Can Use!

April 2006—Issue 5*

perspectives & tools to benefit southern forest resources

Compass is a quarterly publication of the USDA Forest Service Southern Research Station (SRS). As part of the Nation's largest forestry research organization—USDA Forest Service Research and Development—SRS serves 13 Southern States and beyond. The Station's 130 scientists work at more than 20 units located across the region at Federal laboratories, universities, and experimental forests.

Future issues can be obtained by returning the postcard included in this issue.

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The mission of the Southern Research Station is to create the science and technology needed to sustain and enhance southern forest ecosystems and the benefits they provide.

*Issues in 2005: 1 (Winter), 2 (Spring), 3 (Summer), 4 (Fall)

The Soque River in Georgia is a good example of water derived from our National Forests. *(photo by Dave Dwinnell)*

Healthy Forests are Vital to Clean Water

Forests are key to clean water. About 80 percent of the Nation's scarce freshwater resources originate in forests, which cover about one-third of the Nation's land area. The forested land absorbs rain, refills underground aquifers, cools and cleanses water, slows storm runoff, reduces flooding, sustains watershed stability and resilience, and provides critical habitat for fish and wildlife. In addition to these ecological services, forests provide abundant water-based recreation and other benefits that improve the quality of life.

—Jim Sedell. *Water and the Forest Service*. 2000.

Water Pressures Build in the Southeast

by Zoë Hoyle

The water you drink today has literally been around for eons. The same water has been cycling around and around through the hydrologic cycle since before the time of the dinosaurs—falling as rain, flowing through streams to rivers to oceans, evaporating back into the atmosphere.

Water, its availability or lack, determines where—and in what forms—life exists on our planet. We expect water to be available to us all the time: we humans can only live 4 or 5 days without it. Less than 1 percent of the Earth's water is *accessible* fresh water, present on the surface in rivers and lakes, in ground water stored underground, and in the atmosphere. This water is renewed daily by precipitation, cleansed daily by forests and soils.

Across the world over a billion people do not have access to clean drinking water. In the United States, most of us assume our supplies of water are secure, but just over a century ago, clean drinking water was starting to look scarce. From East to West, vast areas of American land had been clearcut and unsustainably farmed, leaving land with no vegetation, the bare soil deeply scored by erosion. Streams and lakes were polluted with sediment and waste; urban water supplies smelled bad and had become a source of disease.

The connection between forests and clean water was clear to the writers of the 1897 Organic Administration Act, which recognized the importance of forest reserves in protecting and enhancing water supplies and reducing flooding. When the National Forest System was established in 1905, one of its first mandates was to restore the watershed function of forests. Today an estimated 80 percent of U.S. freshwater resources originate in forests, with much of the nation's drinking water coming from the estimated 192 million acres of our national forests, which actually make up only 30 percent of U.S. forested land. According to the U.S. Environmental Protection Agency, more than 60 million people in 3,400 communities rely directly on national forests for their drinking water.

The quality of water draining from national forests is typically the highest in the country. Healthy forests provide the best protection against sedimentation and other pollutants, better and more cost-effective filtration systems than any municipal treatment plant. How do forests do it? The tree canopy dissipates the energy of raindrops, reducing landslides, erosion, and sediment. The litter layer maintains a porous soil surface, allowing water to filter in and through, minimizing erosion and supporting nutrient cycling. Multiple levels of vegetation—ground covers, shrubs, trees—also intercept rain, while roots slow runoff. Roots and soil work together to filter out pollutants, and in some cases, trap and store water.

In the South, nearly 90 percent of forested land is held by private nonindustrial landowners; publicly owned lands, though producing high-quality water, can hardly ensure future availability. With increased population and loss of forest cover projected for the South, what will happen to our water supplies?

Water Wars Come to the South

If you live in the South, chances are good that some of the water you drink—whether from the tap or that bottle on your desk—first comes out of the Earth either as ground water or as a trickle over moss-covered rocks, gathering into a stream that passes down through

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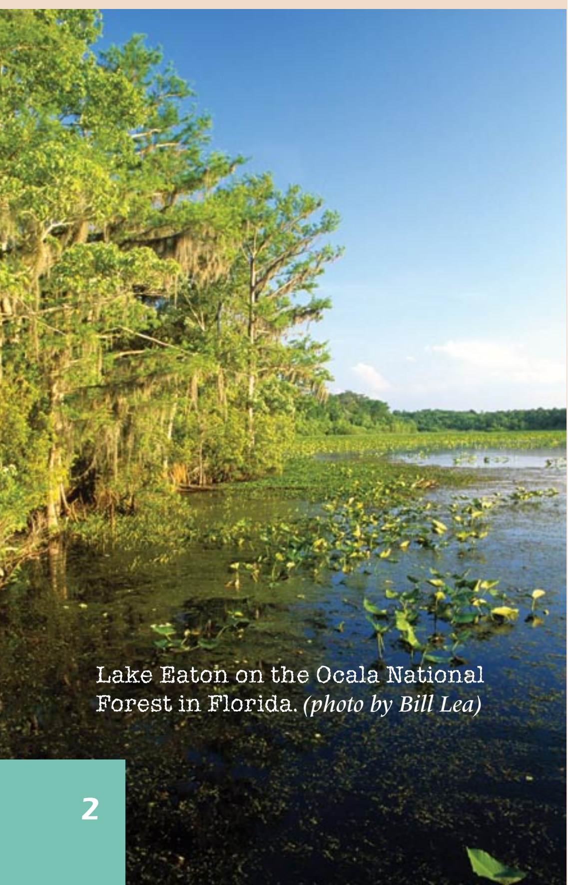
Major Threats to Water Quality

Nutrients	Nitrates from sewage and fertilizers, phosphates from detergents and fertilizers
Sediment	From agricultural fields, construction and logging sites, urban areas, strip-mined land, and eroded stream banks
Bacteria	Carried in inadequately treated sewage and from storm water drains, septic systems, livestock pen runoff, and sewage dumped from boats
Organic materials	From sewage, leaves, grass clippings, and runoff from livestock pens and pastures
Metals	From industrial discharges and in runoff from roads and urban streets, mining activities, and landfills
Pesticides and herbicides	From agricultural fields, lawns, termite control, and golf courses



Lake Eaton on the Ocala National Forest in Florida. *(photo by Bill Lea)*

WATER PRESSURES

(continued from page 1)

forests of hemlock and spruce, oak and poplar, rhododendron and laurel. In the Southern Appalachians, the headwaters of major rivers and streams often as not lie in national forest lands, which provide plentiful and clean sources of drinking water. Until recent decades, you could take your water sources for granted.

Because of plentiful rainfall in the South, water has rarely if ever been a limiting factor for development. Most people living in the area don't think about water scarcity at all unless there's a summer drought and they're asked to stop watering their lawns—which is what happened in areas of North and South Carolina in the summer of 2002.

During the drought of 2002, rivers were so low that some towns came within feet of shutting down municipal water supplies. Fights broke out between neighboring municipalities over the effects of water removals on those downstream. Power plants and other industrial users came under fire for not releasing more water from their dams. Across the southern region, communities came to realize that they had to find ways to get more water—by importing it from somewhere else, planning better, or regulating more.

The years since have found the States of Georgia, Alabama, and Florida embroiled in "tri-State water wars" over water supplies that cross State lines. Other States like Tennessee have begun drawing up plans to protect the waters of their major river basins from being siphoned off by urban areas outside their borders.

"Periods of drought in the last two decades have pushed concerns about water quantity to the forefront," says **Jim Vose**, project leader for the **SRS Coweeta Hydrologic Laboratory** in Otto, NC. "But drought is only part of the picture: A second factor is population growth. We're looking at a 20 to 30 percent increase in demand by 2040."

Add to that a reduction in the forested land streams and rivers flow through. The *Southern Forest Resource Assessment* recently projected that 12 million acres of southern forests will be converted to other uses by 2020, with new land uses just adding to demand for more water. At the current pace of growth, water supplies could be in serious jeopardy in just a few years. "For communities that depend on surface water, around 15 acres of watershed are needed to meet annual water needs for each person, about 30,000 acres for a small town," says Vose.

Not Just Water, *Clean* Water

Water from the forested watersheds of national forests is consistently clean, providing not only quality drinking supplies for humans but also habitat for a wide range of aquatic species. The Southeast contains some of the most diverse populations of aquatic organisms—mussels, fish, crayfish, insects—in the world, with more being discovered each year. With declining supplies of clean water, we stand to lose this incredible natural diversity—as well as the security of knowing the water from our taps is clean enough to drink.

Water quality in the South has been shaped by three centuries of intensive land use, with clearing for agriculture starting in the 1700s, and unregulated logging beginning shortly after the Civil War and lasting through the 1920s. For water quality in the South, the period between 1860 and 1920 was the most destructive known, with widespread clearing of forests without any erosion control measures. Logging peaked in 1909 and stayed high until 1920, when only a few stands of virgin forest remained. Rivers were filled with sediment from mountain slopes; many still run muddy from those times.

The rather recent widespread draining of wetlands, which filter surface water runoff, also affected water quality. Urban expansion brought point-source pollution from factories and sewage plants. Though many of these point sources have been stopped, their legacy remains in the sediment layers of streams and rivers. Now pollution flows in from nonpoint sources, with untold contaminants leaking off roads, landfills, storm systems, and construction sites into surface and ground waters. The primary factor affecting the future of water quality in the South is the constant expansion of nonpoint-source pollution from urban sprawl.

Back to the Forest

Preventing contaminants from ever reaching the stream is the most effective way to deal with pollution. Undisturbed and well-managed forests do this very well. In fact, forest management practices have evolved from the "cut and run" approach at the turn of the century, to practices that help ensure water quality by preserving and enhancing forest health.

An example of forest water-cleaning efficiency can be found in nutrient cycling, the process by which chemicals essential to plant growth are moved through soil, water, and living trees. Nutrients such as nitrogen are important for plant growth; along with phosphorous and potassium, nitrogen is one of the main ingredients in fertilizers. But nitrogen easily transforms into nitrates that can have serious negative effects on human and ecosystem health. Fertilizer production and other human uses have doubled the input of nitrogen into terrestrial ecosystems since the preindustrial period, and have compromised rivers and streams, sometimes leaving the water and its inhabitants oxygen-starved.

Forested watersheds have consistently been shown to have lower sediment and nutrient levels than nonforested watersheds. Few nutrients such as nitrogen are lost from healthy forest ecosystems directly to stream channels because these systems are very efficient at cycling nutrients—especially young forests, which rapidly soak up nutrients from the soil as they grow. The lowest levels of nitrates are found in waters draining undisturbed wildlands, while the highest levels are found in water from agricultural and urban areas.

Water is a finite and necessary resource: as time goes on, even more will be needed. "Municipalities will rely more and more on forested watersheds to offset or mitigate the impacts of population growth, while land use change and climate variability will make it increasingly difficult to keep up with that demand," says **Carl Trettin**, project leader for the **SRS Center for Forested Wetlands Research** near Charleston, SC. "The pressure is on for forest hydrologists to help municipalities find solutions. With our forested watersheds as resources, we can provide the standards for clean water."

How can Forest Service research help secure clean water in the quantities needed across the Southeast? The answer to this question varies with the topographies and climates of the region. In this issue, we will find out what SRS scientists have learned from two distinct settings—the Southern Appalachian uplands and the Coastal Plain of South Carolina.

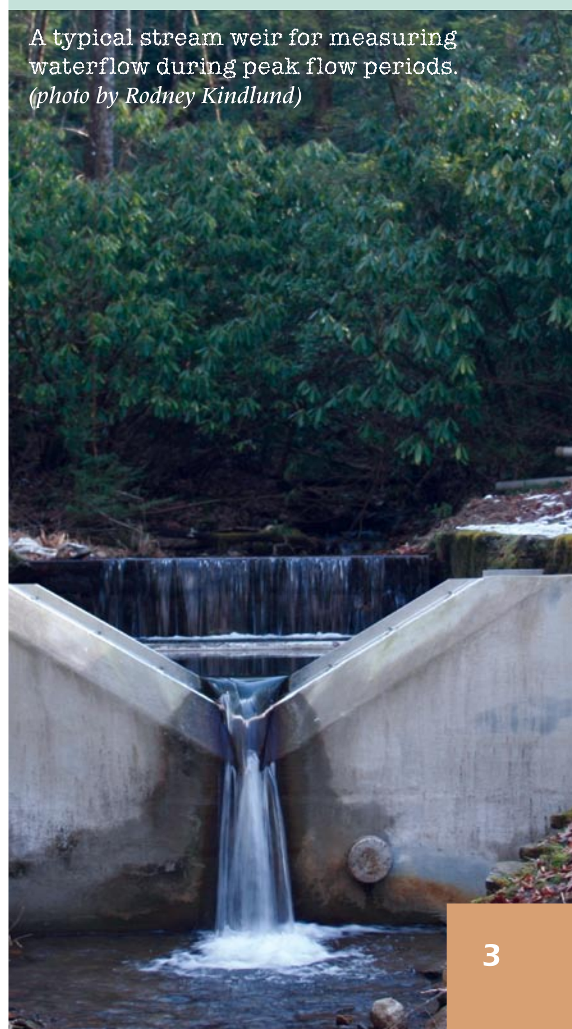
Water Quality in the South

Approximately 30 percent of the South has relatively good water quality, 36 percent moderate water quality problems, and 15 percent more serious water quality problems.

From data covering 1988 to 1998, the leading pollutants were silt and sediment, bacteria and other pathogens, and nitrogen, phosphorous, and other nutrients.

The leading sources of pollution were agriculture and urbanization. Approximately 70 percent of all pollutants came from nonpoint sources.

State reports showed approximately 3,600 miles of rivers and streams impaired by silvicultural activities, with silviculture ranking 9th out of the 10 major sources of water impairment during the period.



A typical stream weir for measuring waterflow during peak flow periods. *(photo by Rodney Kindlund)*

The Hydrologic Cycle

Hydrologic cycle: the constant movement of water rising to the atmosphere as water vapor, cooling to condense and precipitate onto the Earth, then evaporating or transpiring back into the atmosphere.

The following seven processes occur simultaneously, and with the exception of precipitation, continuously.

Condensation: water vapor that turns into liquid water as the result of cooling.

Precipitation: rain, sleet, or snow that results when water vapor becomes too heavy to remain in air currents.

Interception: precipitation caught on leaves or other vegetative surfaces.

Infiltration: rainfall that seeps into the ground.

Surface runoff: precipitation that reaches the surface of the Earth but does not infiltrate.

Subsurface flow: infiltrated water that moves through subsurface pathways into a stream or river.

Evaporation: water converting from a liquid or solid state to a gaseous state from the plant surfaces, soils, and bodies of water.

Transpiration: process where plants move water from the soil to their aboveground parts, then lose it to the atmosphere.

Evapotranspiration: the combined processes of water evaporating from the ground and transpiring from plants—the total water vapor added back to the atmosphere.

WIDENING THE LENS

Water Research at Coweeta Moves to New Levels

by Zoë Hoyle

There's a new buzzword in water research these days: "**ecohydrology.**" The idea is to blend the principles of ecology with traditional watershed hydrology to address the complex issues (invasive species, climate change, wildfire, urbanization, etc.) facing land managers charged with protecting water resources now and into the future.

The word might have been invented to describe what researchers at the SRS **Coweeta Hydrologic Laboratory** near Otto, NC, have been doing for some time. Over the past several decades, Coweeta has taken an interdisciplinary approach to understanding how watershed ecosystems respond to natural and human-caused disturbances**. Jim Vose**, project leader and ecologist at the Coweeta unit, says "our basic philosophy is that if we understand how the ecosystem works—the interconnections between climate, vegetation, soils, and water—we can begin to develop management practices to deal with the consequences of disturbance. This approach requires integrating many scientific disciplines to understand the complex nature of both natural and managed forest ecosystems."

An Ecohydrologic Approach to Insect Invasion

The hemlock woolly adelgid, an exotic insect smaller than a poppy seed, threatens to bring dramatic changes to Southern Appalachian forests. Despite an aggressive campaign to control the adelgids, people in the field think that many of the area's hemlocks will be dead within the next decade, opening up the forest canopy and removing shade from cool mountain streams. Last year, Coweeta researchers set up experiments to look at the effects of hemlock death on riparian zones, and the water quality in the streams that drain out of the region's headwaters.

Coweeta scientists **Barry Clinton** and **Jennifer Knoepp** have brought Chuck Rhoades, a Forest Service research biogeochemist, out to a test site set up to monitor hemlock woolly adelgid damage. Rhoades has come to Coweeta to discuss possibility of planting American chestnut seedlings in areas opened up by dying hemlock. There's still a little snow on the ground, and the forest floor feels deep, spongy. The site is in the riparian zone, about 30 feet from a small stream, and thick with hemlock, rhododendron, yellow-poplar, and locust.

Coweeta researchers Barry Clinton (left) and Jennifer Knoepe (right) at the site used to study the effects of hemlock death on forest streams.
(photo by Rodney Kindlund)

The site is one of 12 set up across the Coweeta basin to predict what will happen to riparian zones, streams, and water quality if—more likely, when—the adelgids kill many of the hemlocks that dominate watersheds in the region. "We girdled some of the hemlocks in this area to simulate mortality for the experiment, but we needn't have bothered," says Clinton, as he points to hemlock branches above us that show the telltale thinning of canopy foliage. "Hemlocks are dying faster here than farther north, where cold winter temperatures slow the adelgids down. We're already seeing death in trees that we first identified as infested in 2003."

If you come upon one of these experimental sites by accident, you might think you've stumbled on some sort of dump site—plastic buckets, poles sticking up everywhere, metal rings around the trees, even laundry baskets scattered around. These tubes and buckets are the instruments forest ecologists have developed to take *in situ* measurements of light, temperature, leaf fall, tree growth, and the movement of nutrients and water through the soil. Putting all this data together allows them to track changes in the water quality of the nearby stream.

So what do insects have to do with water quality? Trees intercept rain and use soil water in transpiration, slowing the force with which water flows into streams. Hemlock is an evergreen, and the year-round foliage moderates soil and stream temperature. By denuding the hemlock canopy and eventually killing the trees, adelgid infestations affect soil processes, as well as stream flow and temperature.

Insects are only one example of the many natural and unnatural forces that can disturb forested watersheds and affect the quality of the water that many of us depend on. To plan for a future that includes loss of forests to development and other land uses—as well as to hurricanes, insects, air pollution, and global climate change—we need to know how our watersheds respond to a wide range of disturbances.

In For the Long Run

It's a good thing that the USDA Forest Service had the foresight to start monitoring climate and streamflow at Coweeta back in the 1930s, when Southern Appalachian forests were just beginning to grow back after the intense timber harvests that began in the 1900s and lasted well into the 1920s. Charged with restoring the watershed function of forested highlands, but with little understanding of regional climate and weather patterns, the Forest Service set up the long-term studies that form the foundation of what we now know about the interplay between forests and water in mountain areas.

Established in 1933 as the **Coweeta Experimental Forest**, the laboratory represents the longest continuous environmental study on any landscape in North America, as well as one of the oldest gauged watershed sites in the world. Located in the Nantahala Mountain Range in western North Carolina, the 5,400-acre laboratory is made up of two adjacent, bowl-shaped basins covered with forest and containing several well-defined watersheds and over 45 miles of stream. In the steep hills of western North Carolina, the way water moves into and down the stream plays a primary role in water quality. Much of what we now know about how water flows in this environment comes from long-term research at the site, which was renamed the Coweeta Hydrologic Laboratory in 1948.

Originally, 32 weirs were installed on streams in the watershed; 16 streams are

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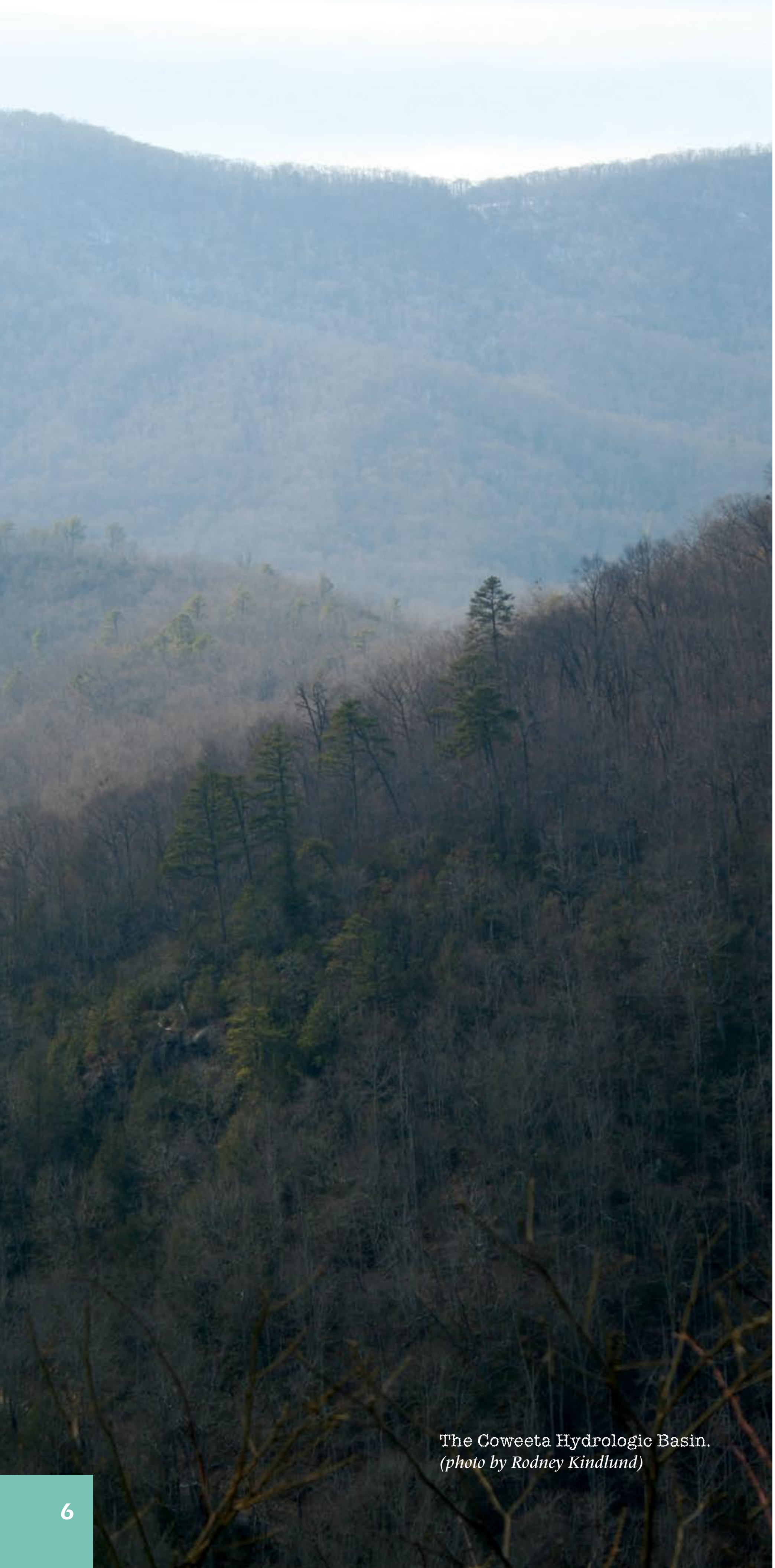

The Coweeta Hydrologic Basin.
(photo by Rodney Kindlund)

WIDENING THE LENS

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still gauged and actively monitored. Eight watersheds have been unmanaged since the 1930s, and are used as controls in paired watershed studies that test the effects of both natural and human disturbances on water quantity and quality. In the 1930s, the Coweeta basin was the perfect place for the Forest Service to study the effects of logging on streams, and to develop best management practices (BMPs) to prevent damage to water quality.

Like most of the Southern Appalachians, the Coweeta basin was heavily harvested in the 1920s. At the time, very little scientific information was available about the impacts of unregulated logging on water quality, but it was clear to the naked eye that large amounts of sediment reached the streams when mountain watersheds were logged. One of the earliest Coweeta studies demonstrated that allowing loggers to access timber as they had always done—by building skid trails directly up steep slopes and roads right next to, sometimes in, streams—was not good for water quality. These practices eventually filled the streams of the basins with sediment, and erosion became such a problem that the roads had to be closed. It was time to change the paradigm for building logging roads in the mountains.

The four paired watershed experiments started in the 1940s provided the science to build better forest roads in the Southern Appalachian Mountains. Researchers chose two watersheds of equal size, as close together as possible, and with as many similar characteristics as possible. They managed one of the pair for clean water production, with tight controls on road construction; they managed the other to maximize timber harvest, with few controls. Over time, Coweeta research has shown that forest roads can be built in the Southern Appalachians without compromising water quality. Current guidelines for forest access roads are almost without exception based on the Coweeta experience.

"Some of the most important early Coweeta research demonstrated that it's not cutting trees *per se* that causes erosion and sediment runoff, but the disturbance of roads and activities required to get the logs out of the woods," says Vose. "The Southern Appalachian region is a very challenging place to build roads. The terrain is steep, with high rainfall and sudden storms that can rapidly erode soil and transport sediment to streams." Vose adds that "the solution to many of these issues is to apply best management practices; research has demonstrated that the proper implementation and maintenance of BMPs can minimize the impacts of road building, logging, and other management activities on water quality."

Besides changing road building practices, the paired watershed experiments at Coweeta have also provided scientists with a basic understanding of the hydrology of the Southern Appalachian region—and how forest management can be used to affect both water quantity and quality.

Quality Rather Than Quantity

"Our long-term studies show what you would expect," says Vose. "Rain, snow, and other types of precipitation provide the source of streamflow, while standing trees—through transpiration, evaporation, and interception—reduce it. We've found that logging increases streamflow by temporarily reducing transpiration and interception, while planted pine forests actually reduce streamflow. The evergreen foliage translates to higher winter, spring, and fall rates of transpiration and interception than in hardwoods."

But that doesn't mean that we can use logging or silviculture to get enough water out of watersheds to meet all future needs. "Although research demonstrates that logging can produce short-term increases in streamflow in the Eastern United States, logging at the levels required to meet future water demands would most likely be unacceptable to the public," says Vose. "Rather than trying to manipulate supplies, it makes more sense to educate the public to reduce water consumption, improve conservation, and plan for scarcity. What we *can* do is ensure the *quality* of the water that flows out of our forested watersheds."

Research has shown that forest management can have major effects on the ability of watersheds to provide clear, cold waters for human consumption and as habitat for aquatic organisms. If the aim is to manage forests to protect water quality for both of these constituencies, forest managers must first know the effects of the practices they use. Again, much of what is known in this area comes from nearly a century of research at Coweeta.

The main water-quality issues in relation to forest management are sediment (primarily from forest roads), nutrients (mainly nitrogen and phosphorous), pesticides, and changes in water temperature. Coweeta research has shown that, in addition to roads and road construction, the forest practices with the most potential for causing erosion and stream sedimentation are tractor skidding (as opposed to cable or aerial log removal methods), and intensive site preparation (treatments to kill existing vegetation to convert to pine, for instance).

When logging activities include the implementation and maintenance

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Key Findings from Coweeta

The Impacts of Forest Management on Water Quality and Quantity

The amount of water flowing from a forest watershed increases after timber harvest, mainly because of reduced transpiration from trees.

The volume of water from storms (stormflow) and maximum peak flows also tend to increase after harvest.

Water yields and changes in stormflow lessen as vegetation grows back.

Increases in the concentrations of nutrients such as nitrogen and phosphorus tend to be short lived.

Leaving stream management zones—buffer strips of uncut trees and shrubs—protects stream temperatures by providing shade.

Though erosion and sedimentation from forest management activities is small compared to other land uses, it can be significantly higher than that on undisturbed forest watersheds.

Natural disturbances such as insect outbreaks can also temporarily increase nutrient losses from forest watersheds.

Poorly designed or maintained roads are the main source for increased sediment levels associated with forest activities.

Streamside management zones of sufficient width and extent are critical for reducing the delivery of pollutants to streams.

Widening the Lens

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of BMPs with the goal of preserving water quality, stream sedimentation is not significant. But when timber is harvested without BMPs—or to clear mountain forests off for agriculture or development—the result is often significant erosion and sedimentation. Decades of research from Coweeta has shown that stream pollution from well-planned forestry activities tends to be local, short term, less frequent and less extensive than that from either agricultural or urban activities. Most pesticides and herbicides currently used for forest management—if applied correctly—are immobilized and degraded in soils to an extent that they pose little risk to streams.

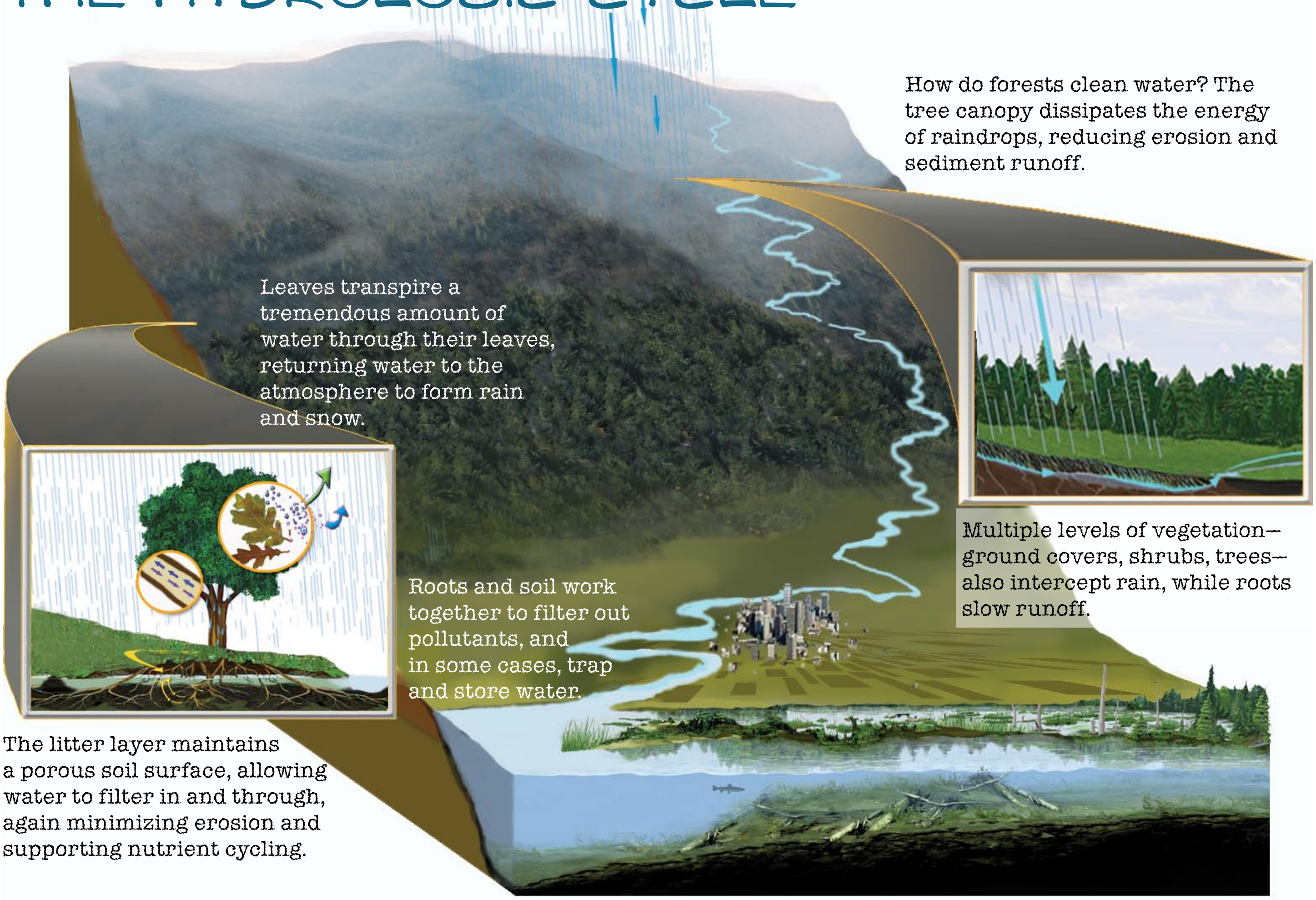
Similarly, when prescribed burning is done correctly, using low-intensity burns, the impact on water quality is low, with nutrient levels in streams returning to pretreatment levels within 9 months of burning**. Katherine Elliott**, an ecologist at Coweeta, has led efforts to understand the impacts of stand restoration burning on water quality in the Southern Appalachian region. "Rapid vegetation regrowth and maintaining a forest floor layer are the keys to keeping nutrients and sediments out of the stream after stand restoration burning," says Elliott.

But what about disturbances not directly under the control of the manager or landowner, such as hurricanes, insect pests, and climate change? Can the water itself tell us when the forest is under stress?

Nitrogen: A Litmus Test for Disturbance

When former project leader **Wayne Swank** arrived at Coweeta in 1968, research expanded to include monitoring stream chemistry to measure the effects of disturbance and detect long-term trends. Swank, who is currently an emeritus scientist at Coweeta, also established a unique and ongoing collaboration with the University of Georgia that led to the selection of Coweeta as one of the first sites in the National Science Foundation Long Term Ecological Research network. In 1972, researchers started stream chemistry measurements at Coweeta; nitrogen, a nutrient that shows a quick response to disturbance, became a natural research focus.

The Hydrologic Cycle



"Nitrogen, an essential element for plant growth, is a good indicator of changes to the forest that might affect water quality," says **Jennifer Knoepp**, a soil research scientist who conducts a wide range of nutrient cycling studies. "As organic nitrogen breaks down in the soil into a form that plants can use, it also forms nitrate, which moves very easily through soil and water. The problem with nitrate is that its structure allows it to easily 'grab' other nutrients and pull them into streams, where, in high concentrations, it can become a major threat to human health."

The nitrogen levels in Coweeta streams are naturally very low. The standard for nitrogen in drinking water is 10 parts per million, while at Coweeta it runs about 50 parts per *billion*. "At Coweeta, no matter what the experiment, we never get water degradation due to nitrogen," says Knoepp. "What we do have is a very sensitive instrument, almost an alert system, for looking at forest disturbance in this basin."

Long-term monitoring on control watersheds has established baselines for nutrients such as nitrogen; changes in baseline levels can alert researchers to previously undetected disturbances. In the 1970s, a spike in nitrate readings from one of the weirs alerted Swank to an outbreak of cankerworm on one of the watersheds, and to a later outbreak of locust stem borer. Coweeta scientists have also had the opportunity to study the effects on stream chemistry of hurricanes, ozone damage, acid deposition—and now the hemlock woolly adelgid.

In addition to serving as signatures of ecosystem response to watershed disturbance, stream chemistry studies provide guidance for streamside management and restoration, notes Vose. "These long-term data are critical for understanding the relationships among

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Coweeta site instrumented for water and soil studies.
(photo by Rodney Kindlund)

The Coweeta Long Term Ecological Research Program

The Coweeta Hydrologic Laboratory has been a **National Science Foundation Long Term Ecological Research (LTER) Program** site since 1980. The program is the center piece of cooperative efforts between Coweeta and the University of Georgia, and includes other major university cooperators such as Duke University, Mars Hill College, University of Minnesota, University of North Carolina at Asheville, University of Wisconsin-Madison, and Virginia Polytechnic Institute and State University.

The Coweeta LTER Program encompasses a broad array of cooperative studies, averaging 30 projects each year involving over 55 graduate and undergraduate students and over 30 senior investigators. Over 200 students have received graduate degrees from research conducted at Coweeta, and the laboratory conducts onsite tours for over 60 groups each year.

Since 1980, the program has expanded from primarily site-based studies to encompass regionwide issues. Coweeta LTER studies focus on human land uses as the primary disturbance on the private lands that include most of the remaining forest in the Southern Appalachians, to uncover how land use change affects ecosystem processes—as well as how land use decisions are influenced by social, economic, and ecological factors.

To access a full list of research programs, as well as articles, datasets, and other materials from the LTER, visit the program Web site at http://coweeta.ecology.uga.edu/.

Widening the Lens

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disturbance, management, and water quality—and for developing the guidance to keep forests healthy and productive—and water protected by the riparian zones that keep nutrients bound up in soils and vegetation. Further, these data have been important for validating computer-based models that predict how Southern Appalachian watersheds might respond to changes in climate and air pollution."

Widening the Lens

Coweeta has long provided—and continues to provide—the best information about managing forested watersheds in the Southern Appalachian region, but Vose is ready to take the research to a new level, to widen the lens to larger landscapes. "To understand and predict how population pressures and land change will affect water quantity and quality in the South, we need to know, for instance, what happens to water as it moves from mountain headwaters through the Piedmont regions and into the Coastal Plain region," says Vose.

Hydrologic processes take place at scales that range from a few yards to millions of acres. Because of the complexity of variables involved, most studies have been done on a small scale, similar to the paired watershed studies at Coweeta. Because large-scale models are based on these small-scale studies, they can't really take into account regional variability. "Most research in this area has looked at small watersheds over a relatively small time period," says Vose. "It's time to shift our focus to larger scales and to cumulative effects over longer periods of time."

If you are familiar with the mountain-to-sea topography of the Carolinas, you can see that it doesn't make sense to predict water supply for the Piedmont or the coast based only on data from Coweeta. "Many of the headwaters in our mountain region are mostly forested, with much of the land located in national forests or national parks, "says Vose. "These watersheds are in good condition in terms of soil and riparian conditions, especially in comparison with some of the agricultural, exurban, and urban areas they flow through. We really don't have a good understanding of how these regions connect in terms of surface water hydrology."

Changes in land ownership as water flows out of the forested headwaters also have to be considered, along with the disturbance resulting from multiple land uses. "We have to start looking at watershed health as an interconnected system," says Vose. "Since most of the land water flows through is held by mixed ownerships, we need to be able to predict future land use patterns and how they will affect water supplies."

Vose and SRS project leaders **Steve McNulty** and **Carl Trettin** are proposing a bold new approach to water supply modeling that incorporates data from hydrologic studies from Coweeta and Trettin's hydrologic laboratory in the Carolina Coastal Plains with the models McNulty's unit has developed to project forest cover and water supply in relation to population and economic growth in the South.

Looking at future water supplies this way becomes a very complex problem, one that involves both physical and biological processes with drivers—climate, land use change, and the effects of insect and pathogen outbreaks—which are constantly changing. If you want to look at the effects of multiple land uses that overlap in time and space over multiple watersheds, you need precise on-the-ground data, as well as the ability to scale up. "In our watershed-level studies, we constantly recalibrate by comparing measurements," says Trettin. "The farther out in scale you get, the more difficult it is to validate models."

Using long-term data from watersheds as the foundation, SRS scientists propose to solve a basic disconnect in current modeling. "A basic problem with existing models is that they don't do a good job of combining physical processes, such as soil water movement, with biological processes, such as transpiration and nutrient cycling," says Vose. "Most models are more strongly based on one or the other. With advances in computing technology and improved understanding of physical and biological processes, we are positioned to develop more complex models at larger scales."

Plugged into the Electric Forest

So how do you link together biological and physical processes: tree physiology and stream chemistry, for instance? For one part of the answer we return to Coweeta, this time to an experimental site high up on the south basin, where ecologist **Chelcy Ford** is developing the type of species-level information that may help us better predict what will happen to our water over the coming decades.

Bob McCollum, a biological technician who's been at Coweeta for over 20 years, leads us down a steep path from the road, over a narrow wooden walkway designed to keep researcher feet off the soil and litter of the forest floor. The mixed hardwood area is highly instrumented—a lot of it built by McCollum—with more of the laundry baskets, tubes, and fluorescent tags, as well as aluminum foil cuffs around some trees. Everything is wired into one jam-packed instrument box. "I call this the electric forest," says McCollum.

Ford peels back the foil cuff wrapped around the trunk of a tulip poplar to

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Chelcy Ford explains how probes are attached for sap flow studies. *(photo by Rodney Kindlund)*

Even a Mile of Forest Makes a Difference in Water Quality

Results from a small-scale experiment in western North Carolina illustrate the importance of national forest lands in ensuring high water quality in the Southern Appalachian region. Conducted by SRS scientists from the **Coweeta Hydrologic Laboratory**, the study, published in the January 2006 issue of the journal *Water, Air, and Soil Pollution*, showed that the quality of water in streams from an area heavily affected by urbanization was significantly improved by its passage through streams flowing in undeveloped forested areas.

For the experiment, researchers **Jim Vose** and **Barry Clinton** located a setting where a stream carried water from a small town into a fork of the Chattooga River while passing through national forest land. They set up three sampling sites—the first below the town where the stream enters the national forest, the second about a mile further down where the stream (now a fork of the Chattooga River) exits the national forest, and the third reference site on a small, undisturbed stream which lies entirely in the national forest.

"There's a waste treatment facility a little over half a mile up from where the stream enters the national forest," says Clinton. "We chose the first sampling site to pick up the cumulative effects of wastewater treatment and other nonpoint-pollution sources such as housing developments, stormwater runoff, and roads."

Samples were collected weekly for over a year using automated samplers. Data was collected on water chemistry and total suspended solids, particles that range

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Widening the Lens

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reveal the probes used to measure sap flow, which gives an indication of transpiration rates from the crown above. "Water, with dissolved minerals, enters tree roots and is pulled up through the xylem to the leaves, where large amounts of water are transpired," says Ford. "There is tremendous variation in sap flow between species. The point of these experiments is to develop a *species-level* understanding of transpiration, which is the only biological component of the water cycle."

For a more complex view, Ford spirals sensors around trees to create 3-dimensional images of sap flow. She's one of the few researchers who can do this type of instrumentation, which adds the visual dimension to gathering sap flow data. "We also look at where the tree is in the landscape, what size it is, and what species," she explains. "Without measuring transpiration at the tree level, you can't accurately measure the impact of losing that species," says Ford.

Just up the road is a second instrumented site in a planted, monoculture pine forest where similar information is being gathered to compare with that from the mixed hardwood site. "What effect does tree species diversity have at the watershed level on water quantity and quality? At the landscape level?" says Ford. "Ultimately, how do we get from the stomate (the opening on a tree leaf through which water evaporates) to the watershed level?"

To look at the effects of species diversity, Ford and others are installing more probes on more trees, so many that they will be able to compare sap flux (the mass flow of water through the trunk) responses from four different species of trees on any one day. "The data we collect at this level will lead to more accurate models at the watershed level, and, tied to stream chemistry data, will give us specific information about what happens, for example, when hemlocks in riparian areas start dying," says Ford.

We've returned full circle to the anticipated loss of hemlocks from the hemlock woolly adelgid. It's a sad situation, but for scientists, an opportunity to watch a rapid and possibly dramatic ecological change and to gather data that will lead to better predictions about the effects of other disturbances—land use change, population growth, hurricanes, insects and pathogens, to name but a few—at the regional scale.

"What's the importance of this tree or that one," says Ford, gesturing to the poplar, oak, and locust that circle us. "Almost no one can answer that in terms of the hydrologic budget. The combination of long-term data from gauged watersheds and species-level estimates of transpiration from Coweeta provide a rare opportunity to understand the ecohydrological role of individual forest species."

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Bob McCollum in the "electric forest." *(photo by Rodney Kindlund)*

...a Mile of Forest Makes a Difference...

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from soil to various types of organic matter. Coming from a wide range of sources, these solids increase after storms; the proportion of this increase is one indication of conditions around a stream. The researchers also collected streamwater samples from all the sites to determine bacterial populations.

Findings showed a definite "cleaning" affect on the stream from passing through just a mile of national forest, with evidence of significant reductions in concentrations of chemicals such as nitrates, ammonium, and phosphorus. In response to storms, total suspended solids increased to a higher level at the urban sampling site and stayed higher longer, probably due to more impervious surfaces and land disturbances increasing sediment loading into streams. Bacterial populations did not change much between the two sites, and, though differing greatly from those at the reference site, were well below standards established by the U.S. Environmental Protection Agency.

"Factors affecting water quality vary so greatly across landscapes, and we advise caution in applying the specific results of this study to all situations," says Vose. "But the patterns we observed do fit with those found in other studies, and suggest that stream sections in undeveloped forests can improve water quality in areas where the headwaters have been heavily affected by urbanization or other land uses."

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Water World

Hydrologic Data Comes of Age in the Coastal Plain

by Zoë Hoyle

With its headwaters in the Blue Ridge Mountains, the Santee River literally stretches across the Carolinas. Clear, cool mountain waters flow down through the Piedmont, gathering width from numerous tributaries—as well as sediment, nutrients, bacteria, and other pollutants. By the time the Santee meets the Atlantic Ocean just north of Charleston, SC, it's wide, slow, and brown—no longer a pristine river.

Just before it enters the sea, the Santee River forms the northern border of the Francis Marion National Forest (Francis Marion), a 250,000-acre tract of Coastal Plain forest northwest of Charleston. Most of the watersheds in the national forest actually drain into the Cooper River to the south, which drains into the Charleston Bay. The Santee-Cooper River Basin is the second largest watershed on the Atlantic coast.

The cleanest water in the area comes out of the Francis Marion. The Forest Service has collected hydrologic data from weirs installed on the forest for over 4 decades, providing baseline information on flow and water quality. Like many other areas across the Southern United States, development is moving closer and closer to national lands, pushing water-quality issues to the forefront. The Francis Marion is a fitting site for a new project by **Devendra Amatya**, research hydrologist with the **SRS Center for Forested Wetlands**, who has brought together a wide range of cooperators interested in using science to ensure future water quality in the Charleston area.

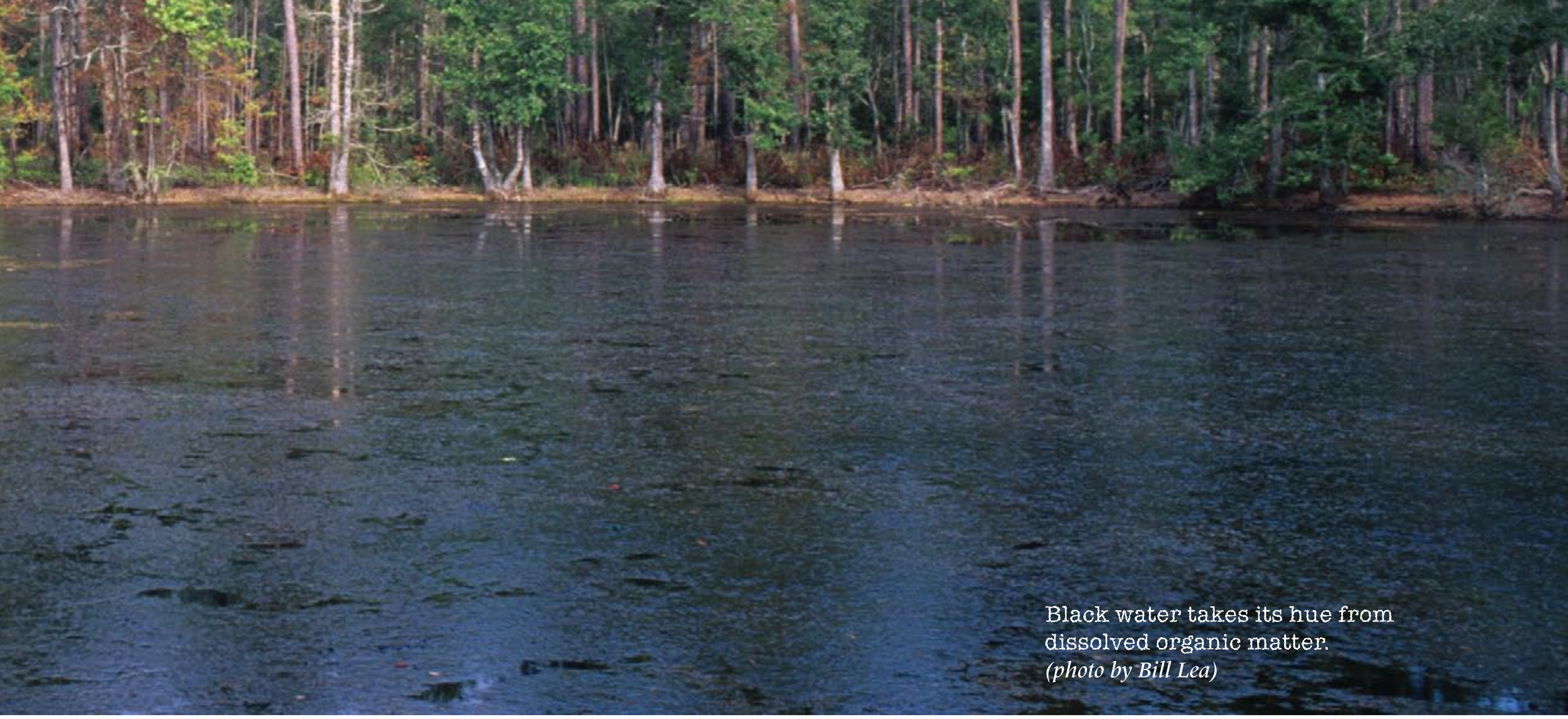
The story really starts at the **Santee Experimental Forest**, a 6,100-acre section of the Francis Marion set aside in 1936 to support the research needed to sustain and manage Coastal Plain forests. In the 1960s, gauged weirs were installed on first- and second-order watersheds in the experimental forest, and on a third-order watershed in the national forest. These are the only sites in low-gradient, naturally drained forested watersheds in the Atlantic Coastal Plain gauged to collect long-term hydrologic data. Data has been recorded at all sites—with some significant breaks—since 1964.

Watersheds are generally defined as upstream areas where rain, snow, and other precipitation drain downstream into a particular stream, river, lake, or wetland. In mountain and even Piedmont areas, this implies visible slope, but you may have to revise your perception of watersheds when you're in the Coastal Plain, where headwaters arise from elevations less than 6 feet above sea level. There's no real sense of slope or even up, as far as the land goes.

Sometimes you get the sense that the ground you are walking on is floating—and you may not be far from wrong. The soils are highly saturated, the streamwater meandering, braided, and wide—the water table shallow. Streams easily overflow their banks into wide floodplains, blurring the distinctions between land and water. Where the streams meet estuaries, saltwater flows back into freshwater and vice versa. Depending on where they start from, rivers can be red (those that originate in the uplands) or black (originating in the Coastal Plain).

A Different Hydrology Altogether

The physics of waterflow is one big difference between mountain and coastal watersheds. "In the mountains, water sluices down ravine-like settings," says **Carl Trettin**, project leader for the research unit, which is based just south of Charleston. "In the coastal area, water moves in a low-energy, diffuse way, literally creeping across the land. This



Black water takes its hue from dissolved organic matter. *(photo by Bill Lea)*

means that, unlike the red rivers—which carry heavy loads of silt and clay down from the mountains—the black water rivers originating in the Coastal Plain transport very little sediment. The dark color comes from the tannic acid formed by decomposing swamp hardwoods and their leaves."

"The riparian zone is much wider than in the mountains," he adds. "As water moves through these wide riparian zones, most of the sediment is captured before it can discharge into the stream. The potential for mitigating nutrients such as nitrogen is much greater because the water is moving slow enough for the denitrifying bacteria to do their job and convert nitrates to nitrogen gas—unlike in the mountains, where the water is moving fast down steep slopes."

Bacteria play an important role in cleaning up pollutants. "These coastal wetlands are bioreactors, where bacteria are constantly converting nutrients," says Trettin. "In one day, a coastal wetland can go from being oxygenated to anaerobic. This makes the environment very dynamic in terms of dealing with pollutants."

These differences in waterflow and pollutant cycling processes between mountain and coastal watersheds underscore the importance of the long-term data gathered from the Santee Experimental Forest weirs, especially now, as changing land uses put pressure on water supplies in Coastal Plain areas.

Waiting for This Moment

The streams in the Santee Experimental Forest have been gauged since the 1960s, but after 1982, there were no Forest Service hydrologists around to analyze the data. Fortunately, there were always technicians on the site, steadily keeping records over the years from both weirs and weather stations, storing them in whatever format was available at the time—paper, tape, floppy disks, you name it. The importance of this long-term data is only now getting recognition, as more researchers and planners find out about its existence.

"I can't stress the value of the data from sustained long-term Forest Service research enough," says Trettin. "In the coastal area, there is tremendous variability in any one year or even within a period of a few years. We can have a heavy rainfall one year followed by a drought the next, with dramatic effects on streamflow and the water table. The interactions between precipitation, evapotranspiration, surface water, and ground-water flows are very complex," he adds. "Not until we have aggregated hydrologic data that span decades can we provide the knowledge to help landowners and managers make informed decisions."

Almost 20 years passed, and in 2002, the Charleston unit finally got a research hydrologist. Trettin gets a bit messianic when describing the convoluted search that ended with Amatya's hire. "I think he was meant to be here," he says. "Now we can move forward with partners, using our long-term hydrologic data with data from developed lands to assess their impacts on water and on Coastal Plain ecosystems—and, at the same time, develop and test the ecohydrologic models that planners and managers need to make decisions."

Since his arrival in 2002, Amatya has been instrumental in setting up key collaborations that look at coastal water issues through the lens of watershed

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studies. In August 2004, he started a research initiative focused on the Turkey Creek watershed in the Francis Marion, which brings together partners from several colleges and universities, Federal Agencies, and private industry to focus on the urbanizing landscape in relation to water quality, and to provide concrete answers to planners. One issue the coalition is working on is dissolved oxygen levels in the area's rivers.

"Lack of dissolved oxygen in the river system places limits on industrial growth around Charleston," says Trettin. "Because of the high level of organic material in black water systems, the water is naturally low in oxygen, but other factors can worsen the condition, leaving the water oxygen deprived."

"Planners have realized that we have this long-term data on waterflow and quality from the only pristine watershed left in the area," adds Amatya. "The Berkeley-Charleston-Dorchester Council of Governments recently hired a consultant to look at the low-oxygen level issue in the Charleston Harbor system. They are using data from our watershed studies as references in developing a water-quality model to set dissolved oxygen levels."

A Three-Tiered Resource Revived

Some of the gauged weirs set up over 40 years ago have been revived to provide the baseline data that will allow scientists and planners to look at the effects of land management and climate on the poorly drained forested watersheds of the Coastal Plain. "Watersheds are great research tools," says Trettin. "Think of a watershed as a funnel that ends at the weir. If we want to see the effects of forest management, or of natural disturbances such as Hurricane Hugo, we can look at what comes out of the end of the funnel in relation to the long-term data we already have."

The gauged weirs were originally set up to study the effects of forest management activities on the soils and waters of the Coastal Plains in response to public concerns about the impacts from a burgeoning timber industry. Two separate gauges were set up on first-order (around 400 acres) watersheds that were contained within the Santee Experimental Forest. These were used for paired watershed studies; one watershed was left undisturbed, while the other was used to test the effects of forest management on water quality and flow. Later, a gauging station was set up on the second-order (around 1,200 acres) watershed that includes both the first-order watersheds and the land lying between them. This was done to allow researchers to look at the effects of scale on hydrologic processes, which would have been very difficult to study with only two small watersheds.

The gauging for the largest study area, the third-order Turkey Creek watershed (around 12,000 acres), was added in 1964 with the help of U.S. Geological Survey (USGS) hydrologists, but flow gauging was discontinued in 1984. Monitoring on all the watersheds was discontinued by the early 1980s, and not resumed until after Hurricane Hugo hit in 1989, damaging most of the forest in the watershed.

Amatya hit the ground running when he started work at the Charleston unit. In 2004, he received a grant from the SRS Challenge Cost-Share Program—with a match from the National Council for Air

Carl Trettin explains one set of soil studies at the Santee Experimental Forest. *(photo by Rodney Kindlund)* and Stream Improvement—to revitalize studies on the third-order Turkey Creek watershed. The first task was to resume hydrologic monitoring of streamflow, followed by water-quality sampling and analysis of historic data.

The Charleston unit worked with USGS through a cooperative agreement with the College of Charleston to reestablish a gauging station on the Turkey Creek watershed in 2005, this time with real-time wireless monitoring of precipitation and streamflow that researchers can access from their desktops. This third-order watershed, which is on the edge of the national forest, presents a unique opportunity to look at the effects of urbanization as development creeps closer and more nearby residents use public lands for recreation.

"We still don't know the cumulative effects of forest management activities such as prescribed fire on forested wetlands," says Amatya. "Long-term data are essential for understanding the hydrologic processes in relation to forest management. The same data can help us measure the effects of land use change as waters flow out of the Francis Marion towards the Charleston Bay."

Keeping It Local

One way that natural resource managers and planners make use of research is by modeling possible outcomes of both land management decisions and natural disasters. "Planners need validated models they can use to make predictions," says Trettin. "We're applying what we know about streamflow to simulate the movement of water, nutrients, and contaminants from our gauged headwaters to output. We use our long-term data to validate and calibrate the models we or other researchers have developed. When we're comfortable with a model, we can use it to predict what happens if you harvest timber or build houses on a similar-sized tributary in the area."

Rather than going regional, Trettin and Amatya are keeping it at the watershed level for now. "As you grow in scale, you literally give up some of the important functions of wetlands, which drop off the radar even at the mile level," says Amatya. "You may also give up temporal understanding of the ecohydrological processes if you shift the time scales from daily out to yearly. The public is generally interested at the scale of their own wetland or community. There is a great deal of interest in the Turkey Creek watershed, which lies on the edge of the national forest and near the Cape Romain National Wildlife Refuge, as a reference site."

Every 6 months, collaborators from 13 different agencies and groups come together as the **Sustainable Coastal Forest Partnership (SCFP)**, a new initiative in the coastal counties of Charleston, Dorchester, and Berkley. The SCFP was formed to help provide the information and research needed to sustain the health of the forested coastal landscape, where water plays such an integral part. At the last meeting, the 23 collaborators discussed a wide range of issues—including mercury pollution.

Researchers discussed the Turkey Creek watershed as a good location to monitor the movement of methylmercury, the form mercury is converted to by bacteria in streams. Concentrations of methymercury have been found to be elevated in the marshes and swamps of the Coastal Plain. Easily absorbed by aquatic organisms, mercury can have grave effects on humans eating contaminated fish. State officials are not only worried about health issues, but the effects on tourism, sports fishing, and other recreation due to high levels of mercury in the Charleston Bay area.

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Andy Harrison demonstrates recently installed instruments to measure ground-water levels. *(photo by Rodney Kindlund)*

Collaborators On Water-related Projects

Agricultural University of Krakow, Poland

Clemson University

College of Charleston

Ducks Unlimited, Inc.

Florida A&M University

Francis Marion National Forest

Jordan, Jones and Golding Company

Mead-Westvaco

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration (NOAA)

National Council for Air and Stream Improvement (NCASI)

North Carolina State University

Santee Cooper Authority

Santee State Park

South Carolina Department of Natural Resources

South Carolina Department of Transportation

South Carolina Forestry Commission

South Carolina Nature Conservancy

Sumter National Forest

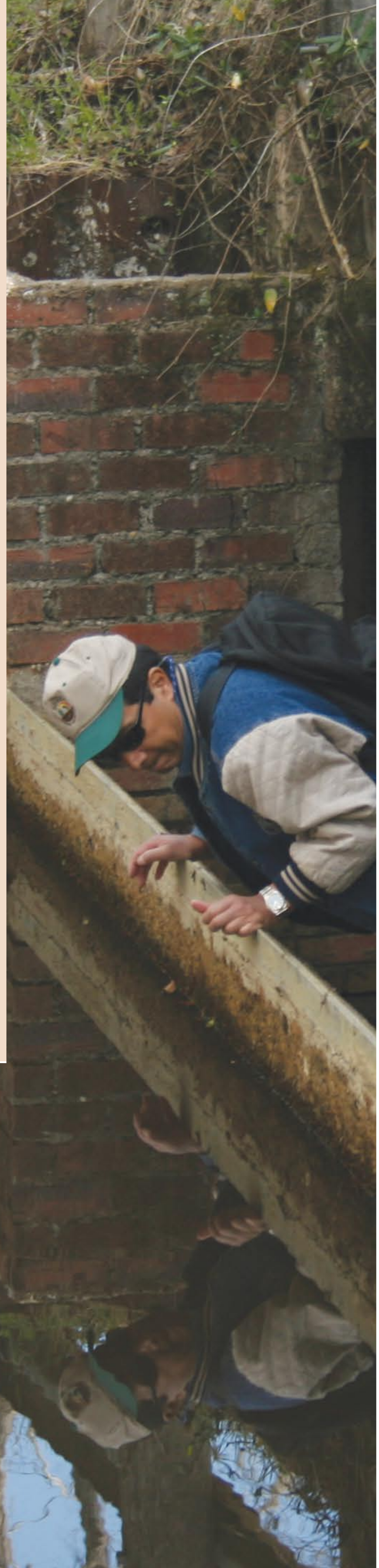
Tetra-Tech, Inc.

Town of Santee, SC

U.S. Geological Survey

USDA Natural Resources Conservation Service

Weyerhauser Company



WATER WORLD

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The new collaboration brings with it the capacity to expand studies into any number of areas. Trettin is using the Turkey Creek watershed to help a local power company look at the feasibility of using small diameter wood thinned from the Francis Marion to generate electricity, and for continuing studies on the effects of prescribed burning and whole-tree thinning. The historical data from the Turkey Creek watershed, along with aerial photographs, are being used to evaluate the long-term impacts of Hurricane Hugo—as well as the effects of the developments already starting up within sight of the watershed.

"By virtue of our long-term data, we in the Forest Service are poised to make a real contribution in this area," says Trettin. "If we've done our job, we should be able to predict what will happen to the water as that development continues."

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Devendra Amatya examines one of the weirs on the Santee Experimental Forest. *(photo by Rodney Kindlund)*

Will We Have Enough?

by Garnet Bass

It takes only a few inches of water to float a kayak. That's one reason I like them. I can scoot back into shallow coves and slide over downed trees visible just below the surface. Yet there I sat, stuck on a mudflat in the middle of Falls Lake, the primary water source for Raleigh, NC. In 2005, for the second time in 4 years, summertime drought had dropped the lake level more than 7 feet, leading the city to impose conservation measures—and leaving me high and, if not quite dry, exceedingly muddy. Was this a portent of things to come?

Fifteen miles south of where I sat, a team with the **SRS Southern Global Change Program** has been studying that very question. Led by project leader **Steve McNulty** and research hydrologist **Ge Sun**, they're creating computer models that will help local officials across the South understand the potential for water shortages in the coming decades.

"If you realize that time after time you're going to have these severe water shortages, now is the time to start measures to try to prevent them—whether it's developing networks to move water from other areas, building reservoir systems, or starting water conservation measures to try to reduce the water demand during those stress periods," says McNulty. "Those are options municipalities can have open, if they're given enough time to prepare for it. Part of what we do here is to give them that time by developing models that accurately predict what will happen in the future."

The models they've created cover almost 700 watersheds and take into account the effects of climate change, population growth, land use, and vegetation patterns. The models also show the effects of ground water depletion and water use by key sectors such as agriculture and thermoelectric power plants.

By the end of the year, the team hopes to have a Web-based program up and running that will allow local planners and policymakers to run their own what-if scenarios. Officials will be able to see not only the probability of drought, but the effects of potential responses; for example, whether a new reservoir would reduce water shortages from 6 years out of 10 to 2 years out of 10. The team is also working to expand the model nationwide.

"Traditionally the Southern Research Station has conducted a lot of location-based forest hydrologic research," says Sun. "The question is, how do we extrapolate those data and scale them up? That's really what our program is focused on. We use modern technology like GIS (geographical information systems) and computer simulation models to scale up to larger areas and make research more relevant to policymaking."

Working with Sun and McNulty are **Jennifer Moore Myers** and **Erika Cohen,** resource information specialists with the global change program. **David Wear**, project leader of the **SRS**

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WILL WE HAVE ENOUGH?

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economics unit located nearby in Research Triangle Park, contributes data on land use change predictions based on timber price fluctuations and population growth.

Overall, the Southeastern United States receives 10 times as much precipitation as needed for human use. If that were spread evenly across the region, year after year, water shortages might be unheard of. But rainfall varies from here to there and from year to year. Equally uneven are the demands placed on water, whether for human consumption, power generation, or crop irrigation. McNulty, Sun, and team built their model layer by layer to reveal both the individual and collective effects of the various factors.

They started with two climate models, each with over 100 years of history and forecasting 100 years into the future. The models differ slightly in how much they predict temperature will increase and whether the future will be wetter or drier than the present. Because the goal is a realistic worst-case scenario—those 3 or 4 years of back-to-back drought that officials actually need to plan for—the differences between the models matter less than the ability to fine tune their forecasts to reflect local conditions. Both of the climate models chosen—one from the Hadley Climate Research Center in Britain and the other from the Canadian Climate Centre—have that capability.

To the climate models, the team added population forecasts. Overall, by 2045, the population of the 13 Southern States is expected to be 90 percent greater than in 1990, but at the watershed level, population change is predicted to vary from a 20-percent decrease to a 500-percent increase.

Then they added changing landcover characteristics, shown in six different classifications from urban to forestland. Forests even got broken down further into two categories. Evergreens, it seems, consume more water than do deciduous trees.

Next, they factored in seven types of water demand, which included how much of the "used" water gets returned to the ecosystem. Because of evaporation, for example, crop irrigation is a far greater drain on available water than residential use, which returns 85 percent of withdrawn water to rivers and streams.

"When we started this work, we thought population was going to be the factor driving water stress in the Southern United States," says McNulty. "It turns out population is very important for water *quality*—the more people you have, the more likely you are to have reduced water quality—but in the quantity sense there are other factors that have a greater impact."

Last came ground-water data. Where ground water from aquifers is the major source of water, aquifer levels will

Looking at the South as a whole, climate change is the leading factor in increasing the potential for water shortages. More important locally are population growth—particularly around Miami and in parts of Virginia, Texas, and North Carolina—and ground-water availability.

(photo by Rodney Kindlund)

drive water stress even in the wettest year on record. Because aquifers can take hundreds or thousands of years to recharge, once that water is gone (and it's dropping dangerously low in some areas), those communities face nothing short of radical change.

The researchers looked first at the effects of each factor, then put them all together. "You can't look at a complex issue just by studying the individual components," says McNulty. "It's not just population change or climate change, but the combination of the two. And it's not just average conditions. You have to look at variability to understand vulnerability. Spatial scales matter, too. Some of the biggest changes will occur at the finest scale."

In a nutshell, here's what they found: Looking at the South as a whole, climate change is the leading factor in increasing the potential for water shortages. More important locally are population growth—particularly around Miami and in parts of Virginia, Texas, and North Carolina—and ground-water availability.

"That's why it's so important to have locally explicit models," says McNulty. "In Texas, ground water is critically important. In other areas, not so much. Also, on a regional scale, precipitation is important, but the less precipitation you have, the more variability matters. A 20-percent drop makes a much bigger difference in Texas, where water stress is already high, than in western North Carolina and eastern Tennessee, where they get 90 inches of rain a year."

As they expand the model nationwide, the researchers are adding in a few more factors. They plan to show the effects of seasonal fluctuations in precipitation as well as annual averages and to make more explicit the connections across watersheds. Some of the Nation's largest metropolitan areas pipe water from distant watersheds. As a result, a light winter snowfall in the Sierra Nevadas will spell trouble for Los Angeles the following summer.

Seasonal variation matters in North Carolina, too. Sun said the team tested its model for rainfall patterns on the southeastern Piedmont in 2002, one of the years Falls Lake and many other reservoirs across North Carolina dropped dangerously low. "That year, the total amount of rainfall was not so bad," he said, "but it didn't fall in summer, when demand for water was highest."

The same thing happened in 2005, leaving me stuck on a mudflat and wondering about the future.

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Don't Forget the Fish and Other Aquatic Organisms

by Kim MacQueen

Crayfish *(Photo by Mark Sanders, City of Austin, TX)*

We're only human. When we think of water quality, we think first of drinking water—*our* drinking water. But the same principals for providing clean, clear water for human use also hold true for freshwater fish and other aquatic wildlife. For the fish, crayfish, mussels, and other animals making their home in the Southeastern United States, the difference between healthy and unhealthy water is the difference between life and death.

And there are a lot of them to consider. More than half the Nation's freshwater fish live here. At nearly 600 species, they represent one of the world's most diverse faunas. The South contains 165 fishes of concern in 14 different families, as well as rare darters, minnows, topminnows, dace, catfishes, and sculpins.

Nearly 270, or 90 percent, of freshwater mussel species occur in the Southeast, the majority in the Tennessee River basin that curves through the middle of the region. Land use changes, channelization, sedimentation, and dam construction have severely affected the viability of this group of animals, which depend on free-flowing water to survive.

The crustacean fauna—mostly crayfish—is also broad and diverse, including 159 species of concern, 60 critically imperiled. Years of agricultural, industrial, and recreational use of forestlands challenges the fish, mussels, and crustaceans. Nearly all are threatened in some way by pollution, damming, sedimentation, and habitat loss.

As one might expect, practices that preserve intact forests produce the highest quality drinking water. They also provide the best habitat for aquatic species, regulating temperature and cleaning water as it percolates through the soil.

In recent years, Best Management Practices and improved road and stream crossing designs have helped keep sediment out of forest streams, but sediment is still a major problem for many aquatic species. Suspended sediment decreases water clarity and makes things difficult for animals trying to see to catch food. As sediment loads increase, fish gills can become clogged, growth rates reduced, and egg and larval development impeded. As sediment settles to the bottom of a stream or river, it can smother eggs and newly hatched larvae or fill in spaces that have provided habitat.

At the **SRS Coldwater Streams and Trout Habitat** unit in Blacksburg, VA, project leader **Andy Dolloff** collects and analyzes data from several long-term studies on the effects of water quality on brook trout and other species. One study, a joint effort with the University of Virginia, tracks the effect of acid rain—the infamous byproduct of human dependence on fossil fuels—on the area's fish populations across several years.

"Water chemistry is one of the most important factors in fish production. When you have well-buffered water, you have greater fish production—with more fish species as well as more and larger individual fish," Dolloff says. "In acidified water, production is decreased, with as few as one to three species present, plus slower growth and frequent failure of reproduction. Life for fish in an acidified stream is precarious."

Many endemic—meaning native and narrowly localized—aquatic animals have adapted to the specific conditions in their home waters. That's why, when human disturbance such as acid rain or excess sediment causes even slight changes in ph or sediment levels, entire populations can be wiped off the map.

That's the story with many crayfishes. Entire species of these endemic crustaceans often live in areas no larger than a county. **Susie Adams**, a researcher with the **SRS Center for**

Bottomland Hardwoods Research unit in Oxford, MS, studies a group that sticks to one specific area of the DeSoto National Forest, which is located in the hardwood bottoms of southeastern Mississippi. Adams has found that, in general, crayfish can adapt a bit faster to ecological disturbance than mussels or some fish. In a recent paper, Adams notes that crayfish populations tend to rebound fairly quickly following drought. And their relatively rapid lifecycle (about 2 years) means they get more chances to reproduce.

That's not the case for freshwater mussels. Of 297 species found in the United States, 269 freshwater mussel species are found in the Southeast. **Mel Warren** and **Wendell Haag**, also with the SRS unit in Oxford, recently studied 26 species of freshwater mussels living in the Little South Fork of the Cumberland River, which flows through Kentucky and Tennessee. Two of these species were protected by the Endangered Species Act, one was a candidate for Federal protection, and 10 others were considered imperiled.

"The Little South Fork also supported a diverse fish fauna and, in general, was considered one of the highest quality upland stream systems in the Southeastern United States," Warren notes. "However, beginning in the early 1980s, drastic mussel declines were documented in the lower Little South Fork, and the future of the stream as a mussel refugium for the Cumberland River system was uncertain."

Strip mining along the lower Little South Fork during the 1970s and 1980s wiped out mussel populations there, but area residents—and Warren and Haag—believed the populations in the upper part of the river to be relatively unscathed. The area was remote and predominately forested, and enjoyed what they called a "protective blanket" of State and Federal statutes, regulations, and management agencies.

But that didn't make any difference. Warren and Haag got to the field to begin data collection on the upper Little South Fork, expecting to find large mussel populations for a wide-ranging ecological study. But they hardly found any mussels at all. They've since surmised that oil drilling, which began along the upper portion of the river in the mid-1980s, had so disturbed the water quality that mussel populations began dying off before they could be studied.

"We had no idea this had happened in the upper river," Haag remembers. "It took several days to process the information. It's depressing as hell."

And that's all too often just what researchers find when they look at specific point-source pollution in one narrow area. But it's a little too easy to use this one study as a lens to look at what's happening to freshwater animals everywhere.

"Sometimes we can tie declines of specific mussel populations to the construction of a dam, stream channelization, or pollution from a specific source," says Haag, "but the worldwide patterns of decline in these animals implies that larger scale disturbances such as sedimentation and nonpoint-source pollution may have an equal impact."

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Brook Trout *(Photo courtesy Sagehen Creek Field Station, University of California, Berkeley)*

Riparian Zones: How Wide Is Enough?

by Kim MacQueen

You're doing well if you can get a preponderance of the South's forest managers to agree on something. It's that way with riparian zones, the areas alongside forest streams, rivers, and lakes that filter sediments and help keep water clean. Sometimes called streamside management zones (SMZs), riparian forests, or forest filter strips, riparian areas are critical to overall water quality and forest health.

Their benefits are numerous: Trees and other vegetation growing in riparian zones (from the Latin *ripa*, meaning bank) provide cool, shady habitat for fish such as trout while they trap phosphorus, nitrogen, and toxins in their roots and leaves. Fallen leaves, wood debris, and vegetation provide food and habitat for forest animals, which also use streamside forests as travel corridors.

For decades—but especially since the Clean Water Act of 1977—scientists, forest managers, and much of the public have understood the need to keep pollution from entering streams. Anywhere on forested lands, and in particular wherever roads cut through, SMZs are essential to reduce watershed contamination. SMZs are the last chance to keep herbicides, oil and grease from vehicles and machinery, sediment from eroding streambanks, or scores of other contaminants out of the water supply.

Steve McNulty, project leader for the **SRS Southern Global Change Program** located in Raleigh, NC, puts it succinctly: "Whenever soil gets into the stream, it has a really negative impact. Bare soil near water can cause stream sedimentation and reduce water quality."

It's agreed that riparian zones are important. However, managers throughout the Southern Appalachian region have differing opinions on how wide riparian zones should be, and how much and what kind of vegetation should be left in place within zones, or how best to manage them over time. More studies are needed to answer these questions and to pinpoint the best ways to maximize water quality and minimize forest management costs to both private and public land managers.

"Even though every State in the region has developed guidelines specifying that SMZs be left along streams, there is no accepted standard width for these zones," says **Andy Dolloff,** project leader of the **SRS Coldwater Streams unit** in Blacksburg, VA. "How wide SMZs need to be depends on the function of concern; the width required to filter sediments and nutrients may be very different from that required for shading streams, or for providing wildlife habitat or travel routes. There is little research on how much timber should be left to protect water quality and other riparian functions."

Researchers from three Southern Research Station units are studying riparian zones from a variety of perspectives, all with the hope of providing forest managers and landowners with the best, most up-to-date information available.

Riparian zones are currently managed using multiple guidelines. SMZs are one type of management guideline; best management practices (BMPs) are another. Forest BMPs differ by State, but generally set forth guidelines for minimizing erosion created by forest logging, road building, and other forms of human disturbance. For example, a BMP may require that soil runoff is diverted onto other forestland and away from water bodies to prevent stream sediment contamination.

That means there are two sets of guidelines with significant overlap, but as yet no clear body of research detailing which management guidelines are most effective for maintaining streamwater quality.

McNulty sums it up nicely. "All the States were required to develop BMP plans for all their current forest management activities. These BMPs called for reducing nonpoint source pollution. Unfortunately, there is still a lot of discussion of exactly *how* to do it."

A First for the Piedmont

With funding from the North Carolina Division of Forestry, McNulty and Southern Global Change Program hydrologist **Ge Sun** have started the first study of riparian zones in Piedmont area forests. The work is an indepth look at how forest logging and alternative road building practices impact sediment inputs and riparian zones over the next 5 years. Initial site information will be collected from three watersheds. Then the first site will be harvested using strict interpretations of BMPs, the second harvested with the more relaxed BMP guidelines typically favored by loggers, and the third left completely alone for use as a control.

The study will also evaluate stream crossings, bridges, and culverts, in an effort to pinpoint the best way to bring logs out while causing the least amount of disturbance to nearby streams. Log bridges are one option, but they create a lot of instream sediment. Temporary metal bridges called bridge mats are an alternative which might work better for reducing stream sedimentation. Water-quality samplers placed above and below bridges and culverts will collect data on several different types of stream crossings.

Riparian Research Essential to Restoration Efforts

Led by project leader **Jim Vose**, researchers at the **Coweeta Hydrologic Laboratory** have looked at the issue of riparian zones for years. Studies in the early 1990s focused on rhododendron, which tend to move in *en masse* after big storms open up forests. Hurricane Opal moved through the Coweeta basin in 1995, taking with her more than 80 percent of the woody biomass in the area. The rhododendron followed, setting up shop in streamside zones.

Coweeta researchers experimented with removing rhododendron and found that removing the plants had very little effect on nutrient movement, and didn't help area water quality. In fact, it made things a bit worse; by disturbing the root-soil connection in streamside zones, removal negatively affected the water quality more than if the rhododendron was left in place.

Studies such as this form the background for a major new Coweeta project to systemically evaluate several different types of riparian buffers. As with the Raleigh-based study, the idea is to find the best combination to protect the watershed, filter nutrients, and shade streams. Work at Coweeta looks at both structural and functional aspects of riparian zones, measuring how the stream responds to different management options.

"When we're finished, we are going to have a very good understanding of the functional width of riparian zones, and we'll have a really good test," Vose says, adding that he realized years ago that "there is surprisingly little research out there; there hasn't been a really rigorous study of riparian zones."

Vose and fellow researchers have set up study sites in several forested areas to measure the effects of leaving no riparian buffer, a 30-foot buffer, or a 100-foot buffer along a stream. Collaborators come from the National Forest System and Virginia Polytechnic Institute and State University (Virginia Tech)—as well as from across disciplines at the Coweeta unit. "Pretty much every scientist at Coweeta is looking at this in some way," Vose says.

Restoration is also key to the Coweeta unit, whose researchers often work with landowners to help them manage land that has been heavily deforested by agriculture, development, and industry. Vose notes that anytime the woody or herb component has been removed, leaving no classic riparian zone, the result is an unstable streamside, where soil is degraded and nutrients aren't filtered from the watershed. For the restoration work, Coweeta researchers are interested in quantifying what happens when the vegetation component is reintroduced.

Looking at the issue from several perspectives is probably the best way to conduct a study so complex—even as it expands researchers' workloads. The fact is, going from asking how riparian zones work to how they can be recreated and enhanced to improve life for streamside fauna is a relatively short step.

"When the study is done," Vose says, "there will probably be no single answer. We may find out that a certain riparian width will provide protection for salamanders but not for other animals, for instance. There will still be some unanswered questions in terms of how we can further enhance riparian zone function once this initial work is done."

Vose adds that "We see this as an evolving study to understand the function of riparian zones. Once you understand that, you can start to ask questions about how to manage them."

Even as they research the basics of riparian zones, scientists have to keep land use in mind. From the landowner's perspective, there are some downsides to this type of streamside management. Areas set aside for ground-water protection can't be used for

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Riparian Zones

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agriculture, development, and in many cases, timber production, and re-establishing streamside zones can be expensive.

Working With Industry in Virginia

At the **SRS Coldwater Streams unit** in Blacksburg, VA, project leader **Andy Dolloff** keeps this in mind. In 2000, the unit began a long-term study to evaluate a variety of SMZ width and harvest options in 18 small watersheds of the Piedmont plateau in Buckingham County, VA. Watersheds in this area lie close to many Civil War era field sites which have since been reclaimed by native shortleaf and Virginia pine; extensive agriculture since the 1700s has led to severe soil erosion and loss of site productivity.

Research at Blacksburg is funded in part by industry partners such as MeadWestvaco, with some studies carried out on land owned by the company, in cooperation with the National Council for Air and Stream Improvement and the Department of Forestry at Virginia Tech. MeadWestvaco employs more stringent standards for air and water quality on its lands than is required by many States, and currently uses 100- or 200-foot riparian zones on their land. The research team's work is designed to help MeadWestvaco and other forest landowners develop ecologically meaningful, cost-effective strategies for protecting water quality during forest harvesting.

During the Blacksburg study's first year, Dolloff and fellow researchers have found that, in general, damage to water quality from logging and forestry practices in central Virginia is low, with SMZs keeping most of the sediment out of streams.

After studying several different widths of riparian zones, the Blacksburg group came across its most significant initial finding—that a relatively small (20 feet) riparian area can be as effective as much larger, costlier areas (50 to 100 feet). As the Blacksburg study is only a year old, Dolloff cautions that the data doesn't yet speak to the best zone length or width for functions such as wildlife protection or for more intensive land uses such as grazing or row cropping. But the idea is that bigger riparian zones might not necessarily be better.

"Conservation professionals should consider that any vegetation along the streamside is better than no zone at all," Dolloff says.

The Blacksburg study should give some comfort to landowners—as well as food for thought for riparian zone studies just beginning or in process. But essentially, all three of the SRS studies are in the same boat: They're just getting started, just learning what works. For now, researchers and landowners alike are making do with the guiding idea that every streamside, road gradient, and runoff situation is different, especially across an area as physically diverse as the Southeastern United States. But efforts to pull together the best knowledge about protecting watersheds are gaining ground.

"We have enough information so that, if we had to right now, we could say that we are looking at 'designer' riparian zones, where conditions are different at every site. But that isn't going to cut it," Dolloff says. "We need to keep collecting data so that we can generalize and let people know how to cause the least amount of damage over average conditions. These are the kinds of major studies that we need to get to that place."

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Black water riparian zone.
(photo by Rodney Kindlund)

REDUCING THE IMPACTS OF FOREST ROADS

by Kim MacQueen

For the single greatest threat to water quality in the forest, look no further than the road that brought you in.

As long as there have been roads into the forest, those roads have dumped sediment runoff into forest streams, damaging water quality. Many forest roads are old; some date back more than 100 years. They're often poorly planned and located, lying right along streambeds. According to environmental regulations and current best management practices (BMPs), they couldn't be built today. Many are still unpaved. A recent study by scientists at the **Coweeta Hydrologic Laboratory** found that no less than 80 percent of the sediment found in forested watersheds was directly attributable to unpaved roads.

"Roads are the arteries that support most activities on the nation's public lands," says **Johnny Grace III**, research engineer with **SRS Forest Operations Research unit** in Auburn, AL. "Previous research in various regions has shown the impact of poorly planned and located roads on water quality. Future research needs to focus on methods and alternatives to reduce the impacts associated with the current road system."

Coweeta scientists have spent a lot of time delineating the impact of forest roads. A 2002 study by researchers **Barry Clinton** and **Jim Vose** examined four different types of forest road surfaces, ranging from an unimproved gravel road to a 2-year-old paved road, to determine which type contributed the most sediment to the watershed. Studying more than 20 miles of roadway, Clinton and Vose measured the amount of total suspended solids deposited in nearby watersheds, using the results to rank road surfaces from least to most responsible for reductions in water quality.

The results were no surprise to scientists who've advocated for more environmentally sound forest roads for more than a decade. The paved, reconstructed road was the best, generating the least amount of contaminants. The unimproved gravel road was the worst, dumping the most contaminants into the water. Not surprisingly, they also found that the more traffic on those roads, the more sediment found its way into the watersheds.

Paving alone doesn't do the trick, though. If you're going to upgrade a roadbed to lessen its effects on the watershed, you should be armed with the best that we know about building environmentally sensitive roads. That's where Johnny Grace's work comes in.

Grace believes that, while it can be tough to measure and model the effectiveness of BMPs in handling sediment runoff, getting a handle on the problem is crucial to sustainable forest management. In his studies, Grace attempts to quantify how sediment moves away from the road, and which practices work best to contain it. He has studied practices that include settling basins, riprap, the black plastic sediment "fences" you often see along roads—and strips of forest vegetation retained along roadsides. Called filter strips, these areas sift out the sediment, organic material, organisms, nutrients, or chemicals in surface runoff water that constitute a pollution hazard.

Until recently, though, not much attention was paid to how much runoff was deposited into filter strips, how far the runoff traveled from roads downslope into the strips, and whether the strips were wide enough to handle the workload. It turns out that, as in the Coweeta study, certain road characteristics had a lot to do with the amount of sediment moving into filter strips.

Johnny Grace collecting data for a road BMP study on the Tuskegee National Forest in Alabama. *(photo by P.E. Steele)*

From a study on sites in the National Forests in Alabama and the Chattahoochee National Forest in Georgia, Grace reported last year that three road characteristics—length, width, and area—were the primary factors influencing sediment deposition lengths. Grace found that sediment often covered areas much larger than the space set aside for filter strips. So the minimum recommended strip widths might not always get the water protection job done, especially where forest roads are at their worst. Questions about the efficacy of vegetation strips along roads still remain. How *long* can filter strips contain sediment from road runoff? How much buildup can they stand before contaminants start to move towards forest streams or into ground-water reserves?

Researchers just don't know for sure, but they're asking the right questions. Working with researchers from the Forest Service, Rocky Mountain Research Station as well as the National Forests in Alabama and the Chattahoochee and Oconee National Forests in Georgia, Grace has studied 236 different "sediment deposition zones," looking at 3 downslope gradients (low, moderate, and high), 2 soil textures (fine and coarse), 3 road ages (5 to10, 11 to 20, and 21+ years), and 2 levels of forest floor vegetation indices (high and low).

"We're looking at whether the capacity of the forest floor to filter sediment-laden runoff is reduced over time. Our preliminary research suggests that this may be the case," Grace reports.

Grace is also involved in other studies that examine how well established BMPs and sediment control practices keep sediment from flowing into runoff water in the first place. It's all part of an effort to gather enough science to mitigate the effects of existing forest roads. The results, Grace says, "will allow us to provide detailed information on sediment control treatments and alternatives to forest managers."

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SNAPSHOT FROM THE FIELD

Grace and Steele Partnership Yields Results

by Claire Payne

Johnny Grace collecting precipitation information using a recording tipping bucket rain gauge. *(photo by P.E. Steele)*

Research engineer **Johnny Grace** focuses on roads and water quality. He knows his work at the **SRS Forest Operations unit** would not be possible without **Preston Steele, Jr.**, the engineering technician with whom he works most often. Grace and Steele take a lot of research road trips from their base in Auburn, AL. "Preston has traveled throughout our region, assisting me in collecting data on roads, soil, and water over the past 10 years," Grace says. This effort is in addition to the support Steele provides to other scientists; he often travels more than 4 months out of the year. Grace adds, "The value of support staff in research is a point that is seldom made."

Grace began working for the Forest Operations unit in 1991 through the Forest Service's cooperative program with Auburn University. An agricultural engineering student, Grace supported harvesting and biological land engineering interaction, forest operation, and productivity and utilization studies. Grace continued working in the Forest Operations unit as an undergraduate and while earning his master's degree at Auburn. SRS hired him in 1996 as a research engineer.

Preston Steele collecting filter bags from the Tuskegee road BMP investigation. *(photo by J.M. Grace III)*

While Grace worked on his Ph.D. at North Carolina State University in Raleigh from 1981 to 1982, Steele kept their projects going and performed field work for the Auburn unit. With skill and dedication, Steele managed data collection, monitored processes, set schedules, and trained students to collect data. Every month or so, Grace traveled to Auburn, where Steele would have everything ready for a trip to the field. When Grace returned to Auburn, he completed his dissertation while researching the interactions of roads and water quality.

Steele began his Forest Service career in 1980 in a 30-day position in the Forest Operations unit. After completing a second appointment for 180 days, Steele became a full-time employee. Since 1981 he has taken photographs, slides, and videos all over the Southeast and in some western venues. The primary subjects are pieces of machinery used to conduct management prescriptions in forested environments. "Feller bunchers, skidders, loaders, cut-to-length systems, and persons performing manual functions such as using a chainsaw have starred in front of my lenses," Steele says. His most memorable time was a 30-day detail in Puerto Rico after Hurricane Hugo hit El Yunque on the Caribbean National Forest. He and a coworker helped assess damage to research plots for reestablishment after the storm. Steele's more recent images are of forest roads and the effects of stormwater movement.

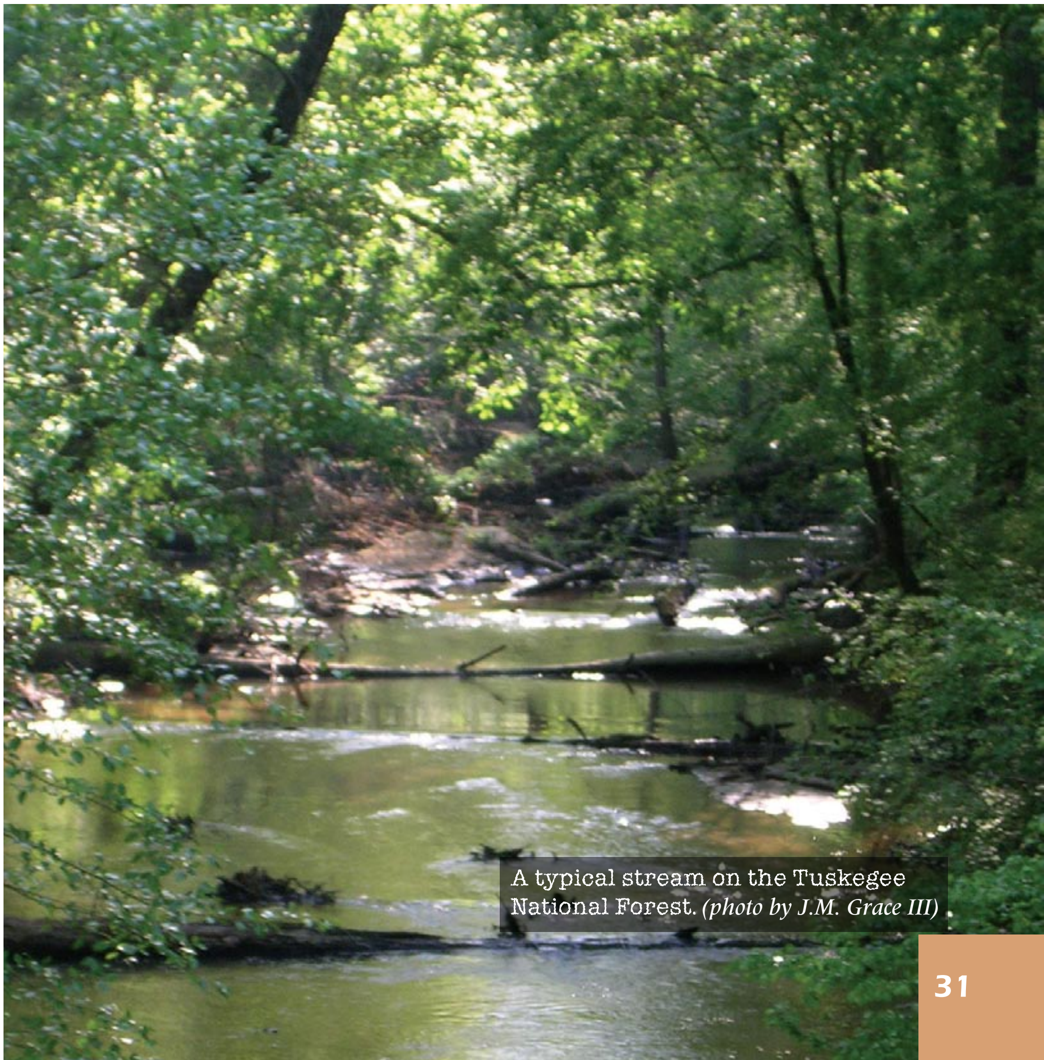
Consistency is one of Steele's best traits, according to Grace. Steele modified the field data sheets Grace developed, adding about seven steps to complete before leaving a site. What initially felt like a pain to the young scientist taught him precision. Grace says, "Preston pays attention to detail, takes careful notes, and reminds me to take pictures."

"You have to have something to present," Steele told Grace. "I want to be the best technician I can be," he adds. "I want to be your Vivien Thomas." (Thomas worked with Dr. Alfred Blalock at Johns Hopkins University, developing a procedure to resolve a congenital heart defect that prevents oxygenation of babies' blood. Thomas' work in the laboratory was essential in creating and performing the procedure to save "blue babies.")

"My career is dedication to the person and the goal they are trying to accomplish. As I have done for scientists in the past, I also do for Johnny," Steele continues. "If he fixes his eyes on a nut, I'm reaching for or handing him a wrench. Also making myself familiar with what the task is leads me to offer suggestions that may be helpful. I have a poster on my wall, and one of the sayings is '2/3 of promotion is motion.' I have no problem with the motion."

Steele has provided many students on-the-job training on various procedures. He shares his acquired knowledge and expertise with peers and scientists. Steele says of training new scientists in field work, "My degree of assistance is bridging what we have done versus what their particular objective is and learning what new methodology they bring to the table."

Working and traveling together has created a special bond between Grace and Steele. Grace says, "Preston knows how I operate and how I want things done. He's ready to go all the time, and he really understands the work. We complete each other's sentences. We're coworkers and friends." Grace adds that there are countless technicians who make scientists' work possible. He includes in that group **James Dowdell**, another "world-class technician" who has worked for the Forest Operations unit for 30 years.



A typical stream on the Tuskegee National Forest. *(photo by J.M. Grace III)*

You Can Help Ensure Good Water Quality

By now, you have a sense how interconnected our water systems are, literally flowing from the mountains to the sea. There's a lot you can do on your own property—whether you have a small yard in the city or hundreds of acres in the country—to help improve water quality.

In Your Own Backyard

Prevent wastes from your home or yard—landscaping debris, pet waste, automotive products, household chemicals, paint and home restoration products—from getting into streets and washing down storm drains.

Collect water from your roof into barrels or rain gardens, or disperse it through grass, mulch, or gravel.

Plant in tune with the climate of your area so that you can minimize watering your lawn and garden.

Keep the exposure of bare ground to a minimum. Compost, mulch, and/or plant immediately after exposing bare soil. Separate bare soil from surface waters; don't allow water to flow across or through bare ground to surface waters.

Avoid disturbing the soil on steep slopes. Keep these and other sensitive areas planted, ideally with native plants.

Use pesticides and lawn chemicals conservatively, and time applications for the least runoff. Think about replacing your lawn with native ground coverings to reduce the use of chemicals.

Replace paved areas with vegetation or permeable material wherever possible.

In Rural Settings

Leave a forested or vegetative buffer near streams and around wetland areas. Stabilize eroding shorelines.

For farming and livestock operations, use Best Management Practices (BMP) such as low tillage, cover cropping, mulching, filter strips, integrated pest management, and animal waste management, to keep agricultural contaminants away from streams. Avoid compacting the soil with heavy machinery.

Keep livestock well away from streams and rivers.

When building roads, use BMPs, staying away from streams and adhering to local grade requirements. Design roads to disperse runoff properly. (BMP guidelines and manuals are available from your State forestry agency.)

Landowner's

TOOLBOX

A weir in the Southern Appalachians. *(photo by Rodney Kindlund)*

Recommended Reading

Most technical reports and articles listed below are available in full text from the SRS publications database at http://www.srs.fs.usda.gov/pubs/, or from TreeSearch, the Forest Service research publication database, at http://www.treesearch.fs.fed.us/.

Water Pressures Build in the South

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Will We Have Enough?

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Don't Forget the Fish and Other Aquatic Organisms

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Reducing the Impacts of Forest Roads

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The Santee Experimental Forest, one of 19 experimental forests maintained and studied by the Southern Research Station. *(photo by Rodney Kindlund)*

Since the 1920s, the USDA Forest Service has maintained a system of experimental forests to test hypotheses and collect long-term data about the ecological effects of fire, grazing, insect infestations, air pollution, and other disturbances. In the South, researchers from Federal agencies and universities use 15 active experimental forests for studies ranging from the practices needed to maintain healthy forests, to the water filtration functions of forests, to habitat restoration for endangered species.

Experimental forests are some of the few places in the United States where long-term data are collected about forests and how they change over time. These living laboratories also serve as demonstration sites where cooperators and landowners can see the results of different forest management options.

WHAT CAN EXPERIMENTAL FORESTS TEACH US ABOUT CLEAN WATER?

In 1933, the U.S. Government acquired land in Berkeley County, near Charleston, SC, to form the Francis Marion National Forest. In 1937, 6,100 acres of the Francis Marion National Forest were allocated as the **Santee Experimental Forest** to support research needed to sustain and manage Coastal Plain forests.

The Santee Experimental Forest includes parts of the oldest colonized land in the United States. King Charles II granted the land to Thomas Colleton in 1683, and eventually it became incorporated into the Limerick Plantation in 1707. During that time, the upland was cleared and used to raise livestock and produce naval stores (tar, pitch, turpentine, pine oil, rosin, and terpenes extracted from pine), while rice and indigo were cultivated in the bottomlands. Between 1897 and 1929, the area was heavily logged.

Early research on the Santee focused on thinning and fire management in loblolly pine stands. Forest hydrology and silviculture (forest management activity, including timber harvesting, forest regeneration, and fertilization) were added to the research program over the years. The large experimental forest contains all of the major forest types; hence research findings are applicable to most of the southeastern coastal areas.

The Santee also contains four gauged watersheds, which are fundamental to studying the quantity and movement of water across the landscape and for understanding how land management practices affect water quality. The first long-term water quality observations on the Santee began in the 1960s, and the site has been used subsequently for several other long-term water-related studies, such as the effects of prescribed fire on stream water quality.

These long-term studies point out that the water balance, or the source of water and its fate, needs to be a major consideration for landowners. Water originates as precipitation, ground water, or as overland flow from flood waters. Conversely the water leaves a site by surface or subsurface drainage, evaporation, or through transpiration by plants. In these Coastal Plain forests, precipitation is the dominant source of water, and transpiration is the primary means of removing water from the site; land use practices that alter the presence or absence of vegetation can be expected to alter the amount of water draining from the site. With respect to water quality, the key finding is that these coastal forests can be managed without degrading water quality, and that wetlands are an integral component of the landscape for providing clean water. Wetlands filter sediments, nutrients, and some chemicals that can degrade water quality and are an important food supply for the organisms that inhabit coastal streams and rivers. Research showing the value of forested wetlands is important because those ecological functions can be destroyed when the wetland is converted to another use, such as agricultural or suburban development.

The watershed studies on the Santee are relevant to all who live and work in the coastal areas because they provide the basis for understanding not only the role of the forested wetlands in an undisturbed state, but also for interpreting the effects of development on water resources and quality.

around the STATION...

Station Scientists Help Build Participation in the Conservation Reserve Program

SRS scientists **Emile Gardiner** and **Ted Leininger** worked with USDA policymakers to update a Conservation Reserve Practice 31 (CP-31) to provide greater economic incentives for landowners to convert agricultural land to forest. Without increased financial incentives, landowners could get more money from the prevailing soil rental rates for agriculture than the Government would pay them for planting hardwoods in wetland soils. Extra financial incentive could make conversion of agricultural land to forests an attractive land use option. Gardiner, research forester, and Leininger, project leader for the **Center for Bottomland Hardwoods Research**, realized the need to increase revenue options.

Over a 10-year period, Gardiner, Leininger, and others at the Stoneville, MS unit have developed a restoration technique to intercrop multiple hardwood species. The intercropping technique involves interplanting red oaks or other bottomland tree species beneath an established eastern cottonwood plantation. This stand establishment practice results in the development of a two-storied forest that can provide landowners with several income streams.

The revised version of CP-31 resulted in a marked increase in landowner enrollment in the special 500,000-acre set-aside designated by the Secretary of Agriculture. From the time the USDA announced the initial program in spring 2003 until the revised conservation practice was released in May 2005, 10,680 acres were enrolled in the program. During the following 6 months, an additional 21,400 acres were enrolled, a 200 percent increase.

"The Farm Services Agency employees with whom we worked to accomplish the revised conservation practice said that the new directive had a marked positive effect on the program and that it showed promise for further increasing enrollment," according to Leininger. On November 11, 2005, the update to Conservation Practice 31, issued initially as Notice CRP-496 on May 18, 2005, was incorporated into the Farm Service Agency's two Conservation Reserve Program Policies and Procedures Handbooks as a permanent directive.

The Conservation Reserve Practice was designed to restore wetlands, enhance water quality, and sequester greenhouse gases. Bottomland hardwoods have the potential to sequester significant amounts of greenhouse gases, and markets are emerging for the trading of carbon emissions credits. If a participant in the CRP program agrees to sell carbon credits to a company, the terms and conditions of the CRP contract must not be impacted. The sale of credits, which would yield another revenue source, would be solely between the landowner and the carbon company.

Experimental Forests

1	Bent Creek	NC
2	Blue Valley	NC
3	Coweeta	NC
4	John C. Calhoun	SC
5	Santee	SC
6	Scull Shoals	GA
7	Hitchiti	GA
8	Olustee	FL
9	Chipola	FL
10	Escambia	AL
11	Tallahatchee	MS
12	Delta	MS
13	Harrison	MS
14	Palustris	LA
15	Stephen F. Austin	TX
16	Crossett	AR
17	Alum Creek	AR
18	Sylamore	AR
19	Henry F. Koen	AR

You "Mite" Recognize This Name

In the city of Aydin in the Aegean region of Turkey, entomologists discovered the mite *Pyemotes johnmoseri* on figs during the period 2003 to 2004. Named after **John Moser**, SRS emeritus entomologist, the mite is "an important predator of a bark beetle that is a serious pest of figs in Turkey," according to Moser**.** In the *Journal of Entomology* article "*Pyemotes johnmoseri* (Khaustov) (Acari: Pyemotidae) As A Parasitoid of Xylophagous Insects from Aydin, Turkey," Ibrahim Cakmak, Tulin Aksit, and Sultan Cobanoglu describe the male and female as a new record for the mite fauna of Turkey and state that the species attacked *Hypoborus ficus*. Cakmak and Aksit are faculty members at the University of Adnan Menderes in Aydin. Cobanoglu is on faculty at the Department of Plant Protection, University of Ankara, Turkey.

Moser retired from the Southern Research Station in 1989 after a 31 year career with the Forest Service. He still works every day in the **Ecology, Biology, and Management of Bark Beetles and Invasive Forest Insects of Southern Conifers** unit in Pineville, LA. Project leader **Kier Klepzig** says, "John is *the* world authority on mites associated with bark beetles and among the most recognized authorities on mites worldwide. He has long been a great asset to the Station and one we treasure."

Chinese entomologists Yu and Liang originally honored Moser by naming a species of Chinese mite after him. They first described the species, a member of the genus *Pyemotes*, in 1996 and called it *Pyemotes moseri*. In 1998 when writing about mites associated with bark beetles in Crimea, the Ukranian entomologist Khaustov referred to a different mite species as *Pyemotes moseri*, unaware the name was already taken. In 2004, when Cakmak, Aksit, and Cobanoglu were studying the mite attacking the bark beetles attacking Turkish figs, Khaustov proposed the replacement name *Pyemotes johnmoseri* for the species he studied in Crimea.

John Moser will take some time away from the lab in Pineville this year to participate in the international meeting of acarologists (those who study mites and ticks) in Amsterdam. When asked why he still goes to work every day, Moser replied, "I've never worked a day in my life. This is my hobby!"

John Moser excavating a leaf-cutting ant nest. *(photo by Erich Vallery)*

The dogwoods in bloom in spring at SRS Headquarters, Asheville, NC *(Rodney Kindlund)*

NEW PRODUCTS

Southern Pine Ecosystems

1 Craul, Philip J.; Kush, John S.; Boyer, William D. 2005. **Longleaf pine site zones**. Gen. Tech. Rep. SRS-89. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 23 p.

The authors delineate six major climatic areas of the longleaf pine region. They subdivide these areas into 21 site zones, each of which is deemed homogenous with respect to climate, physiography, and soils. The site zones are mapped and their climate, physiography, and soils described. The authors recommend that plantings of longleaf pine in any of the six major climatic areas of the longleaf region be made with a seed source from the same area.

2 Grace, J.M. III; Skaggs, R.W.; Cassel, D.K. 2006. **Soil physical changes associated with forest harvesting operations on an organic soil.** Journal of Soil Science Society of America. 70: 503-509.

The influence of forest operations on forest soil and water continues to be an issue of concern in forest management. However, poorly drained forested watersheds with organic soil surface horizons have not been extensively investigated. A study was initiated to investigate the effect of harvesting operations in the Tidewater region of North Carolina on soils classified as shallow organic soils. Compaction caused by the harvest operation increased bulk density (D_b) from 0.22 to 0.27 g cm $^{-3}$, decreased saturated hydraulic conductivity (k_{sat}) from 397 to 82 cm h^{-1}, and decreased the drained volume for a given water table depth.

from the Southern Research Station...

Wetlands, Bottomlands, and Streams

3 Adams, Susan B. 2005. **Katrina: boon or bust for freshwater fish communities?** Watershed. Fall & Winter: 19-21, 23.

Hurricane Katrina was the most damaging storm to hit the Mississippi Gulf Coast in recent history. Although catastrophic in human terms, was Katrina a disaster for freshwater ecosystems? Were the storm and its impacts on freshwater fish communities "natural"? The naturalness of the storm's effects on freshwater communities varies depending on previous anthropogenic alterations of ecosystems. Long-term effects will further depend on human actions following the storm. Although many fish, especially near the coast, were killed, populations are expected to rebound. In addition, the storm will leave an extremely beneficial ecological legacy in the form of copious wood (trees and root wads) deposited in streams and rivers, where it will provide vital habitat complexity for years to come.

4 Amatya, D.M.; Trettin, C.C.; Skaggs, R.W. [and others]. 2005. **Five hydrologic studies conducted by or in cooperation with the Center for Forested Wetlands Research, U.S. Department of Agriculture Forest Service**. Res. Pap. SRS-40. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 22 p.

The U.S. Department of Agriculture Forest Service Center for Forested Wetlands Research has conducted or cooperated in studies designed to improve understanding of fundamental hydrologic and biogeochemical processes that link aquatic and terrestrial ecosystems. The topics of the include: (1) soil moisture dynamics, flow regimes, and water chemistry of low-gradient forested wetlands; (2) effects of various water management and silvicultural management practices; (3) questions related to public concerns about the need for protection, restoration, and sustainable management of forested wetlands; (4) hydrology and water quality of intensively managed short-rotation woody crop plantations; and (5) surface-water and ground-water interactions between Carolina bays and their surrounding uplands. Recommendations are provided for using knowledge gained through these and other studies as a basis for expanding needed hydrologic research with collaborators to address major areas of water-related issues in the Southeast.

5 Dosskey, M.G.; D.E. Eisenhauer, D.E.; and M.J. Helmers, M.J. 2005. **Establishing conservation buffers using precision information.** Journal of Soil and Water Conservation 60 (6): 349-354.

To reduce water pollution, grass or forest vegetation is often located between agricultural fields and streams to trap sediment and fertilizer in runoff before it enters streams. Currently, buffers are installed having uniform width along a stream. However, runoff typically flows unevenly from agricultural fields and overwhelms some portions of buffer, while other portions do not contact runoff. We propose a new approach—vary the width of buffers to match the filtering needs of every location along the stream. This approach is made possible using detailed topographic maps, global positioning devices, geographic information systems, and improved mathematical models. This approach would achieve substantially greater water quality benefit from each acre of buffer.

6 Grace, J.M. III. 2006. **A new design to evaluate erosion and sediment control.** In: Proceedings, Environmental Connection 2006. Colorado Springs, CO: International Erosion Control Association: 153-162.

Controlling sediment movement is a common objective in most forestry best management practices (BMPs). Monitoring designs for effective evaluations of erosion and sediment control practices are critical. General engineering design aspects involved in evaluating erosion control, sediment control, and BMPs on the forest landscape are presented in this work. Statistical considerations to optimize data collection and increase the probability of statistically valid results are presented. In addition, we present an innovative study design (real world) and application to evaluate the effectiveness of three road sediment control treatments in filtering sediment-laden storm runoff: settling basins, sediment basin with riser control, and hay bale barriers.

7 Mulhouse, John M.; De Steven, Diane; Lide, Robert F.; Sharitz, Rebecca R. 2005. **Effects of dominant species on vegetation change in Carolina bay wetlands following a multi-year drought**. Journal of Torrey Botanical Society. 132(3): 411-420.

Wetland vegetation is strongly dependent upon climate-influenced hydrologic conditions, and plant composition responds in generally consistent ways to droughts. However, the extent of species composition change during drought may be influenced by the pre-existing structure of wetland vegetation. We characterized the vegetation of 10 herbaceous Carolina bay wetlands on the South Carolina Upper Coastal Plain during a period of average rainfall and again near the end of a four-year drought. Aquatic species decreased during the drought in all wetlands, regardless of vegetation group. Compared to grass/sedge marshes, pond/meadow wetlands acquired more species, particularly non-wetland species, during the drought. Pond/meadow wetlands also had greater increases in the abundances of species that require unflooded conditions to establish. The results suggest that Carolina bay vegetation dynamics may differ as a function of dominant vegetation and climate driven variation in wetland hydrologic condition.

Mountain and Highland Ecosystems

8 Clinton, Barton D.; Vose, James M. 2006. **Variation in streamwater quality in an urban headwater stream in the Southern Appalachians**. Water, Air, and Soil Pollution. 169: 331-353.

Land use is one of the most important factors determining water quality. As human populations increase and land use patterns change, resource managers, planners, and regulators need to understand the impacts of urbanization on water quality and aquatic resources. We examined the influence of a forested landscape on the quality of water in a stream originating on an urban landscape. Over the roughly 2-km reach of this stream there were significant reductions in some nitrogen and phosphorus compounds due to the stream's inherent ability to improve water quality through a variety of in-stream processes when inputs are minimized. In addition, bacteria populations declined as did total suspended solids. This study illustrates the importance of undisturbed stream reaches in mitigating against point and non-point sources of nutrients and sediment.

9 Predny, Mary L.; Chamberlain, James L. 2005. **Bloodroot (*Sanguinaria canadensis*): an annotated bibliography**. Gen. Tech. Rep. SRS-86. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 55 p.

Bloodroot is a spring-blooming herbaceous perennial found in hardwood forests throughout the Appalachian Mountain regions and eastern United States. The common name and the scientific name *Sanguinaria* refers to the plant's blood-red sap, which contains alkaloids that make the plant so valuable. Native Americans used bloodroot as a dye, love charm, and medicine. Bloodroot was described in medicinal pharmacopoeias as early as the 1800s, with detailed descriptions of the plant, its chemical constituents, and therapeutic values. Bloodroot is primarily wild-harvested for domestic and international markets. This report describes the characteristics and growth habits of bloodroot, summarizes the plant's many uses, reviews the global market and trade, examines the conservation status of the plant, and identifies future research needs.

10 Predny, Mary L.; Chamberlain, James L. 2005. **Galax (*Galax urceolata*): an annotated bibliography**. Gen. Tech. Rep. SRS-87. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 33 p.

Galax is an evergreen groundcover harvested for use in the floral industry. The plant's durable, shiny green leaves turn red in the fall, and are popular background foliage in floral arrangements. People living in western North Carolina and other rural Appalachian locations have harvested galax for supplemental incomes since the late 19th century. Today, more than 90 percent of the harvesters are of Latino origin. Experienced harvesters can collect about 5000 leaves a day and generate from $20 to $120, depending on the prices which varies with the season, size and color of the leaves, as well as market demand. Industry concern for the availability and sustainability of galax prompted the U.S. Forest Service to restrict the harvest season, and to undertake studies to determine sustainable harvest levels. This book describes plant's characteristics and growth habits, summarizes its many uses, reviews trade and market conditions, examines its conservation status and identifies future research needs.

11 Predny, Mary L.; Chamberlain, James L. 2005. **Goldenseal (*Hydrastis canadensis*): an annotated bibliography**. Gen. Tech. Rep. SRS-88. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 67 p.

Goldenseal, a member of the buttercup family (Ranunculaceae), is an herbaceous perennial found in rich hardwood forests of eastern United States. Originally used by Native Americans as a medicine and a dye, the herb was adopted by European settlers in the 19th century. The alkaloids in goldenseal have antibiotic, anti-inflammatory and anti-spasmodic effects. Growing awareness of the plant's medicinal values has increased world-wide consumption, which, combined with loss of habitat, has greatly reduced wild populations. In 1997, Goldenseal was listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Demand for cultivated roots has increased as wild populations become scarce, motivating research into propagation and cultivation techniques.

Inventory and Monitoring

12 Brandeis, Thomas J.; Kuegler, Olaf; Knowe, Steven A. 2005. **Equations for merchantable volume for subtropical moist and wet forests of Puerto Rico**. Res. Pap. SRS-39. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 15 p.

In Puerto Rico, where locally grown woods are primarily used for furniture and crafts production, estimation of wood volume makes it possible to estimate the monetary value of one of the many commodities and services forests provide to society. In the forest inventories of 1980 and 1990, workers calculated stem volume directly by applying geometric formulae to bole sections of merchantable trees. Field crews recorded several diameter and height measurements along the bole of each tree. If tree volume estimates were based on fewer tree measurements, this would significantly increase field crew productivity. For this reason, tree volume equations have been derived from Puerto Rican forest inventory data by directly calculating stem volume, then creating regression equations that estimate inside and outside bark merchantable stem volume from tree diameter at breast height and total height.

13 Johnson, Tony G.; Wells, John L. 2005. **Georgia's timber industry—an assessment of timber product output and use, 2003**. Resour. Bull. SRS-104. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 46 p.

This report contains the findings of a 2003 canvass of all primary wood-using plants in Georgia, and presents changes in product output and residue use since 2001. It complements the Forest Inventory and Analysis periodic inventory of volume and removals from the States' timberland. The canvass was conducted to determine the amount and source of wood receipts and annual timber product drain, by county, in 2003 and to determine interstate and cross-regional movement of industrial roundwood. Only primary wood-using mills were canvassed. Primary mills are those that process roundwood in log or bolt form or as chipped roundwood. Examples of industrial roundwood products are saw logs, pulpwood, veneer logs, poles, and logs used for composite board products.

Large-Scale Assessment and Monitoring

14 Liu, Yongqiang. 2005. **Land breeze and thermals: a scale threshold to distinguish their effects**. Advances in Atmospheric Sciences. 22(6): 889-902.

Land breeze is a type of mesoscale circulation developed due to thermal forcing over a heterogeneous landscape. It can contribute to atmospheric dynamic and hydrologic processes through affecting heat and water fluxes on the land-atmosphere interface and generating shallow convective precipitation. If the scale of the landscape heterogeneity is smaller than a certain size, however, the resulting land breeze becomes weak and mixed with other thermal convections, like thermals. This study seeks to identify a scale threshold to distinguish the effects between land breeze and thermals. The results suggest that the effects of land breeze can be clearly distinguished from those of thermals only if the size of the landscape heterogeneity is larger than the scale threshold of about 5 km for dry atmospheric processes or about 15 km for moist ones.

15 Liu, Yongqiang; Avissar, Roni. 2005. **Modeling of the global water cycle—analytical models.** In: Anderson, M.G., ed. Encyclopedia of Hydrological Sciences. New York: John Wiley & Sons: 2781-2794.

Both numerical and analytical models of coupled atmosphere and its underlying ground components (land, ocean,

Instruments used to measure carbon releaased from the forest floor. *(photo by Zoë Hoyle)* ice) are useful tools for modeling the global and regional water cycle. Unlike complex three-dimensional climate models, analytical models are able to provide more direct and intuitive figures of variability and processes in a highly simplified system. They can be an especially efficient alternative for studying the continental water cycle. This article describes the analytical models developed based on soil and atmospheric water and energy conservation equations. We use a fourth-order model to illustrate the perturbation equation, solutions, and physical interpretation. We present our understanding of some water cycle variability issues, including timescale, persistence, and major physical parameters and processes.

Wildland-Urban Interface and Urban Forestry

16 Genton, Marc G.; Butry, David T.; Gumpertz, Marcia L.; Prestemon, Jeffrey P. 2006. **Spatio-temporal analysis of wildfire ignitions in the St. Johns River Water Management District, Florida.** International Journal of Wildland Fire. 15: 87-97.

We analyze the spatio-temporal structure of wildfire ignitions in the St. Johns River Water Management District in northeastern Florida. We show that wildfire events occur in clusters. Clustering correlates with irregular distribution of fire ignitions, including lightning and human sources, and fuels on the landscape. In addition, we define a relative clustering index that summarizes the amount of clustering over various spatial scales. We carry our analysis in three steps: purely temporal, purely spatial, and spatio-temporal. Our results show that arson and lightning are the leading causes of wildfires in this region and that ignitions by railroad, lightning, and arson are spatially more clustered than ignitions by other accidental causes.

Foundation Programs

17 Clarke, John W.; White, Marshall S.; Araman, Philip A. 2005. **Effect of stringer repair methods and repair frequency on performance.** Pallet Enterprise. 25(2): 68-73.

Over 135 million wooden pallets were repaired for reuse in 1995. Notched stringers are one of the most commonly damaged components. Metal plates, half companion stringers, and full companion stringers are repair methods described in the U.S. industry standard published by the American Society of Mechanical Engineers. This study evaluated the effect of these three stringer repair methods on the bending strength and stiffness of 48x40 GMA-style pallets spanning the pallet stringers.

18 Dumroese, Kasten R.; James, Robert L. 2005. **Root diseases in bareroot and container nurseries of the Pacific Northwest: epidemiology, management, and effects on outplanting performance.** New Forests. 30: 185-202.

In forest and conservation nurseries in the Pacific Northwest, seedling production can be limited by root diseases caused by fungi. These root pathogens are encouraged by water saturated soils or medium. Infected seedlings usually have yellowish or dead needles or leaves with extensive root decay; one serious root pathogen often causes serious root decay without shoot symptoms. The best approach to reduce losses from these diseases is to use a holistic integrated pest management program. This program should combine chemical controls with cultural practices, particularly those that increase soil permeability and drainage and reduce potential sources of inoculum, especially by disinfesting seeds and containers reused for crops. We found, in general, that seedlings meeting nursery specifications for outplanting on forest soil but having these disease organisms on their root systems perform as well as non-infected seedlings.

19 Hwang, Chin-Yin; Hse, Chung-Yun; Shupe, Todd F. 2005. **Effects of recycled fiber on the properties of fiberboard panels.** Forest Products Journal. 55(11): 66-64.

This study examined the effects of recycled and virgin wood fiber on the properties of fiberboard. Replacing virgin fiber with recycled fiber adversely affected physical and mechanical properties of fiberboard. Bending properties and dimensional stability were linearly dependent on virgin fiber ratios. Based on strength properties, panels with 20 and 40 percent recycled fiber contents conformed to standards for class 4-service and class S-industrialite hardboard, respectively. All panels with recycled fiber content greater than 40 percent failed to meet any commercial requirement.

20 Lin, Lianzhen; Hse, Chung-Yun. 2005. **Liquefaction of CCA-treated wood and elimination of metals from the solvent by precipitation.** Holzforschung. 59: 285-288.

Spent chromated copper arsenate (CCA)-treated wood was liquefied in polyethylene glycol 400/glycerin (2:1 w/w). Sulfuric acid (95-98 percent) and ferrous salts ($FeSO_4 \bullet 7H_2O$ or $FeCl_2 \bullet 4H_2O$) were used as catalysts and additives, respectively. The resulting liquefied CCA-treated wood was diluted with aqueous solvents and was then mixed with complexion/precipitation agents, followed by precipitation or filtration to remove the toxic metal-bearing sediment. As a result, more than 90 percent of Cu, Cr, or As was removed.

Mosses and ground cover help retain soil moisture. *(photo by Rodney Kindlund)*

Ice storms provide water to the forest. *(photo by Zoë Hoyle)*

Research Work Units

Location & Project Leader	Unit	Name & Web Site	Phone
Asheville, NC David Loftis	4101	Ecology and Management of Southern Appalachian Hardwood Forests www.srs.fs.usda.gov/bentcreek	828-667-5261
Asheville, NC Danny Lee	4853	Eastern Forest Environmental Threat Assessment Center	828-257-4854
Athens, GA John Stanturf	4104	Disturbance and the Management of Southern Pine Ecosystems www.srs.fs.usda.gov/disturbance	706-559-4315
Athens, GA Jim Hanula	4505	Insects and Diseases of Southern Forests www.srs.fs.usda.gov/4505	706-559-4285
Athens, GA Ken Cordell	4901	Assessing Trends, Values, and Rural Community Benefits from Outdoor Recreation and Wilderness in Forest Ecosystems www.srs.fs.usda.gov/trends	706-559-4264
Auburn, AL Kris Connor	4105	Vegetation Management Research and Longleaf Pine Research for Southern Forest Ecosystems www.srs.fs.usda.gov/4105	334-826-8700
Auburn, AL Robert Rummer	4703	Biological/Engineering Systems and Technologies for Ecological Management of Forest Resources www.srs.fs.usda.gov/forestops	334-826-8700
Blacksburg, VA Andrew Dolloff	4202	Coldwater Streams and Trout Habitat in the Southern Appalachians www.trout.forprod.vt.edu	540-231-4016
Blacksburg, VA Philip Araman	4702	Integrated Life Cycle of Wood: Tree Quality, Processing, and Recycling www.srs4702.forprod.vt.edu	540-231-4016
Charleston, SC Carl Trettin	4103	Center for Forested Wetlands Research www.srs.fs.usda.gov/charleston	843-727-4271
Clemson, SC Susan Loeb	4201	Endangered, Threatened, and Sensitive Wildlife and Plant Species in Southern Forests www.srs.fs.usda.gov/4201	864-656-3284
Franklin, NC James Vose	4351	Evaluation of Watershed Ecosystem Responses to Natural, Management, and Other Human Disturbances	828-524-2128
Gainesville, FL Ed Macie	4951	Southern Center for Wildland-Urban Interface Research and Information www.interfacesouth.org	352-376-3213

Cells used for water table experiments at the Santee Experimental Forest. *(photo by Rodney Kindlund)*

Soil lysimeters. *(photo by Rodney Kindlund)*

Research Work Units *(Continued)*

Location & Project Leader	Unit	Name & Web Site	Phone
Huntsville, AL Greg Ruark	4551	National Agroforestry Center www.nac.gov	256-372-4540
Knoxville, TN Bill Burkman	4801	Forest Inventory and Analysis www.srsfia2.fs.fed.us	865-862-2000
Monticello, AR James Guldin	4106	Managing Upland Forest Ecosystems in the Midsouth www.srs.fs.usda.gov/4106	870-367-3464
Nacogdoches, TX Ronald Thill	4251	Integrated Management of Wildlife Habitat and Timber Resources www.srs.fs.usda.gov/wildlife	936-569-7981
New Orleans, LA Rodney Busby	4802	Evaluation of Legal, Tax, and Economic Influences on Forest Resource Management www.srs.fs.usda.gov/4802	504-589-6652
Pineville, LA Kris Connor	4111	Ecology and Management of Even-Aged Southern Pine Forests www.srs.fs.usda.gov/4111	334-826-8700
Pineville, LA Kier Klepzig	4501	Ecology, Biology, and Management of Bark Beetles and Invasive Forest Insects of Southern Conifers www.srs.fs.usda.gov/4501	318-473-7232
Pineville, LA Les Groom	4701	Utilization of Southern Forest Resources www.srs.fs.usda.gov/4701	318-473-7268
Raleigh, NC Steven McNulty	4852	Southern Global Change Program www.sgcp.ncsu.edu	919-513-2974
Research Triangle Park, NC Kurt Johnsen	4154	Biological Foundations of Southern Forest Productivity and Sustainability www.srs.fs.usda.gov/soils/soilhome.htm	919-549-4092
Research Triangle Park, NC William Bechtold	4803	Forest Health Monitoring http://srs.fs.usda.gov/4803	919-549-4014
Research Triangle Park, NC David Wear	4851	Economics of Forest Protection and Management www.srs.fs.usda.gov/econ	919-549-4093
Saucier, MS Dana Nelson	4153	Southern Institute of Forest Genetics	228-832-2747
Starkville, MS Terry Wagner	4502	Wood Products Insect Research www.srs.fs.usda.gov/termites	662-338-3100
Stoneville, MS Ted Leininger	4155	Center for Bottomland Hardwoods Research www.srs.fs.usda.gov/cbhr	662-686-3154

"Linking science and human purpose, adaptive management serves as a compass for us to use in searching for a sustainable future."

—Kai N. Lee, The Compass and Gyroscope—Integrating Science and Politics for the Environment. *

COMPASS
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Address Correction Requested

Tennessee bottomlands in the Lower Mississippi Alluvial Valley is habitat for bald cypress *(Taxodium distichum)*. *(Photo by Bill Lea)*

Next Issue...

This issue covered SRS watershed research based in the Southern Appalachian mountains and in the Coastal Plain of South Carolina. For our next issue, we will travel west to the Lower Mississippi Alluvial Valley, the site of a major collaborative effort to restore the bottomland hardwood forests that once helped control floods, clean water, and provide habitat for the area's rich diversity of animals, birds, fish, mussels, and other living beings.

Ask A Scientist...

- Do you have a question you would like to ask about southern forests and water quality?
- Email your question to cpayne@fs.fed.us
- We will feature one of your questions—with answers from our scientists—in our next issue.

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