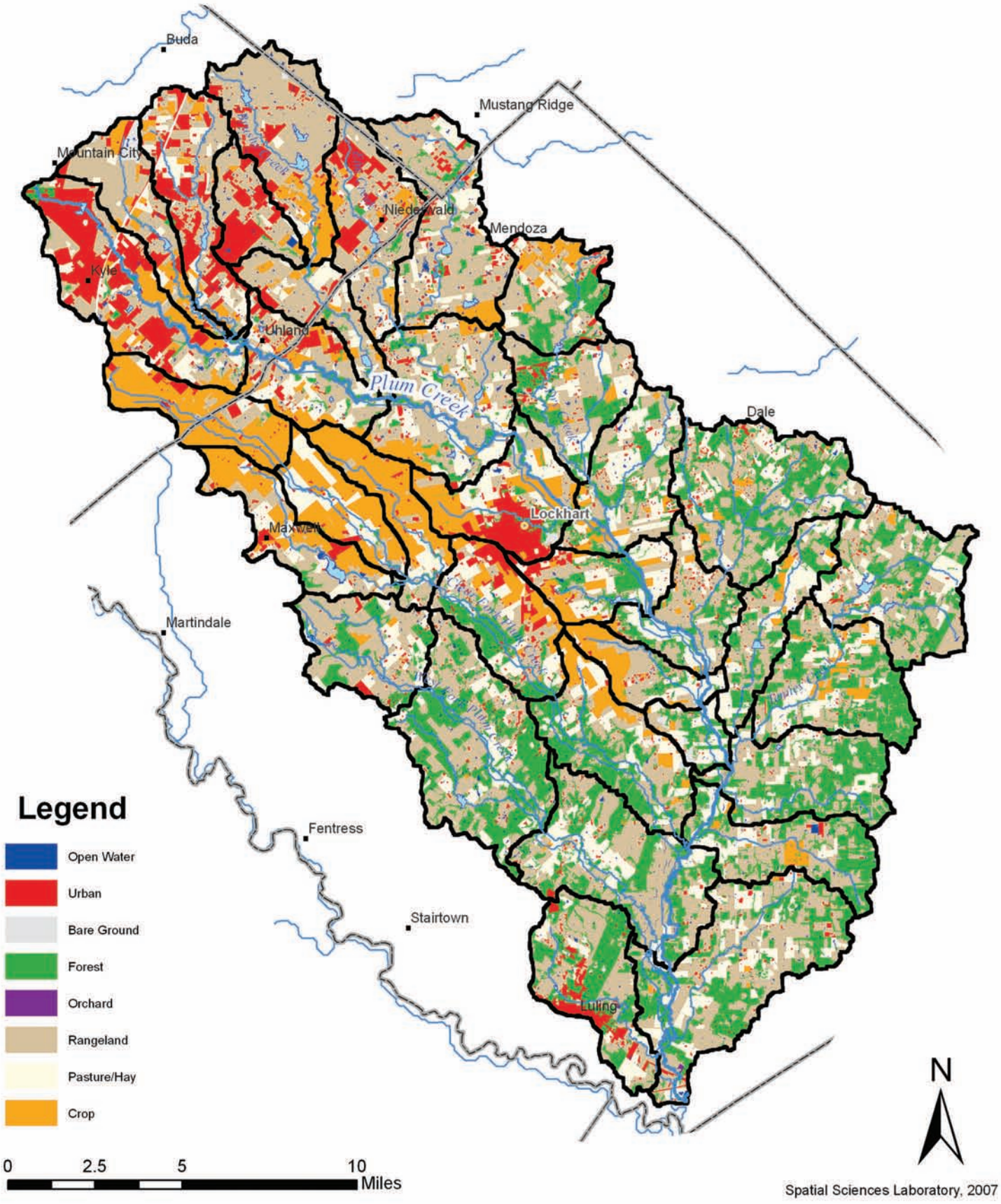
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Spatial Sciences Laboratory, 2007

MIMICKING NATURE

Computer model helps manage nation's, world's waters

In the 1980s, a group of scientists in a small research building in Temple, Texas, began a journey to mimic how watersheds work. Today, a major product of their efforts—SWAT—is used throughout Texas, the nation and the world.

SWAT, the Soil and Water Assessment Tool, is a sophisticated computer model that predicts the impacts of weather, soils, land use and land management on water supplies as well as nonpoint and point source pollution in small to large watersheds. Information such as rainfall amount, soil type, and the amount of nutrients and pesticides applied to the land over the years are fed into the model. Geographical Information Systems (GIS) are also integrated into the computer program that has 400 to 500 mathematical equations with more than 50,000 lines of computer code.

The model predicts how much water, sediment, nitrogen, phosphorus, pesticides, bacteria and other pollutants are running off the land and getting into lakes and rivers, and the impact different water management decisions could have.

"We're trying to mimic nature," said Dr. Jeff Arnold, research leader and agricultural engineer for the Grassland Soil and Water Research Laboratory in Temple, part of the U.S. Department of Agriculture's Agricultural Research Service (ARS). "We give our best estimate of what's going to happen.

"And SWAT's estimation gives decision makers a tool to solve water quality problems, Arnold said.

Dr. Raghavan Srinivasan, director of Texas A&M University's Spatial Sciences Laboratory and professor in the Departments of Ecosystem Science and Management, and Biological and Agricultural Engineering, agreed.

"For policy makers, models such as SWAT can serve as virtual laboratories for testing the effectiveness of alternative environmental policies and pollution control programs," he said.

SWAT is a continuation of models developed over 30 years at the ARS laboratory in Temple. Srinivasan, who was at Blackland Research and Extension Center at the time, and Arnold worked together with other Experiment Station, USDA Natural Resources Conservation Service (NRCS) and university scientists to develop SWAT and its national spatial databases and GIS interfaces.

"Srinivasan took these large-scale databases—the soils data and land use and topography—and really pulled all those together in a form we could use in the models," Arnold said. He explained that GIS takes the maps and associated data and spatially pulls everything together, automatically develops all the SWAT inputs and then displays the information on maps. "Without that application, the model's use would be very limited."

One of the big drivers for developing the model was determining environmental impacts of different conservation practices, Arnold said. Congress, through the Resources Conservation Act, requires NRCS to report to Congress every 10 years on the status of the nation's soil and water resources and evaluate conservation practices.

So, in the early 1990s, the researchers sold NRCS on the idea of using EPIC (Erosion Productivity Impact Calculator), SWAT and GIS to model the

48 contiguous states, simulating the effects management activities have on water quantity and quality in watersheds, Srinivasan said. The result was the Hydrologic Modeling of the United States or HUMUS project, a $1 million five-year project. Before HUMUS, NRCS relied on field observations and statistical approaches to estimate the impacts of conservation programs.

"This was the very first time we were able to model the continent using EPIC and SWAT models," Srinivasan said. "There were no models at that time for such a large area."

The latest national assessment for NRCS, Conservation Effects Assessment Project, or CEAP, is currently being developed. In this assessment, the scientists are using SWAT to incorporate outputs from APEX (EPIC's successor), which simulates cultivated lands. SWAT routes pollutants such as sediment, nutrients and pesticides through streams, rivers and lakes to the sea, Arnold said.

"The USDA Farm Program has spent billions of dollars supporting conservation practices with the farmers, and they want to know the environmental impacts of these practices," Arnold said.

Because of the success of the HUMUS project, the SWAT research team started working with the U.S. Environmental Protection Agency (EPA) and state environmental agencies in the late 1990s to evaluate the environmental impacts of pollutants at the local watershed level in support of the federal Clean Water Act. EPA's Office of Science and Technology developed a tool kit—Better Assessment Science Integration point and Non-point Sources or BASINS—to help states analyze their impaired water bodies, estimate Total Maximum Daily Loads (TMDLs) and evaluate various best management practices suggested for each pollutant. SWAT, GIS and the databases are part of that tool kit.

Today, many states across the country use SWAT in their TMDL programs.

Dr. Jeff Arnold, research leader and agricultural engineer for the ARS's Grassland Soil and Water Research Laboratory in Temple, examines one of the SWAT's watershed maps. SWAT is a river basin-scale model developed to quantify the impact of land management practices in large, complex watersheds.

Dr. Raghavan Srinivasan, director, and Jennifer Jacobs, senior research associate, Spatial Sciences Laboratory, work on generating land use maps for one of the SWAT projects.

In Texas, the Texas Commission on Environmental Quality and Texas State Soil and Water Conservation Board use SWAT to develop TMDLs for bacteria impairments. The SWAT model characterizes the watershed, identifying the source of the impairment, grouping the water segments based on the source of the impairment, and developing TMDLs in a most cost- and time-efficient manner, Srinivasan said.

In 2007, Arnold and Srinivasan began working on the Hydrologic and Water Quality System, or HAWQS, project, an extension of HUMUS. HAWQS, which will incorporate SWAT and another water quality modeling tool—U.S. Geological Survey's Spatially Referenced Regressions on Watershed Attributes (SPARROW)—will model seven categories of pollutants, including bacteria and heavy metals. It will provide information that estimates human health risk, drinking water treatment costs and criteria exceedence frequencies for these pollutants.

This three-year project, funded by the EPA, will use state-of-the-art GIS and more detailed databases to provide much more information about the watersheds, Srinivasan said. In the HUMUS project, the research team divided the country into 2,100 watersheds for analysis; the HAWQS project research team is dividing it into 2.7 million watersheds.

"Having more detailed information helps water managers and policy makers to pinpoint the hot spot areas of pollution, so they can evaluate the areas, make changes and bring those areas within water quality standards," Srinivasan said.

Another important and growing use of SWAT is determining the impacts of climate change in the United States and abroad, Arnold said. Global circulation models help predict what is going to happen to temperature and precipitation. Information from those models is fed into SWAT to see what changes will occur to the water supply, reservoir levels and aquifer recharge based on the predicted global climate changes.

Srinivasan and other SWAT developers and users travel around the country and the world, conducting workshops and teaching SWAT and related tools. To date, Srinivasan has conducted 30 international workshops and 50 U.S. workshops.

"We really wanted to deliver a tool that is usable and useful and applied to solve real-world assessments rather than a pure research tool that sits on a shelf," Srinivasan said. "We made the decision to take the technology to the users.

"SWAT is really starting to take off in a much more significant way to solve water quality and water quantity issues around the world," Srinivasan said, adding that 300 peer-reviewed publications have been written based on SWAT.

For this, they are glad. "We really want to make an impact," he said.

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