quality of life of the community overall," Skinner says.

She says other benefits of cutting greenhouse gases could include reduced traffic congestion, health problems related to urban smog, and even some hazard-related insurance premiums.

When a municipality passes a resolution to join the campaign, ICLEI helps to draw up a local action plan. It includes a municipal energy profile to determine emissions in a chosen baseline year, an inventory of energy use, and a goal for energy use and emissions for a target year.

Identifying measures to reduce emissions could include technical fixes such as retrofitting buildings with energy efficiency technologies, and policy changes concerning land usage that reduces the reliance on automobiles, and energy patterns.

Skinner says the measures most worth pursuing have clearly defined costs and benefits, achieve multiple environmental and social benefits, are within the appropriate power of local authorities to implement, cut a significant percentage of greenhouse gases, and, perhaps most important, gain popular political support.

Other municipalities that have joined the campaign include Overland Park, Kansas, a Great Plains city of 150,000 people. Since the city, which is part of metropolitan Kansas City, joined the campaign in June 1997, it has cut 14,600 tons of greenhouse gases through recycling, mass transit, and other projects, according to Environmental Compliance Manager George Moody.

City Councillor Jay Lehnertz says that while some people are concerned about the potential impact of global climate change on Kansas' agricultural base, "the bottom line is that we are convinced that there is an economic advantage" to reducing greenhouse gases.

Denver, Colo., another participant in the campaign, has drawn up a plan to reduce CO_2 by 1-2% per year between 1988 and 2005, and 20% overall. The city has enacted several programs, including a "green fleets" initiative that reduces the number of fleet vehicles and the miles traveled, and changes the fuel used; land use planning that reduces pollution; and tree planting to absorb CO_2. Just by retrofitting the heating system in Mile High Stadium, the city cut CO_2 by 1,600 tons per year.

In other countries, the program also has seen a number of positive results. In Saarbrucken, Germany, a program including district heating and cooling systems, solar rooftop panels, and street lighting has cut CO_2 emissions by 15% below the city's baseline. And Toronto, Canada, which was among the first cities to set a goal of 20% greenhouse gas reduction, already has reduced emissions by 7%.

Other municipalities in the campaign include: Budapest, Hungary; Calcutta, India; Entebbe, Uganda; Hanoi, Vietnam; Jerusalem, Israel; Milan, Italy; and Tehran, Iran.

Skinner says that some municipalities that may not have already signed up with the campaign may have their own energy efficiency programs, or be overwhelmed by other concerns.

She says that the campaign is proving wrong those who say that reducing greenhouse gases brings dire economic consequences. Skinner says that in many instances, reducing gases actually has saved money and also brought other benefits to communities.

For further information about Cities for Climate Change, view the ICLEI Web site: http://www.iclei.org.—*Randy Showstack*

Assessing Nonpoint Source Pollution in the Vadose Zone

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Sustainable agriculture is viewed as the only viable means of meeting the food demands of the world's projected population of 11 billion by the year 2050. Sustainable agriculture is predicated on a delicate balance of maximizing crop productivity and maintaining economic stability while minimizing the use of finite natural resources and avoiding the detrimental environmental impacts of associated nonpoint source (NPS) pollutants. NPS pollutants include pesticides, fertilizers, trace elements, salts, sediments, etc., and are known to be carcinogenic, mutagenic, or teratogenic. NPS pollutants threaten sustainable agriculture and are recognized as the single greatest threat to surface and subsurface drinking water resources.

Against this backdrop scientists met to address the application of advanced information technologies to NPS pollution in soil at the 1997 Joint AGU Chapman/SSSA Outreach Conference, "Application of GIS, Remote Sensing, Geostatistics, and Solute Transport Modeling to the Assessment of Nonpoint Source Pollutants in the Vadose Zone." The objective of the conference was to explore multidisciplinary approaches for assessing NPS pollutants in the unsaturated region from the soil surface to the groundwater table (vadose zone). The conference provided a forum to stimulate interaction between the subdisciplines of spatial statistics, remote sensing, geographic information systems (GIS), and solute transport modeling to enhance the development and evaluation of techniques for the measurement, inventory, and modeling of NPS pollution in soil and subsurface waters.

The conference answered two questions related to assessing NPS pollution vulnerability with GIS technology: What is currently possible and what is on the horizon? Perhaps the forthcoming greatest technological advance for modeling and assessing NPS pollution in the vadose zone will be the ability to perform regional-scale simulations with a system that integrates GIS; solute transport modeling; pedotransfer functions, neural networks, and remote sensing for estimating and/or measuring transport properties; geostatistics for characterizing variability structures and spatial interpolation; fuzzy set theory for handling vague and imprecise data; spatial and temporal analysis; and uncertainty analysis to allow decision-makers to evaluate the reliability of information.

Conference Agenda

One hundred and two scientists from nine countries participated during the 4-1/2 day conference and presented a total of 8 keynote papers, 22 invited papers, and 51 volunteered papers. The papers covered GPS, GIS, spatial statistics, remote sensing, solute transport modeling, neural networks, transfer functions, fuzzy logic, scale and scaling, and uncertainty analysis as these pertain to assessing NPS pollution in the vadose zone.

A keynote address concerning the role of environmental modeling in the decision-making process kicked off the conference. Even though policy-makers and environmental modelers are converging, the policy-making process is necessarily about politics. Models used in that realm are most likely to be applied as political weapons, not as unbiased tools. The notion that science and technology will mitigate environmental problems on a "truth wins" basis is probably illusionary. Subsequent keynote addresses dealt with the advanced information technologies needed to assess NPS pollutants in the vadose zone, including (1) current and future trends in the development of integrated GIS methodologies and data-capturing technologies; (2) the virtues of an integrated analysis of both vadose zone and groundwater processes to address aquifer vulnerability by applying geomorphological modeling and hydrostratigraphic structure to account for the spatial variability of flow within and below the vadose zone; (3) stochastic modeling of NPS pollutants in the vadose zone at regional scales as being the most viable solute transport approach because extensive spatial variability of water flow and solute transport properties make deterministic modeling unfeasible at this scale, necessitating some form

of approximate stochastic approach using a local model representation that extrapolates from limited sample data; (4) the role of spatio-temporal statistical modeling; and (5) general and specific applications of remote sensing and noninvasive techniques.

Perhaps the most controversial, thought-provoking presentation was a keynote paper about scaling spatial predictability by Philippe Baveye, which stabbed directly at the heart of distributed parameter modeling, and thereby the use of GIS as a viable approach for assessing NPS pollutants. An analogy was drawn between the present state of knowledge of modeling NPS pollution and the development of thermodynamic gas laws from physical theories of particle dynamics. The analogy caused pause for thought. Despite the inability of Newton's fundamental equations of a particle in motion to predict individual motions of gas particles in a container, an independent line of theory led to the formulation of the thermodynamic gas laws. Thus, despite the inability to predict larger scale behavior from smaller scale conceptual understandings, there are coarser scale, simpler descriptions that allow accurate prediction of the average behavior of the system. Analogously, scientists may be studying NPS pollution at a level of understanding and detail dictated by measurement instruments, such as remote sensing, and information technology tools such as GIS rather than at a level dictated by the appropriate conceptual framework.

Furthermore, the fundamental unit for landscape study is often specified as a catchment or a watershed, or even more arbitrarily by survey or geopolitical boundaries (that is, quarter section lines or water district boundaries), without knowing if these units are meaningful or whether they are the appropriate levels of aggregation for subsurface solute transport. It may be that policy-makers are asking scientists to predict at a level of detail something that is inherently unpredictable. This suggests the need for exploration of the scales, or ranges of scales, at which the dynamics of processes are drastically simplified.

The invited presentations were intended to be more parochial than the keynote presentations by focusing on specific issues concerning the assessment of NPS pollutants in the vadose zone. An integrated Earth science/ economics-based approach provided an estimate of the societal value of information for assessing NPS pollution. From a transport modeling perspective, the multiscale effects of mass transfer processes on contaminant transport at a watershed scale were examined and the uncertainties arising when local scale processes are upscaled to a watershed were quantified. The difficulty of validating models for large regions was attributed to the challenging issues of model structure, non-linearity, complexity, spatial and temporal variability, and scale transition errors that make it difficult to detect errors in model structure and parameterization over large regions.

The single greatest challenge to modeling and assessing NPS pollutants is obtaining sufficient spatial and temporal data. Viable estimation and parameterization approaches include applying artificial neural networks and the group method of data handling or developing pedo-transfer functions (PTFs), and the utilization of similar media scaling and conditional simulations with soft data to parameterize flow and transport models. Remote sensing and noninvasive techniques are crucial for providing direct or indirect surface and subsurface hydrologic measurements. The derivation of soil hydraulic properties in the vadose zone from remote sensing and the spatial delineation of actual and relative evapotranspiration from remote sensing instrumentation and energy balance equations remain as areas of current and future study.

The ability to delineate and quantify spatial variability is a key to applying GIS to model NPS pollutants. Spatial variability can be incorporated into existing soils databases by estimating spatial dependence from existing data, applying robust statistical methods such as bootstrapping, applying remotely sensed data, and taking more samples based on current information. Fuzzy logic and inference techniques derive accurate and detailed soil spatial information, allowing the realistic characterization of the joint spatial distribution of landscape parameters for distributed modeling at the watershed scale. The application of fractals as a primary model for the distribution of soil properties and modeling solute transport in porous media was illustrated with compelling evidence provided for the utility of this approach.

Many of the volunteered papers focused on integrated information technology approaches and case studies. A particularly noteworthy and encouraging trend in contrast to earlier published papers of GIS-linked NPS pollution modeling was the significant increase in the application of uncertainty analysis to augment the modeling studies as a source of reliability information. Three important advances in assessing NPS pollution vulnerability that were reported by the volunteered papers included evaluating the worth of supplemental chemical, climatic, and soil data; adopting the Jury transfer function model to regional scales; and extending geostatistical analysis into the time dimension.

Future Directions

Even though tremendous advances have been made in assessing NPS pollution in the vadose zone during the last decade [*Corwin and Loague*, 1996; *Corwin et al.*, 1997], much remains to be done. The direction of future research needs became evident at the conference. The pertinent areas requiring development include (1) instrumentation and methodology for the geospatial establishment of stream-tube boundaries (that is, spatial domains of statistically homogeneous properties of solute transport) and the fuzzy boundaries between stream-tubes; (2) remote sensing and noninvasive techniques for measuring solute transport model parameters at multiple scales in a cost-effective manner; (3) a clearer understanding of the issues of upscaling of spatial data and its aggregation, as well as downscaling and disaggregation; and (4) ultimately, the integration of scientific, economic, and political considerations to make NPS pollution assessments with advanced information technologies a decision-maker's, rather than a purely scientific, tool.

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The 1997 Joint AGU Chapman/SSSA Outreach Conference, "Application of GIS, Remote Sensing, Geostatistics, and Solute Transport Modeling to the Assessment of Nonpoint Source Pollutants in the Vadose Zone," was held October 19-24, 1997, in Riverside, California, USA.

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