New Waves
The Research Newsletter of the Texas Water Resources Institute
Volume 10, Number 4, December 1997

TWRI Study Develops GIS of Rice-Growing Areas

Researchers at Texas A&M University have created a spatial database with extensive information on Texas' rice-growing areas. They hope information from this project will lay the framework for studies of how changes in water use and water quality may affect coastal watersheds of the Lower Colorado River. The project, which was funded by the Texas Water Resources Institute (TWRI), was carried out by Robert Coulson, a landscape ecologist in the Entomology Department, and graduate students Maria Guzman and Yancy Craft of the Geography Department.

"The goal of the project was to develop a framework that researchers and policy makers could use to answer a number of 'what-if' questions that may arise now and in the future about water management in the region," Coulson says. "The beauty of using geographic information systems (GIS) is that we can store a lot of spatial data and easily display how changes in policies or natural resources affect much of the region." For example, what would be the impact of changes in federal farm support programs on water use in the region and the amount of water flowing into rice fields? How would transferring water use from agricultural to urban sectors impact the number of migratory waterfowl that visit the area?

Maria Guzman and Robert Coulson examine maps of Texas rice growing areas they developed using a GIS.

Initially, the researchers contacted more than 30 data repositories in the rice-growing portions of Colorado, Matagorda, and Wharton counties. Interviews and site visits were conducted with many agencies and universities to determine existing information on soils, watersheds, land use, and wildlife habitat. Often, this information had to be converted into a common format. The team also mapped the boundaries of three irrigation districts in the region, and identified tracts historically used for rice irrigation. Ultimately, the researchers developed a 432-megabyte geographic information system (GIS) that is available on a CD-ROM disk.

Coulson is now teaching a landscape ecology graduate class, in which students are using the GIS database to assess how changes in water use and reductions in rice irrigation may affect the overall ecology of the region as well as the numbers of geese and other waterfowl that utilize the site.

"We want to share this information with others who want to study these issues," Coulson says. "We don't have the resources to conduct research for others based on queries they submit to us, but we do want to make this database a tool others can utilize." The GIS runs on ARCView and ARCInfo software and is available by contacting Coulson at coulson@unix.tamu.edu or (409) 845-9725. Guzman can be contacted at melos@geog.tamu.edu.

TAMU Studies Use of 'Precision Farming' to Reduce Fertilizer, Nutrient Inputs

Space-age technology combined with traditional farming techniques may help to protect Texas water quality, according to leaders of a demonstration project now being carried out by scientists at Texas A&M University (TAMU).

The project, which is funded by the Texas State Soil and Water Conservation Board and the U.S. Environmental Protection Agency, focuses on using high tech approaches to apply the specific rates of nitrogen that match the needs of corn fields near Temple, TX. Lead scientists include George Sabbagh, Ann Kenimer, and Steve Searcy and graduate students Muhammad Akbar and Jody Roades of the TAMU Agricultural Engineering Department.

TAMU students Walt Rakowitz amnd Muhammad Akbar insert a GPS receiver in this field near Temple, TX.

The scientists are working with a farmer in the area, who has voluntarily donated two of his corn fields to the research. In one field, pesticides and fertilizers are applied using conventional methods in which a set amount is distributed to the whole field. In a nearby experimental plot, the researchers use precision agriculture to apply inputs only specifically where they are needed.

"Traditionally," Sabbagh explains, "farmers would apply the same amount of nitrogen fertilizer to their field as if it were one homogenous unit. Because nitrogen is relatively inexpensive, producers often applied extra fertilizer over the whole field to guarantee a good yield." In reality, however, a single field is really comprised of a complex variety of soils that require different amounts of fertilizer. "The challenge is to identify and learn the specific characteristics of each field and to then match fertilizer and pesticide applications to meet those unique needs," Sabbagh says.

In precision farming, a field is first divided into sections so that it represents a grid of uniform-sized squares. Soil samples are then taken from each square in the grid and a soil profile of the field is produced from the samples.

Later, farmers can use a technology called a global positioning system (GPS) to site the exact location of precise parts of their field. GPS calculates these measurements using a network of 24 satellites orbiting about 12,000 miles above the Earth.

The next step is to install a computer with a GPS tracking system in a harvester, tractor, or combine. During harvesting, the computer would record how much corn is collected from each of the different areas on the field and the GPS would gather data on what part of the field the corn was harvested from. Using this information, farmers can develop a yield map of the field that will show what parts of the field produce less corn. "The advantage is that, before the next growing season, problems with the lesser yielding portions can be resolved," Sabbagh says. "Less fertilizer may be needed if corn yields are consistently low." Finally, the soil samples are combined with the yield data to determine how much nitrogen fertilizer will be needed for the next growing season.

When the time comes to fertilize the field during the next growing season, the map of the field and nitrogen fertilizer needs for each portion of the field are entered into a computer, which is equipped with GPS and connected to a fertilizer applicator. As the farmer drives over the field, the computer automatically adjusts the amount of fertilizer applied to each portion of the field to optimize application.

"This project is significant," Sabbagh says, "because farmers using this method will only apply the amount of fertilizer that is needed for a given field." Farmers using this technology will be less likely to apply excess amounts of nitrogen fertilizer, which could run off into nearby rivers and streams. Ultimately, Sabbagh says, the quality of nearby surface and ground waters could be improved if enough farmers utilized precision agriculture methods.

The scientists also used the GPS to develop a topographical map which shows low points of the field and where the runoff waters can be rechanneled so the researchers can collect samples.

After the growing season, the scientists will compare data from both fields to determine how applying fertilizer at site-specific rates through precision farming impacted water quality. The researchers will also assess if the farmers saved money because less fertilizer had to be applied.

Sabbagh says precision agriculture can also be used for pesticide application. As with fertilizer application, pesticides have typically been applied uniformly throughout the fields. With the GPS technology, insect infestations can be pinpointed to specific sections of the field. Airplanes can be equipped with similar technology so that they would only apply enough pesticides to cover specific areas that are afflicted with insect pests. As a

result, excessive amounts of pesticides would not be applied and the risk of runoff pollution would be lessened.

For details, contact Sabbagh at (409) 845-4973 or gsabbagh@tamu.edu, or Kenimer at (409) 845-3677 or a-kenimer@tamu.edu, or Searcy at (409) 845-3668 or s-searcy@tamu.edu.

Improving Water Markets to Manage Droughts

Researchers: Gregory Characklis and Philip Bedient, Environmental Science and Engineering Department, Rice University, Houston, TX, and Ronald Griffin, Agricultural Economics Department, Texas A&M University, College Station, TX.

Problem: Since 1971, water in the Lower Rio Grande Valley has been allocated according to a system of court-established water rights. Rights were designated for municipal (includes industrial and domestic) or irrigation use, with provisions for buying, selling, and leasing them. As part of this adjudication, a reserve corresponding to the full annual complement of municipal rights was established. Since 1971, municipalities have increased their share of regional water by purchasing and converting irrigation rights to municipal use. Correspondingly, the size of the municipal reserve is periodically increased. While the reserve is meant to represent 100% of municipal rights, municipalities consistently exercise only 60% of their allocation. Because this water is protected, irrigators bear most of the adverse impacts during drought, receiving only a pro rata share of the water entitled them. If population reaches projected levels and administrative practices remain unchanged, the gap between municipal allocation and use could grow to 200,000 acre-feet (AF). While this water is not wasted (it is used to insulate the municipal users from scarcity), it could be very effective in lessening the regional impacts of drought. The distinction between user types results in limits on some transactions. While the selling of rights between sectors is permitted, intersectoral water leasing is prohibited as it might allow municipalities to profit from their elevated status by leasing to irrigators. Purchasing rights is expensive ($700-800 per AF), and the unpredictability of drought makes the decision to buy rights which will be exercised during scarcity difficult to assess. Leasing is inexpensive ($10 to $60 per AF) and allows for decisions based on current information, adding valuable flexibility to the market in drought years. Leasing is allowed between similar uses, but the prohibition on intersectoral transactions has led to a price disparity. From 1994 to 1997 the lease price for irrigation water rose as high as $60 per AF, while municipal water leased for $30 per AF or less. This suggests the distinction between uses may limit regional welfare.

Objectives: To investigate the economic consequences of eliminating municipal water prioritization, and thus the rationale for limiting lease transactions.

Methods: A model evaluating optimal water allocation and value in a competitive Valley water market was developed. The model includes demand and cost functions representative of multiple segments within both the municipal and irrigation sectors.

Summary: Results suggest that even under a 'worst case' scenario, municipalities would compete effectively for water without a price rise that would significantly impact water bills. The existence of supplementary safeguards already within the system further weakens arguments for extending municipal prioritization. Erasing the distinction between rights will not deprive municipalities of water, but simply allow them to enter into voluntary leasing agreements with both irrigators and other municipalities. Elimination of the separation between rights holders will bring surplus water from the municipal reserve into fuller use. Such an arrangement can provide the system with improved efficiency and responsiveness when reacting to conditions of water scarcity.

Reference: A paper on this topic, "Improving the Ability of a Water Market to Efficiently Manage Drought," is now being developed. For details, contact Griffin at (409) 845-2333 or http://www.puc.state.tx.us/telecomm/areacodes/index.cfm.

The Evolution of Mexico's Water Laws and Policies

Researcher: C. Richard Bath, Political Science Department, University of Texas - El Paso (UTEP), El Paso, TX.

Problem: The Paso del Norte region stretches from El Paso, TX to Dona Ana County, NM to Ciudad Juarez, Mexico. This area is critically short of water, but common water supplies service the whole region. Unfortunately, Texas, New Mexico, and the state and federal government in Mexico all utilize unique philosophies and laws to regulate water supplies and water quality. Because the concepts and development of Mexico's water laws are largely unknown to parties in the United States, it is difficult to develop a comprehensive management and planning system that would make sense for both sides of the border.

Objectives: 1) To describe the long-term historical evolution of Mexican water laws, 2) to highlight Mexico water laws prior to and after 1992, and 3) to provide insights into how these laws affect the way in which Mexico manages its water resources.

Background Information: The paper reviews the development of Mexico water laws since ancient times, when the Mayan and Aztec empires flourished. The paper describes many specific conditions under which waters are legally categorized and how those conditions developed. The Spanish had not developed laws to manage water resources and water rights for many years and conflicts over water allocations to small landowners were a major factor in Mexico's Civil War. In 1934, under President Lazaro Cardenas, Mexico passed its first significant environmental policies. In the presidential election of 1992, water and environmental policies were made a major issue for the first time. A national water plan was passed in 1972 that emphasizes systematic planning and use of water resources and the formulation of alternative programs for water development. The overall pattern of water development, Bath suggests, benefited large farms that produced valuable export crops and generated income. The public sector was called on to provide the funds to build and maintain key components of water resources infrastructure. Bath differentiates between water laws and policies that were in place before and after 1992.

Prior to 1992, the general trend was towards centralized planning and funding of water developments. After 1992, and the election of President Carlos Salinas de Gortari, Mexico embarked on a whole new political and economic direction. The major impact was the withdrawal of the state from its domination of the economy, through privatization and deregulation of many areas, including water resources. The General Law of Ecological Equilibrium and Environmental Protection (1988) gives federal agencies the responsibility for water pollution and the management of natural resources, including water.

General Conclusions and Implications: Recent developments in Mexico water law, especially those implemented after the passage of the North American Free Trade Agreement (NAFTA), will significantly influence how Mexico is likely to manage its waters. For example, Bath suggests that Mexico needs a "new culture" of water in which the value of water will be recognized to guarantee it is used efficiently, and that a new economic, technological, and cultural focus is needed so that waters will be used rationally. Changes in water laws are vitally needed because government in Mexico is now more participatory, and because of the increased perception of the role of water in the overall well-being of the country. Bath recommends that the security and legal certainty of beneficial use of water needs to be established to permit long-term planning by the private and public sectors, and that the beneficial, efficient and rational use of water is needed to modernize agricultural, urban, and industrial water use. Legal incentives that encourage private investment will be critically important in the near future as Mexico relies increasingly on these means to meet its water and wastewater needs.

Reference: Bath, C. R., "Mexican Water Law and Policy," 1997, UTEP Political Science Report. Bath can be contacted at (915) 747-7980 or cbath@utep.edu.

Managing Water Quality through Planned Intervention

Researchers: Jan McNitt and Eric Guidry, Texas Institute for Applied Environmental Research (TIAER), Tarleton State University, Stephenville, TX.

Problem: The upper North Bosque River watershed in North Central Texas contains the largest concentration of dairies in Texas (100 dairy facilities and 35,000 dairy cows). Water quality monitoring in the region indicates there are correlations between intensive agricultural land use in the watershed and stream pollution in downstream areas. TIAER has studied agricultural impacts on water quality in the region, including management strategies that can be enacted to lessen pollution. A strategy being explored by TIAER is the use of the Planned Intervention Microwatershed Approach (PIMA). New guidelines from the U.S. Environmental Protection Agency, passed in the 1996 Safe Drinking Water Act, call for programs that, in some respects, mirror the PIMA approach.

Objectives: To explain the PIMA management framework, as utilized in the upper North Bosque watershed, and to compare it to new management policies outlined by EPA.

Background Information: PIMA is conceptually different from command and control methods used to combat pollution. Instead, it focuses on planning and land management strategies that employ cooperation among landowners, conservation agencies, and environmental regulators. A key assumption is that state agricultural agencies and local conservation districts will serve as the primary institutions to induce voluntary behavioral change among agricultural producers targeted as significant sources of nonpoint source pollution. The Texas State Soil and Water Conservation Board cooperates with agricultural producers to draft and implement water quality management plans and to institute corrective actions when problems occur. PIMA works to improve citizen participation. Microwatershed councils are established which provide a forum where members can meet to identify and discuss local pollution problems and consider water quality improvement plans. TIAER suggests that these councils can provide an institutional mechanism for confronting "bad actors," who continue to pollute. The idea is that recalcitrant individuals may be more inclined to lessen pollution if they are faced with censure from their peers or if they are seriously out of line with community standards. Landowners with identified problems, who refuse to remedy complaints or who are in violation of environmental laws, are referred to the Texas Natural Resource Conservation Commission for enforcement. TIAER is now using PIMA in a study of the Lake Waco/ Bosque River watershed that is funded by the U.S. Department of Agriculture (USDA). Objectives of this study are to: 1) develop nutrient loadings; 2) identify microwatersheds with high nutrient loadings; 3) reduce in-stream nutrient loadings; 4) maintain and support water quality monitoring; and 5) develop a tool for watershed management others can use. TIAER and a local conservation district identified a microwatershed with high nutrient loads, Goose Branch Stream, as a pilot project for implementing PIMA. This watershed covers 3,625 acres and includes eight dairies, roughly 3,700 dairy cows, and more than 100 fields where dairy wastes are being land applied.

EPA's New Approach: Amendments to the 1996 Safe Drinking Water Act require EPA to increase protection of source waters. This includes: 1) delineating the boundaries of source waters, 2) identifying potential contaminant sources; 3) evaluating the susceptibility of source waters to specific contaminants; and 4) conveying results to the public. The Safe Drinking Water Act emphasizes a proactive approach to protect source waters to prevent pollution. Voluntary programs (stream monitoring) are combined with regulatory efforts to achieve goals. EPA's program promotes communication, including making information about contaminant sources, watershed assessments, and susceptibility analyses available to the public.

Comparing the Programs: PIMA is consistent with the new EPA programs under the 1996 Safe Drinking Water Act in that both efforts recommend the use of a variety of voluntary and regulatory initiatives. Both programs target pollution hot spots as a way to remedy key water quality concerns. The programs dovetail in the organizational structure - EPA recommends that teams be used to assess key pollution problems while PIMA utilizes watershed management councils. PIMA's voluntary compliance loop inserts a step into the regulatory process that helps ensure environmental standards will be maintained. Finally, the authors suggest that if processes now used to ensure that

agricultural producers meet environmental goals were modified, higher water quality goals could be met.

Reference: McNitt, J., and E. Guidry, "A Micro-Watershed Approach for Water Quality Protection: A Policy Response to Agricultural Nonpoint Source Pollution," in Water Resources Management: Preparing for the 21st Century, American Water Works Association, 1997.

Air Pollution from Municipal Sewers and Wastewater Plants

Researcher: Richard Corsi, Civil Engineering Department, University of Texas at Austin, Austin, TX.

Problem: Discharges of volatile organic compounds (VOCs) to municipal sewers have historically led to concerns related to whether the buildup of gases can increase of the risk of explosions, potential adverse impacts on biological wastewater treatment systems, and toxic effects on natural waters. Recently, new concerns have arisen about emissions of VOCs and hazardous air pollutants (HAPs) from publicly-owned wastewater treatment plants.

Objectives: Goals of this paper are to review the state-of-the-art research in this field and to answer the following questions: 1) What fraction of VOC and HAP discharges to sewers are emitted to the ambient atmosphere prior to reaching a downstream wastewater treatment plant? 2) what level of air pollution discharges are found near wastewater plants? 3) are HAP emissions evenly distributed or do they occur at a few isolated locations?

Background Information: This paper explains many well-researched issues and describes the transfer of gaseous and liquid masses in sewers, air exchange rates between sewers and the ambient atmosphere, emission monitoring strategies, and applications of mass balance equations. It describes the use of a model called CORAL+, which allows users to estimate VOC emissions from municipal sewers using data on collection systems, organic releases, and computer algorithms.

General Conclusions and Implications: According to Corsi, significant strides have been made to ascertain the relative significance of HAP emissions from municipal sewers, and new tools continue to be developed which provide additional analytical capabilities. Results of many studies suggest that a significant fraction of volatile HAP discharges are emitted prior to reaching wastewater treatment plants. In many cities, VOC emissions from sewers are at least as great as those from downstream treatment plants and may be much higher. If emissions occur at only a few sites, the magnitude of the contamination may warrant significant concern regarding localized public health risks. There is still a great deal of uncertainty associated with spatial distribution of emissions. Spatial distributions of HAP emissions and corresponding hot spots should receive high priority.

Reference: Corsi, R., "VOC Emissions from Municipal Sewers," in Proceedings of Conference on Control of Odors and VOC Emissions, Water Environment Federation, 1997.

How and Why the Brazos River Changes Course

Researchers: John R. Giardino, Geology and Geophysics Department and Office of Graduate Studies, Texas A&M University, College Station, TX, and B. Marcus Gillespie, Geology and Geophysics Department, Northwest Missouri State University, Maryville, MO.

Problem: Since the 1950s, much research in fluvial geomorphology has been directed toward the issues associated with how and why rivers meander. These studies are needed because rivers threaten structures such as bridges and dams when they change course. In addition, the amount of sediment deposited or eroded by meandering rivers can alter flood risks and impact riparian zones. It would be useful if the cause of changing river patterns could be better understood and predicted so that losses associated with meandering river channels could be avoided.

Objectives: 1) To describe the character of three contiguous reaches of the Brazos River below Waco, and 2) to determine the influence of discharges and the geological composition of the river channel on the movements of the river.

Background Information: Three reaches of the Brazos River were studied: the upper reach begins south of Waco and extends to the confluence of the Brazos River and the Little River; the middle part extends to the junction of the Brazos River and the Navasota River; and the lower reach flows downstream to Hempstead. The portion of the Brazos River investigated in this study is characterized by unconsolidated sands, silts, and clays that are interspersed with occasional outcrops of sediments and rock. The Brazos River channel ranges from roughly 33 to 54 feet deep and varies from roughly 330 to 420 feet in width. Maximum flows typically occur in the spring, and the banks of the river flood four or five times each century. Numerous dams regulate the flow of the river, including nine structures on tributaries that enter this section of the river and roughly 150 flow-retarding structures.

Methods: To measure the changes in the channel over time, maps of the centerline were created from 231 aerial photographs and entered into a geographic information system (GIS). The aerial photographs covered the period from 1939 through 1988. Discharges were characterized according to total flows and maximum annual flows. Changes in total suspended solids (TSS) levels were correlated with flows. The strength of the river banks was characterized by collecting 65 samples from the walls of streambeds and examining the percent of slit and clay contained in them. Many morphometric parameters were studied, including the amount of curvature in selected river bends, the relationship between curvature of the channel and the width of the river, and the number and extent of simple and compound river bends.

Results and Analyses: The Brazos River has experienced a significant reduction in the magnitude and frequency of large discharges, as well as TSS loads associated with high flow events. These factors account for the decrease in channel width and the degree to which the river migrates and changes its course. These phenomena are attributable to the many dams that regulate flows along the river. The study shows that the size of the bends is influenced more by the composition of the river channels than by peak flows. The results also indicates that the behavior of a single river bend cannot be treated as an isolated process. The study suggests that the processes that control bend evolution may be so complex that it may be impossible to predict river migration and change in the Brazos River basin. Finally, this project reveals that many principles used to develop models of river migration may be extremely limited in their applicability, because they are based on a very small set of rivers.

Reference: Gillespie, B., and J. Giardino, "The Nature of Channel Planform Change - The Brazos River (Texas)," Texas Journal of Science, May 1997.

UT Assesses How Agriculture Impacts Great Plains

How has agricultural production affected the environment of the Great Plains? That's the subject of a recent study by researchers at the University of Texas at Austin (UT), Colorado State University (CSU), and Pennsylvania State University (PSU).

The research was conducted by a team of researchers which included Myron Gutmann of the UT History Department; William Parton, Dennis Ojima, Ingrid Burke, and Kathy Galvin of CSU, and William Easterling of the PSU Geography Department.

In the project, the scientists examined how agricultural production has changed the Great Plains ecosystem. The studies involve not only computer modeling of the impact of pesticide use on soil and water quality, but also socioeconomic and demographic factors that may have contributed to these changes.

The researchers note that roughly 80% of native tallgrasses have been plowed under and replaced with croplands in the eastern part of the region. In the western section of the Great Plains, 50 to 65% of shortgrasses have been replaced by agricultural fields.

The use of improved plant varieties and the increased use of fertilizers, pesticides and herbicides since the 1940s has dramatically increased the cultivation of such crops as winter wheat and corn, the authors say. At the same time, however, this increased use of fertilizer may have increased nitrate leaching, nitrous oxide soil emissions, and a reduction of methane consumption by soils.

For more information, contact Gutmann at (512) 471-8358 or myron@prc.utexas.edu or Parton at (970) 491-1987 or billp@poa.nrel.colostate.edu.

BRC, Baylor Study Use of Neural Networks to Predict Flows

Researchers with the Texas Agricultural Experiment Station's Blackland Research Center (BRC) at Temple and Baylor University (BU) are investigating whether the use of non-linear statistical methods better predict peak flows from Texas rivers. The study was led by Ranjan Muttiah and Raghavan Srinivasan of BRC and Peter Allen of the BU Geology Department.

Muttiah explains that the use of neural networks, which are a non-linear system formed from simple linear calculating units that can be trained to use and interpret complex data sets. Muttiah says the use of neural networks could better simulate flood flows and provide insights into such issues as sediment runoff, stream bed and bank erosion, and the proper sizing of drainage channels.

Specifically, this project assessed if neural networks could accurately replicate peak discharges in many watersheds in Texas and other regions. Stream characteristics, peak flows over a two-year period, drainage areas, basin elevations, and slopes were obtained for many watersheds in the U.S. and Texas. Stream characteristics and mean annual rainfall were input into the neural network.

Muttiah says the project shows that, in general, the neural networks better predicted two-year peak flows than previous methods. However, it was still difficult to predict peak flows for the Rio Grande, in particular because rainfall patterns are so sporadic and there is so little precipitation. The study also used neural networks to estimate flood flows in other Texas watersheds, and yielded improved results for many watersheds.

For details, contact Muttiah at (254) 770-6670 or muttiah@brcsun0.tamu.edu or Allen at (254) 755-2361 or Peter_Allen@baylor.edu.

TPWD Works to Prevent Erosion at San Jacinto State Park

TPWD is working with many other agencies and businesses to restore the wetlands and marches near the San Jacinto State Historical Park

The Texas Parks and Wildlife Department (TPWD), other state agencies and private businesses are teaming up to preserve 300 acres of marsh land at San Jacinto State Historical Park. The Park is best known as the scene of the battle that won Texas independence from Mexico in 1836. The 570-foot San Jacinto Monument and the Battleship Texas is moored along Buffalo Bayou and hosts roughly 1.5 million visitors annually. The park covers more than 1,000 acres, and boasts a 300-acre marsh system and 9,000 feet of unprotected shoreline. Since World War II, subsidence and erosion have resulted in the loss of many acres of park land, including low bluffs which once protected the marsh from erosion and salt water.

Since 1993, TPWD has been planning the restoration of wetlands at the park. In 1996, Texaco donated nearly $20,000 to protect the most critical shoreline areas including a prehistoric site that is more than 2,000 years old. Texaco's donation provides for the deposition of broken concrete along the shoreline. The concrete will slow the erosion of the marsh and will provide a habitat for wildlife, a hard substrate for barnacles, and places for crustaceans and small fish to hide.

In the near future, TPWD hopes to protect 200 more acres of the San Jacinto wetlands system. Some of the strategies being considered include applying dredge material to build up the low-lying areas and planting native marsh grasses.

For details, contact park manager Russell Kuykendall at (281) 479-2431.

Texas A&M Publishes Toxic Releases Inventory

Researchers with the Texas A&M University Rural Sociology Department have recently published a report describing toxic releases in Texas for 1994. The report, The Toxic Releases Inventory (1994), was written by John Thomas and Patricia Harveson. It was published by the Rural Sociology Department in 1997.

Sections of the report describe the toxic releases inventory, transfers and releases of carcinogenic chemicals, and a year-to-year comparison of toxic releases and transfers. A particularly useful section of the report details the amount and types of toxic chemicals that industries contribute to water and air supplies, lands, and underground injection programs for many Texas counties.

The report is available on the WWW at http://www-txsdc.tamu.edu/tri.html. For more information, contact Harveson at (409) 845-5332 or harveson@txsdcsun.tamu.edu, or Thomas at (409) 845-5332 or jthomas@rsocsun.tamu.edu.

UT Press Book Discusses Ecology, Management of Forests

A book describing the ecological aspects of forests has been published by the University of Texas Press. The book, Forests - A Naturalist's Guide to Woodland Trees, was written by Laurence Walker of Nacogdoches, TX, who has managed forests for 50 years.

The book begins by describing such broad issues as seeds and seedlings, tree roots, and ecological succession. A number of major tree types are described including needle leaf firs, many types of pines, and broadleaf trees. The book concludes by describing how forests should be managed in the future.

For details or to order the book, contact the UT Press at (800) 252-3206 or visit their WWW site at http://www.utexas.edu/utpress.

Texas Tech Press Book Describes Playa Lake Vegetation

The Texas Tech University Press recently published a book describing the plants and grasses that can be found near playa lakes on the Texas High Plains. The book, Common Flora of the Playa Lakes, was co-authored by Loren Smith of the Range and Wildlife Management Department at Texas Tech University and David Haukos of the U.S. Fish and Wildlife Service.

The book guide provides quick, accurate identification of 72 of the most common plants occurring in playa wetlands, located the Texas High Plains and other Great Plain states. More than 300 plant species have been identified at roughly 30,000 playa lakes in the region. The book describes plants by species and lists them alphabetically. Color photographs of many species are also included to make field identification easier. The book also provides an introduction to playa wetlands and a brief history of how playa lakes have been affected by human development.

For details or to purchase the book, contact the Texas Tech Press at (800) 832-4042 or ttup@ttu.edu.

USGS Publishes Texas Topographic Data Sets on CD-ROM

The U.S. Geological Survey (USGS) has published topographic data sets for Texas river basins on a CD-ROM disk. The CD presents information on a scale of 1: 250,000. It was developed by Lu L. Tan of the USGS Austin District, in cooperation with the Texas Natural Resource Conservation Commission.

The CD contains data on topography and the direction and accumulation of flows as well as many GIF images. Data on the CD can be easily imported into geographic information systems. The information was developed using 150 digital elevation models.

For details about the CD or a report that describes the project, contact Tan at (512) 873-3081 or lltan@maildtxast.cr.usgs.gov.

TAMUG Hopes To Use Dunes To Stop Beach Erosion

A marine biologist at Texas A&M University - Galveston (TAMUG) hopes to stem the tide and learn how to prevent beach erosion by rebuilding sand dunes along Galveston Island. In the project, TAMUG researcher Jim Webb wants to field test methods he believes may work best to slow erosion in a Galveston subdivision that is literally washing away. The project focuses on the Pirates' Beach subdivision, which is faced with a critical erosion problem.

"We've got houses in this area that are literally falling into the Gulf," Webb says. "Water has cut underneath some of the foundations of the houses. We're trying to restore the dunes, renourish the beach and get some protection in front."

Initially, Webb and coworkers will take 1,000 bales of hay, line them up along a one-mile stretch of beach, and cover them with 26,000 cubic yards of sand. Later, they plan to add

45,000 plants to hold the sand in place. The study will evaluate the best ways to restore washed out dunes. Normally, Webb says, beaches and the dunes form a natural barrier to prevent erosion by blocking wave action and providing a source of sand to the beach. However, in Galveston, the jetties that protect the ship channel have cut off coastal currents, and slashed the supply of new sand to the island's west end, which accelerates erosion in the subdivision.

Erosion after heavy storms is a recurring problem for homes like this one in the Pirates' Beach Subdivision near Galveston.

For details, contact Webb at (409) 740-4542 or webbj@tamug.tamu.edu.

UTEP Helps Border Residents Install Wastewater Systems

A pilot outreach project between the University of Texas - El Paso (UTEP) and a regional non-profit organization is working to design and install functioning on-site wastewater treatment and disposal systems for people who could not otherwise afford them.

The project, which is now in its second year, is being conducted through the UTEP Center for Environmental Resources Management (CERM), in partnership with the El Paso Interreligion Sponsoring Organization (EPISO).

The initial phase of the study involved helping residents in El Paso area colonias which are not scheduled to receive wastewater treatment in the near future. UTEP and EPISO staff members worked to create a "septic system cooperative," which was designed to help individuals purchase materials at low cost and use "sweat equity" to construct functioning systems. CERM staff also provided engineering support to make sure these systems conformed to state regulations. Much of this work was led by Jeffery Brannon of the UTEP Economics and Finance Department.

In the next phase of the project, UTEP has been working to find ways to help area residents improve wastewater conditions by bringing together university experts with area residents, additional volunteer groups, and area government entities. So far, UTEP and EPISO have installed 45 on-site wastewater treatment systems for individual households as well as a system for a health clinic.

This project has been supported by many groups, including the Ford Foundation, Levi Strauss, the U.S. Environmental Protection Agency, and others. For more information

about this project, contact Nancy Lowery at CERM at (915) 747-5494 or nlowery@utep.edu.

Rice, Texas A&M, Study How South Texas Cities Choose to Develop, Diversify Water Supplies

How do cities decide whether to develop groundwater or surface water supplies, how do economics play a key role in the decision making process, and how is this relevant to South Texas ? These are some of the issues being investigated in a research project being conducted by scientists at Rice University and Texas A&M University (TAMU).

Rice University graduate student Sylvestre Gaudin and researcher Peter Mieszkowski of the Rice U. Economics Department discuss how and why South Texas cities develop water supplies.

The research is being conducted by Rice graduate student Sylvestre Gaudin, under the direction of researcher Peter Mieszkowski of the Economics Department. Ron Griffin of the TAMU Agricultural Economics Department is contributing to the project. The research is sponsored by Rice's Energy and Environmental Systems Institute (EESI), which provided initial support.

The overall goal of the study is to gain a better understanding of which factors should be considered when cities plan for future water supplies and decide to expand their existing supplies or develop new ones. The researchers hope to be able to measure to what extent cities may want to diversify their water sources in order to reduce the risk of future shortages.

The South Texas region is rich in examples of cities which are depleting their groundwater and considering switching to surface water for various reasons. The research involves case studies of four rapidly growing communities in the region - San Antonio and New Braunfels on the Edwards aquifer, El Paso on the Hueco Bolson, and Houston on the Chicot and Evangeline Aquifers. Each city is faced with different economic, environmental, and hydrologic problems which will be examined separately. Comparing the data from the case studies and the predictions of the economic model, the researchers hope to gain knowledge about the implied values of environmental and economic costs associated with the depletion of groundwater and the use of lower quality surface water.

For details, contact Mieszkowski at (713) 527-4875 or mieszko@rice.edu, Gaudin at sgaudin@rice.edu, or Griffin at (409) 845-7049 or ron-griffin@tamu.edu. More information about EESI can be obtained by contacting them at (713) 527-4685 or visiting their WWW site at http://www.rice.edu/eesi.

TAMU, UT Scientists Assess Border Environment

Traditionally, resource assessments focus only on national resources. How many river miles are there in the United States? But how do you characterize conditions in a rapidly developing river corridor with a sensitive ecosystem that spans two nations? That's the challenge facing water resources managers throughout the Rio Grande watershed.

Recently, the Texas Higher Education Coordinating Board (THECB) funded a study to develop a framework to promote the responsible and orderly development of the resources in the Texas-Mexico border area. Juan Homero Hinojosa of Texas A&M International University, a lead researcher in the study, explains the project will "not only to fill in gaps in the Texas border region, but will incorporate data from Mexico."

The project is a joint effort of the University of Texas (UT) and Texas A&M University (TAMU) system universities in the Rio Grande border region. Other key researchers include Jay Raney of UT; Eric Rieken of UT - Pan American; Charles Groat of UT - El Paso; and Gene Paull of UT - Brownsville.

The project will assess the natural resources in the region by building on geologic data sets and developing information on groundwater supplies, hydrocarbons, and land use. The study will also provide guidance and recommendations for data compilations along the border and situations where data must be merged and the loss of information minimized. The project will encourage data transfer and staff interactions between border institutions and local agencies.

Each university will concentrate on a specific region of the border. Ultimately, a seamless compilation of resource data along the Texas-Mexico border will be compiled. The information collected can be used to assess the surface and groundwater needs of the region and to analyze land uses. "We will try to assess the quality and quantity of the water in the area and determine how to best preserve water supplies," Hinojosa explains.

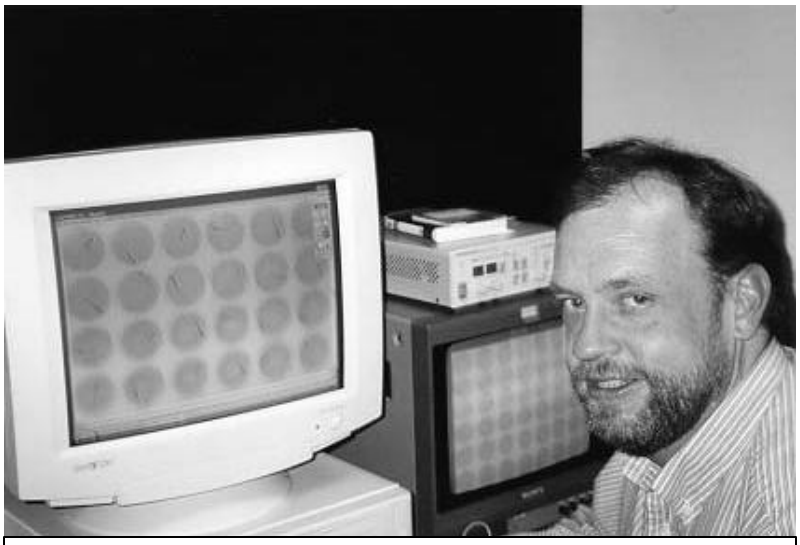
For details, contact Hinojosa at (956) 326-2595 or jhhinojosa@tamiu.edu; Raney at (512) 471-5357 or raneyj@begv.beg.utexas.edu; or Rieken at (956) 381-3526; or Groat at (915) 747-5954 or cgroat@utep.edu; or Paull at (956) 544-8896 or paullgs@utb1.utb.edu.

UH Studies Zebrafish to Learn About Circadian Rhythms

Very little is known about how to treat people with circadian rhythm disorders, which are commonly caused by jet lag and shift work. Recently, Gregory Cahill of the Biology Department at the University of Houston, received a grant from THECB to identify vertebrate circadian clock genes through examination of mutations in zebrafish.

The species is a valuable new model for mutational analysis of this type, "because the genes identified in zebrafish should have closer matches to human genes and you can economically test thousands of fish," notes Cahill. Last year more than 2,000 mutants that identify over 600 of the genes involved in vertebrate embryonic development were identified in zebrafish.

The primary goal of this research is to identify genes in zebrafish that affect circadian rhythms. Adult male zebrafish will be treated with N-ethyl-N-nitrosourea to induce mutations. After one month of recovery, the treated males will be bred with normal female zebrafish to produce a generation of offspring. The offspring will be tested for circadian rhythm changes. "A zebrafish has a normal cycle length of 25.5 hours. We will monitor the activity levels of the fish to determine circadian cycles," Cahill says. Fish with cycles of more or less than 25.5 hours will be identified as having mutated clock genes.



Greg Cahill observes zebrafish on this behavior-recording apparatus

Identifying the genes that affect biological clocks could be useful to agriculture. Some animals only breed in seasonal cycles which now can be controlled by changes in light levels. If the genes that affected biological clocks were known, the animals could be treated in a more targeted manner. The same concept applies to humans with a circadian rhythm disorder. If the genes were known, humans could be treated in a better and faster way than simply adjusting light and dark levels.

For details, contact Cahill at (713) 743-2694 or gcahill@uh.edu.

Texas Tech Examines Fish Endocrine Disrupters

Scientists from Texas Tech University were recently awarded a THECB research grant to develop a computerized assay to detect behavioral changes in aquatic organisms exposed to potential endocrine and hormonal disruptors. The project is led by Nathan Collie and Kent Rylander of the Biological Sciences Department, and Reynaldo Patino and Nick Parker of the Cooperative Fish and Wildlife Research Unit.

In the project, the researchers will monitor the behavior of fathead minnows to determine if they can be used as a sensitive early warning system to detect endocrine disruptors in toxins. Male and female minnows will be separated in identical tanks until pairs are placed together in another aquarium for behavior observation. Researchers will observe behavior of normal male-male, male-female, and female-female reactions. Then, the fish in three experimental aquariums will be exposed to one of three different endocrine disruptors-alkyl phenols, PCBs, or DDTs. Adult fish from the progeny of the original exposed fish will routinely be placed in paired situations to observe their behavior.

The behavior of the fish will be monitored using a computerized social interaction analysis system. Collie explains that "the technology has been used before to quantify the behavior of mammals, but only recently has it been adapted for use with fish. The challenge with fish is that they move in three dimensions, while mammals move in only two." After the researchers have determined a common way for the fish to react when introduced to a known toxin, they will be able to apply the knowledge to unknown toxins.

For details, contact Collie at (806) 742-2726 or m4nlc@ttacs.ttu.edu; or Rylander at (806) 742-2727 or icrmk@ttacs.ttu.edu; or Parker at (806) 742-2851 or nparker@ttu.edu; or Patino at (806) 742-2851 or n6ren@ttacs.ttu.edu.

THECB Awards 35 Water Resources Research Projects

Recently, the Texas Higher Education Coordinating Board (THECB) funded a significant number of water resources and environmental research projects. Data from the board show that water resources and environmental projects accounted for 16 advanced research program (ARP) studies totaling $1.74 million, and 17 advanced technology program (ATP) projects worth roughly $3.92 million. One water resources project was awarded through the ATP Technology Transfer and Development program for $228,912.

The projects can also be grouped into subject areas. In the advanced research program (ARP), the board awarded water resources and environmental grants in the following categories: atmospheric sciences (three projects, $258,877); biological sciences (two projects, $249,219); earth sciences (two projects, $209,800); engineering (two studies, $299,606); marine sciences (seven projects, $702,577). In the ATP, the Board funded water resources and environmental grants in these areas: aquaculture and agriculture (six projects, $1.09 million); computer engineering (one project, $169,933); environmental science and engineering, recycling, and water resources (seven projects, $2.07 million), and marine technology (three projects, $565,248).

In this and future issues of New Waves, we'll feature summaries of many of these projects as well as ways to contact the scientists conducting the research. A complete list of projects that have a broad connection to environmental and water science are shown below.

1997 Advanced Research Program (ARP) Grant Recipients

Atmospheric Sciences
"Detection of Localized Structures In Hurricane Windfields," $58,754, Richard Peterson,Texas Tech University (TTU).
"Numerical Model Study of Hurricane Boundary Layer Winds," $69,488, Chia-Bo Chang and Arthur Doggett, TTU.
"Improving the Detection and Warning of Severe Weather Using Doppler Radar," $130,815, Michael Biggerstaff, Texas A&M University (TAMU).

Biological Sciences

"Mutational Analysis of Circadian Rhythmicity in Zebrafish," $156,246, Gregory Cahill, University of Houston (UH).
"Global Change in the 21st Century: the Effect of Elevated CO2 on Grassland Water Budgets," $92,973, Robert Jackson, University of Texas at Austin (UT).

Earth Sciences
"Tracing Fluid Flow in the Vicinity of Salt Domes in Geopressured Sedimentary Basins," $94,000, Regina Capuano, UH.
"Computation of Transport Properties from Thin-Section Images," $115,800, Kishore K. Mohanty, UH, and $51,200, Liwen Shih, University of Houston - Clear Lake (UHCL).

Engineering
"Effective Waste Treatment by Wetlands with Wetting and Drying Cycles," $185,400, Nick Parker and Clifford Fedler, TTU.
"Studies On Salinity and Temperature Transients in Sea Water Aquaculture Ponds," $114,206, Nagaraja Shamsundar and Stanley Kleis, UH.

Marine Sciences
"Roles of Nitrogen to Phosphorus Supply Ratio and Grazer Pressure in Maintenance of the Texas Brown Tide," $58,903, Hudson DeYoe, University of Texas at Pan American (UTPA), and $53,979, Terry Whitledge, University of Texas Marine Science Institute (UTMSI).
"Pollutant Induced Feminization of Male Fish: Is It a Problem in Texas Estuaries?," $78,375, Peter Thomas, UTMSI.
"Transport Mechanisms in Larval Fish Recruitment: Do Nearshore Retention Zones Promote Stochastic Immigration?," $97,416, Joan Holt and Scott Holt, UTMSI.
"Investigation into Non Steady-State Sediment-Water Exchange Processes," $100,991, Gary Gill, Texas A&M University at Galveston (TAMUG).
"The Use of Stable Isotope Tracers and Fatty Acid Signatures to Determine the Diet of Marine Mammals," $88,200, Graham Worthy, TAMUG.
"Reconstruction of Terrestrial 129-I Inputs into Marine Environments," $96,358, Peter Santschi, TAMUG.
"Numerical Wave Tank Simulations for Irregular Multi-Directional Waves," $128,355, Moo-Hyun Kim; Jose Roesset, Texas Engineering Experiment Station (TEES).

1997 Advanced Technology Program (ATP) Grant Recipients

Agriculture and Aquaculture
"Public Health, Vibrio and Texas Oysters: Post-Harvest Remediation," $198,867, John Schwarz, TAMUG.
"Enhancement of Red Drum Growth through Environmental Manipulation of Anabolic Hormone Cycles," $166,023, Duncan MacKenzie, TAMU.
"Novel Technology to Accelerate Gene Discovery for Texas Agriculture," $191,565, John Mullet, Texas Agricultural Experiment Station (TAES).
"Methods for Improved Detection and Prevention of Shrimp Baculovirus Disease," $195,278, Linda Guarino and Paul Frelier, TAES.

"Developing Multiple Stress Resistant Sorghum for Texas Using Molecular Markers," $159,158, Gary Peterson and Darrell Rosenow, TAES.
"Hierarchies and Coalitions in Cooperative Regional Water Management in Texas," $179,274, Bruce McCarl and Fred Boadu, TAES.

Computer and Information Engineering
"Numerical Modeling of Subsurface Flows in Porous Media," $169,933, Richard Ewing and Joseph Pasciak, TAMU.

Environmental Science Engineering, Recycling, and Water Resources
"Remote Sensing of Rio Grande Delta Marshes," $74,139, Frank Judd and Robert Lonard, UTPA, and $84,783, Melba Crawford, UT.
"Cost-Effective Waste Treatment through Aquatic Protein Production," $189,000, Clifford Fedler and Nick Parker, TTU.
"Novel Mass Spectrometric Strategies for Analysis of Fire Ant Killers in Soil and Water," $85,635, Jennifer Brodbelt, UT, and $92,466, Stephan Bach, University of Texas at San Antonio.
"Computer Modeling for Risk Assessment and Design in Environmental Remediation Using Parallel Finite Elements," $221,364, Mary Wheeler and Graham Carey, UT.
"Capacity Building for Resource Assessment and Responsible Development, Texas-Mexico Border Region," $485,214, Jay Raney, UT; $104,510, Eric Rieken, UTPA; $111,128, Charles Groat, University of Texas at El Paso; $70,785 Gene Paull, University of Texas at Brownsville, and $129,732, Juan Hinojosa, Texas A&M International University.
"Measuring Atmospheric Precipitable Water Vapor in Texas Using the Global Positioning System," $173,250, Robert Nerem and P. Abusali, UT.
"GPS and Texas High Resolution Geoid for Coastal Environmental Management, Engineering, and Hazard Assessment," $107,111, Gary Jeffress, Texas A&M University - Corpus Christi (TAMUCC), and $92,510, Carlos Aiken, University of Texas at Dallas, and $77,595, Bob Schutz, UT.

Marine Technology
"Aquaculture Technologies for the Enhancement of Marine Fisheries Resources," $186,571, Connie Arnold and Joan Holt, UTMSI.
"BBOBS: A New Generation of Broadband Ocean Bottom Seismograph," $148,007, Yosio Nakamura and Jay Pulliam, UT.
"Brillouin LIDAR for Ocean Temperature and Sound Velocity Profiling," $230,670, Edward Fry and George Kattawar, TAMU.

1997 ATP Development and Transfer Grant Recipients
"Pilot-Scale Commercial Production of Specific-Pathogen-Free Shrimp in a Biosecure Facility," $126,021, Phillip Lee, UT Medical Branch at Galveston, and $102,891, Addison Lawrence, TAES.

Texas A&M Explore Institutional Constraints that Limit Drought Management

It's well known that last year's drought was devastating. Crops withered. Many cities implemented severe water conservation measures and, in some cases, nearly ran out of water altogether. The flow in many major rivers slowed to a trickle.

What lessons can be learned from that drought and others that occurred previously? Can water management structures and programs be made more efficient so that the impact of future droughts, which will come, is less severe?

A research project now being conducted at Texas A&M University (TAMU) is examining many of these issues. Lead scientists include TAMU Agricultural Economics Department researchers John Ellis and Ron Lacewell. Other TAMU System scientists involved in the project include Raghavan Srinivasan of the Texas Agricultural Experiment Station's Blackland Research Center at Temple, and Seiichi Miyamoto of the TAMU Agricultural Research and Extension Center in El Paso. Other cooperators include Frank Ward, Tom McGuckin, and J. Philip King of New Mexico State University, and Robert Ward and Marshall Frasier of Colorado State University. The study was funded by the National Institutes for Water Research. The Texas Water Resources Institute (TWRI) is administering the TAMU portion of the grant.

TAMU's role in the project involves gathering data and analyzing trends in the Rio Grande River below Fort Quitman. Ellis and Lacewell have visited many of the water districts that manage irrigation supplies in South Texas and throughout the Middle and Lower Rio Grande Valley. They also acquired data sets from many agencies that work in the region, including the International Boundary and Water Commission and the Texas Water Development Board. With that data, they utilized computer optimization models to estimate the economic effect of broad types of management policies on the economic welfare of the cities, farmers, and other water users throughout the region.

"The overall goal of the project is to identify and rank which institutional constraints have the greatest adverse impact on how water managers can respond to droughts," Lacewell said. "We want to minimize the negative impact of prolonged droughts and identify strategies that can be implemented to give water managers as many choices as possible to counteract water shortages."

In the first year of the study, Lacewell and Ellis have narrowed the wide list of possible management challenges into a few narrowly targeted hot spots. "Some of the management philosophies and structures that we will likely focus on include state and federal laws that dictate that you must use water supplies to keep water rights, key differences in water laws between individual states in the region, and, in Texas, water management by irrigation districts where they may be opportunities for cooperation," Lacewell says.

In South Texas and the Lower Rio Grande Valley, Ellis noted, most of the water supplies are owned by irrigation districts. "There is a potential to get individual farmers to

improve water conservation significantly on the farm, but it's difficult to get agricultural producers excited about saving water when the district holds the water rights," he says.

Another issue facing the region is that urban water demands are increasing rapidly, even though most of the water rights are now held by agricultural interests. "We're conducting economic analyses to determine opportunities for water markets," Lacewell says. "We're exploring scenarios in which urban areas may want to invest to improve the water use efficiency of agricultural users in exchange for being able to obtain some of the 'saved' water."

For details, contact Lacewell at (409) 845-8476 or r-lacewell@tamu.edu or Ellis at (409) 845-6095 or jellis@tamu.edu. TWRI can be contacted at (409) 845-8571 or twri@tamu.edu.

UT, UNM to Study Third Party Impacts of Water Transfers

How should "third party" effects be evaluated when surface water rights are transferred and how can uncertainties be incorporated into this process? These are some of the questions that researchers at the University of Texas at Austin (UT) and the University of New Mexico (UNM) will address in a new project funded by the U.S. Geological Survey (USGS).

Lead scientists in the project are David Eaton of the Lyndon Baines Johnson School of Public Affairs at UT, Peter Wilcoxen of the UT Economics Department, and Al Utton of the UNM Law School.

The goal of the project is to develop methods to assess the third party effects of water transfers, and to identify methods through which these parties could be compensated, if necessary. Third parties, Eaton says, may include waters that serve secondary economic uses as well as streamflows used to protect the environment and those that provide recreation. Alternative "non-economic" methods of valuing surface waters will be investigated to evaluate the impact of transfers on resources that are hard to value economically.

In the early stages of the project, the researchers will facilitate and conduct focus groups of water users in the Guadalupe-Blanco River basin in Texas to gather data on buyers and sellers and to develop metrics for water valuation. Later, uncertainties and stochastic variables will be addressed that may affect the value of water transfers to third parties.

Ultimately, Eaton believes the project may provide data that may make water markets easier to implement. He also hopes to develop better methods to appraise water supplies using economic and operational variables and to evaluate and quantify third party effects.

TWRI will administer the USGS grant for this project. For details about the research, contact Eaton at (512) 471-4962, Wilcoxen at (512) 475-8531 or wilcoxen@eco.utexas.edu, or Utton at (505) 277-1002.

"Ph.D. Pipeline" WWW Site Describes Environmental Engineering Programs in TAMU System

Detailed information on engineering and environmental science programs and research conducted at many Texas A&M University (TAMU) System institutions can be found at the "Environmental Engineering PH.D. Pipeline" World Wide Web (WWW) site, which was a joint development of TAMU and TAMU - Kingsville (TAMUK). The WWW site contains information on environmental research and academic programs at TAMUK, TAMU, TAMU - Corpus Christi, and the Texas Engineering Experiment Station. The WWW site also provides details about environmental courses offered throughout the System at each institution via distance learning. Links to external sites including the Texas General Land Office and other sites of related interest are also provided. The goal of the Pipeline program is to enhance research opportunities at all TAMU System campuses and to provide educational experiences at multiple levels to all students. For details, visit the WWW site at http://pipeline.tamuk.edu or e-mail the webmaster at amartinez@pipeline.tamuk.edu.

UT Bureau of Economic Geology WWW Site Descirbes Research in Hydrogeology, Coastal Studies

Information about a wide range of water resources and environmental research is available from the University of Texas at Austin's Bureau of Economic Geology (BEG) World Wide Web (WWW) site. The major components of the WWW site describe BEG research in hydrogeology, coastal studies, and environmental science. The site also describes BEG capabilities in developing geographic information systems (GIS) as well as research capabilities and involvement in international programs. The site also lists publications and products that can be obtained from BEG. Some of the specific water resources projects that are described on this site include a study to determine shoreline movement between Sabine Pass and the Brazos River, and research to investigate the origin and recharge of playa lakes. BEG can be contacted at (512) 471-1534 or begmail@begv.beg.utexas.edu. The WWW site address is http://www.utexas.edu/depts/beg/.

EPA WWW Site Lets Users Access Watershed Data

The U.S. Environmental Protection Agency (EPA) has created a World Wide Web (WWW) site, "The Index of Watershed Indicators," that lets users access comprehensive information about individual watersheds. The WWW site allows users to select watersheds through an interactive map or by searching for the name of a watershed, river, or stream. A wide range of water quality data can be accessed, including ambient water quality, runoff pollution, wastewater discharges, health advisories issued for pollutants in fish tissues, contaminated sediments, and sources of drinking water. Information can also be accessed about such subjects as aquatic and wetlands species that are at risk, pollutant loads, the vulnerability of estuaries to pollution, and how dam construction in a watershed may have altered streamflows. The site also lets visitors learn about watershed protection programs and allows them to contact watershed protection organizations and

agencies. According to data on the WWW site, 16% of all watersheds have good water quality; 36 percent exhibit moderate water quality; and 21% show signs of serious problems. In general terms, data on the site suggest that one in 14 watersheds in the United States are vulnerable to pollution. The address for this site is http://www.epa.gov/surf/iwi.

TAMUCC Develops WWW Site with Nueces River Basin Data

A World Wide Web (WWW) site that contains interactive information about water quality data in the Nueces River Basin has been developed by scientists at Texas A&M University - Corpus Christi (TAMUCC). The WWW site, "Texas Clean River Program: Nueces Basins Database Interface," was developed by Rocky Freund and Patrick Michaud of the TAMUCC College of Science. The site allows users to select a point on a clickable map and be linked to water quality and hydrology information about that location. The WWW site also provides links to data on water quality, surface water, and flows for the region, as well as printed reports. The address of the WWW site is http://robin.tamucc.edu. For details, contact Freund at rfreund@cbi.tamucc.edu or (512) 994-2376, or Michaud at michaud@tamucc.edu or (512) 994-2751.