New Waves
The Research Newsletter of the Texas Water Resources Institute

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250 Participants, 117 Speakers Make Water for Texas Conference a Success

As you read this issue of *New Waves*, you'll be getting a small glimpse into what occurred at the Texas Water Resources Institute's 24th "Water for Texas" Conference that took place January 26-27 in Austin. Many of the articles in this issue are taken from talks that were given at the Conference. The Conference was sponsored by TWRI, the Texas Water Development Board, and the Texas Water Conservation Association. It drew 250 participants who came learned about water and environmental research at Texas universities, as well as work done by others. Conference sessions dealt with water conservation and reuse, water supplies, groundwater quality, aquatic biology, coastal studies, and water policy.

Speakers included 117 researchers, who described their studies. Representatives of state and federal agencies elaborated on their research programs and research needs in a plenary session. The lunch keynote speaker was Roger Elliott of the Texas Higher Education Coordinating Board, who spoke about the Board's research programs.

"We feel this meeting was a great success, because it brought together people from different disciplines, so they could get a broader picture of water research," said TWRI Director Wayne Jordan. "It gave scientists and policy makers information and insights about research that is going on that can solve pressing needs. The meeting also brought potential collaborators together who may cooperate on future research."

TWRI published a 726-page proceedings. For details about the Conference, call TWRI at (409) 845-1851.

Access TWRI on the Internet

Information about TWRI and other water and environmental related issues in Texas is now available over the internet. TWRI has developed a "world wide web" site called Texas WaterNet that lets users access and download information on TWRI publications and programs and lets them link to sites with additional information.

TWRI Information Specialist Ric Jensen developed the site along with student workers Jonathan Jones and Steve Fuller. "More people will be able to read our publications and learn about TWRI. They will get to see color photos about our research and technology transfer programs. They won't have to keep scores of back issues of our newsletters, because they're now available on-line," Jensen says.

Texas WaterNet now includes the text, photographs, and graphics of recent issues of all four TWRI quarterly newsletters. WaterNet includes a complete list of speakers from TWRI's 1995 "Water for Texas Conference," lets users read about TWRI research projects, and provides information about TWRI personnel.

The WWW site also allows users to search for any keyword that has appeared in any TWRI publication and lets them automatically read the entire article.

Future plans for the site include posting abstracts of all TWRI technical reports and back issues of newsletters, developing an index of TWRI publications, and allowing users to search and download information from TWRI's directory of Texas university scientists with water related expertise.

Texas WaterNet can be accessed at the following URL: <http://twri.tamu.edu/>. Internet users can view the site with Mosaic or Netscape or Lynx software. For more details, contact Jensen at (409) 845-8571. His e-mail address is rjensen@tamu.edu.

UT, Texas A&M, UT-PA Biologists Study Fish Populations in Texas Rivers

A unique, comprehensive study that compares the populations and diversity of fish in Texas rivers has just been completed by a joint research team involving scientists from the University of Texas at Austin (UT), Texas A&M University, and the University of Texas-Pan American (UT-PA).

To understand this study and its importance, you have to go back to 1953. That's when Clark Hubbs of the UT Zoology Department led efforts to sample 130 inland freshwater habitats and the fish that live in them at sites throughout Texas. In 1986, Hubbs went back to these same sites, and sampled them at the same time of year using the same methods. Nearly 70,000 individual fish, representing 153 species and 21 families were collected. The idea was to compare how these ecosystems and fish communities had changed over a long time period.

Surprisingly, even though this large and unique data set had been collected it had not been quantitatively analyzed until 1994. Then, two of Hubbs' former graduate students who took part in some of the 1986 sampling enter the picture. Kirk Winemiller of the Texas A&M Wildlife and Fisheries Sciences Department and Robert Edwards of the UT-PA Biology Department worked with Hubbs to analyze the data. Allison Anderson, a graduate student of Winemiller's, performed much of the computer analyses.

What do the results show? In general, there are many changes in the abundance of specific fish families in many river basins throughout Texas. Populations of silversides increased by 900%, and mosquitofish and shad also increased at many sites. On the other hand, numbers of suckers dropped by 800%, while populations of catfish, darters, and pupfishes decreased in many watersheds. Several fishes were found in spring-fed habitats in the 1953 survey are no longer found in Texas and appear to be extinct.

Winemiller says the survey suggests that the construction and operation of dams may be a key reason for many of the observed changes. That's because dams alter natural in-stream flows, eliminate large areas of flowing water habitats, and modify temperatures and nutrients. He also believes that some species like mosquitofish are small and opportunistic and are able to rapidly colonize disturbed habitats. When ecosystems change, these species may begin to dominate rivers and lakes.

For details, contact Winemiller at (409) 862-4020 or kow1956@zeus.tamu.edu , Edwards at (210) 381-3545 or rjeb6d0@panam3.panam.edu"> rjeb6d0@panam3.panam.edu , or Hubbs at (512) 471-1176.

Use of Constructed Wetlands to Treat Diazinon

Researchers: Richard Guinn, Ken Dickson, and Tom Waller, Institute of Applied Science (IAS), University of North Texas, Denton, TX, and Jim Coulter, City of Denton Environmental Services, Denton, TX.

Problem: Federal regulations require cities to monitor wastewater effluents to determine if they are toxic to aquatic life. In many parts of Texas, monitoring has shown that low levels of diazinon (a pesticide that is widely used to control grub worms, fire ants and household insects) are toxic to aquatic organisms. Mixing only 5 grams of 25% strength diazinon (the level available to the general public) with 1 million gallons of water often kills water fleas (*C. Dubia*) used in biomonitoring tests. Many cities are now investigating ways to reduce levels of diazinon and other toxic chemicals before they enter rivers and streams. The use of constructed wetlands may be a viable strategy to reduce diazinon concentrations.

Objective: To evaluate the use of constructed wetlands to reduce diazinon levels in municipal wastewaters to non-toxic levels.

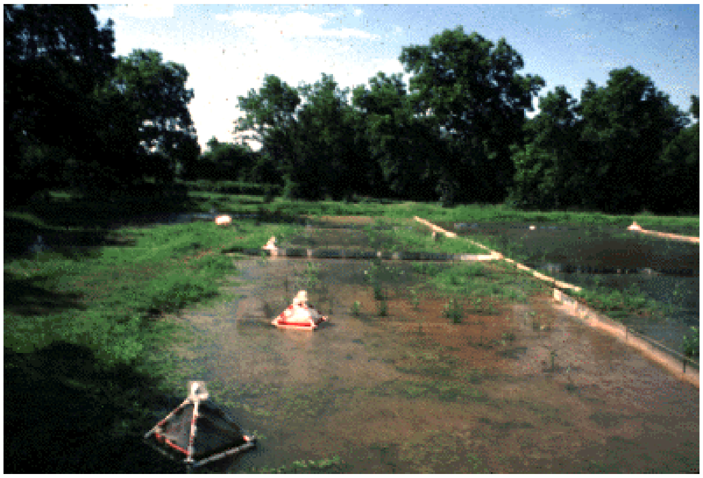
Methodology: Research was conducted at Denton's 15 million gallon per day Pecan Creek Wastewater Treatment Plant. Construction of the wetland began in the Fall of 1992. Aquatic plants were transported from the U.S. Army Corps of Engineers Lewisville Aquatic Ecosystem Research Facility to the site in the Spring of 1993. The wetland was planted with arrowhead, pickerel weed, and bulrush. Gambusia minnows were added to control mosquitoes. The wetland consists of a clay liner that is covered with sediments from an existing on-site pond. The wetland measures 150' x 150', is 6" to 24" deep, and can store 150,000 gallons of wastewater. It is divided by earthen berms and baffles that help water flow through the system and a valve controls the amount of water that enters the wetland. It can be easily modified so that additional wetland cells can be created as needed. The wetland receives treated, dechlorinated, municipal wastewater from the treatment plant. After treatment, wastewaters flow back into the head of the plant. Six sampling stations were established in the wetlands. Diazinon levels are measured using a diazinon plate kit and gas chromatograph (GC). *C. Dubia* toxicity tests were conducted using EPA methods at the IAS Aquatic Toxicology Lab.

Results: In the Summer of 1994, the wetlands received roughly 5,000 gallons per day, which was typically retained for 30 days. Toxicity testing using *C. Dubia* showed widespread mortality at the site wastewaters first entered the wetland, but little toxicity elsewhere. Tests in August 1994 showed that diazinon entered the system at levels of 0.5 ug per liter (ug/L), but was reduced to less than 0.05 ug/L after 48 hours. Other results suggest that diazinon levels may be higher after heavy rains, because of urban runoff and leaks and infiltration through sanitary sewers. Diazinon levels entering the treatment plant and the wetlands fluctuate widely. As a result, it is impossible to determine if the diazinon and resulting toxicity are being biodegraded and eliminated or simply diluted.

Follow-Up Studies: The study has since been redesigned to better determine if biodegradation is occurring. Effluents entering the wetland are spiked with a consistent dose of diazinon (0.5 ug/L). The flow to the wetland was increased to 15,000 gallons per day and will be detained for 10 days. In November 1994, a trial run of the spiking experiment was conducted. Due to the cold temperatures the biological activity in the wetland was lower than would be expected in warmer months and little degradation occurred. More spiking studies will be conducted this Spring. Results from those studies will be used to help determine the optimum diazinon levels and flow regimes needed for future research.

Reference: Guinn, Richard, Jim Coulter, and Kenneth Dickson, "Use of a Constructed Wetland to Reduce Diazinon Toxicity in a Municipal Wastewater Effluent," in *Proceedings of the 24th Water for Texas Conference*, TWRI, 1995.

This experimental wetlands is being used to determine if it can remove pollutants and pesticides from runoff water.



The wetlands was equipped with many sampling sites (cages) where samples of aquatic species were collected.

In this photo, Richard Guinn of the University of North Texas takes a water quality sample from the wetlands.

Geochemistry and Stable Isotopes in an Urbanized Watershed

Researchers: Debra Hercod and Robert Gregory, Geological Sciences Dept., Southern Methodist University, Dallas, TX, and Patrick Brady, Sandia National Laboratories, Albuquerque, NM.

Problem: Public concerns about surface water quality and its impact on human health have created a need to predict urban water quality. The movement of toxic chemicals and nutrients in urban environments is largely controlled by geological and geographical characteristics in watersheds. It is now impossible to predict overall water quality trends, due to the complexity of dealing with many different sources of water, contaminants and geologic formations.

Objectives: To determine if natural trace elements (dissolved ions and stable isotopes) can provide an indirect method to assess changes in geochemistry and water quality in urban watersheds.

Background Information: The White Rock Creek watershed covers a 66-square mile area that begins in Collin County, goes through Dallas and White Rock Lake, and merges downstream with the Trinity River. The bedrock geology of the watershed is dominated by the Austin Chalk formation. The watershed overlies the Lower and Middle Austin Chalk, which consists of interbedded chalks and marls. Layers within the Austin chalk range from pure chalk (carbonite) to bentonite (clay).

Methodology: White Rock Creek was sampled at the U.S. Geological Survey stream gauge site in North Dallas. During periods of baseflow, the creek was sampled up to three times per week. Following storm events, samples were taken every 6 to 12 hours for 3 days. Water temperature and pH were measured in the field. Roughly 120 samples were analyzed for pH, alkalinity, sulfate, dissolved calcium, sodium, magnesium, silica, strontium, potassium, and barium. Roughly 75 samples were analyzed for oxygen and hydrogen isotope ratios. Multiple samples of Austin chalk were collected from five sites in the watershed to determine typical bulk concentrations of chemicals. Chemical analyses were performed with gravimetric methods and direct current plasma atomic emission spectroscopy.

Results: This study suggests that bedrock dissolution is the primary control on baseflow chemistry, even though the watershed has become heavily urbanized. This may be applicable to other urbanized watersheds with similar hydrogeological conditions. Stable isotope data confirm that evaporation is an important influence on the isotopes found in the creek, especially during the Summer months when evaporation is high and during and immediately following storm events. Individual storms were shown to alter the isotope composition in the creek for as long as a week after precipitation occurred.

Reference: Hercod, Debra, Robert Gregory, and Patrick Brady, "Geochemical and Stable Isotope Variations in Baseflow from an Urbanized Watershed: White Rock Creek, Dallas, TX," in *Proceedings from the 24th Water for Texas Conference*, TWRI, 1995.

Impact of Streamflows on Growth of Texas Wild Rice

Researcher: Paula Power, Biology Department, Southwest Texas State University, San Marcos, TX.

Introduction: Sediments and water movement are important factors that regulate the growth and distribution of aquatic plants (macrophytes). Different types of sediments may influence the amount of key nutrients needed for plant growth. Relatively slow water currents may increase plant metabolism by delivering nutrients, while higher flows can be harmful. Texas wild rice (*Zizania texana*) is an endangered plant that is only found in the San Marcos River in Hays County, TX. This species may be endangered because of reduced flows in the San Marcos River due to overpumping of the Edwards Aquifer, and the alteration of river habitats.

Objectives: To quantify and compare the growth response of Texas wild rice when grown under natural conditions in different flow regimes and in different textured sediments.

This photo provides an overhead view of Spring Lake, San Marcos Springs, and the San Marcos River. Flows from the river are essnetial to the growth of Texas wild rice, which is an endangered plant species.

Methodology: Two sediment types from the San Marcos River were used for this experiment: 1) gravel collected from the confluence of Sessoms Creek and the San Marcos River and 2) sandy clay loam collected from the San Marcos River. A sample of each sediment was sent to the Texas A&M University Soil Testing Laboratory and analyzed for Kjeldahl nitrogen, phosphorus, texture, and organic content. Sediments were placed in 4" pots and one germinated Texas wild rice seed was placed in each pot. Seedlings were grown and became rooted under controlled conditions for five weeks. Pots were transferred to 3 sites in Spring Lake with different currents. There were 3 plots in each site, and each plot contained 3-5 plants growing in gravel and sandy clay loam. Current velocity was measured near each plot weekly at 40% and 80% of total depth. Plants were protected from herbivores by floating cages. Currents were measured before and after each cage was placed. After six weeks, plants were harvested. Plants badly damaged by herbivores or by submerged organisms were discarded. The number of stalks and leaf length were recorded. Plants were dried and weighed.

Results: Average flows for each site were calculated. Flows varied from 3.4 to 3.9 feet per second (f/s) at the fastest site, from 1.3 to 1.4 f/s at a site with moderate flows, and from 0.5 to 0.6 f/s at the slowest site. Water depth varied from 2.2 to 2.6 feet at all sites.

Sediments were designated as being sandy clay or loam and gravel, based on texture analysis. Sandy clay loam soils consisted of equal parts silt and clay and 56% sand, while gravel soils were comprised of 79% gravel, 16% sand and minor amounts of clay and silt. Sandy clay loam sediments had more organic matter content, Kjeldahl nitrogen and phosphorus than gravel soils. Texas wild rice plants were significantly more productive in sandy clay loam than in gravel, because there were low nutrient levels in the gravel. Total biomass of plants grown in sandy clay loam in fast flowing water was nine times greater than those grown in gravel. Plants grew much better in sandy clay loam in moderately and slow flowing water. Stalk production was significantly influenced by sediment type and current velocity and was greatest in plants grown in sandy clay loam in fast flowing water. Leaves were significantly shorter in plants growing in fast water when compared with plants growing in medium or slow moving water. Results suggest that Texas wild rice may be tolerant of higher currents because it can alter flow characteristics within beds by acting as a filter that slows current velocity and increases fine sediment and detritus deposition. This supports the opinion that the continued existence of wild rice may be dependent on maintaining historic average springflows in the San Marcos River.

Reference: Power, Paula, "Growth Response to Zizania texana (Texas wild rice) Under Three Current Regimes and Two Sediments in Spring Lake, Hays County, TX," in *Proceedings of the 24th Water for Texas Conference*, TWRI, College Station, TX, 1995.

Economic Feasibility of Shrimp Aquaculture in West Texas

Researchers: David Britt, Ron Lacewell, Wade Griffin, Agricultural Economics Department, and Jim Davis and Bill Neill, Wildlife and Fisheries Sciences Dept., Texas A&M University, College Station, TX; and Jaroy Moore, Texas Agricultural Experiment Station, Pecos, TX.

Problem: A research and demonstration shrimp farm was established at Imperial, TX, near Pecos in 1991. Results showed that large numbers of shrimp could be produced. The economic feasibility of West Texas aquaculture operations needs to be studied.

Objectives: To address the economic and financial feasibility of shrimp production in West Texas. Economic feasibility refers to estimated annual costs and returns, while financial feasibility relates to cash flow analyses.

Methods: A hypothetical shrimp farm was simulated at Imperial, TX, that covers 120 acres and includes 24 five-acre ponds, a rock quarry, a feed storage unit, a greenhouse, worksheds, and offices. The strategy is to produce two crops of shrimp each year. Greenhouses are used to "head start" the shrimp before they are placed in grow-out ponds. Water from all the ponds is pumped to the rock quarry. In the economic and financial analyses, a computer spreadsheet was applied using Lotus 1-2-3 software. A biological model was also developed and applied that generated alternative scenarios for shrimp yields, the size of shrimp, and risks of failure.

Assumptions: Cost estimates were based on experience from South Texas shrimp farms and operations at Imperial. The estimated cost to initially construct ponds and to purchase and install pumps was $500,000. It was estimated that the cost for equipment would be $312,000 (paddle wheels were the biggest cost). Projected major annual fixed costs were amortization of the initial investment ($812,000), and salaries for managers ($48,000). Major estimated operational costs were for feed ($0.56 per pound), purchase of post larval shrimp ($9.75 per 1,000 shrimp), fertilizer, and energy for pumping and aeration. Shrimp prices were estimated to range from $6 / lb. for large shrimp (34 count) to $3/ lb. for smaller shrimp. The researchers used the biological model to account for fluctuations in growth and survival rates, harvest size, and harvest date.

Results: Economic and financial analyses were conducted using deterministic (all factors are known with certainty) and stochastic (introduction of risk) methods. The deterministic analyses were performed first. They show that the total annual cost would be roughly $1 million, which includes more than $150,000 of fixed costs. To break even, the facility would have to produce roughly 4,382 pounds of shrimp tails per acre. The first harvest would have to sell for $6/ lb., while the second harvest would have to sell for $5.45/ lb. Annual estimated net returns could be $42,000. When stochastic and sensitivity analyses are included, over half of all the simulations that were run showed a "0" or negative rate of return, while the average internal rate of return was less than 1%. This is despite the fact that half the simulation runs did not include a "catastrophic" event like a large shrimp kill. It needs to be emphasized that these results are only preliminary and more work is being done.

Reference: Britt, D., R. Lacewell, W. Griffin, J. Moore, Jim Davis, and W. Neill, "Economic Implications of Shrimp Aquaculture in West Texas," *Proceedings of the 24th Water for Texas Conference*, 1995.

Impact of Mandated Freshwater Releases on Nueces Bay

Researchers: Terry Whitledge and Dean Stockwell, University of Texas Marine Science Institute, Port Aransas, TX.

Problem: In 1990, the Texas Water Commission (TWC) required that "interim" freshwater releases be made over a five-year period to maintain the aquatic ecosystem in the Nueces Bay and Estuary. The freshwater releases were based on 1) the firm yield of nearby reservoirs, 2) relationships between freshwater inflow and fisheries yields, and 3) the likelihood that key levels of freshwater inflows could be supplied, based on historic rainfall and inflow data. Studying relationships between freshwater inflows, water quality, and aquatic organisms can help determine how the freshwater releases affect the Bay ecosystem.

Objective: 1) To evaluate data from 1990 to 1995 to assess how freshwater releases affect Nueces Bay, and 2) to determine if delivering treated wastewater to an inner part of the Bay (Rincon Delta) could improve biological productivity by supplying nutrients.

Methodology: Since 1990, monthly samples have been gathered in Nueces Bay and the lower Nueces River for salinity, temperature, dissolved oxygen, nitrate, nitrite, ammonium, phosphate, silicate, plant pigments, water transparency, and primary productivity in the water column. Samples were collected at 25 sites for hydrography, nutrients and plankton pigments, while 5 sites included measurements of primary biological productivity. Vertical profiles were taken for salinity, temperature, and dissolved oxygen. Since 1992, the Conrad Blucher Institute at Texas A&M University-Corpus Christi has continuously monitored freshwater inflows at two sites in Nueces Bay. The location of many of these sampling sites was noted with global positioning system software and/or by reference to structures like wellheads and pipelines.

Results: As expected, freshwater inflows dominate the salinity response observed in Nueces Bay. The highest mean monthly salinity levels in Nueces Bay typically occur in Winter months when rainfall and reservoir releases are minimal. Salinity levels are typically lowest in late Spring and early Summer when heavy rainfall occurs. Nitrate levels in raw water of the Nueces River increased dramatically in December 1991 following heavy rains. Increased inflows generated high loadings of nitrate into Nueces Bay. Levels of dissolved inorganic nitrogen (needed to support plant growth) appear to increase with higher salinity concentrations. This may be due to remineralization processes. Chlorophyll levels are highest in the Fall, and increase after large freshwater inflows. The highest rates of primary biological productivity occurred each Summer, shortly after freshwater releases and natural inflows. Overall rates of primary productivity are not influenced strongly by salinity. Increased primary production of phytoplankton and microphytobenthos could be expected to occur if Nueces River water or wastewater effluents are diverted into the Rincon Delta, rather than flowing down the Nueces River and bypassing coastal marshes. The overall biological productivity was 2-3 times greater in Rincon Delta than in upper Nueces Bay, although a sudden brown tide bloom in the Bay increased productivity by a factor of 8. The quantity of primary phytoplankton production in the Nueces River downstream of the wastewater plant and in the upper Bay was compared to estimate the effect of supplying treated wastewater. The results show that ambient river water in the delta may increase primary production by 200 or 300%, while diverting wastewater could boost production by 500%.

Reference: Whitledge, Terry, and Dean Stockwell, "Effects of Mandated Freshwater Releases on the Nutrient and Pigment Environment in Nueces Bay and Rincon Delta: 1990-95," in *Proceedings of the 24th Water for Texas Conference*, TWRI, 1995.

Texas A&M Restores Wetlands at Lignite Mines

Researchers at Texas A&M are testing techniques to create wetlands from lands that have been severely disturbed by lignite coal mining.

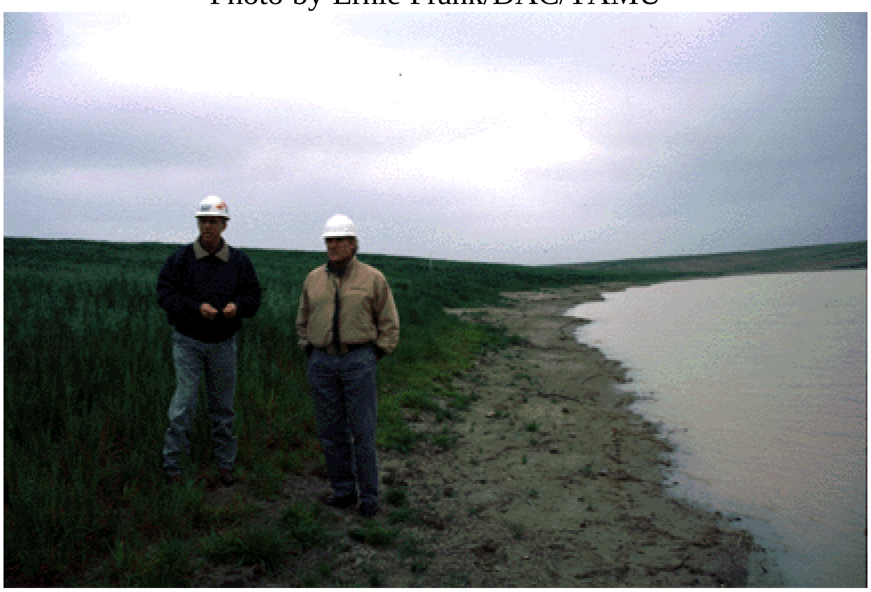
Jon Rodiek of the Landscape Architecture and Urban Planning Department leads the efforts, in cooperation with Hubert Nelson, the manager of the land department at the Texas Municipal Power Agency (TMPA). The research includes extensive hands-on work at 29-acres on the TMPA mine at Carlos, which is located 30 miles east of Texas A&M University.

The problem, Rodiek says, is that many layers of soil have to be literally turned upside-down when lignite is mined. After an area has been mined and "end lakes" are left over, TMPA officials then have to reassemble the various soil layers and create a functional ecosystem.

Much of Rodiek's work centers around two areas. First, Rodiek is working to create wetlands that are hydrologically sound. In other words, he is designing wetlands that will be naturally linked together to make the best use of rainfall and runoff. As part of that work, Rodiek has developed a process to restore wetlands that uses information on topography, soils and vegetation. Rodiek is also investigating problems involving wetland plant succession. Rodiek says that, in many cases, people attempt to create a wetland by first planting trees. He believes that a succession of species, beginning with grass and cover crops, probably need to be planted before trees are introduced to make wetland restoration efforts a success.

For details, call Rodiek at (409) 845-1221.

Photo by Ernie Frank/DAC/TAMU



Texas A&M researcher Jon Rodiek (in light jacket) and Hubert Nelson examine vegetation growth in a newly restored wetland.

This photo shows the large amounts of soil and groundwater systems that are disturbed when lignite mining occurs.

Shortly after an area is mind, small lakes are created. At first, many of these areas have no vegetation but are just comprised of bare soils. Planting grasses helps rebuild the ecosystem.

UNT, TNRCC Analyze Water Conservation in Texas Industries

A researcher with the University of North Texas is working with the Texas Natural Resource Conservation Commission (TNRCC) to develop information on industrial water use and conservation.

Last Summer, Carol Stuewe and Stacy Dukes Rhone of the TNRCC Conservation Staff circulated a survey on water use and conservation to 856 different types of manufacturing firms and industries. Manufacturers were classified by using standard industrial codes (SICs). The survey questioned the firms on such issues as the importance of water conservation, whether firms had plans or strategies in place to reduce water use, problems that hinder water conservation efforts, financial savings achieved because of conservation and reuse, and other issues. More than 625 companies in 16 SIC codes responded. The data were analyzed by Mike Nieswiadomy of the Economics Department of the University of North Texas.

What do the results show? First, water conservation is thought to be most important by the food, apparel, and petroleum industries. Second, roughly half of industries dealing with textiles, apparel, stone, clay, glass, concrete and minerals have conservation plans in place. The economic impact of conservation and water problems were the major reasons for lessening water use. Third, several industries indicated that they want to reduce water use and significantly increase recycling and reuse. Finally, survey responses suggest that relative water costs are highest for such industries as petroleum refining, chemicals, paper, food, and electrical/computer manufacturing.

Information on this study was presented at the 1995 Water for Texas Conference. For details, contact Nieswiadomy at (817) 565-2244 or mike@econ.unt.edu or Stuewe at (512) 239-6105.

TNRCC Study Asks, "How Much Does Pollution Cost?"

One of the major topics being debated in Congress now is the cost associated with various environmental regulations. Still, assessing something like the cost of pollution has always been difficult.

Now, a study being conducted by the Texas Natural Resources Conservation Commission and many other state agencies attempts to put a price tag on the economic impact of water quality problems on fishing, swimming, boating and water-based recreation. The study, a statewide comparative risk assessment, is being led by project manager Wendy Gordon. Planner Sylvia Amaya and program analyst/economist Kariann Sokulsky of the TNRCC are overseeing the socioeconomic working group.

The first step was to identify which Texas waters were not meeting their legally designated uses for aquatic life, fish consumption, and swimming. Using state water quality data, it was established that 83 Texas water bodies are not meeting their assigned uses for aquatic life and swimming.

Amaya and Sokulsky then focused on the amount that recreational use may be limited by pollution. They analyzed data from the Texas Parks and Wildlife Department on the number of visitors to recreational areas and the money they spent. Using those figures, they estimated the number of recreational users that could not use Texas' waters and the amount of money they would have spent. Results suggest that pollution keeps as many as 230,000 people from using Texas waters for recreation at a cost of more than $356,000 annually. In the future, this method may be used to determine other types of economic losses that can be attributed to water quality problems.

For details, contact Amaya at (512) 239-4811 or Sokulsky at (512) 239-4307.

Texas A&M-Kingsville Study Assesses Impact of Shrimp Farms on Water Quality

Researchers at Texas A&M University-Kingsville have just released a preliminary study that assesses the impact of large shrimp farms near Arroyo City on coastal water quality and suggests treatment methods that may be viable.

The water quality assessment was funded by TWRI and was conducted by Andrew Ernest of the Environmental Engineering Department and graduate student Shakir Koneru. The goal of the study was to characterize whether shrimp farm effluent was deteriorating water quality in the Arroyo Colorado by increasing levels of ammonia, total suspended solids and by causing nuisance odors and other aesthetic problems.

In the project, Ernest and Koneru monitored water quality from individual ponds, segments of drainage canals, and discharge stations. The Arroyo Colorado was monitored one mile upstream and two miles downstream of the shrimp farm at different locations and depths. Water quality samples were taken before and during times when shrimp were harvested, and were analyzed for metals, nutrients, chlorophyll levels and particle sizes.

The preliminary results show that, during pre-harvesting, levels of total suspended solids (TSS) are significantly higher in ponds and are very high in areas immediately downstream of the shrimp farm. Chlorophyll a levels were lower than normal during pre-harvesting. During harvesting, TSS levels are very high at the main discharge station in the river, and elevated ammonia concentrations may be toxic to fish and other aquatic life and may be causing eutrophication.

Ernest suggests that primary sedimentation ponds, a constructed wetland with a reed-rock filter, and/or lining drainage canals and the sides of ponds are steps that can be taken to improve the water quality problems.

This paper was presented at the Water for Texas Conference. For details, call Ernest at (512) 595-3041.

UT Study Assesses Impact of Urbanization on Barton Springs

Researchers at the University of Texas Center for Research in Water Resources (CRWR) have begun efforts to learn more about the water quality and hydrology of Barton Springs, as part of an effort to help safeguard it from pollution. Barton Springs is one of Austin's most beloved natural resources, is well known for its clear and clean waters, and is widely used as a recreational site. Preserving the high water quality in Barton Springs from non-point source pollution is a significant challenge because the watershed is becoming heavily urbanized.

Barton Springs (above) is one of Austin's favorite spots for outdoor swimming.

The study is being conducted by Mike Barrett and Randall Charbeneau of the UT CRWR. Their goal is to develop a computer simulation model that can be used to assess how increased urban development impact affects the volume and quality of runoff water and water quality in the springs. The model can be used to evaluate water quality control strategies, and to predict changes in pollutant levels in the aquifer and in the springs. To develop the model, the UT researchers will gather information on subsurface geology, locations of faults and wells, aquifer properties, recharge parameters, chemical transformations, flow routing, and other factors.

For more details, call Barrett at (512) 471-3131 or send him e-mail at Mbarrett@mail.utexas.edu.

TWDB Assesses Potential for Wastewater Reuse in Texas

A study by the Texas Water Development Board (TWDB) examines the amount of wastewater reuse that is now occurring in Texas, and estimates how widespread reuse may be in the future.

The study was conducted by Abu Sayeed and Bill Hoffman of the TWDB Water Conservation Division. They gathered data on various forms of water reuse now being implemented (including irrigation, and recycling and reuse in various manufacturing processes). Results show that roughly 65,000 acre feet (AF) of wastewater is being reused daily in Texas. Although that number may seem impressive, keep in mind that more 1.7 million AF (roughly 55% of household water use) is now returned to streams as wastewater that could be captured and reused.

To evaluate the potential for increased reuse, Sayeed and Hoffman examined TWDB water use projections and TNRCC wastewater return flow data on a county-by-county basis. Agricultural, steam-electric (cooling tower) and manufacturing demands were projected. Wastewater reuse by manufacturing was estimated for specific industries. In addition, Sayeed and Hoffman also developed case studies for "high" and "low" levels of reuse.

The results show that the potential for water reuse in Texas can be as high as 1.04 million AF by the year 2000 and 1.67 million AF by the year 2050. Even under the low case projections, wastewater reuse is estimated at roughly 790,000 AF in the year 2000 and 1.3 million AF by the year 2050. These estimates are much higher than the amount that wastewater is being reused now. Finally, Sayeed and Hoffman note that urbanized areas with large populations probably have the greatest potential to improve the amount of reuse, in large part because they generate high volumes of wastewater. This paper was presented at the TWRI Water for Texas Conference. For details, call Sayeed or Hoffman at (512) 463-7932.

TWRI Publishes Water for Texas Proceedings, New Technical Reports

New publications available from the Texas Water Resources Institute include the Proceedings from the 1995 Water for Texas Conference and technical reports.

The 726-page proceedings, *Water for Texas: Research Leads the Way*, contains more than 80 papers that describe recent water and environmental research at Texas universities as well as work by other groups. It was edited by TWRI information specialist Ric Jensen. A limited number of these books are for sale for $30 each.

TWRI has also published a new technical report, *A Farm Level Evaluation of Agricultural Profit and Ground Water Quality: Texas Seymour Aquifer* (TR-168) by Manzoor Chowdhurry, Ron Lacewell, Bruce McCarl, and Teofilo Ozuna of the Texas A&M University Agricultural Economics Department, Billy L. Harris of the Texas A&M University Soil and Crop Sciences Department, Paul Dyke of the Texas Agricultural Experiment Station at Temple, and Verel Benson of the USDA/ Agricultural Research Service at Temple. The report examines alternative farm management practices and policies that may reduce groundwater pollution in the region.

Other recent technical reports include: *Legal and Institutional Barriers to Water Marketing in Texas* (TR 167) by Ron Kaiser, *Environmental Issues of the U.S.-Mexico Border Region: A Workshop Summary* (TR 166) by Howard Malstrom and Wayne Jordan, and *Reservoir and River System Reliability Considering Water Rights and Water Quality* (TR 165) by Ralph Wurbs, Gerardo Sanchez Torres, and David Dunn.

To order any of these publications or to obtain a publications list, call TWRI at (409) 845-1851.

Texas A&M Press Books Deal with Drinking Water, Role of Galveston in World War II

The Texas A&M University Press has recently published two new books that focus on issues as diverse as drinking water and the activity of German u-boats near Galveston in World War II .

Drinking Water: Refreshing Answers to All Your Questions was written by James Symons of the Civil Engineering Department at the University of Houston. The 726-page book contains straight-forward, easy to understand answers on many questions about public drinking water supplies.

Torpedoes in the Gulf: Galveston and the U-Boats (1942-43) was written by Melanie Wiggins, a freelance writer who lives in Galveston. The book is an account of how 24 German submarines entered the Gulf of Mexico between 1942-43 and sank 56 merchant ships and damaged 14 others. The book is based on interviews Wiggins conducted with many German U-boat veterans and U.S. Navy and Merchant Marine personnel.

To order a copy, call the Texas A&M Press at (800) 826-8911.

Texas Tech Press Publishes Book on Playa Lake Ecosystems

The Texas Tech University Press has recently published a lavishly illustrated book that describes the many playa lakes found in Texas and other Great Plains states.

The 134-page book, *Playas: Jewels of the Plains*, was written by Jim Steiert, a former associate editor of the *Texas Farmer Stockman* who grew up on the High Plains. Chapters of the book focus on the history of the playas, how playa lakes influenced life on the Llano Estacado, relationships between playas, agriculture, playa ecosystems, protecting and enhancing the lakes, and the future of playas. The book contains 75 color photographs that were taken by Wyman Meinzer, a photographer of a book titled *The Roadrunner* that was also published by the Texas Tech Press.

For more information on how to order a copy, contact the Texas Tech Press at (800) 832-4042.

Photo by Wyman Meinzer

This bird, an American avocet, sieves through a shallow Texas playa to find food. These shorebirds appear at playas shortly after the lakes are recharged by rains.

Playa lakes also provide needed habitats for a number of animals including racoons and *migratory birds like these (below).*

Playa lakes also support a rich ecosystem that includes wildflowers and other plants.

Tarleton State Report Studies Dairy Odor Problems

Researchers with the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University have published a report that examines how waste management problems at Central Texas dairies may be producing foul odors. The report, *Preliminary Research Concerning the Character, Sources, and Intensity of Odors from Dairy Operations in Erath County, TX,* includes sections written by John Sweeten of the Texas A&M University Agricultural Engineering Department, and TIAER researchers Larry Frarey, Blair Bremberg, Anne McFarland, Wayne Sharp, and Gary Franklin. The report describes odor management strategies, legal and policy aspects, Texas regulations, field measurements, and use of simulation models. The report outlines how proper dairy management operations that include lagoon sizing and aeration, nutrient loadings, manure and sludge composting, and drainage can reduce odor problems. For details, call McFarland at (817) 968-9567.

TAMU-CC Coastal Studies Center Publishes New Reports About Oil Spill Impacts, Fisheries Management, Wetlands

A number of new technical reports have been published by the Center for Coastal Studies at Texas A&M University-Corpus Christi.

Environmental Impact and Recovery of the Exxon Pipeline Oil Spill and Burn Site, Upper Copano Bay, Year One (TAMU-CC 9402) was written by J. Wes Tunnell, David Hicks, and Beau Hardegree of the Center. A follow-up study with the same title focuses on year two efforts (TAMU-CC 9501) and was written by Tunnel, Hardegree, Hicks and Kim Withers. Both studies focus on environmental damage that occurred when a 10-foot section of an underground oil transfer pipeline burst in San Patricio County in 1992.

Fisheries Management Plans for Texas Coastal National Wildlife Areas: Laguna Atascosa (TAMU-CC 9308) was written by L. David Hoke of the Center. It describes the development of a fisheries management plan for the region, and contains information on wildlife, aquatic species, public use, and species descriptions.

Estuarine Faunal Use in a Mitigation Project, Nueces Delta, TX, Year Four (TAMU-CC 9306), was written by Brien A. Nicolau of the Center. The report evaluates on-going efforts to successfully create a man-made wetlands. It contains information on hydrologic parameters, vegetation, aquatic species, and water quality.

Development and Implementation of the Adopt a Wetlands Program: 1993 Status Report was written by Nivra Kelley of the Center, who also coordinates the program. The report includes information on development and implementation of the Adopt a Wetlands program, outreach efforts, and partnerships. An appendix includes fact sheets, brochures, and an education guide.

For more information on any of these reports, call the Center at (512) 994-2736.

TTI Reports Assess Impact of Potential GIWW Closure

Researchers at the Texas Transportation Institute (TTI) at Texas A&M University have recently published two studies about how a temporary or long-term closure of parts of the Gulf Intracoastal Waterway (GIWW) could affect Texas highway transportation.

A final report, *Closure of the GIWW and Its Impact on the Texas Highway Transportation System* (Research Report 1283-F), was written by TTI researchers Stephen Roop, Daryl Wang, Richard Dickinson, and Gordon Clarke. An interim report with the same title (Research Report 1283-I) was written by Roop, Wang, and Kay McAllister.

The basis for the study is that the GIWW could be temporarily closed if the canal faced structural problems, if natural disasters like hurricanes occurred, or if regulatory or economic problems developed. The reports assess how the closure of GIWW would affect different aspects of transportation including inland navigation, highway traffic and others. It contains information on past GIWW closings and their impacts. Scenarios are described that may cause potentially damaging environmental impacts, such as spills of hazardous materials.

The reports are available by contacting TTI at (409) 845-2623. For more details, contact Roop at (409) 845-5815 or s-roop@tamu.edu.

UT Book Examines How Global Warming May Affect Texas

The University of Texas Press has just published a book that contains recent predictions of how global climate change may affect Texas water supplies.

The report, *The Impact of Global Warming on Texas*, was edited by Jurgen Schmandt of the UT LBJ School of Public Affairs and the Center for Global Studies at the Houston Advanced Research Council, and Judith Clarkson, a consultant to the Center.

Individual chapters were written by Gerald North and John Griffiths of the Texas A&M University Meteorology Department, Juan Valdes of the Texas A&M University Civil Engineering Department, Bruce McCarl, Teofilo Ozuna, and Lonnie Jones of the Texas A&M University Agricultural Economics Department, Wolfgang Roeseler of the Texas A&M Department of Urban and Regional Planning, James Norwine of the Geosciences Department at Texas A&M University-Kingsville, Wesley Rosenthal of the Texas Agricultural Experiment Station at Temple, George Ward of the UT Center for Research in Water Resources, and others. Chapters deal with such varied topics as the impact of global warming on water resources, estuaries, biodiversity, agriculture, urban areas, and the economy, and outline possible policy options to deal with the problem.

To order a copy, contact the UT Press at (800) 252-3206.

1995 Texas On-Site Wastewater Proceedings Published

A new conference proceedings has been published that contains information on new advances in the design and operations of on-site wastewater treatment systems in Texas.

The proceedings from the 1995 Conference of the Texas On-Site Wastewater Treatment Research Council are titled, *We're Creating Solutions*. The proceedings include papers by Council Chairman Bill Harris of the Texas A&M University Soil and Crop Sciences Department, Dudley Burton and David Jumper of the Environmental Studies Department at Baylor University, Andrew Kruzic of the Civil Engineering Department of the University of Texas at Arlington, and Dennis Hoffman of the Texas Agricultural Experiment Station at Temple. Some of the topics covered in the proceedings include the use of new technologies, managing on-site programs, site evaluation and system selection, pre-treatment, and disposal.

A limited number of proceedings are still available for $20. To order, call Conference organizer Denise Rhodes at (512) 482-0321.

TCU Researchers Use GIS, Satellite Data to Estimate Erosion, Soil Losses

Researchers with the Environmental Sciences Program at Texas Christian University (TCU) are working to develop erosion and soil loss maps using geographic information systems. Lead researchers in the study include Ken Morgan, Arthur Busbey, Leo Newland, and Neven Kresic and graduate student Franziska Brun.

The project involved using the Soil Conservation Service's (SCS) Universal Soil Loss Equation and a geographic information system (GIS) to generate computerized maps and data files that show where soil losses and erosion occur in Tarrant County. Data on rainfall and soil erosion potential were obtained from the SCS. Topographic maps were developed from U.S. Geological Survey digital elevation models. Land use was determined by using Multispec software on a Macintosh computer to analyze a Landsat satellite image of the watershed. The data was then input into a GIS using GRASS software from the U.S. Army Corps of Engineers. Erosion sensitivity was first determined on a pixel by pixel basis, and was then multiplied by land uses to develop estimates for soil losses. The study produced a soil loss map of Tarrant County that clearly shows soil losses within individual watersheds. The project shows that automated methods can be used to quickly and inexpensively assess erosion potential. Information on this project was presented at the 1995 Water for Texas Conference. For details, call Morgan at (817) 921-7273 or e-mail him at morgan@gamma.is.tcu.edu"> morgan@gamma.is.tcu.edu.

UH Researchers Evaluate How, Why, San Jacinto River Changed Course After Massive 1994 Floods

When massive floods descended on Houston last fall, most area residents probably viewed the event only as a large pain in the neck. A University of Houston researcher took a different perspective -- he viewed the floods as a research opportunity.

In October of 1994, the remnants of Hurricane Rosa brought heavy rains into Southeast Texas. A convection cell fed by the jet stream subsequently formed, pumping in large amounts of rainfall from the Gulf of Mexico. A "super cell" developed that dropped up to 30 inches of rain on the region in just four days. The storm generated peak flows of 360,000 cubic feet per second and raised the level of the San Jacinto River 19 feet above its flood stage. William Duprè and graduate student Scott Snyder of the UH Geosciences Department have analyzed the effect of these intense storms on the flow of the lower San Jacinto River. Their studies focus on the stretch of the river between Lake Houston and Galveston Bay.

Duprè and Snyder first conducted field studies to examine how and where the river changed its course as a result of the floods. They compared that information to maps and photographs that show the location of the river prior to the flooding. They then examined human activities that may affect the river's course such as dams, bulkheads that stabilize river banks, pipeline crossings, subsidence due to groundwater pumping, and mining the floodplain for sand.

Duprè says the high river level and rapid flows made the river create a new 300-foot wide channel (a meander cut-off) that temporarily shortened its course by 3 miles. This new channel excavated oil and gas pipelines that ruptured and later ignited, setting much of the river on fire. The flood also dumped large amounts of sand in many areas. Many foundations of homes or buildings were damaged or destroyed due to large scour pits that formed as the river topped its banks. One subdivision, Rio Villa, that was on a peninsula was temporarily turned into an island until the road was rebuilt by the highway department.

What can be learned from the flooding? Duprè believes the place where river temporarily changed its course appears to correspond to an earlier course of the river. The break-out occurred at the lowest spot on a natural levee that was protected by a bulkhead. Sand pit mining may have aggravated the situation by removing vegetation that would slow the river's flows and lessen erosion. When next large flood occurs, Duprè says the river will likely reoccupy this new course because it is a shorter, easier path.

This research was presented at the 1995 Water for Texas Conference. For details, contact Duprè at (713) 743-3425 . His e-mail address is: wdupre@uh.edu.

This wrecked home (above, below) shows the effects of massive floods along the Lower

San Jacinto River in October 1994.

This photograph shows how far water levels rose during the Houston floods. The light grey line about halfway up these trees was the highest point floodwaters rose to during the floods. Please also note the large amount of dirt and sediments that flowed into the area with the floods.

Baylor Researchers Assess Runoff, Juniper Water Use, in Washita Watershed

Researchers at Baylor University are conducting a comprehensive study to assess how rainfall flows into complex Central Texas groundwater systems, and to examine if juniper trees are intercepting significant amounts of water before it can recharge local aquifers.

Peter Allen and Carol Tatay (far right) of the Baylor University Geology Department take samples from this stream that runs through the Washita Prairie in Central Texas. A goal of this study was to determine how ground water and surface water flows interact in the region.

The study is being conducted by researcher Peter Allen and graduate student Carol Tatay of Baylor's Geology Department. It focuses on the Washita Prairie, a 76-acre watershed located 12 miles north of Waco in McLennan County.

In the study, the researchers first identified four hydrology zones: 1) overland or surface flow, 2) shallow soil flow, 3) shallow fracture flow, and 4) deep flow. Shallow soil flows includes the A and B soil horizons, where crop roots would typically penetrate. The shallow fracture flow zone is highly fractured and weathered and contributes to streamflow. The deep flow zone is less fractured and provides flows to down-dip aquifers.

In February 1994, the researchers established eight monitoring sites along the watershed to represent typical soil depths, vegetation, slopes and locations. At each site, data is recorded on rainfall, runoff, shallow soil flow, and soil moisture. Shallow soil flows are monitored by using gypsum blocks, mini-piezometers, and soil troughs. Shallow fracture flows and deep flows are measured with piezometers.

Allen and Tatay say that the project has yielded some interesting results. For example, nearly 30 inches of rain fell through September, 1994, but 67% of the storms have generated less than 2" of rainfall. As a result, the only flows that have been measured so far are to the shallow overland and shallow soil flow zones. The key factors that influence runoff appear to be storm intensity and duration. Significantly, the researchers believe that juniper trees in the watershed intercept at least 15% of the rainfall before it can be recharged. This suggests that removing large numbers of junipers could increase the amount of water that flows into shallow soils, but may not boost water levels in deeper flow zones and aquifers.

Information on this project was presented at the 1995 Water for Texas Conference. For details, contact Allen at (817) 755-2361 or Tatay at Tatay@aol.com"> Tatay@aol.com.

Texas Tech Scientists Evaluate How Buffalograsses, Bermudagrass Perform Under Varying Levels of Irrigation

In many arid parts of Texas and the Southwest, landscapers and homeowners are investigating the use of Buffalograss to determine if it can save water while still looking attractive. Recently, a research project at Texas Tech University compared the performance of three Buffalograsses and a Bermudagrass irrigated with varying water levels.

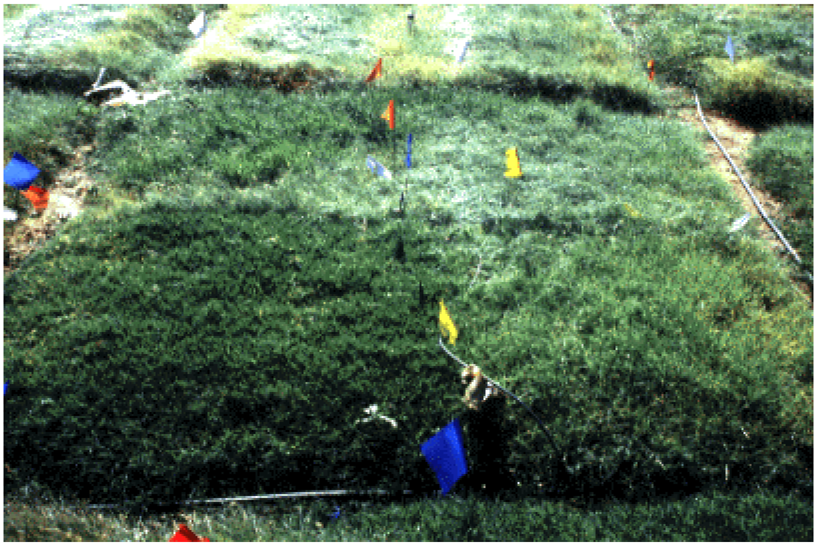
The study was performed by Richard Zartman and Cynthia McKenney of the Texas Tech Plant and Soil Science Department. Turfgrasses that were evaluated include Prairie Buffalograss, Texoka Buffalograss, Common Buffalograss and TexTurf 10 Bermudagrass. Turf plots were established in the Summer of 1992 and the grasses were maintained with minimum irrigation that winter. Beginning in the Spring of 1993, a variable irrigation regime was implemented in which the grasses received 0%, 50% and 100% of the estimated daily evaporation. The grasses were grown on the Texas Tech campus. An expert panel evaluated them for turf quality, density and survivability. Root-length density was measured at 6-inch intervals to a depth of three feet.

1993 results show that there was no significant difference among the grasses in turf density or quality. Turf density was highest for Texoka Buffalograss and lowest for TexTurf 10 Bermudagrass. Turf quality was highest for Texoka Buffalograss and lowest for Prairie Buffalograss. In 1994, survivability was highest for Common Buffalograss and poorest for Prairie Buffalograss. Density was highest for Texoka Buffalograss and lowest for Common Buffalograss. Quality decreased dramatically among many of the turfgrasses because less irrigation was applied. TexTurf 10 Bermudagrass had the best turf quality rating, while Prairie Buffalograss had the lowest.

Root-length analyses show that there were significant differences among turfgrasses at depths of 0 to 6 inches and at depths of 30 to 36 inches. When irrigation was not applied and at the 50% irrigation level, TexTurf 10 had lower root length densities than the Buffalograsses. At full irrigation, TexTurf 10 had the highest root length density. Zartman says that even though many people feel that Buffalograsses use less water than other grasses, turf quality still suffered when irrigation was not applied. To perform well, TexTurf 10 Bermudagrass must be kept moist. Buffalograsses can maintain deep root systems even under limited irrigation.

This paper was presented at the 1995 Water for Texas Conference. For details, call Zartman at (806) 742-1626 or send him e-mail at Zrich@Tttacs.ttu.edu .

This photos shows an overview of experiments at Texas Tech University by Richard Zartman and Cythia McKinney to compare water use among turfgrasses. Zartman and McKinney wanted to determine if Buffalo grasses use less water than conventional turfgrasses like St. Augustine and Bermuda grass.



Much of this research included visually observing how the different turfgrasses looked and grew when varying amounts of water are applied. The research confirms that homeowners want to save water, but also want an attractive lawn.

TAES El Paso Study Uses High Tech Methods to Examine Whether Border Aquifer is Contaminated by Fecal Bacteria

Suresh Pillai, a microbiologist with the Texas Agricultural Experiment Station at El Paso, is using high-tech methods to determine the source of fecal contamination in shallow groundwaters along the Texas-Mexico border. The study is needed because there are concerns that groundwater in the region may be contaminated. The likely sources of fecal contamination are raw sewage discharged from Juarez and/or inadequate or poorly functioning on-site wastewater systems. As a result, the rates for viral-borne diseases like Hepatitis A are much higher than normal in nearby colonias (areas without drinking water and wastewater treatment).

Student worker Edgar Rubio (to left) and TAES technician Kenneth Widmer take this sample from a septic drainfield near El Paso.

Pillai first collected samples from 19 groundwater wells used for drinking water at colonias near San Elizario. Bacterial isolates were obtained and the genotypes and phenotypes were identified to determine if the bacteria resulted from sewage contamination. Pillai then used genetic finger-printing (DNA amplification) and conventional microbiological methods to compare the different bacteria strains and to assess if they may have come from a common source.

The results of the research show that none of the groundwater samples contained the fecal coliform *E. Coli* bacteria, which is commonly used to test for the presence of sewage, although many related species of "enterobacteria" were found. The bacteria found in different wells were not genetically similar enough to suggest that large amounts of contamination originated from a single source. Antibiotic resistance studies suggest that the bacterial populations in the groundwater are probably native to the shallow aquifer.

Pillai says the results show that methods now commonly used to test for fecal contamination may not be reliable and that new technologies like the DNA analyses used in this study may be needed.

This project was presented at the 1995 Water for Texas Conference. For details, call Pillai at (915) 859-9111.

Texas A&M, Oklahoma U., Researchers Study Subsurface Microbes and Microbial Geochemistry

Remediation of contaminated aquifers is a growing concern. Because certain natural bacteria have shown the ability to degrade a number of pollutants including benzene, phenols, and trichloroethylene, *in situ* bioremediation has been proposed as a simple solution to this difficult problem. With this growing interest in *in situ* bioremediation, scientists at Texas A&M University and the University of Oklahoma are trying to understand the nature of the Earth's deep subsurface biosphere.

The study is being conducted by Ethan Grossman of the Texas A&M Department of Geology & Geophysics, Jim Ammerman of the Texas A&M Department of Oceanography, and Joe Suflita at the University of Oklahoma. The researchers are studying factors that control the distribution, origin, impact, and survival of subsurface microorganisms. The project is funded by U.S. Department of Energy's Subsurface Science Program. The researchers hope to answer questions like are the bacteria in Eocene aquifer sediments in Texas the progeny of bacteria buried with the sediments 40 million years ago, or were they transported into the aquifer with groundwater and thus at the surface as recently as 100s of years ago?

Lloyd Morris (left) of the Texas A&M Oceanography Department and Darryl Martino of the Texas A&M Geology Department obtain groundwater samples.

The researchers are interested in the factors that may have allowed bacterial communities to survive for up to 40 million years. They are examining the possibility that ecological relationships exist between the different bacterial communities of different strata. Do bacteria in aquitards supply substrate and nutrients to bacteria in aquifers? Do methane-producing bacteria in aquitard shales supply methane to methane-consuming bacteria in aquifer sands? Do fermenting bacteria in organic-rich shales provide end products like acetate for sulfate-reducing, acetate-oxidizing bacteria? These microbial interactions might be mechanisms for long term survival in the nutrient-poor subsurface environment.

The study will compare and contrast microbial populations and geochemical environments in different lithologies, and look for geochemical gradients that would provide evidence for nutrient and oxidizing-agent fluxes. To date, Eocene sediments have been cored on the Texas A&M campus to depths of 100 feet, and wells have been installed. The sediments provide a variety of lithologies and microbial environments, including sands, silts, clays, and lignites. During drilling, cores are carried back to the lab, aseptically trimmed to remove the contaminated exterior, and sampled for microbiological, isotopic, and geochemical analyses. Inert tracers are sent down the hole to check for surface contamination.

Preliminary results show 250 to 15,000 viable aerobic bacterial cells are present per gram of sediment. Methane-consuming bacteria and anaerobic sulfate reducing bacteria (SRB) are common in many core intervals. Groundwaters are anoxic and yield high iron and sulfate contents, low sulfide levels, and abundant SRB. Work continues to characterize the sediment bacterial populations and related geochemistry, including the use of stable sulfur isotopes on sedimentary sulfide and sulfate to examine the impact of SRB and other organisms. Future efforts will focus on drilling deeper to sample zones of bacterial methane production.

This paper was presented at the 1995 Water for Texas Conference. For details, call Grossman at (409) 845-063 or send him e-mail at elg2249@geopsun.tamu.edu.

Texas Tech, TAES Researchers Assess How Widespread Use of Efficient Irrigation Technology Affects Groundwater Levels

Researchers with Texas Tech University and the Texas Agricultural Experiment (TAES) are studying how limited groundwater supplies affect the use of irrigation and crop patterns on the Texas High Plains. The research is led by Eduardo Segarra and Yinjie Feng of the Texas Tech Agricultural Economics Department and William Lyle, an agricultural engineer with TAES in Lubbock.

Bill Lyle (above) of the Texas Agricultural Experiment Station at Lubbock has conducted extensive research on how to make irrigation systems like this one that are used for agricultural crop production more water efficient.

The studies center on the use of dynamic computer models over a 50-year planning horizon to simulate tillage and irrigation practices and operating and irrigation costs under such constraints as operating capital and land availability. The researchers also simulated various depths to groundwater and groundwater supply conditions. The objective function of the models was to maximize the present value of returns to land, management, and aquifer levels.

Modeling results suggest that current cropping patterns are far from optimal, based on current groundwater levels, prices, and capital constraints. The modeling efforts projected that irrigated cotton should increase substantially, while dryland cotton, irrigated sorghum, and irrigated corn could be greatly reduced. Modeling scenarios in which pumping lifts were varied suggest that increased depths to groundwater would probably reduce irrigated acreage by increasing irrigation costs and reducing operating capital. When reduced groundwater supplies were simulated, the amount of dryland cotton increases sharply and irrigated acreage decreases.

Segarra says that many lessons can be learned from this study. First, the amount of available groundwater will probably influence crop patterns and irrigation use more than pumping lifts. Irrigated acreage is not likely to decline in the next 20 to 30 years, except in areas where groundwater supplies are already low. Finally, adoption of more efficient irrigation technology may not lead to groundwater conservation. Instead, it may trigger increases in irrigated acreage that may offset per acre water savings. For details, call Segarra at (806) 742-2022 or Lyle at (806) 746-6101.