Texas Water Resources Institute
Annual Technical Report
FY 2003

Introduction

The Mission of the Texas Water Resources Institute is to:

(1) Provide leadership for Experiment Station and Extension research and education water programs statewide, coordinating with scientists, specialists, county agents, administrative personnel and other agencies and water groups. (2) Serve as the designated Water Resources Research Institute for the State of Texas, as part of the National Institutes for Water Research Program and established by the Texas Legislature. (3) Obtain and manage external funds for research, academic programs, outreach, and education projects. (4) Establish TWRI as the focal point for water research and outreach efforts within the Texas A&M University System. (5) Develop relationships with policymakers, elected officials and water resources leaders throughout Texas. (6) Identify emerging water resources issues that may be significant funding sources, and communicate these issues to researchers, stakeholders, and the public. (7) Communicate TWRI projects, research opportunities, research results, resource materials, and water resources news to the public. (8) Support and help faciliatate water related academic programs and administer scholarship programs for students involved in water related studies.

Research Program

During 2003-04, the Texas Water Resources Institute funded 12 research projects to graduate students at universities throughout Texas. Students were supported at Texas A&M University (9 projects); the University of Texas at Austin (2); and the University of Texas at El Paso (1).

These studies covered several broad subjects, including the following: brush control to improve water yields (3 projects); the development and application of computer models (3); hydrology (3); water conservation (1); groundwater (3); surface water (3); water use (3); bays and estuaries (1); aquatic ecosystems (2); water policies (1); the economics of water use (1); water treatment (1); non-point pollution (1); and water quality (5). Note that several projects include more than 1 topic.

Jason Afinowicz of the Texas A&M University (TAMU) Biological and Agricultural Engineering Department developed and tested methods to identify sites where brush control is most likely to be successful in increasing water yields using such methods as geographic information systems (GIS), computer models, and remote sensing. Jonathan Goodall of the Civil Engineering Department at the University of Texas at Austin (UT) worked to couple complex hydrologic models so they can be displayed and queried through such GIS applications as the ArcHydro software package. Catalina Ordonez of the University of Texas at El Paso explored water quality along a remote and sparsely populated reach of the Rio Grande (the Forgotten River) as well as whether pollutants may be naturally remediated. Roger Havlak of Soil and Crop Sciences Department at TAMU investigated how individual components of landscapes influence water use and assessed whether the water-use behavior of homeowners was affected by whether they had taken part in conservation education programs. Leslie Randolph of the TAMU

Geology and Geosciences Department examined groundwater formations in Central Texas to identify how radon levels vary in the regions groundwater and sought to assess how geologic conditions affect radioactivity concentrations. Alyce Lee of the Oceanography Department at TAMU examined how algae in Texas bays respond to increased salinity of estuarine waters that may result from reductions in freshwater inflows. Alyson McDonald of the TAMU Rangeland Ecology and Management Department carried out field studies along the Pecos River in West Texas. She sought to better understand how water yields created by clearing salt cedar are partitioned to surface and ground waters in the region. Ju Young Lee of the TAMU Civil Engineering Department investigated the relationships between agricultural crop production and water use in the Edwards Aquifer region using state-of-the-art computer models. Gil Strassberg of the UT Civil Engineering Department created digital libraries that will help the ArcHydro GIS better analyze and model issues relating to groundwater resources. Yoko Masue of the TAMU Soil and Crop Sciences Department worked with researchers in the TAMU Civil Engineering Department to evaluate methods to treat and remove arsenic contaminants using compounds that include mixtures of aluminum and iron. Brandon McDonald of the TAMU Soil and Crop Sciences Department worked to estimate how nutrients associated with composted dairy manure are assimilated when they are used to grow turfgrass sod as well as the potential for nonpoint pollution from runoff associated with turfgrass production and use. Shane Porter of the TAMU Biological and Agricultural Engineering Department tested the use of a rainfall simulator to determine how water is partitioned between brush species that are being considered for brush control measures.

Determining a Method for Targeting Brush Control Through Remote Sensing, GIS, and Hydrologic Modeling

Basic Information

Title:	Determining a Method for Targeting Brush Control Through Remote Sensing, GIS, and Hydrologic Modeling
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Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Models, Surface Water
Descriptors:	Brush Control, Hydrology, Computer Models
Principal Investigators:	Jason D. Afinowicz, Clyde L. Munster

Publication

1. Jason D. Afinowicz, Clyde L. Munster, Bradford P. Wilcox. 2003. Using the SWAT Model to Optimize Water Yield from Brush Control in the Upper Guadalupe River Basin. American Geophysical Union, Fall Meeting. Poster presentation.
2. Jason D. Afinowicz, Clyde L. Munster, Bradford P. Wilcox, Ronald E. Lacey. In Review. An Efficient Process for Assessing Wooded Plant Cover by Remote Sensing. Journal of Range Management.
3. Jason D. Afinowicz, Clyde L. Munster, Bradford P. Wilcox. Pending Submission. Modeling the Effects of Brush Management for Increasing Water Yield on the Edwards Plateau, Texas. Journal of the American Water Resources Association.

Verification of a Methodology for Targeting Brush Control to Maximize Water Yield Through Hydrologic Modeling

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Abstract

Brush control strategies have been implemented for many traditional grasslands that have been impaired by wooded species. However, little information is known concerning what site specific characteristics may be most beneficial for increasing water yields by returning shrub encroached areas to native grasslands. This paper discusses a number of potential targeting criteria for successful brush management and outlines a methodology for testing the role of steep slope, brush density, and shallow soils on successful use of vegetation replacement for increasing water yield.

Introduction

In the past century, shrub encroachment over the herbaceous rangelands of the southwestern United States has been recognized as a consistent phenomenon that has drastically altered the traditional landscape (Humphrey, 1958). The proliferation of these native but previously non-dominant species has been attributed to a variety of causes including human induced changes and atmospheric adjustment in the form of CO_2 enrichment. However, the most important factors for the movement of wooded species from upland slopes to herbaceous lowlands are, more than likely, the increase in range grazing and the reduced frequency of fire events (Van Auken, 2000).

Most of the unwanted brush species have been varieties of juniper (*Juniperus ashei and Juniperus pinchotti*) and mesquite (*Prosopis glandulosa*). It is believed that these species may be more taxing upon the available water supply of arid and semiarid regions by way of their interception mechanics and transpiration of water to the atmosphere. Plot scale studies in Texas have indicated a potential per hectare savings of between 375,000 to 935,000 liters of water per year by returning juniper dominated rangeland to herbaceous species (Owens, 1996). By estimating the effects of vegetation replacement over a basin sized scale, many studies have added merit to this notion of brush management as a viable option for easing water issues in water-scarce regions (Brown and Raines, 2002; Bednarz et al., 2001; Wu et al., 2001; Red River Authority, 2000).

Arrington et al. (2002) experimented with several scenarios for brush control in an effort to minimize ecological impacts on native animal and aquatic species as well as ensure slope stability and prevent erosion following brush control. The study examined the effects of brush control for increasing water yield while implementing several best management practices (BMPs). These included preventing brush removal on slopes greater than 15%, instituting a 75-m "no-cut" buffer strip on either side of stream channels, and the selective cutting of brush to allow for wildlife habitat outside of immediate riparian areas. Results indicated that brush management could produce favorable results while still implementing BMPs for protecting local ecology. Thought the study provided very useful information for making brush management ecologically friendly, no attention was given to maximizing removal efficiency for water yield.

The State of Texas has already begun the subsidized removal of brush with hopes of increasing available water through the use of a cost-sharing program regulated through the Texas State Soil and Water Conservation Board (TSSWCB). In 2002, expenditures for program implementation and research totaled $24 million. Most of the efforts of this program have been aimed at renovating the North Concho River watershed with an expected cost of the additional water averaging $43 dollars per million liters. This estimate is less than half of the projected cost of alternate sources of water (TSSWCB, 2002).

However promising the projections may appear, a specific methodology for targeting prime locations for brush management would be beneficial to both economics and hydrology. Currently, though consideration is to be given for local characteristics when choosing sites for brush control, there are no standards for locating ideal areas for treatment (TSSWCB, 2002). If certain characteristics were identified as significantly beneficial to the cause of enhancing water yield, land owners owning property meeting these characteristics could be targeted for the cost-share plan before owners of less desirable land. In effect, brush control funds would be spent in the most effective and efficient manner.

Several characteristics have been either theorized or tested in the past for enhancing the effects of brush removal from range environments. Hibbert (1983) and Bosch and Hewlett (1982) indicated a maximization of effect from vegetation replacement in locations where annual precipitation exceeded a threshold of 450 mm. Steep slopes have also been found to be vital in brush control scenarios where overland flow is a goal (Wright et al., 1976). Wilcox (2002) also proposes three additional factors for maximizing water yield in rangelands: 1) heavy brush cover, 2) shallow soils to allow rapid entry of water to the subsoil, and 3) geologic substructure that allows water to permeate past the root zone to avoid uptake by plants.

This study aims to examine these characteristics and evaluate their effects upon rangeland hydrology through the use of the Soil and Water Assessment Tool (SWAT) and explain the progress of the continuing research into the targeting of brush management.

Area of Study

The region chosen for modeling in this study lies in the Upper Guadalupe River watershed (HUC 12100201) of Central Texas (Figure 1). The more than 3,700 km^2 area drains into Canyon Lake near New Braunfels where it enters the Middle Guadalupe River. The region of particular interest lies above the USGS gauging station (USGS #08167500) at the community of Spring Branch, located west of Canyon Lake, that has a drainage area of nearly 3,400 km^2 (USGS, 2003).

Average annual precipitation in the Upper Guadalupe River watershed ranges from approximately 660 mm along the far western edge of the watershed to as much as 900 mm in the eastern portion of the basin (PRISM, 2002). Temperatures range from a low mean monthly temperature of 8°C in January to a high monthly mean of approximately 27°C in July.

Local topography varies between rolling hills and steep rocky outcrops. Land cover is predominately rangeland, most of which is dominated by woody species. These factors encourage ranching rather that traditional farming practices throughout all but the lowland valleys in the basin.

Geology is characterized by fractured substrate consisting largely of Upper and Lower Glen Rose limestone that underlies an Edwards limestone layer in upland areas (Texas Bureau of Economic Geology, 1986 and 1982). These highly porous karst structures can be easily seen below the predominant shallow soil layers. Common soil types throughout the watershed include Eckrant, Tarrant, and Purves series.

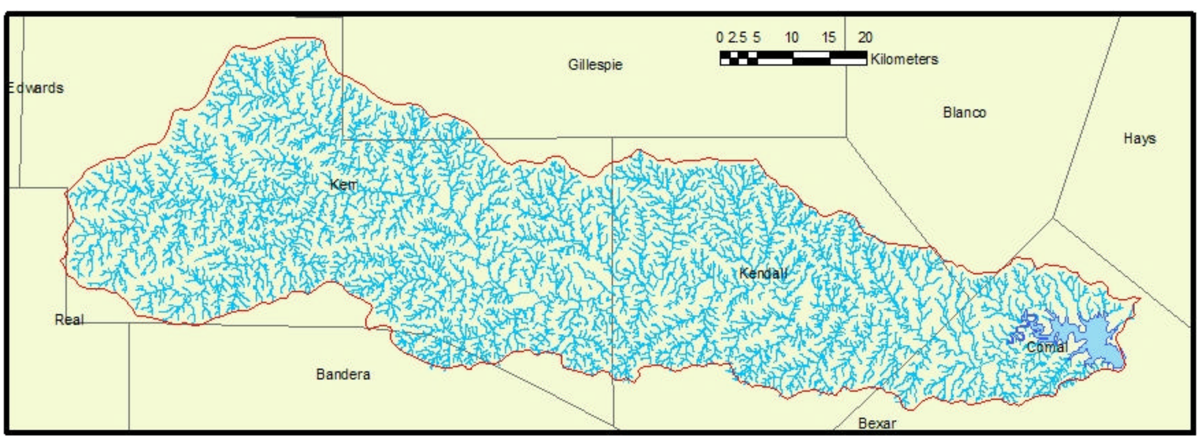

Figure 1: Map of the Upper Guadalupe River Watershed, Texas

Methods

To effectively evaluate the role of the aforementioned characteristics on water availability changes brought upon by the removal of wooded plants it is necessary to utilize: 1) a model that is capable of simulating hydrology for complex scenarios including soil thickness, hillslope, and the effects of land cover for the entire water balance including evaporation and transpiration, and 2) sufficient available data to drive the model that will realistically characterize these factors for a real world scenario. For the needs of this study, the SWAT model was selected because of its comprehensive inclusion of the entire watershed cycle and its ability to accept data from a variety of highly detailed sources. These reasons have also led to the use of SWAT in a number of other brush related studies (Arrington et al., 2002; Bednarz et al., 2000).

Because the study watershed lies within an area receiving more than 450 mm of precipitation annually, regional effects of climate were disregarded for this study. The entire watershed was selected for simulated treatment without regard to annual rain patterns.

Geology was also neglected as a characteristic for brush removal site selection. Insufficient spatial information exists to properly characterize the influence of this parameter even though the model is capable of incorporating subsurface characteristics through the use of an external subroutine (Sophecleous and Perkins, 2000).

Data collection

Data selection for the remaining parameters (land cover, soil series, and topography) was conducted with special attention to providing data for the model that would best characterize the conditions that are to be tested. In the case of land cover, no dataset was readily available for use in quantifying the amount of wooded cover. A first priority of the study aimed to create a suitable data product from Landsat ETM+ imagery of the watershed and associated aerial photography in the form of Digital Orthopoto Quadrangles (DOQs). Multiple Resolution Land Cover (MRLC) data was used in conjunction with the multispectral Landsat imagery to train a Bayesian classifier for determining coarse classifications for the study area. These classifications included rangeland, wooded land, agricultural fields, and various urban lancovers. The use of the MRLC dataset, produced from information gathered prior to 1992, and Landsat imagery contemporary to 1999, allowed the creation of an updated land cover dataset that would represent the extent of wooded growth for analysis and also create a general land cover set for use in the SWAT model.

The coarse land cover set described above was further refined with the use of spectrally classified high resolution aerial photography to estimate the amount of wooded cover and define each pixel of range land cover according the amount of observed wooded growth as one of four categories: heavy wooded cover (>50%), moderate wooded cover (20-50%), light wooded cover (5-20%), or open range (<5%). By further categorizing land cover by the amount of wooded growth present, it is possible to assign a separate curve number to each class to properly represent the effects of varying ratios of brush to herbaceous growth on hydrology.

Additionally, the effects of slope were accounted for in the model to realize its role in increasing water yield from vegetation replacement. Though the SWAT model does not automatically incorporate slope for adjusting curve numbers, this can be conducted manually for varying amounts of slope by further characterizing land cover classes by not only coarse description and the amount of wooded cover, but also by the slope present. These further divided classes can then be assigned an adjusted curve number according to the grade of the land (Arrington et al.). For the purpose of this study, slope was determined by the analysis of a composite 30-m National Elevation Dataset (NED) for the Upper Guadalupe River watershed. Regions with a slope of less than 8% were considered generally flat and received no curve number adjustment. Land with a slope between 8 and 15% were considered moderate slopes and had an associated curve number that was adjusted to reflect this change. Regions with slopes greater than 15% were considered steep slopes and the associated curve numbers were adjusted accordingly. Range with heavy, moderate, and light brush, along with herbaceous rangeland covers were all analyzed for slope in this manner and received adjusted curve numbers to ensure effective parameterization of slope effects.

Equation [1] was used to adjust runoff values using the standard moisture condition II curve number (CN_2), the adjusted curve number for moisture condition III (CN_2), and the average percent slope of the response unit (*slp*).

$$CN_{2S} = \frac{(CN_3 - CN_2)}{3} \cdot [1 - 2 \cdot \exp(-13.86 \cdot slp)] + CN_2 \qquad [1]$$

Adjustment for CN_3 was performed using equation [2] (Neitsch et al., 2001).

$$CN_3 = CN_2 \cdot \exp[0.00673 \cdot (100 - CN_2)] \qquad [2]$$

Soil data was obtained in the form of the NRCS Soil Survey Geographic (SSURGO) database. These datasets, which are comparable to traditional paper soil survey maps) provide the most highly detailed spatial information available for soil types. SSURGO datasets were obtained for Bandera, Comal, Blanco, Gillespie, Kendall, Kerr, and Real counties and mosaiced to provide complete soil coverage for the entire watershed. Because some of the datasets were provided in the new SSURGO 2.0, there was no method available for incorporating the information in the soil database directly into the model as has been performed for the older SSURGO 1.0 datasets (Buland, 2003). To fill in this information gap, tabular information from the Texas State Soil Geographic database (STATSGO) was keyed to the dominant soil series for each spatial map unit in the SSURGO database.

In addition to the information required to characterize the brush covered regions to be modeled in this study, a variety of other inputs were obtained for use in driving the SWAT model. Topographic data for watershed delineation and subbasin parameterization was obtained from the same mosaiced NED used in determining regions of steep slope for curve number adjustment. Hydrography was provided by the National Hydrography Dateset for aid in delineating the stream body. Climate data for precipitation was obtained from the National Climate Data Center for seven stations in and around the Upper Guadalupe River watershed, and three of these stations also provided temperature information. A period of record between 1987 and through 2001 was obtained for use in calibration, validation, and simulations. Additional climate data, including missing values from the weather record, was estimated from statistical data using SWAT's weather generator.

Setting up the model

The SWAT model was prepared for simulation by delineating the Upper Guadalupe River watershed. A subbasin threshold of 2000 ha was used in an effort to optimize model performance and detail. The addition of soil and land cover layers was performed to create Hydrologic Response Units (HRUs) that provided a reasonable assessment of heterogeneity without proving overly taxing on the model engine. Significance thresholds of 1% and 3% were set for subbasin land cover content and land cover soil content values, respectively.

For initial simulations, default values for SWAT variables were used until calibration could yield more precise information for the model. An exception to this is the use of a baseflow a value obtained from stream gauge analysis with a baseflow filter. Automated techniques for determining this baseflow vale have been commonly accepted as reliable ways of paramaterizing baseflow in hydrologic models (Arnold et al., 1995). The importance of this parameter in karst hydrologic systems was illustrated by Spruhill et al. (2000) and provided good reason for added attention to this value.

Future Progress

The research described throughout this paper is ongoing and will require additional effort to yield results for determining the importance of the proposed factors for selection of sites for brush removal.

Model calibration and validation

Model calibration is currently being performed above USGS gauge #08165300 on the North Fork of the Guadalupe River; a drainage area of approximately 36,000 ha. The same stream gauging data that was used in baseflow analysis will be used to calibrate the model for channel flow and baseflow on a daily timestep for the period between 1987 and 2001. Upon completion of this process, validation will be performed using the neighboring Johnson Creek watershed that encompasses 29,000 ha (Above USGS gauge #08166000).

Brush removal simulations

Upon successful calibration and validation of the SWAT model, simulations will be conducted to evaluate the effects of the hypothesized targeting criteria on water yield following brush management. This will be carried out by modeling the Upper Guadalupe River watershed above Canyon Lake for a control condition, as well as five control scenarios (Figure 2).

Scenario	No Brush Removal	Wildlife Restrictions	Focusing Criteria		
			8<Slope<15%	Brush>50%	Soil<1-m
I	•				
II		•			
III		•	•		
IV		•		•	
V		•			•
VI		•	•	•	•

Figure 2: Overview of brush control scenarios.

Scenario I will provide a control condition to compare the brush removal simulations to. The land cover set used will be representative of the Upper Guadalupe River watershed at the time of the remote sensing study and the same as the data used in calibration and validation phases of the model.

Scenario II will demonstrate the most complete removal of heavy and moderate brush throughout the watershed by replacing these land covers with light brush. Consideration for the location of management will only be made for slopes greater than 15% and 75-m no-cut zones around water bodies where brush will not be removed, as recommended by Arrington et al. (2002). These criteria will be used to limit brush control for all of the following removal schemes. This scenario will simulate removal effects without regard to the focusing criteria discussed by this paper.

Scenario III will limit brush clearing to only the heavy and moderate brush found on slopes between 8 and 15%. Scenario IV will explore the effect of brush cover on removal efficiency by removing only heavy brush from the watershed and leaving moderate brush behind. Soil depth will be examined in Scenario V by limiting control to regions with shallow soils of less than 1-m in depth. Finally, Scenario VI will take into account all of the proposed criteria by selecting only regions of moderate slope, heavy brush, shallow soil, and no wildlife restrictions. The percentages of heavy, moderate, and light brush present in each scenario are illustrated in Figure 3.

Scenario	Heavy Brush	Moderate Brush	Light Brush
I	54.36	27.38	7.47
II	14.3	6.01	69.27
III	48.09	24.31	17.17
IV	14.3	27.19	48.09
V	26.07	12.16	51.35
VI	49.47	27.19	12.91

Figure 3: Percent of heavy, moderate, and light brush land covers for each scenario.

Analysis will be conducted by observing the difference in water yield (including groundwater recharge and surface flow) between the scenario I (control) condition and the experimental condition on a basis of water yield increase per hectare of treatment. The proposed focusing criteria will be judged on a basis of how effective they are at targeting the most important brush impaired locations for control.

Conclusions

This paper presents a list of potential criteria for brush control site selection to increase water yield in semiarid and arid range environments that are impaired by wooded species. The SWAT model is evaluated for use in determining the importance of three of the proposed rules and it is demonstrated that the model is capable of simulating the hydrology to a necessary degree to ascertain the importance of slope, brush cover density, and soil depth in choosing sites for management.

Additionally, a plan is described for using the model to evaluate these criteria on a basis of their efficiency for locating the most important locations for management for water yield. Completion of the prescribed course of action will prove to be a benefit to understanding the role of certain factors on the effectiveness of vegetation replacement as a BMP and also the way that brush management should be approached for maximum benefit.

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Coupling Modular Hydrologic Models with GIS

Basic Information

Title:	Coupling Modular Hydrologic Models with GIS
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End Date:	2/28/2004
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Research Category:	Engineering
Focus Category:	Models, Hydrology, Floods
Descriptors:	Geographic Information Systems, Computer Models
Principal Investigators:	Jonathan Goodall, David R. Maidment

Publication

1. Goodall, J. L. and D. R. Maidment (2004). Representation of Spatial and Temporal Data in ArcGIS. AWRA 2004 Spring Specialty Conference: GIS and Water Resources III, Nashville, NC.
2. Goodall, J. L. and T. Whiteaker (2003). Water Quality Modeling in GIS. GIS Hydro 2003: Preconference to the ESRI International User's Conference, San Diego, CA.
3. Sorenson, J. K., J. L. Goodall, D.R. Maidment. (2004). Arc Hydro Time Series Framework for Defining Hydroperiod Inundation. AWRA 2004 Spring Specialty Conference: GIS and Water Resources III, Nashville, NC.
4. Zoun, R., D. R. Maidment, J.L. Goodall. (2003). GIS as a Tool for Assisting TMDL Development. Twenty-Third Annual ESRI International User Conference, San Diego, CA.

Coupling Modular Hydrologic Models with Geographic Information Systems

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PROGRESS REPORT

February 20, 2004

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Center for Research in Water Resources

The objective of this project was to investigate using dynamic linked library (DLL) files as a method for linking processing routines with spatial and temporal data stored in geographic information systems (GIS). DLL files can contain legacy and original code written in any COM-compliant language and can be accessed through any COM-compliant language. This means, for example, code written in Fortran can be called from a Macro written in Visual Basic of Applications in ArcGIS.

This concept was tested with two test cases: (1) estimating the non-point source fecal coliform loading to Galveston Bay, Texas and (2) estimating the point and non-point source nitrogen loading along the Guadalupe River, Texas using the USGS SPARROW model regression equatio ns(2003; Zoun, Maidment et al. 2003). Both of these test cases used a tool developed at the Center for Research in Water Resources (CRWR) for processing an Arc Hydro Schematic Network. Background on Schematic Network Processing can be found on the web at the following URL:

http://www.crwr.utexas.edu/gis/gishydro03/Schematics/SchematicNetwork.htm.

The first test case (Figure 1) included subroutines stored in a DLL file that estimated in-stream decay as a first-order chemical reaction, and the each bay's concentration using CFSTR (Constant flow stirred tank reactor) assumptions. The estimated long term bay concentrations matched observed concentrations in each bay segment.

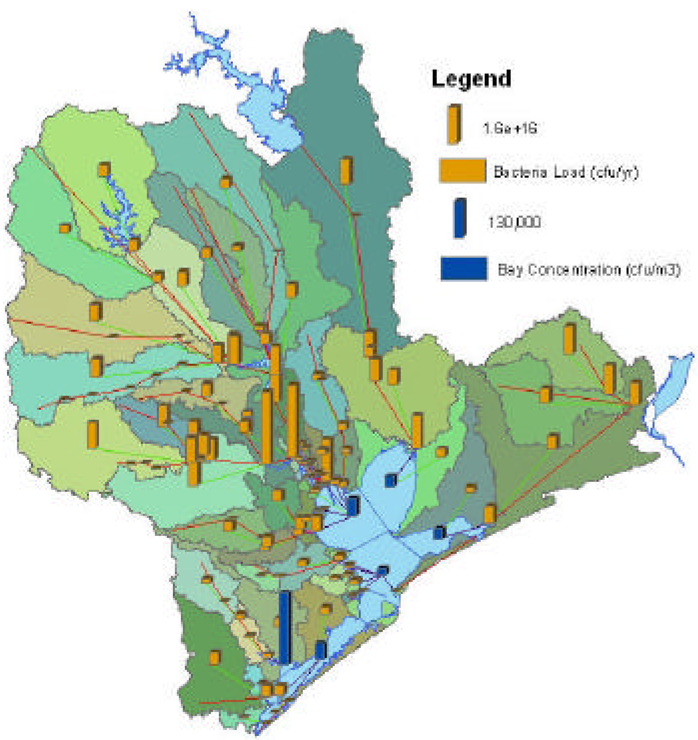


Figure 1 – Case Study 1 estimated non-point fecal coliform bacteria delivered to Galveston Bay

The second test case used the USGS SPARROW (SPAtial Referenced Regression on Watershed Attributes) model to estimate land-to-river decay and in-stream decay processes. Functions to estimate the non-point source loading within each watershed and the in-stream decay for each river reach were stored in a DLL file and used in conjunction with the Schematic Network Processing tool to estimate non-point and point source loadings for

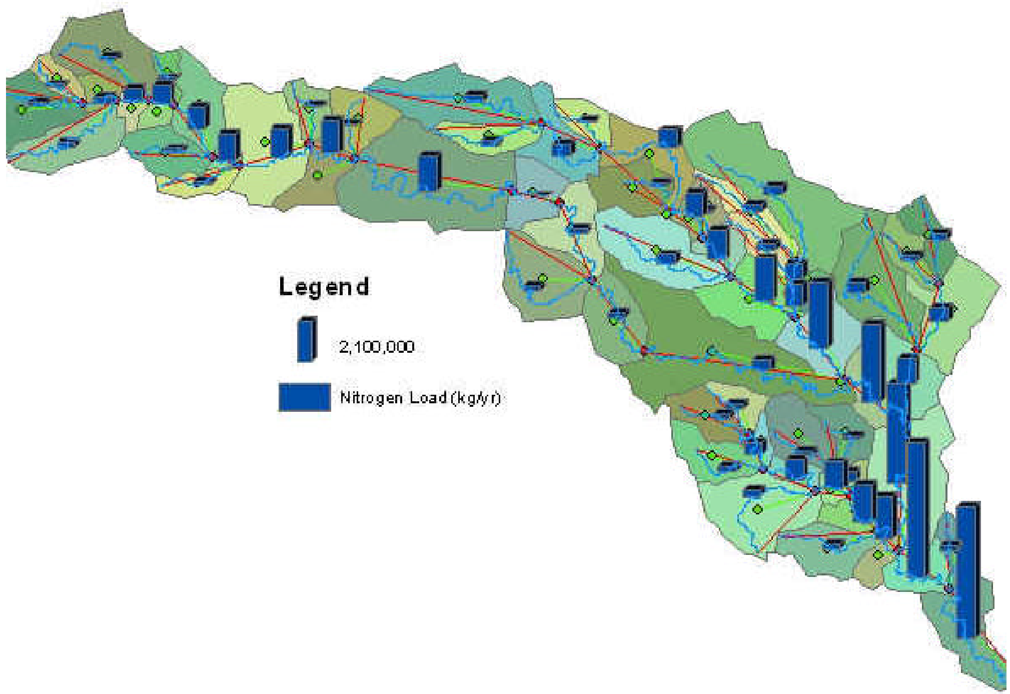


Figure – Case Study 2 estimated point and non-point nitrogen loading along the Guadalupe River.

Both test cases were to estimate the long-term loading (kg/yr) and did not account for seasonal variability. This is in part because geographic information systems are not particular strong at dealing with temporal data. Recent research at CRWR has focused on developing a framework for storing time series and spatiotemporal data in a GIS database(Goodall and Maidment 2004; Sorenson, Goodall et al. 2004). This research is necessary for establishing the foundation for integrating geospatial data common in GIS with time series data common in many industry standard water resources simulation models.

Following are the publications resulting from this research:

WHAT WE HAVE LEARNED

We have learned through this research that storing modular simulation functions and subroutines in DLL files provides a powerful means for linking processing routines with geospatial data in GIS. A major benefit is that the routines written in a DLL file can be accessed through many software systems. One can write generic, modular functions and routines in a DLL file that can be accessed through Macro routines in Excel or GIS. The functions in the DLL file can be used in Excel just as predefined functions. The same functions in the same DLL can be used in GIS to estimate non-point source pollutant load. This suggests the possibility of sharing processing routines as freely as sharing data. The key to making this happen is clear documentation of the functions and subroutines and for the functions and subroutines to be developed in a generic manner that accepts universal data types (numeric, character, arrays, etc.).

We have also learned through this research that a major obstacle to water resources analysis in GIS is extending GIS to include time series and spatiotemporal data. Without a formalized methodology for incorporating time into GIS, dynamic water resources processing routines, such as those used by the Army Corps of Engineering Hydrologic Engineering Center (HEC) models, can not be used in GIS. Time series measured at a gage must be linked to the geospatial location of the gage; flood inundation polygons must be temporally referenced so that one can visualize a dynamic flood event; rain measured by NEXRAD and stored as rasters must be stored in a time-indexed series.

PROGRESS ON FUNDS EXPENDATURE

The remaining balance for the research funds is $2,081.76. The main purchase thus far has been for a laptop computer ($1,930.34). The remaining money is being allocated to attend a conference where the final results of this research project will be presented. The exact conference is yet to be determined.

PROGRESS ON GRADUATE DEGREE PROGRAM

I am in my third year of graduate school. I received my master's degree in civil engineering from the University of Texas in May of 2003. In August of 2003 I successfully passed the Ph.D. qualifying exam and in January 2004 was accepted as a Ph.D. candidate. The final steps in obtaining my degree are to propose and defend a dissertation. I have completed a first draft of the dissertation proposal and am making revisions suggested by my supervising professor, Dr. David Maidment. The anticipated proposal defense date is March 12, 2004 and the anticipated dissertation defense date is the summer of 2005.

ADDITIONAL FUNDING RELATED TO THIS PROJECT

This project has not yet directly led to any additional funding.

Predicting Water Use in Urban Residential Landscapes

Basic Information

Title:	Predicting Water Use in Urban Residential Landscapes
Project Number:	2003TX88B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	31
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Use, Conservation, Irrigation
Descriptors:	Landscape Water Use, Urban Water Conservation
Principal Investigators:	Roger D. Havlak, Richard H. White

Publication

1. Havlak, R.D., White, R. H., Chalmers, D. R. Mackay, W. A., Thomas, J. C. PREDICTING WATER USE IN URBAN RESIDENTIAL LANDSCAPES, Texas A&M University, Texas Agricultural Experiment Station, Texas Cooperative Extension. Presented at 2003 Texas Water Summit.
2. Havlak, R., Are You Doing What You Can to Manage Turf Irrigation? Texas Cooperative Extension, San Antonio, Texas. Presentation to the 2004 Texas Nursery and Landscape Association Annual conference.
3. Havlak, Roger., "Water Use in Home Landscape," Texas Cooperative Extension. 2004 Annual Conference of the Texas Turfgrass Producers Association.
4. Soil Water Dynamics in Urban Landscapes. Presentation given at the 2003 Annual Conference of the American Society of Agronomy.
5. Combined Water Use of Turf and Woody Ornamentals in an Irrigated South Texas Landscape. Masters. May 2004.
6. White, R., Havlak, R., Nations, J., Pannkuk, T. Thomas, J., Chalmers, D., and Dewey, D. 2004. How much water is enough? Using pet to develop water budgets for residential landscapes. Texas Water 2004. Proceedings of the Texas Section, American Water Works Association, Arlington, Texas. April 5-9, 2004.

TEXAS WATER RESOURCES INSTITUTE
U. S. GEOLOGICAL SURVEY GRANT

PROGRESS REPORT
2002—2004

TITLE:

"Predicting Water Use in Urban Residential Landscapes"

PROJECT LEADERS:

Dr. Richard White, Professor—Turfgrass , Texas A&M University
Roger D. Havlak, Extension Turfgrass, Texas A&M University

SUMMARY OF PROGRESS:

The focus of our research is to develop a water conservation guide for municipalities to use that will allow them to evaluate existing landscape water use data and provide a mechanism for evaluating conservation outreach programs. To reach this objective, landscape water use needed to be analyzed both as actual plant water use and homeowner water use.

Three methods were used to test and meet our objectives:

1. Instrument a multiple species landscape with moisture sensors to monitor actual water use and compare it to potential evapotranspiration.
2. Monitor demonstration sites of both xeric and mesic landscapes and compare homeowner water use for trained versus untrained participants.
3. Compare homeowner water use among 2-5 year old, 8-12 year old, and 20+ year old landscapes with potential evapotranspiration.

In November 2002, a multiple species landscape located at the Weslaco Extension and Research Center was instrumented with 192 ECHO moisture sensors. This site is comprised of a walnut tree, dwarf yaupon, ficus shrub, rose bushes, crepe myrtles, and St. Augustinegrass. Eight inch sensors were placed vertically in the sandy loam soil at 64 locations and in three depths—0 to 8 inches, 8 to 16 inches, and 16 to 24 inches. A grid pattern was used as well as line transects throughout the site and moisture data is being collected at half-hour intervals using multiplexers, data loggers, and modems. Data will be collected for a minimum of one year and is currently being analyzed to determine: soil moisture extraction patterns, differences in actual evapotranspiration rates among vegetation types, if correlations exist between actual and potential evapotranspiration for the research site, and monthly landscape coefficients. Analysis for this site will be completed as well as a Master of Science thesis submitted by April 2004. A second site is being assessed in the College Station, Texas region, and plans are being made to have this site instrumented by June 2004.

Another method being used to determine landscape water use is a project named the 'Texas *ELITE* Water Conservation Project' ("ELITE" standing for Efficient Landscape Irrigation Through Education). In May 2003, 12 landscapes were identified for this project—6 being xeric type landscapes and the other 6 mesic (typical) landscapes. The Hidalgo County Master Gardeners have made a commitment to this project through 2004 and are responsible for the evaluations and monitoring of the sites. Participating homeowners are being categorized as either a response unit site (well trained homeowners—water use efficient site) or a standard practice site (untrained homeowners—site just being evaluated and water use documented). All sites had soil samples taken and totalizing water meters installed. Comparisons of landscape water use will be made between trained versus untrained homeowners and xeric versus mesic landscapes. Another analysis of this project will be to determine if water use totals from a group of similar landscapes can be used to predict and/or represent water use from other similar landscapes in a region.

The third method to achieve our objectives is to analyze actual homeowner water use data from a participating municipality having landscapes of 2-5 years old, 8-12 years old, and 20+ years old with similar lot sizes and values. Comparisons will be made between monthly potential evapotranspiration and actual water use per household per month for each neighborhood for the past 3-5 years. Evaluations will be made to determine if correlations exist between homeowner water use, age of landscape, and potential evapotranspiration. Currently, the data has been retrieved and is being analyzed. In addition, a presentation will be made at the Texas Water Works Association Conference in April 2004 focusing on our findings.

Biotic Responses to Reduced Freshwater Inputs into Texas Bays: Hypersalinity Effects on Benthic Microalgal Community Structure and Function

Basic Information

Title:	Biotic Responses to Reduced Freshwater Inputs into Texas Bays: Hypersalinity Effects on Benthic Microalgal Community Structure and Function
Project Number:	2003TX89B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	8
Research Category:	Biological Sciences
Focus Category:	Surface Water, Wetlands, Ecology
Descriptors:	Bays and Estuaries, Aquatic Biology, Freshwater Inflows
Principal Investigators:	Alyce R. Lee, James L. Pinckney

Publication

1. Gould, D. M. & E. D. Gallagher. Field measurement of specific growth rate, biomass, and primary production of benthic diatoms of Savin Hill Cove, Boston. Limnology and Oceanography, v.35, n.8, 1990, p.1757-1770. 1990.
2. Lee, Alyce, Pinckney, James. "A Spatial Study of Benthic Microalgae in an Intertidal Sandflat at East Beach in Galveston, Texas." (Poster)

Biotic Responses to Reduced Freshwater Inputs into Texas Bays: Hypersalinity Effects on Benthic Microalgal Community Structure and Function

Principal Investigator (graduate student): Alyce R. Lee, Texas A&M University, 3146 TAMU, Department of Oceanography, College Station, Texas 77843. Office: (979) 458-3323. Email: alyce@ocean.tamu.edu.

Co-Principal Investigator (faculty advisor): James L. Pinckney, Texas A&M University, 3146 TAMU, Department of Oceanography, College Station, Texas 77843. Office: (979) 458-1028. Email: pinckney@ocean.tamu.edu.

Funding Period: Mar. 2003 – Feb. 2004

This report addresses the important research being done under this grant, experiments performed and the preliminary results, progress on my degree plan, papers or poster presentations and any publications, expenditures of the funds, and other work supported by this grant. The primary focus of this project is the impact that salinity in Galveston Bay, Galveston, TX will have on benthic microalgae (BMA) should it increase due to decreased freshwater into Galveston Bay. Freshwater entering the Bay is expected to decrease in the future because of an increase in the human population within the Galveston Bay watershed, thereby increasing freshwater consumption.

BMA may be a significant source of carbon in Galveston Bay, which helps to support the higher trophic levels. Marine food webs are very dynamic and susceptible to change; therefore, any change in BMA production could alter carbon and energy flow to higher trophic levels. A change in salinity could affect BMA production, which is the basis for this project's null hypotheses. The hypotheses to be examined are; ***H_{01}:*** A 25% increase in salinity will not result in a significant shift in BMA community composition at an intertidal sandflat at East Beach, Galveston Island, Galveston, TX., and ***H_{02}:*** A 25% increase in salinity will not result a reduction in BMA biomass and primary production at an intertidal sandflat at East Beach, Galveston Island, Galveston, TX.

The preliminary phase of this study has been completed. Two salinity manipulation experiments have been performed, one within the laboratory at Texas A&M University, College Station, TX, and the other *in situ* at East Beach. An additional experiment is scheduled to be done *in situ*, in March 2004. The results from these two experiments have led to improvements in the experimental design which will be implemented in March, 2004.

The first experiment was done under controlled conditions (incubator) in the laboratory. A total of 12 sediment cores (7.8 cm ID) and four 2-liter containers of ambient water were collected from an intertidal sandflat at East Beach, Galveston, TX June 10, 2003. The samples and field water were transported to the laboratory in College Station, TX, where the cores were placed in shallow containers, put into an incubator with an average irradiance of 75 µE m^{-2} s^{-1}, which was significantly lower than ambient irradiance of approximately 2200 µE m^{-2} s^{-1}. Although the lights in the incubator could not mimic the irradiance level at East Beach, the ambient temperature at East Beach was easily controlled.

The experiment design consisted of four treatments, control (23psu), deionized water (0psu), 1:1 DL (12psu), and high (45psu) with 9 replicates for each treatment. The field water was placed in the shallow container for the control and for the 1:1 DL treatments was diluted by an equal amount of laboratory deionized water. This water was exchanged every third day. The deionized water treatment used laboratory deionized water and the high treatment used a laboratory mixture of Instant Ocean® and deionized water. The experiment was allowed to run for 22 days.

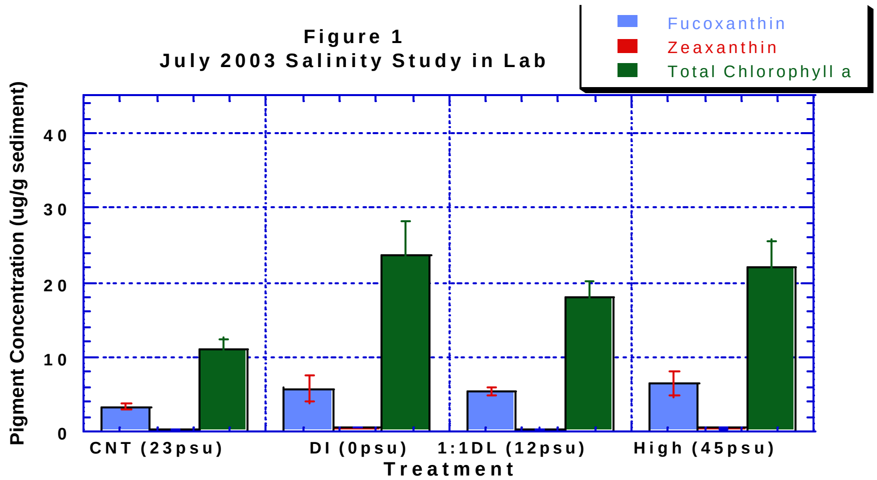
The second study was performed in the field at an intertidal sandflat at East Beach, Galveston, TX, latitude 29° 20.024 N longitude 094° 44.200 W. The field study allowed for ambient temperature and light to be maintained. A total of 6 sediment cores were collected in petri dishes, placed in shallow containers with 2 petri dishes in each container, and left at the site where the cores were collected.

This experimental design consisted of 3 treatments, control (28psu), deionized water (0psu), and 1:1 DL (14psu) with 6 replicates for each treatment. A high salinity treatment was not added to this bioassay because of insufficient volume of Instant Ocean® and deionized water. As in the previous experiment the field water was placed in the shallow containers for the control and for the 1:1 DL treatments were diluted by an equal amount of laboratory deionized water. This water was exchanged with new water every morning before 9 am. The experiment was allowed to run for 3 days.

At the end both experiments 3 subcores were collected from each sediment core and petri dish using a 1.1 cm ID polyethylene core tube. The top 3 mm of each subcore was extruded and collected into a microfuge tube, which was then placed in a -80?C freezer until further analysis. The samples were extracted and analyzed by high performance liquid chromatography (HPLC) for photopigment (chlorophylls and carotenoids) determinations. The different pigments concentrations provide a measure of the different algal groups in the sediment and their relative abundances.

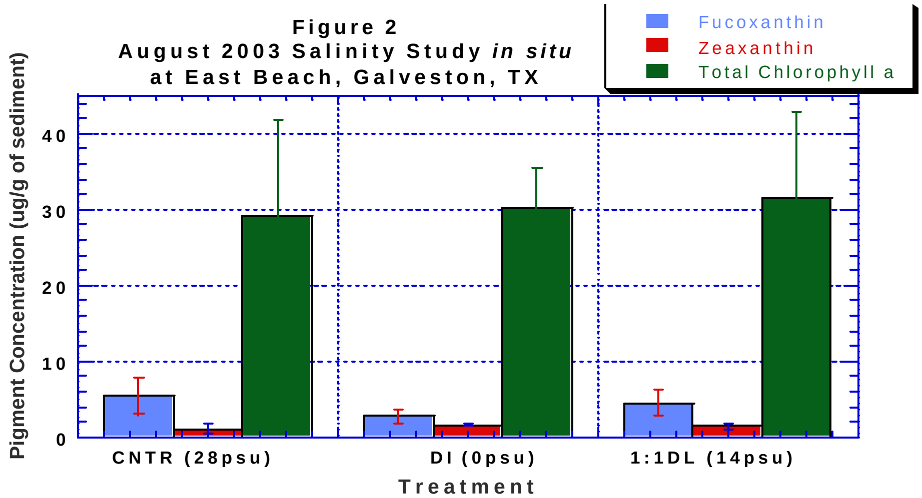
Figures 1 and 2 summarize the results of the previous two experiments. In figure 1, there is an increase in total community biomass, indicated by the total chlorophyll *a* pigment, in the DI, 1:1 DL, and high compared to the control. The relative abundance of the diatoms and cyanobacteria, indicated by the pigments fucoxanthin and zeaxanthin, respectively, show very little change between the 4 experimental treatments. BMA showed growth, but community composition did not change. Growth at 45psu was similar to growth at 0psu. Control showed little growth relative to others. Addition of water, regardless of salinity, enhanced growth.

Figure 1
July 2003 Salinity Study in Lab



The results from the laboratory are circumspect because of concerns that were observed during the bioassay, which need to be addressed. First, the samples were taken from the field with a light intensity of approximately 2000 μE m^{-2} s^{-1} and placed in an incubator with irradiance intensity approximating 75 μE m^{-2} s^{-1}. The samples might not have been acclimated to the lower light intensity prior to starting the bioassay. Second, the salinity in the field water containers kept increasing during the duration of the bioassay; therefore, the salinity of the samples fluctuated as well. Third, the water in the containers might not have been changed frequently enough, also leading to the fluctuations in salinity. Finally, the experiment might have been allowed to run for too long, which could lead to the salinity fluctuation within the containers.

Figure 2 for the *in situ* experiment illustrates that there is very little significant change in the relative abundance of all three pigments, fucoxanthin, zeaxanthin, and total chlorophyll *a*. This lack of change indicates that the relative abundance of the community has not shifted to favor another algal group nor is the relative abundance of the community as whole affected by the different treatments.



The samples collected for the *in situ* experiment were maintained at an ambient temperature and irradiance. The salinity did not vary between water exchanges for the duration of the bioassay. However, the experiment might have benefited from being allowed to run for one week to see if the biomass doubled. While the growth rate has not been verified for BMA in Galveston Bay, an estimated rate using Gould's (Gould & Gallagher, 1990) results, using a growth rate of 0.21 μ^{-d} indicate that the relative abundance of the total biomass would double in approximately 6 days. Although, the water was exchanged daily, one night during the experiment a storm front moved in and diluted the treatments. Finally, for the last two days of the experiment, morning showers occurred and the water had to be exchanged twice during a 24 hour period.

The results from these two experiments are preliminary and have not been published. The bases of these two studies have illustrated what requirements are needed for future studies for a better assessment of BMA's biotic response to changes in salinity. Irradiance levels and temperature are better represented when the bioassay is conducted in the field than in a laboratory setting. Therefore, future studies will be done in the field. In addition, productivity measurements using microelectrodes will be done on the sediment cores at the end of the experiment and compared to the results from the HPLC analysis. This measurement will also demonstrate if BMA primary productivity is responding to the change in salinity, and if so, by how much. Also, an additional treatment will be added to the experiment, which will be a 25% increase in salinity above the control treatment. This will be done by determining the salinity of the control and adjusting a saline solution of Instant Ocean® to 25% greater than the control.

My dissertation will include a chapter on the effects of salinity on BMA, which is expected to be completed by the end of 2005. I have completed the majority of my coursework as outlined on my degree plan, with the final course being completed in the fall of 2004. Preliminary written and oral exams were completed on November 5, 2003, approved by my committee and the Dean of the Oceanography Department, and submitted to the Office of Graduate Studies. The proposal defense for my dissertation is tentatively scheduled for sometime in March, 2004.

With respect to the original $4,182, there is $1,775 left in the account as of February 13, 2004. A request for a no cost extension will be submitted in a separate letter addressed to you. The majority of the funds were utilized for travel expenses to and from East Beach, Galveston, TX for sample collection. The remaining funds will also be used for travel costs to East Beach, Galveston, TX in March to repeat the August 2003 *in situ* experiment.

In conclusion, the results of these two experiments were preliminary and allowed me to determine what requirements are necessary for future experiments in order to better address the hypotheses stated. Finally, a final report will be submitted to your office at the end of my dissertation, as well as copies of any papers, abstracts, and citations that come of the work funded by this grant.

Quantification of Stochastic Crop-Water Production Functions and Net Profit-Water Functions for Agriculture on the Edwards Aquifer

Basic Information

Title:	Quantification of Stochastic Crop-Water Production Functions and Net Profit-Water Functions for Agriculture on the Edwards Aquifer
Project Number:	2003TX90B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	5
Research Category:	Engineering
Focus Category:	Agriculture, Irrigation, Water Use
Descriptors:	Computer Models, Agricultural Water Use, Irrigation
Principal Investigators:	Ju Young Lee, Kelly Brumbelow

Publication

1. Brumbelow, K. and J.Y. Lee, WGEN-Sky and WFILL: Extension of the WGEN model to include sky cover condition and data filling capabilities, Agric. and Forest Meteor., 2004. (in preperation)
2. Brumbelow, K. and J.Y. Lee, Use of net-profit water functions to assess implications of an irrigation limit policy for the Edwards Aquifer, Texas, J. of Water Resour. Plan. Mgmt., 2004. (in preperation)

Quantification of Stochastic Crop-Water Production Functions and Net Profit-Water Functions for Agriculture on the Edwards Aquifer

Progress Report

February 27, 2004

Ju Young Lee and Kelly Brumbelow

Department of Civil Engineering
Texas A&M University
College Station, Texas

1. Introduction

This report summarizes the progress to date of research supported by the Texas Water Resources Institute through the 2003-2004 USGS Scholarship Program. Mr. Ju Young Lee was awarded funding under this program for a project to quantify representative relationships between irrigation application and crop yield and net profit for the region overlying the Edwards Aquifer in central Texas. Toward that end, progress has been made in three primary tasks: (1) formulation of a data filling algorithm to estimate missing meteorological data for input into crop/irrigation simulations, (2) determination of crop-water production functions (CWPF's) for the study area, and (3) economic analysis to derive net profit-water functions (NPWF's) from the CWPF's. Results from this research will be used to prepare 2 articles for publication in peer-reviewed journals, and Mr. Lee has made progress in defining his doctoral dissertation topic. Each of the accomplishments made under the TWRI/USGS grant is described further below.

2. Data Filling Algorithm for Incomplete Meteorological Datasets

One of the chief difficulties in applying physiologically based crop models (such as those described by Tsuji et al., 1998, etc.) to long-term simulation has been the lack of suitable meteorological data in some locations needed for model input. Past studies have addressed this problem primarily through regression relationships and have often focused on a limited number of parameters (e.g., Hook and McClendon, 1992). One option that has been incorporated into commonly used software has been stochastic generation of all meteorological data, and the WGEN model (Richardson, 1981) has often been used for this purpose. This model is an attractive statistical descriptor of daily meteorology because of its well-defined cross- and auto-correlation structures, and its parsimony in parameter storage. In this project, the WGEN model has been modified in two phases for the purposes of developing a flexible and efficient data filling tool.

The first modification was to change the primary description of daily meteorological state from a binary wet/dry one to a quaternary one based on both precipitation and sky cover condition: "dry clear," " dry cloudy," " wet clear," and "wet cloudy." Thus, the Markov chain used to determine precipitation occurrence each day was changed from a two-state to a four-state model with 12 transition probabilities needed for each day rather than the 2 needed in the original model. All daily parameters (i.e., precipitation amount, maximum daily temperature, minimum daily temperature, relative humidity, number of hours of sunshine, and wind run) were then quantified for each of the four precipitation/sky states. Because of the newly determined importance of sky cover condition, this form of the stochastic weather generator was named "WGEN-Sky."

The increased number of parameters is significant in WGEN-Sky compared to the original WGEN. The original model required Fourier series expressions for 23 independent parameters as well as two 5 by 5 correlation matrices; WGEN-Sky requires expressions for 54 independent parameters as well as the same sized correlation matrices. However, comparison of long generated series to actually measured data has shown that

WGEN-Sky does generate improved sequences compared to WGEN. Figure 1 shows a comparison of mean number of sunshine hours for the calendar year divided into 14-day periods as measured at San Antonio, Texas, and as generated by the WGEN and WGEN-Sky models. While the original model provides an adequate representation of sunshine hours, the WGEN-Sky generated series more closely resembles the actual data including the mid-Spring "dip" in sunshine due to increased convective cloud cover. This improvement is significant for agricultural modeling where solar radiation is a driving input to photosynthesis and plant development. Figures 2a-c compare the frequency of occurrence of each of the four precipitation/sky states as measured at San Antonio (Figure 2a), as generated by WGEN (Figure 2b), and as generated by WGEN-Sky (Figure 2c). As expected, WGEN-Sky produces a more accurate set of frequencies than does WGEN. The full value of this fact is realized in the second modification to the original weather generator.

The second modification to the original weather generator was to convert it to fill in missing weather data values using as much information from known values as possible. As mentioned above the quantification of cross- and auto-correlation structures in WGEN makes its original methodology well-suited to this task. In addition, the greater specificity in parameter trends determined by the combined precipitation/sky states in WGEN-Sky allow for greater confidence in the estimation for each missing value. The data filling version of the weather generator has been named WFILL in recognition of its heritage from WGEN and its new role.

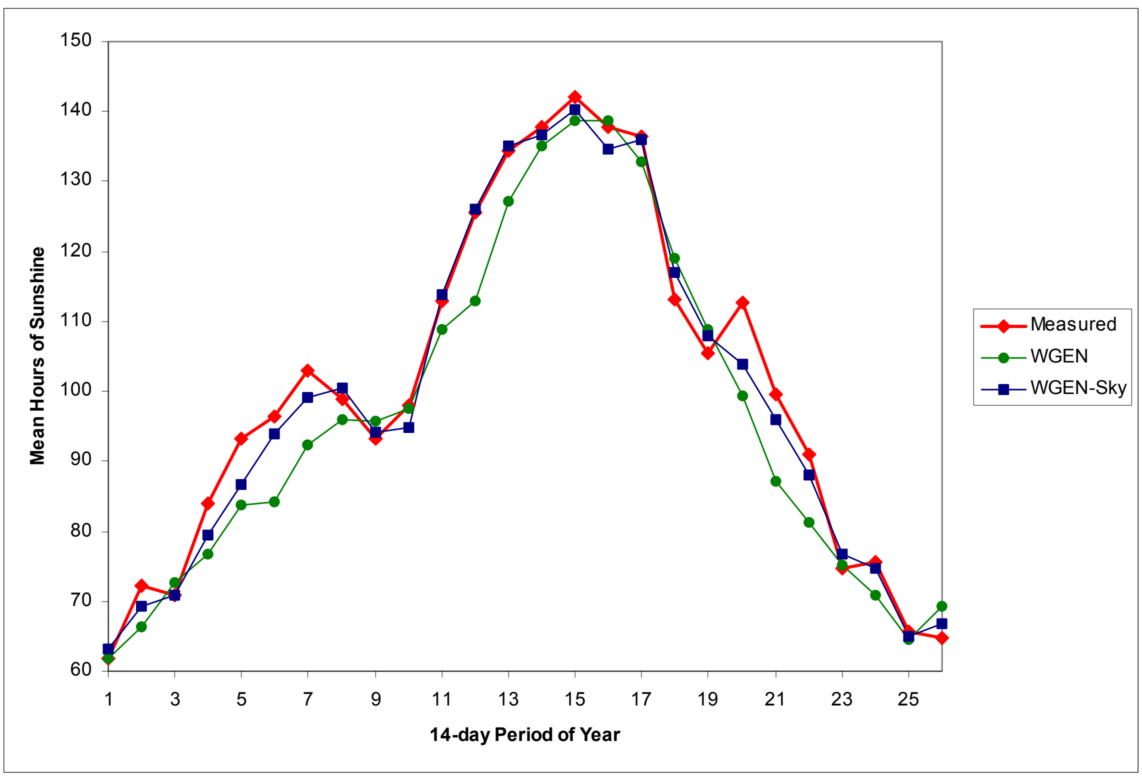


Figure 1. Comparison of mean numbers of sunshine hours generated by WGEN and WGEN-Sky versus measured data at San Antonio, Texas.

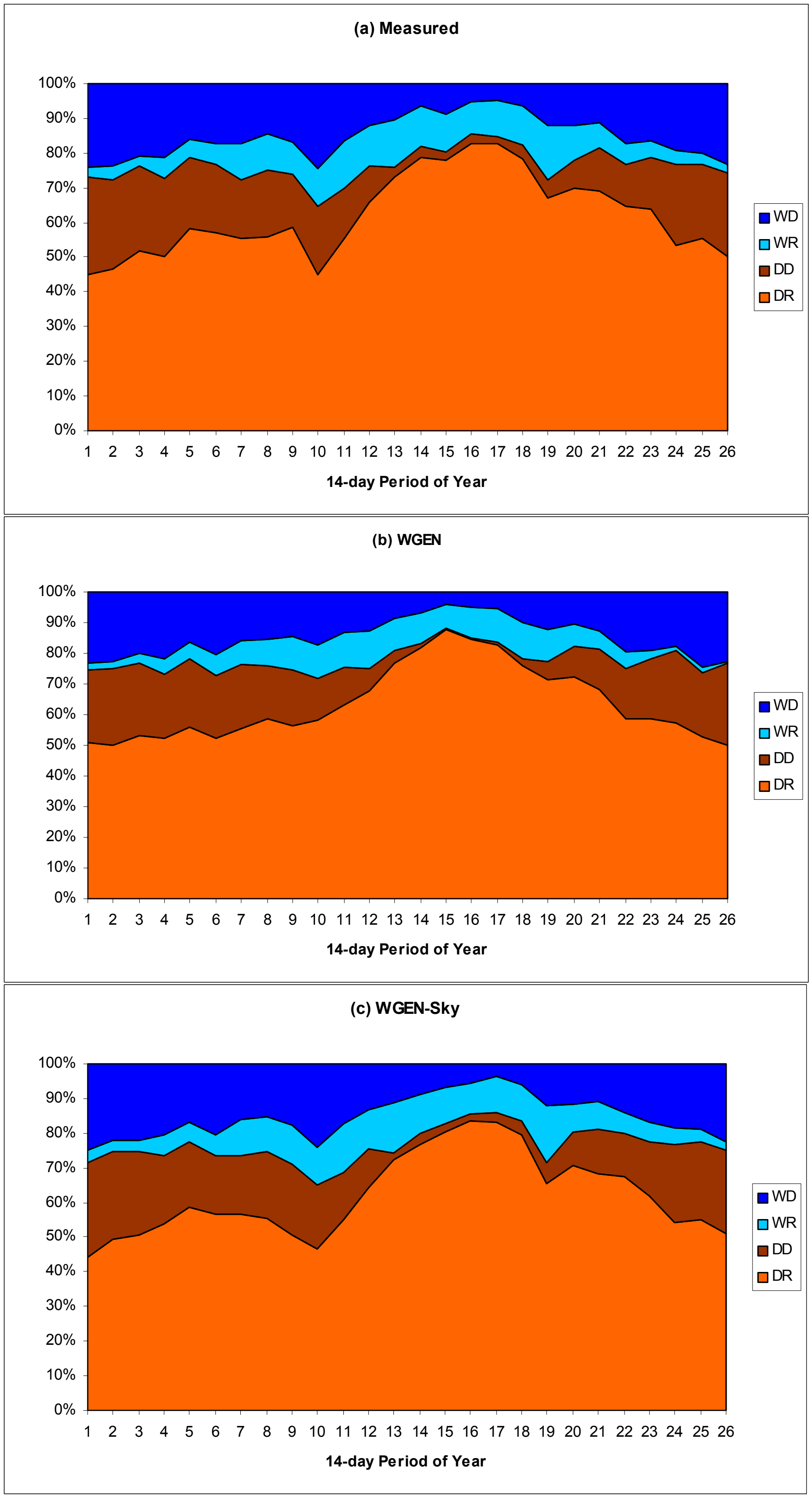


Figure 2. Comparison of frequency of occurrences of dry clear (DR), dry cloudy (DD), wet clear (WR), and wet cloudy (WD) days as measured at San Antonio and generated by the WGEN and WGEN-Sky models.

WFILL estimates each day's missing weather data by a three-step process. First, if the precipitation/sky state is not known from measured data, it is estimated using a Bayesian conditional probability calculation. All available data except wind run is included as possible in this calculation. Conditional probability of each possible precipitation/sky state is calculated by comparing each known data value to its expected statistical distribution under each state (Figure 3 provides a schematic example of this). The highest conditional probability found determines the estimated state for that day. In a verification study, the 6-year record at San Antonio was processed by WFILL, and precipitation/sky state was determined with a median conditional probability of 96.2%, a minimum conditional probability of 52.1%, and conditional probability was greater than 90% in over 46 years of the filled record. Thus, this procedure was judged to perform quite well in estimating precipitation/sky state.

The second step in the WFILL daily estimation process is to estimate deviations from mean values (i.e., normalized residuals) for each missing parameter. WGEN includes the equation of Matalas (1967) for a first-order autoregressive process on a multi-dimensional state with known cross- and auto-correlations among state variables. This equation includes a vector of same-day noise for generation purposes. In the data filling mode, WFILL back-solves this equation for the noise terms for known parameters and assumes zero noise for unknown parameters. The equation is then forward-solved with the newly determined noise components. This process capitalizes on all known parameters by including their correlative influence on unknown values at both lag-1 and lag-0 increments. The third step in the WFILL process is to then calculate values for missing parameters using mean and variance appropriate to the estimated state and residual estimated from the second step.

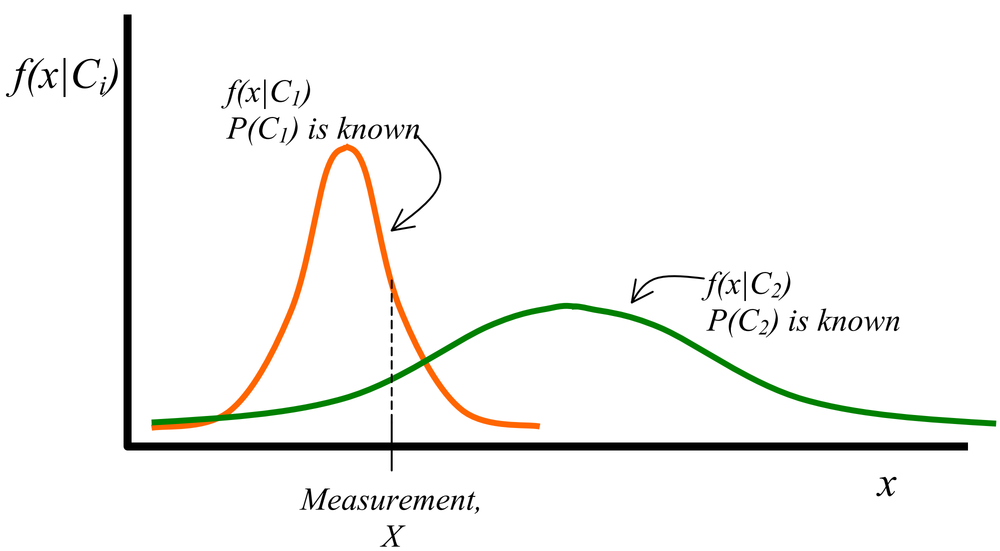


Figure 3. Schematic representation of conditional probability calculation for precipitation/sky state conditioned on measured meteorological data.

WFILL is flexible in that in can work with any number of missing values each day as long as WGEN-Sky parameters have been previously determined for the site in question. Metadata is produced for each day's computations to report on the likely quality of the estimated values (i.e., probability of precipitation/sky state, number of values estimated, frequency distribution of back-solved noise, etc.). The utility of the model is illustrated by the example of the San Antonio verification study where out of a 56-year record, only 5.8 years have all 6 needed parameters for crop model simulation. Use of WFILL allows the entire 56 years of data to be used with preservation of important climatic trends.

3. Functions of Irrigation versus Crop Yield and Net Profit for the Edwards Aquifer Region

The major goal of this project is to quantify representative functions of crop yield and net profit as functions of irrigation application for several crops on the western reach of the Edwards Aquifer. At this time only preliminary results have been obtained for these tasks. Work is continuing to finish this part of the research project. The preliminary results are discussed below.

To date, simulations have been run for corn grown at Uvalde, Texas, on Uvalde silty clay loam soil. Using measured meteorological data available at Uvalde (precipitation, daily maximum and minimum temperatures), parameters for other weather data derived from measurements made at San Antonio, and the WFILL algorithm, a record of 94 years of climatic data was reconstructed and used for 94 computational trials. Each computational trial produced a single crop-water production function (i.e., yield vs. irrigation function). These were then aggregated to construct a probability distribution of CWPF's as shown in Figure 4. These results are still considered preliminary and subject to continued revision as input data checks continue. There is also much work left to be done to assess the CWPF's for other soil types, locations, and crops. This work will be done in the next several months.

Net profit-water functions are also left to be developed in this project. As these require derivation of the CWPF's first, this step will be done after those functions are complete. Required economic data to compute net profit relationships (i.e., fixed and variable costs, market prices for water, etc.) have been collected.

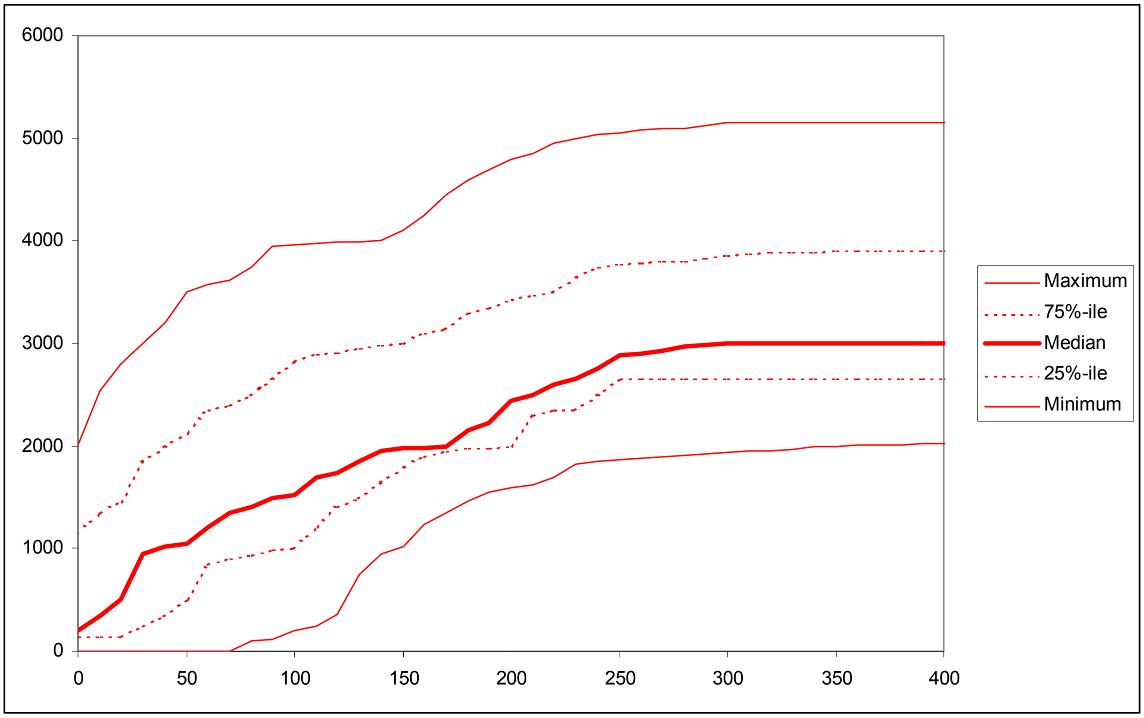


Figure 4. Preliminary result of determination for crop-water production function for corn grown at Uvalde, Texas, on Uvalde silty clay loam.

4. Publications and Other Research Products

The results from this project will be published as two articles in peer-reviewed journals. Preliminary citations for the articles are:

Brumbelow, K. and J.Y. Lee, WGEN-Sky and WFILL: Extension of the WGEN model to include sky cover condition and data filling capabilities, *Agric. and Forest Meteor.*, 2004. (in preparation)

Brumbelow, K. and J.Y. Lee, Use of net profit-water functions to assess implications of an irrigation limit policy for the Edwards Aquifer, Texas, *J. of Water Resour. Plan. Mgmt.,* 2004. (in preparation)

The modified weather generator WGEN-Sky and data filling program WFILL will be made publicly available from Kelly Brumbelow's professional web site http://ceprofs.tamu.edu/kbrumbelow/.

5. Student Progress

Mr. Ju Young Lee has made progress towards completion of his doctoral degree in the course of this project. During the project period he has completed doctoral qualifying examinations. He is currently at work in drafting a dissertation proposal on irrigation planning and management, which draws upon the experiences gained in this project.

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Matalas, N.C. 1967. Mathematical assessment of synthetic hydrology. *Water Resour. Res., 3(4),* 937-945.

Richardson, C.W. 1981. Stochastic simulation of daily precipitation, temperature, and solar radiation. *Water Resour. Res., 17(1),* 182-190.

Tsuji, G.Y., G. Hoogenboom, and P.K. Thornton (eds.). 1998. *Understanding Options for Agricultural Production.* Kluwer Academic Publishers, Dordrecht, Netherlands.

Adsorption, Desorption, and Stabilization Behavior of Arsenic on Al3+-substituted Fe3+-Hydrous Oxides

Basic Information

Title:	Adsorption, Desorption, and Stabilization Behavior of Arsenic on Al3+-substituted Fe3+-Hydrous Oxides
Project Number:	2003TX91B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	5
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Geochemical Processes
Descriptors:	Groundwater Quality, Arsenic, Water Treatment
Principal Investigators:	Yoko Masue, Richard H. Loeppert

Publication

1. Masue, Y., R.H. Loeppert, G.N. White, and T. Kramer. 2003. Adsorption, desorption, and stabilization behavior of arsenic(V) on Al3+ substituted Fe3+ oxides. P.88-89. In Abstracts, the 7th International Conference on the Biochemistry of Trace Elements, Uppsala, Sweden, 15-18 June.2003
2. Masue, Y., R.H. Loeppert, and T. Kramer. 2003. Influence of counterion on adsorption and desorption behavior of arsenic on ferrihydrite and Al-substituted analogs was presented at American Society of Agronomy annual meeting in Denver, CO, 2-6 November. 2003

Adsorption, Desorption, and Stabilization Behavior of Arsenic on Ferrihydrite and Al-substituted Analogs.

Progress Report

February 24, 2004

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1. Research Progress

Introduction

Arsenic introduced by natural processes or human activities can result in the contamination of water and soils. The removal of arsenic from water is necessary if the water is to be consumed by humans (Nriagu, 2002). Counterion effect has been recognized as a possible factor influencing ligand adsorption reactions in aqueous systems. Understanding the counterion effect could help to comprehend mobility of arsenic in a variety of environments to improve treatment of arsenic-containing wastewater, and to stabilize residual materials. Furthermore, Al or Fe hydroxides are commonly used as adsorption agents in water treatment systems (Hering et al., 1996). However, there has been very little attention to mixed Fe/Al oxides as adsorbents. The use of mixed Fe/Al systems could present an interesting alternative for As treatment and disposal, since Al hydroxide is not affected by redox processes. In addition, most Fe oxides present in soils are Al substituted (Schwertmann and Taylor, 1989); therefore, it is essential to understand the adsorption behavior of Al substituted Fe oxides to fully understand As retention in soils.

Objectives

To investigate the possible use of mixed Fe/Al adsorbents in water treatment by studying:

- Adsorption and desorption of As
- The effect of counterions, Ca^{2+} versus Na^{+}, and counterion concentration on As retention
- Mineralogy of precipitated Fe/Al hydroxide phases and their incubation products

Materials and Methods

I. Synthesis of ferrihydrite and Al-substituted analogs

Al-substituted ferrihydrite samples were prepared at 1:0, 97:3, 9:1, 8:2, 7:3, 6:4, 5:5, and 0:1 Fe:Al molar ratios by varying the $Fe(NO_3)_3$:$Al(NO_3)_3$ molar ratio in the method for synthesis of two-line ferrihydrite (Schwertmann and Cornell, 1991). An x-ray diffraction pattern of each product was obtained to identify its mineralogical composition. Al substituted hydrous oxides were also prepared at 1:0, and 8:2 Fe:Al molar ratios by using saturated $Ca(OH)_2$ or 0.1 M NaOH to adjust pH to 7-8, to obtain systems with Ca or Na exclusively. The volumes of saturated $Ca(OH)_2$ or 0.1 M NaOH solution needed were recorded to determine the accurate concentrations of Ca and Na in the systems. The saturated $Ca(OH)_2$ solution used was prepared under N_2 atmosphere at room temperature, and it was titrated with HCl to determine its concentration

II. Adsorption envelopes of As^V on Al-substituted ferrihydrite samples at different Fe: Al molar ratios

Adsorption envelopes of As^V on the Fe/Al oxide products were obtained in 0.1 M NaCl at a As:(Fe+Al) molar ratio of 0.05:1. The pH values of separate samples were adjusted between 3 and 11 by adding HCl or NaOH, and suspensions were equilibrated 24 h on a platform shaker. Upon completion of the reaction, samples were centrifuged, and the pH of the supernate was obtained. The samples were filtered through 0.2 mm nominal pore size membrane filters.

III. Adsorption envelopes of As^V and As^{III} in Ca and Na systems

Adsorption envelopes of As^V on the Fe/Al oxide products in Ca and Na systems were obtained. Ca and Na concentrations were adjusted using $Ca(NO_3)_2 \cdot 4H_2O$ and $NaNO_3$ salt solutions. The pH values of separate samples were adjusted between 3 and 11 by adding HNO_3 or NaOH and equilibrated 24 h on a rotary shaker. Upon the completion of the reaction, samples were centrifuged, and the pH of the supernate was obtained. The samples were filtered through 0.2 mm nominal pore size membrane filters.

IV. Adsorption isotherms of As^V in Ca and Na systems

Adsorption isotherms of As^V on the Fe/Al oxide products in Ca and Na systems were obtained at pH 5 and pH 8 in 0.1 M $Ca(NO_3)_2 \cdot 4H_2O$ and $NaNO_3$ with As:(Fe+Al) molar ratios ranging from 0.0125:1 to 0.5:1. The pH values of separate samples were adjusted by adding HNO_3 or NaOH, and the volume of each sample was brought to 30 ml. Samples were equilibrated 24 h on a rotary shaker. Upon completion of the reaction, samples were centrifuged and filtered through 0.2 mm nominal pore size membrane filters.

V. Stability of ferrihydrite and Al-substituted analogs

Stabilities of 1:0 and 8:2 Fe:Al oxides were examined at pH 4 and 10. A set of samples was prepared to give an As:(Fe+Al) molar ratio of 0.05:1, and the pH was adjusted by adding HCl or NaOH. A set of samples without As(V) was also prepared with identical oxide concentrations. Samples were incubated at 70^{o}C, and subsamples were taken after 12, 24, 48, and 96 h. As(V) was added to the subsamples which were incubated without As(V), and deionized water was added to the samples which were incubated with As(V) to ensure equal concentrations of As, Fe and Al. The subsamples were adjusted to pH 7.0 with HCl or NaOH, and they were aged at room temperature for 2 h to allow adsorption of As. Samples were centrifuged, filtered, and analyzed for total dissolved As by FI-HG-AAS. Residual oxides were washed with deionized water, and analyzed using XRD. Samples were also extracted with ammonium oxalate at pH 3 in the dark to determine the proportion of poorly crystalline Fe oxide.

VI. Arsenic analysis

As was analyzed using FI-HG-AAS. 5 M HCl and 15 % $NaBH_4$ + 5 % NaOH were used as eluents during flow injection to convert As species present in solution to arsine. As^V

standard solution was used for total As analysis with the As^{V} experiments and As^{III} standard solution was used for total As analysis with the As^{III} experiments. The matrices of the standard were deionized water.

Results and Discussions

I. Synthesis of ferrihydrite and Al-substituted analogs

Al was incorporated into the poorly crystalline ferrihydrite structure up to approximately 0.30 Al:(Fe+Al) molar ratio (Figure 1); however, a trace of gibbsite, crystalline Al hydrous oxide, was observed at 0.30 Al:(Fe+Al). Gibbsite was observed as a coprecipitated product with Al:(Fe+Al) molar ratios greater than 0.40 (Figure 1). The 8:2 oxide resulted in a XRD pattern almost identical to that of ferrihydrite. This poorly crystalline phase is desirable in water treatment as it provides high surface area.

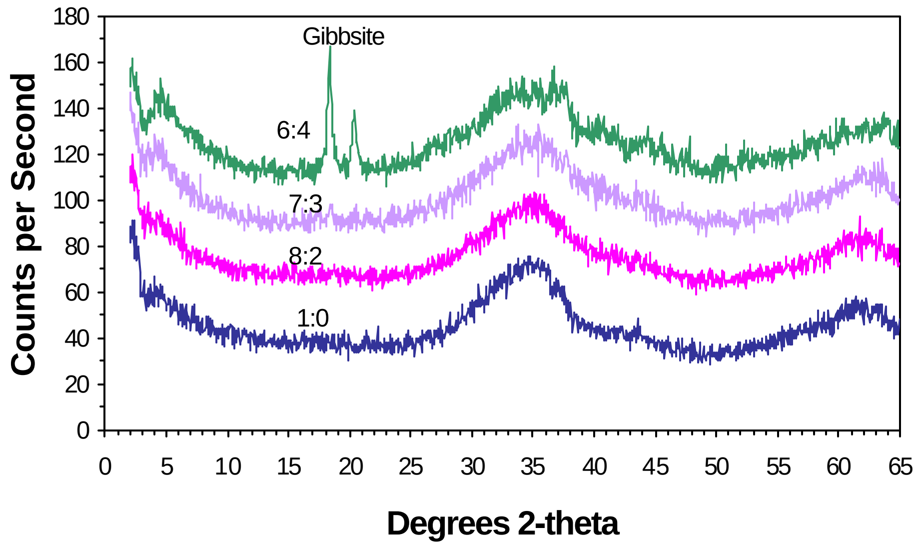

Figure 1. XRD patterns of ferrihydrite and Al-substituted analogs.

II. Adsorption envelopes of As^{V} on Al-substituted ferrihydrite samples at different Fe: Al molar ratios

Strong retention of As^{V} was observed throughout the pH range of 3 to 6.5 with ferrihydrite and its Al-substituted analogs (Figure 2). Adsorption of As^{V} on Al hydroxide (0:1) was much less compared to that on the Fe/Al oxides (Figure 2). This study indicates that Al substitution did not result in a decrease in arsenic retention.

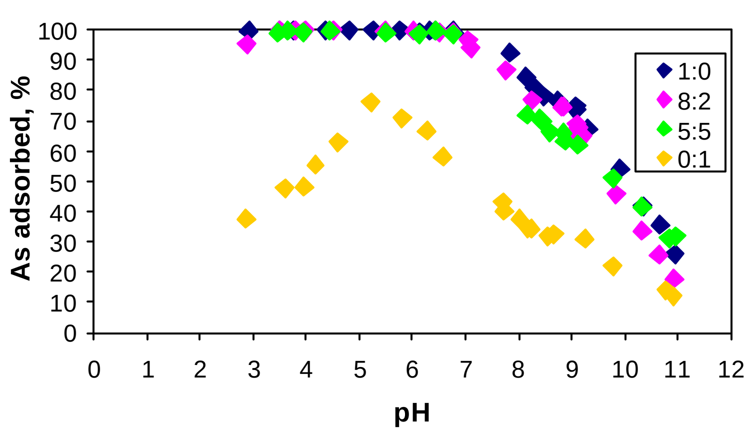

Figure 2. Adsorption envelopes of As^{V} on Al-substituted ferrihydrite at different Fe:Al molar ratios.

III. Adsorption envelopes of As^{V} and As^{III} in Ca and Na systems

As^{V} retention was greater in the Ca system compared to that in the Na system (Figures 3 and 4). Strong retention of As^{V} was observed throughout the pH range of 3 to 6 with 0.1:1 As:(Fe+Al) molar ratio, and 3 to 8 with 0.025:1 As:(Fe+Al) molar ratio (Figures 3 and 4). Significant effect of Al substitution and counterion concentration were not observed (Figures 3, 4, 5, and 6). This result suggests that the Ca in water treatment might be beneficial to improve the retention of arsenic on residual material; although, Na is most commonly used in current conventional water treatment plants.

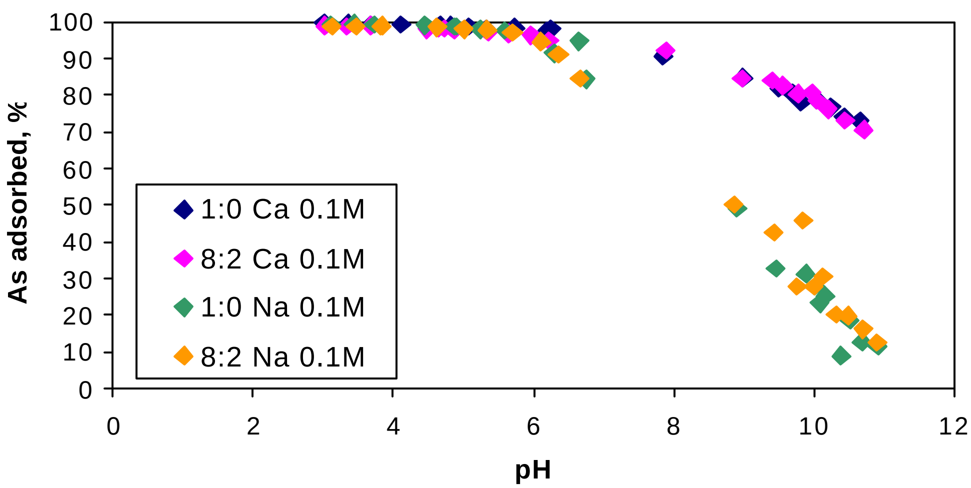

Figure 3. Adsorption envelopes of As^{V} in 0.1 M Ca and Na at a 0.1:1 As:(Fe+Al) molar ratio.

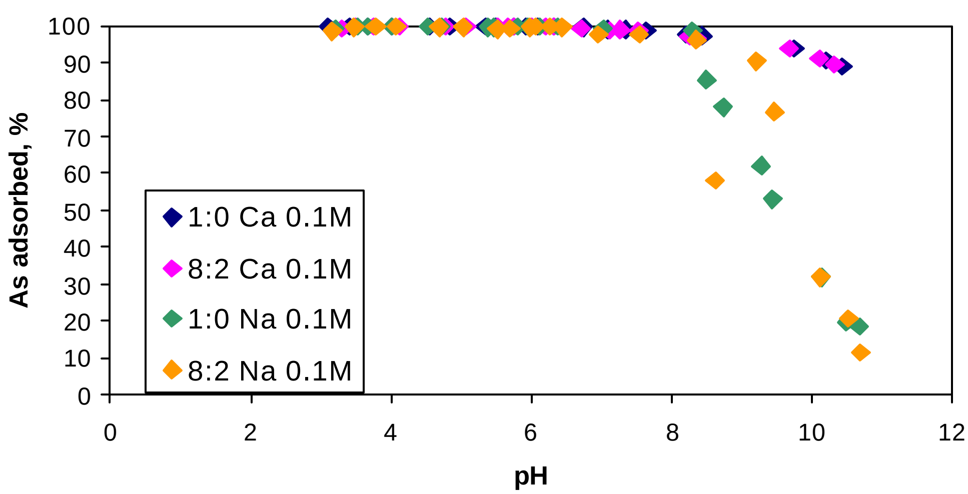

Figure 4. Adsorption envelopes of As^{V} in 0.1 M Ca and Na at a 0.025:1 As:(Fe+Al) molar ratio.

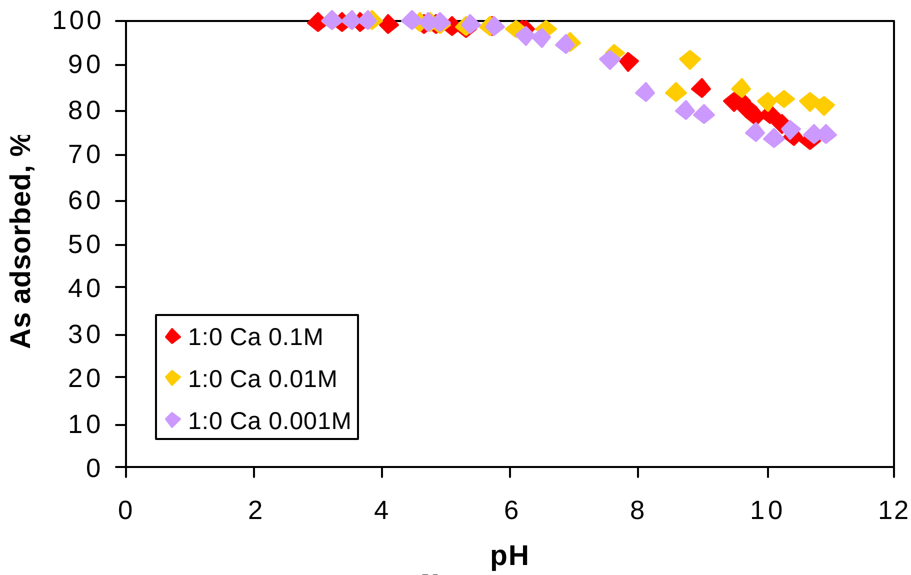

Figure 5. Adsorption envelopes of As^{V} in 0.1, 0.01, and 0.001M Ca at a 0.1:1 As:Fe molar ratio.

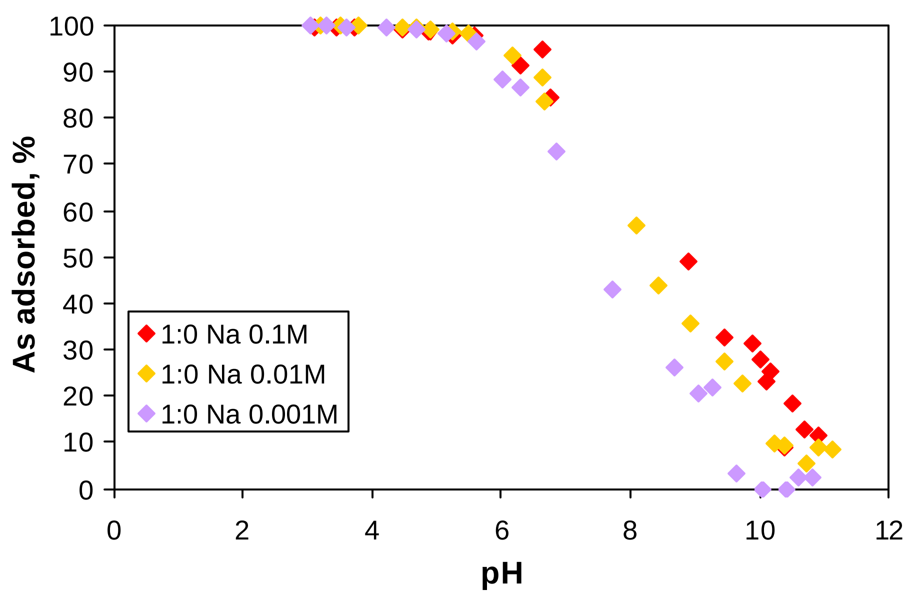

Figure 6. Adsorption envelopes of As^{V} in 0.1, 0.01, and 0.001M Na at 0.1:1 As:Fe molar ratio.

IV. Adsorption isotherms of As^V in Ca and Na systems

Ca systems had higher adsorption capacity compared to Na systems at both pH 5 and 8 (Figures 7, and 8). At pH 5, the effect of Al substitution was negligible (Figure 7). At pH 8, pure Fe oxides had greater retention of As^V at most As:(Fe+Al) molar ratios (Figure 8).

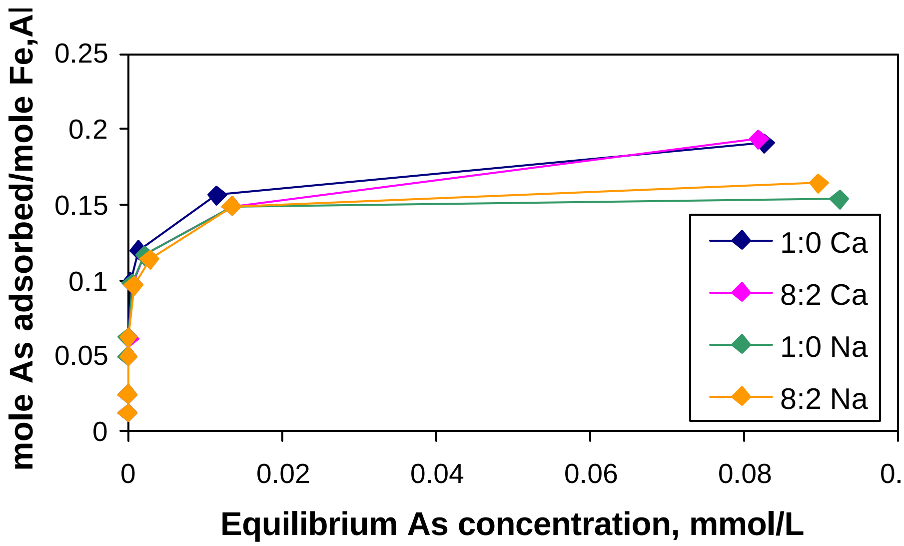

Figure 7. Adsorption isotherms of As^V at pH 5.

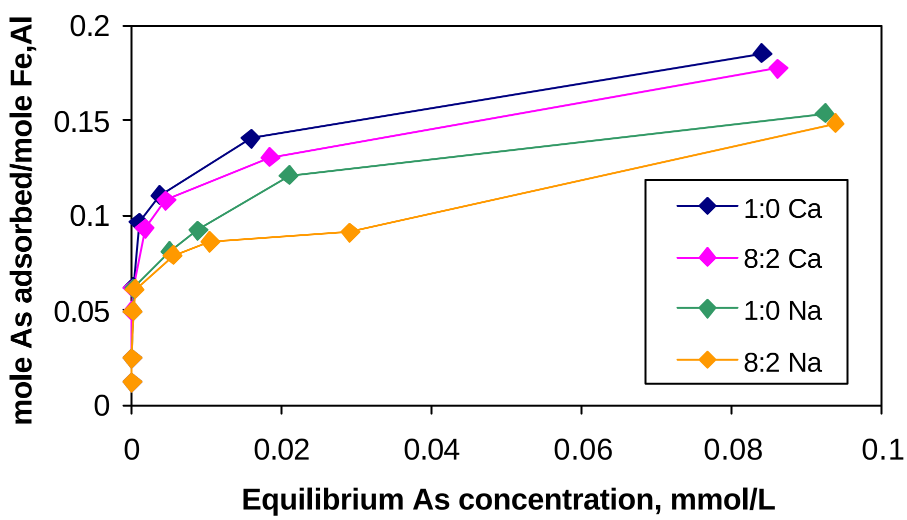

Figure 8. Adsorption isotherms of As^V at pH 8.

V. Stability of ferrihydrite and Al-substituted analogs

Ammonium oxalate extractable Fe is a portion Fe that is poorly crystalline. Poorly crystalline oxide is desirable for water treatment as it provides higher surface area for As adsorption. This study indicates that Al substitution slowed the transformation of ferrihydrite to a crystalline phase (Table 1 and Figure 9, 10 and 11). In addition, arsenic retarded the transformation of ferrihydrite to a crystalline phase (Table 1). Oxides equilibrated at pH 4 transformed more slowly than those equilibrated at pH 10 (Figure 10 and 11).

	Incubated with As	Incubated without As
Treatment	AOE Fe/Total Fe, %	
1:0 pH 10	97	0
1:0 pH 4	95	53
8:2 pH 10	99	64
8:2 pH 4	100	100

Table 1. Proportion of ammonium oxalate extractable Fe over total Fe, %.

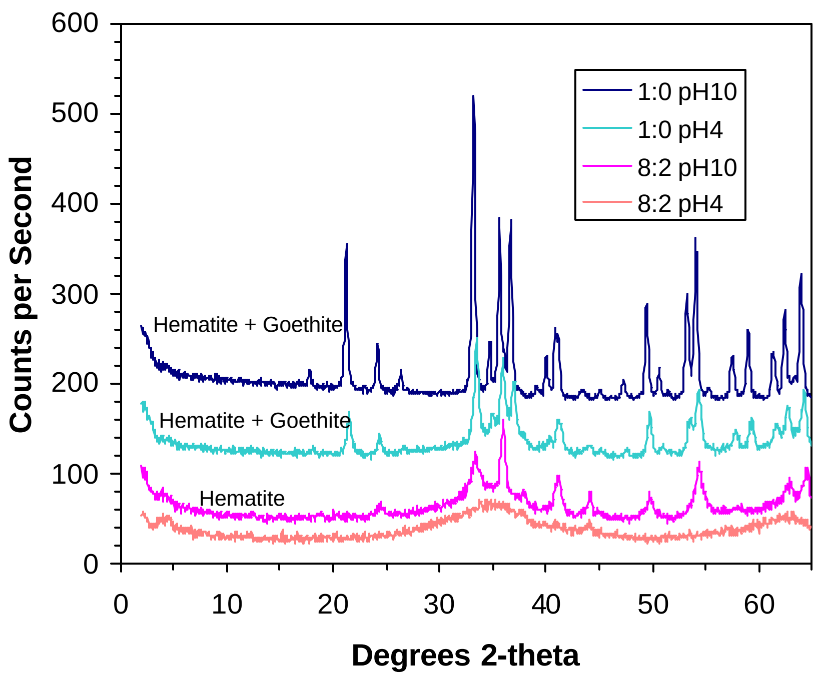

Figure 9. XRD patterns of the oxides, incubated without As for 96h.

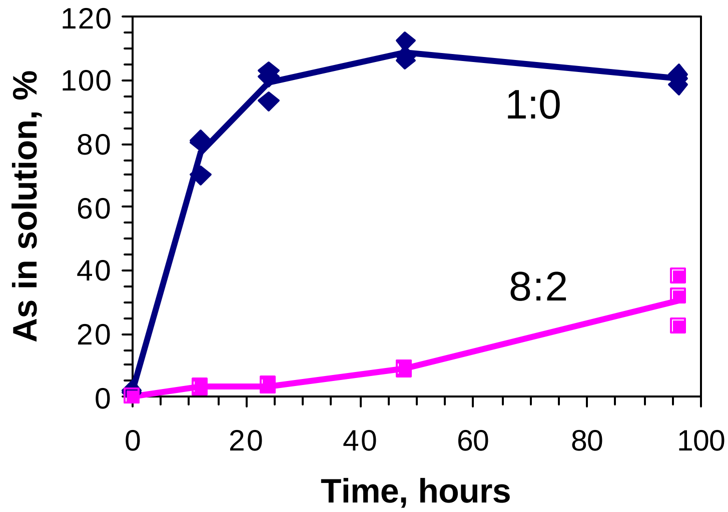

Figure 10. As remaining in solution,%, as a function of time for the oxides originally incubated without As at pH 10.

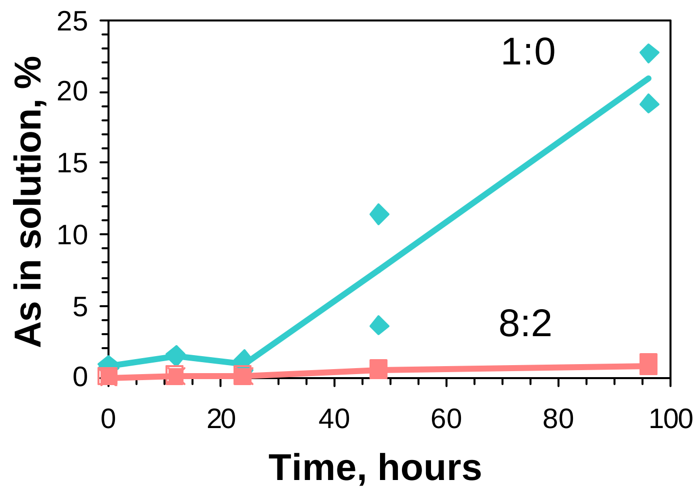

Figure 11. As remaining in solution,%, as a function of time forthe oxides originally incubated without As at pH 4

Conclusions

Al was completely incorporated in the poorly crystalline structure up to 20%. Al substitution did not result in a significant decrease in arsenic retention at 0.05:1 As:(Fe+Al) molar ratio. Retention of both As^{V} and As^{III} were substantially greater in the presence of Ca counterion compared to Na counterion especially above pH 7. Ca counterion in water treatment might be useful to improve the retention of arsenic on residual material.

Coprecipitation of Al^{3+} during precipitation of poorly crystalline Fe/Al hydroxide resulted in a product that was more stable against transformation to well crystalline goethite or hematite. The Fe/Al mixed oxides provided a better retention of As with time compared to pure Fe oxide due to the higher surface area. The Fe/Al mixed oxides could be an effective alternative for water treatment.

Research in Progress

Adsorption behavior of As^{III} are being examined with ferrihydrite and Al-substituted analogs. As^{III} adsorption in Ca and Na systems will be also studied. In addition, desorption behavior of As^{V} and As^{III} will be examined with phosphate and sulfate.

The use of Si to improve the stability of the residual material with Al-substituted ferrihydrite will be investigated. Si retards the transformation of poorly crystalline Fe oxide to crystalline Fe oxide such as goethite; therefore, the presence of Si might help maintain the surface area to provide site for binding. We will also explore the possibility of synthesizing porous media using Si and Al-substituted ferrihydrite.

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2. Publications and presentations

Masue, Y., R.H. Loeppert, G.N. White, and T. Kramer. 2003. Adsorption, desorption, and stabilization behavior of arsenic(V) on Al^{3+} substituted Fe^{3+} oxides. P.88-89. *In*

Abstracts, the 7th International Conference on the Biochemistry of Trace Elements, Uppsala, Sweden, 15-18 June.2003

Masue, Y., R.H. Loeppert, and T. Kramer. 2003. Influence of counterion on adsorption and desorption behavior of arsenic on ferrihydrite and Al-substituted analogs was presented at American Society of Agronomy annual meeting in Denver, CO, 2-6 November. 2003

3. Budget

Provided funds were entirely expended on the tuition, travel expenses to present the research, and the books.

4. Degree program

Yoko Masue is expected to complete M.S. in Soil Science in August 2004.

Monitoring and Evaluation of the Pecos River Ecosystem Project

Basic Information

Title:	Monitoring and Evaluation of the Pecos River Ecosystem Project
Project Number:	2003TX92B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	23
Research Category:	Biological Sciences
Focus Category:	Water Use, Ecology, Hydrology
Descriptors:	Brush Control, Hydrology, Computer Models
Principal Investigators:	Alyson K. McDonald, Charles R. Hart

Publication

1. Pecos River Ecosystem Project: Past. Present and Future, Texas Water Summit, Austin November 2003

Monitoring and Evaluation of the Pecos River Ecosystem Project

In 1999, shallow monitoring wells were installed at two sites within a study area along the Pecos River in Loving County, Texas. In 2000, one site was treated with Arsenal herbicide to control saltcedar and the other site was left untreated. The wells are equipped with water level sensors and data loggers, which record the average hourly water level. The hourly water levels are used to calculate net drawdown or recharge for each day during the growing season (April – October). Water salvage from saltcedar control is estimated by comparing pre treatment water level data to post treatment water level data for both sites using the EPA Paired Watershed Study Design protocol. Preliminary analysis indicates saltcedar control may yield 50% to 70% reduction in water loss at the study site on the Pecos River.

If saltcedar control results in substantial water salvage, will downstream flows increase or will groundwater storage increase? This question will be addressed in three stages: (1) Characterize shallow aquifer: A map of alluvial sediments will be developed to diagram subsurface flow patterns. Previous borehole exploration revealed a clay layer, which may limit vertical water flow within the shallow aquifer. This task is to delineate the extent of the shallow aquifer by drilling additional boreholes at untreated and treated plots along the Pecos River. Soil and water samples will be collected and analyzed, as needed, to determine spatial variation in hydrological properties. **Boreholes were drilled and soil samples were collected in one foot increments to the depth of the water table. Particle size analysis has been completed for boreholes 1-4 (Tables 1-4). A soil classification triangle, which is based on percent particle size, was used to assign specific yield to each one foot increment;** (2) Installation of additional monitoring wells: There are 5 existing monitoring wells at each site on one side of the river. In order to better understand flow regimes, additional wells will be drilled on the other side of the river from the existing well network. Dataloggers will be used to record hourly changes in the water level in each of the new wells. Collected water level information will be processed to construct a flow net within the shallow aquifer. The flow net will be used to define the interaction between surface water and ground water, which will be used to assess volume and direction of flow. **Six new monitoring wells were established. The wells will be equipped with water level sensors and loggers. The water level information will be used to configure subsurface flow patterns;** and (3) Flow measurements: To establish the relationship between surface water and ground water, designated releases from Red Bluff Reservoir will be scheduled. Multiple releases will be monitored for a period of several days during the project period to detect any seasonal changes in the shallow aquifer response to saltcedar control. Seepage losses, or gains, by the river will be calculated and the factors that influence seepage losses and gains will be assessed.

During the releases, surface water flow will be measured at the upstream boundary of the untreated site, at the divide between untreated and treated sites and at the downstream boundary of the treated site. At the same time the hourly water level in each of the wells will be recorded to determine impacts of increased river flow on the shallow aquifer flow. conduct flow measurements with designated releases from Red Bluff Reservoir. **Stage 3 will begin this summer.**

A laser level was purchased with these grant funds. It will be used to record relative elevations among wells and boreholes, which will enable is to map the alluvial sediments and determine subsurface flow direction. Well pipe, well points, extensions for the bucket auger, and water level loggers also were purchased with the grant funds.

Figure 1. Monitoring well with datalogger, Pecos River, Loving County, Texas.

Table 1. Soil particle size distribution, texture and specific yield for borehole 1, Pecos River Site A, Reeves County, Texas.

Borehole 1	Sand (%)	Silt (%)	Clay (%)	Texture	Specific Yield (%)
0-1	8.29	27.54	64.17	clay	<1
1-2’	5.98	38.46	55.56	clay	<1
2-3’	13.22	45.56	41.22	silty clay	2
3-4’	31.40	39.53	29.07	clay loam	5
4-5’	25.49	26.30	48.21	clay	1
5-6’	19.29	26.55	54.16	clay	<1
6-7’	15.54	19.49	64.97	clay	<1
7-8’	6.53	22.86	70.61	clay	<1
8-9’	1.34	22.32	76.35	clay	<1
9-10’	2.72	24.86	72.42	clay	<1
10-11’	2.23	36.33	61.44	clay	<1
11-12’	1.68	23.03	75.29	clay	<1

Table 2. Soil particle size distribution, texture and specific yield for borehole 2, Pecos River Site A, Reeves County, Texas.

Borehole 2	Sand (%)	Silt (%)	Clay (%)	Texture	Specific Yield (%)
0-1’	12.54	29.32	58.14	clay	<1
1-2’	37.39	49.36	13.25	loam	12
2-3’	34.55	45.38	20.06	loam	8
3-4’	29.04	49.21	21.75	loam	8
4-5’	73.63	19.20	7.17	loamy sand	25
5-6’	78.08	14.81	7.11	loamy sand	28
6-7’	88.78	6.28	4.94	sand	35
7-8’	81.14	11.28	7.58	loamy sand	25
8-9’	78.72	10.27	11.01	sandy loam	20
9-10’	43.57	35.80	20.62	loam	10
10-11’	1.04	43.85	55.11	clay	<1
11-12’	3.92	24.77	71.31	clay	<1
12-13’	7.43	26.62	65.95	clay	<1
13-14’	4.82	23.21	71.97	clay	<1
14-15’	1.16	40.83	58.01	clay	<1
15-16’	1.13	23.99	74.88	clay	<1
16-17’	17.06	34.03	48.92	clay	1
17-18’	40.49	41.04	18.47	loam	10

Table 3. Soil particle size distribution, texture and specific yield for borehole 3, Pecos River Site A, Reeves County, Texas.

Borehole 3	Sand (%)	Silt (%)	Clay (%)	Texture	Specific Yield (%)
0-1	27.72	51.84	20.44	silt loam	8
1-2’	42.25	41.92	15.83	loam	12
2-3’	5.32	30.69	63.99	clay	<1
3-4’	16.22	31.74	52.04	clay	<1
4-5’	39.63	46.66	13.71	loam	15
5-6’	36.02	40.01	23.97	loam	5
6-7’	36.57	42.13	21.30	loam	8
7-8’	27.17	49.97	22.86	loam	7
8-9’	45.05	38.58	16.37	loam	12
9-10’	33.15	48.41	18.44	loam	10
10-11’	57.76	29.57	12.67	silt loam	17
11-12’	77.02	15.67	7.31	silt loam	28
12-13’	80.22	15.61	4.16	loamy sand	28
13-14’	80.29	13.40	6.32	loamy sand	28
14-15’	84.85	11.04	4.12	loamy sand	35
15-16’	55.99	31.65	12.36	sandy loam	20
16-17’	24.48	38.67	36.86	clay loam	3
17-18’	23.16	26.12	50.72	clay	<1
18-19’	16.42	23.36	60.22	clay	<1
19-20’	7.41	28.11	64.48	clay	<1
20-21’	7.58	29.20	63.21	clay	<1
21-22’	4.65	28.09	67.27	clay	<1
22-23’	3.08	39.01	57.91	clay	<1

Table 4. Soil particle size distribution, texture and specific yield for borehole 4, Pecos River Site B, Reeves County, Texas.

Borehole 4	Sand (%)	Silt (%)	Clay (%)	Texture	Specific Yield (%)
0-1	7.56	26.84	65.60	clay	<1
1-2’	23.59	26.59	49.82	clay	1
2-3’	34.39	44.60	21.00	loam	5
3-4’	45.75	38.37	15.87	loam	15
4-5’	46.83	38.32	14.85	loam	12
5-6’	57.97	27.20	14.83	sandy loam	15
6-7’	69.10	20.12	10.78	sandy loam	15
7-8’	49.62	15.20	35.18	sandy clay	<1

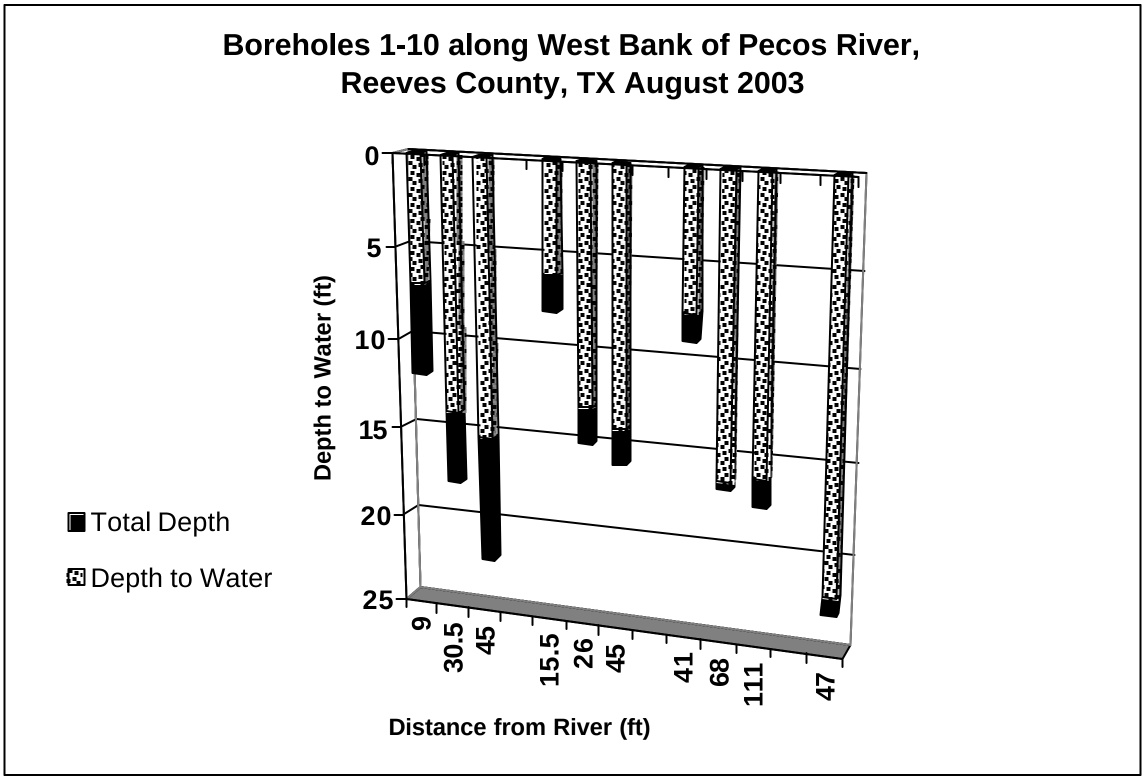

Figure 2. Total depth and depth to water, boreholes 1-10, Reeves County, Texas. Depths are from soil surface and do not include elevational differences.

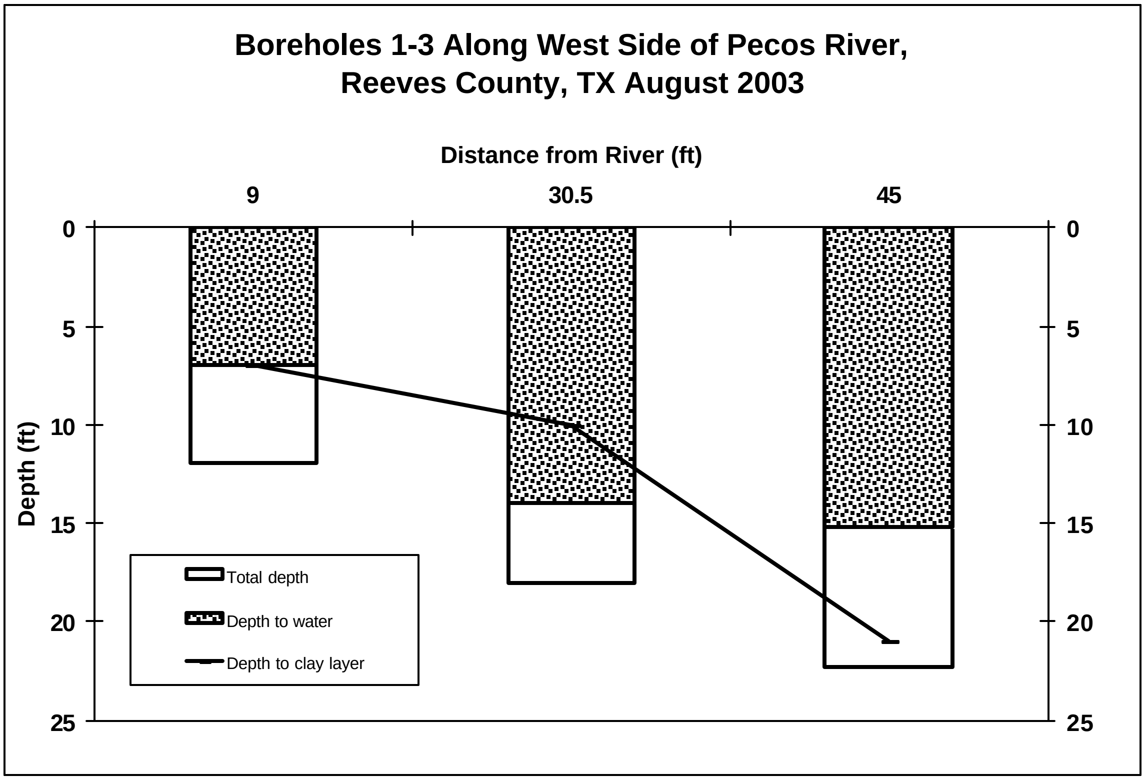

Figure 3. Total depth, depth to water and depth of clay layer, boreholes 1-3, Pecos River Site A, Reeves County, Texas. Depths are from soil surface and do not include elevational differences.

Poster Presentation:

'Pecos River Ecosystem Project: Past. Present and Future', Texas Water Summit, Austin November 2003

Graduate Degree Program:

I am a PhD student in the Department of Rangeland Ecology and Management. I will complete my coursework in Fall 2005 and Spring 2006.

Future Work:

This funding allowed me to purchase equipment and set up a well network and prepare for the next project phase, which includes seasonal seepage runs, water level monitoring and construction of flow nets.

Relating Nutrient Imports to Exports and Losses During Sod Production

Basic Information

Title:	Relating Nutrient Imports to Exports and Losses During Sod Production
Project Number:	2003TX93B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	8
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Non Point Pollution
Descriptors:	Composted Dairy Manure, Wastewater Reuse, Agricultural Nonpoint Source Pollution
Principal Investigators:	Brandon McDonald, Don Vietor

Publication

1. Richards, Chad, Clyde Munster, Don Vietor, George Stewart, I. Choi, and Brandon McDonald. 2003. "Calibration of the SWAT Model for Modeling Manure Nutrient Imports in Turfgrass Sod to a Suburban Watershed." Proceedings of the American Society for Agricultural Engineering Conference on Total Maximum Daily Loads, Albuquerque, NM, 2003.
2. Stewart, George, Clyde Munster, Don Vietor, Chad Richards, I. Choi, and Brandon McDonald. 2003. "Calibration of the Geographic Information System-SWAT Model for the Simulation of Phosphorus Export in Turfgrass Sod in the North Bosque River Watershed." Proceedings of the American Society for Agricultural Engineering Conference on Total Maximum Daily Loads, Albuquerque, NM, 2003.
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Relating Nutrient Imports to Exports and Losses during Sod Production
Progress Report

Brandon McDonald

Research

I have finished collecting data for my research project titled, “The Fate of Manure Phosphorus During Production and Harvest of Turfgrass Sod”. I am currently analyzing this data and preparing it for my Master’s Thesis. My project began in the summer of 2002. The project has paired 1.3 ha ‘Tifway’ bermudagrass sod fields with a 1% slope. Composite soil samples were taken and analyzed prior to establishing the bermudagrass sod. The fields were planted in June 2002. Soil samples were taken to a 90 cm depth in September before composted dairy manure was applied to the north field. Another round of 0-90 cm soil samples were taken in January 2003. In late May and early June, the turfgrass sod was harvested and used commercially. After this harvest, 0-90 cm soil samples were once again taken and another application of composted dairy manure was applied to the north field. In November 2003, the turfgrass was harvested and a final set of 0-90 cm soil samples were taken. All 0-90 cm soil samples were taken on 12 point grid on each field, and divided into 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, and 60-90 cm depth increments in order to look more closely at where nitrogen and phosphorus are partitioned in the soil profile.

Throughout the duration of this project, 0-5 cm samples were taken in coordination with significant runoff events in order to correlate P in runoff water and that in the surface layer of the soil. All 0-5 cm soil samples represent a composite sampling taken from each field.

The students in the Biological and Agricultural Engineering Department have worked with collection and analysis of the runoff water. In addition, water infiltration measurements were taken in May, July, and August. A soil water retention study was also conducted in August 2003.

Learning

The learning opportunities from this project have been tremendous. Although I have not finished analyzing the data, I have observed that the composted manure helps to produce high quality turfgrass that re-establishes very quickly after harvest. A preliminary analysis indicates that commercial sod grown on a clay soil with composted manure rates similar to those used in my research will not have problems with excessive P leaching or runoff.

In addition to what I have learned from the research, I have gained valuable experience from being able to grow turfgrass sod in a commercial setting. I gained experience in soil preparation, planting, establishment, fertilization, chemical applications, irrigation, and harvesting procedures. I have also benefited from learning soil analysis techniques, interpretation of complex data, and from working with a diverse research team of faculty and graduate students.

Progress Made in Spending Funds

As of mid February I have approximately $989.68 remaining from this grant. This will soon be depleted on supplies needed to finish my research.

Progress on My Graduate Program

I am currently working on my last semester of class work needed to complete my Master's Thesis. I plan to graduate in August of this year.

Natural Remediation of Contaminants Along the Forgotten River Stretch of the Rio Grande

Basic Information

Title:	Natural Remediation of Contaminants Along the Forgotten River Stretch of the Rio Grande
Project Number:	2003TX94B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	16
Research Category:	Biological Sciences
Focus Category:	Ecology, Water Quality, Hydrology
Descriptors:	rivers, Aquatic Biology, Water Quality
Principal Investigators:	Catalina Ordonez, Lisa J. Bain

Publication

1. Ordonez, C., and Bain, L.J. "Impact of heavy metals on macroinvertebrates and fish along the forgotten stretch f the Rio Grande," presented at the 1st Annual Desert Southwest Society of Environmental Toxicology and Chemistry meeting, June 25-26, 2004.

Natural Remediation of Contaminants along the Forgotten River Stretch of the Rio Grande

The purpose of this study was to measure the chemical and ecological gradient in the Forgotten River from Fort Quitman down to Presidio. This study included several sampling times during the year to asses the levels of metals, the chemical parameters and the impact on the benthic macroinvertebrate communities. As part of the investigation conducted under the TWRI-USGS grant that was provided, two sampling periods were performed, and a third one is planned for February 2004. The sampling times were modified from the original proposal due to the fact that seasonality could play an important role on modifying the hydrology of the river. Therefore, four sampling times per year, one in each season, for two years are planned to complete this project. The first sampling time was conducted in July 2003 and the second one in October 2003. The goal was to sample 6-10 site along the Forgotten River, but due to the inaccessibility of the roads, only 5 sites were sampled (Figure 1). These sites included one directly upstream from the cities of Presidio/Ojinaga (Site 1, GPS N 29° 36.219', W 104° 27.118'), one site near Candelaria (Site 2, GPS N 30° 8.005', W 104° 4.351'), two sites that were accessed through farms roads (Site 3 GPS N 30° 22.017', W 104° 48.708' and Site 4 GPS N 30° 35.113, W 104° 53.570), and one site at the International Boundary and Water Commission (IBWC) monitoring station at Fort Quitman (Site 5, GPS N 31° 5.252' W 105°36.578). Each sampling period included measurements of water chemistry utilizing an YSI Model 85 oxygen, conductivity, salinity and temperature meter. These parameters were examined because they are relevant for metal speciation and bioavailability as well as for

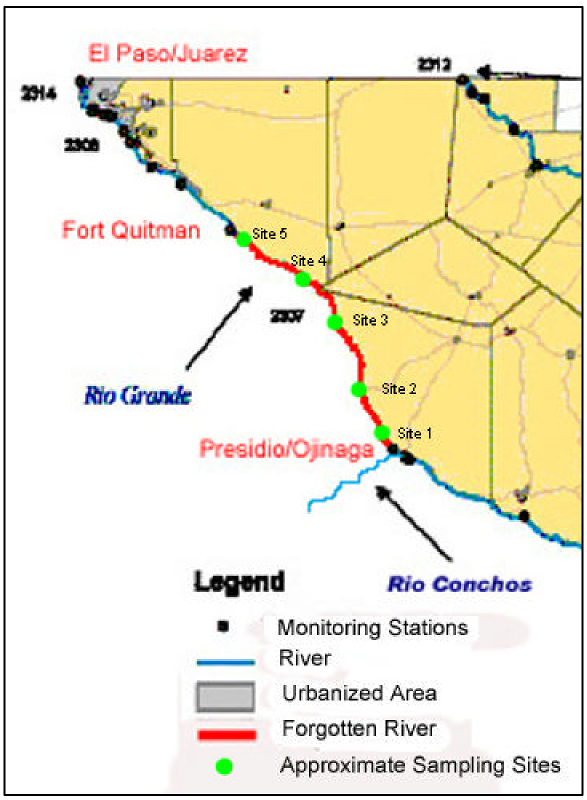


Figure 1. Forgotten River map showing approximate sampling sites.

existence of aquatic life. River physical parameters were also analyzed such as river width, depth and flow. This was done using a measuring tape and a graduated pole. The flow was approximated by allowing a floating object to flow for 10 meters and timing it, or where possible the measurements were takes from the IBWC real time measurements web page. These measurements will then be compared with other sites as well as with the same site at different sampling times. From the analysis of these parameters a correlation of metal concentration at different sites and chemical/physical parameters is expected. This will be important in determining if the presence of more water, i.e. more dilution, allows for the reduction of concentration of metals, along the gradient. Also, the parameters are going to form part of the analysis of the impact of the metals on the community. It might be possible to see that not only the presence of the metals can be disturbing the community but also the lack of water, the high salinity, or the temperature could be playing an important role.

For the collection of water and sediments there were a total of two composite samples along the width of the river at two different points in every sampling site. The water was collected by grab using 500 ml plastic bottles. All of the samples were taken facing upstream to avoid contamination. After the collection, they were acidified using two milliliters of pure nitric acid to maintain the metals in solution. They were stored on ice until arrival to the laboratory where they were stored at 4 °C. Before the metals were analyzed the samples were filtered using a 0.45µm Millipore filter, and then they were analyzed using a Perkin-Elmer Inductively Coupled Plasma spectrometer (Optima 4300 DV ICP-OES) (EPA 200.7). The metals that were analyzed (As, Cr, Cu, Ni, Pb, Zn, Cd, and Fe) were determined from looking at previous studies done in the river. The EPA found high levels of these metals in sites near El Paso/Juarez and downstream of the Forgotten River in sediments, but metals were also detected in water and fish tissue (EPA, 1997). Another study found high levels of lead and zinc in the El Paso/Juarez region, and the rest of the metals were also detected mainly in the sediments (Rios-Arana et al, 2003). In order to be able to determine if there is a concentration gradient due to the fact that the river flows undisturbed for 200 miles, the same metals that have been found in previous studies were analyzed.

The sediments were collected using a bottom sampling dredge. They were placed in 500 ml plastic bottles, and stored on ice until arrival to the laboratory where they were kept at -20°C. To analyze the sediments following EPA method 200.7, 15 ml plastic tubes were filled with sediments from each site, and then placed in a lyophilizer to freeze dry them for 48 hours. After the sediments were freeze dried, one gram per sample was microwave digested in pure nitric acid following EPA method 3051. The same metals that were analyzed in the water samples were also analyzed in the sediments utilizing the ICP/OAS.

Figure 2. Benthic macroinvertebrate sampling along the bank of the river in site 1 along the Forgotten River.

The collection of benthic macroinvertebrates was done according to EPA standards using a rectangular dipnet sampling along bank vegetation of the river (Figure 2). There were approximately 100 dips at each site. The macroinvertebrates were stored in glass jars containing 70% ethanol. In the laboratory, the organisms from each site were counted and identified to the family level. Benthic macroinvertebrates were used because they can be used as representatives of a particular site, in other words, drift of organisms from other areas is minimized. Analysis of biodiversity and species richness of benthic macroinvertebrates was done to determine the health of the system. The overall number of organisms was determined to show species richness at each site. For the biodiversity indices, the total number of species at each site was assessed. The numbers were predicted to be lowered as the site is more impacted, e.g. closer to El Paso/Juarez. The purpose of sampling macroinvertebrates was to determine if there is a shift in community compositions that is reflective of the metal pollution gradient. Several studies have shown that elevated levels of metals correspond with reduced species diversity and species richness (Clements et al, 2002). This part of the study will show the degree of impact of metals on community structure of macroinvertebrates following a pollution gradient. An interpretation of the results obtained from the indices, can be that the chemical/physical conditions of the river and the concentration of metals in the water and sediments are impacting the community structure of invertebrates.

Figure 3. Collection of fish using a seine at site 4 in the Forgotten River.

The collection of fish, proved to be a much harder task than it was expected. The water levels at the different sampling sites were very low, and thus the fish that were collected were small. The sampling was done using seines, and 10-20 fish of several species were collected at each site (Figure 3). The fish were euthanized with an overdose of MS-222 (1g/L) on site, and they were stored in dry ice until they were brought to the laboratory, where they were placed in a -80°C freezer. Biomarker expression, such as serum vitallogenin, hepatic metallothionein levels, and hepatic glutathione is still pending to be analyzed in these fish to assess metal exposure.

Preliminary Results

The chemical and physical parameters obtained from the two sampling times can be observed on table 1. From the measurements takes it can be observe that conductivity and salinity is much higher at site number 5, which is the site that is closest to El Paso. The other parameters seem to

		July 29 & 29 2003					October 18 & 19 2003				
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5
Chemical Parameters	Water Temperature (°C)	23.3	20.1	22.8	23.3	32.8	22.5	17.2	18.4	16.1	25.6
	Dissolved Oxygen (mg/L)	5.9	7.2	5.85	5.6	10.7	6.22	6.92	6.1	4.27	12.49
	Conductivity (uS)	755	519	209.9	988	6330	1532	568	668	791	5470
	Salinity (ppt)	0.4	0.3	0.1	0.5	2.9	0.8	0.3	0.3	0.4	3
Physical Parameters	Flow estimate (cm/sec)	100	58.8	0.865	0.4035	0.88	N/A	stagnant	stagnant	stagnant	N/A
	Depth Average (cm)	38	63	21	57	19	19	17.5	16	36	16.25
	Width Average (m)	10.1	6.53	14	6	25.4	18.3	5.35	8.6	3.92	14.34

Table 1. Chemical and physical parameters obtained from the two sampling times (July and October) at the five different sites along the Forgotten River stretch.
N/A= Not available

vary among the sites, but in general site 3 seems to have lower levels of the chemical measurements taken. Further analysis and more sampling periods are necessary to determine if in fact a pattern or a gradient exists as you get further away from El Paso/Juarez.

When total dissolved metals in the water were analyzed from the July sampling, the levels were undetectable for many metals except for Fe, which was also found at high levels during the October sampling (data not shown). When sediments were analyzed, many metals were detected as expected. Both sampling times reveal a pattern of higher concentration of metals in site 3.

All the benthic macroinvertebrates were analyzed to family and the data is pending to be analyzed. Nevertheless, figure 5 shows how many families (showing diversity) were found at each site in July and October. The number of families seems to decrease with closeness to El Paso, but this needs to be further analyzed to see if in fact we find a correlation with the concentration of metals in the sediments and a decreased biodiversity.

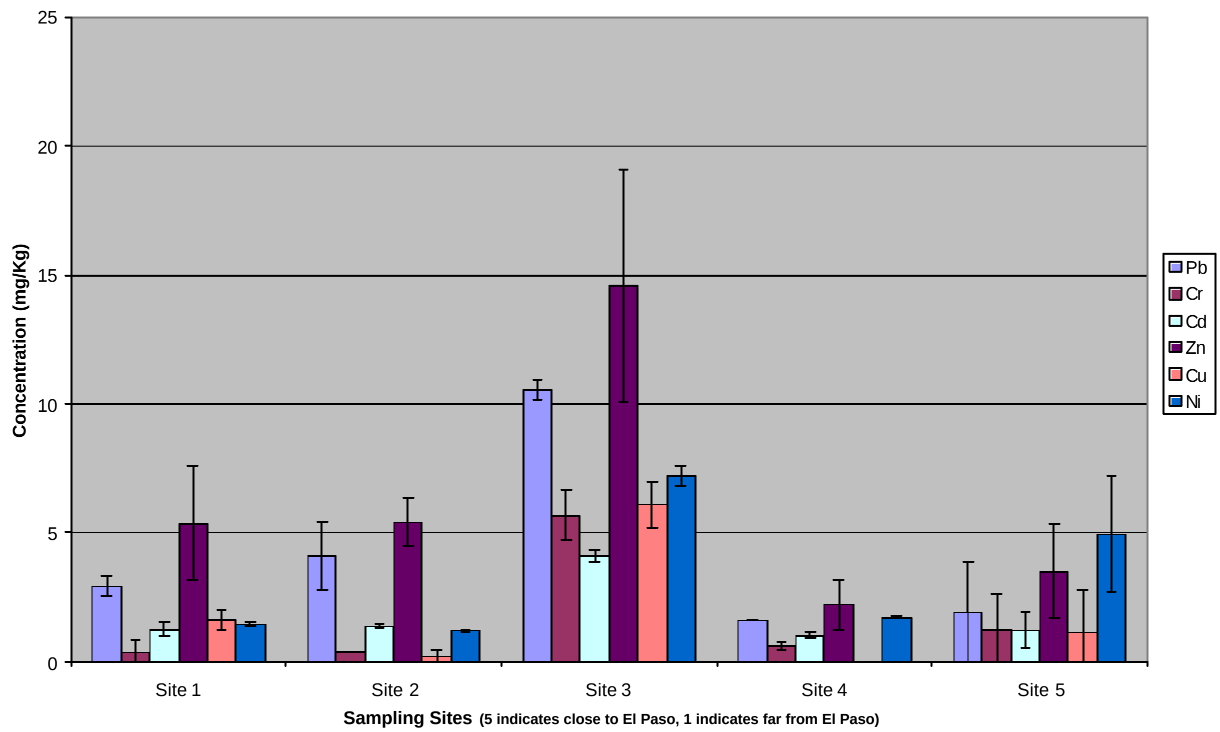


Figure 3. Total recoverable metals from sediments obtained in July. Bars indicate mean ± SD.

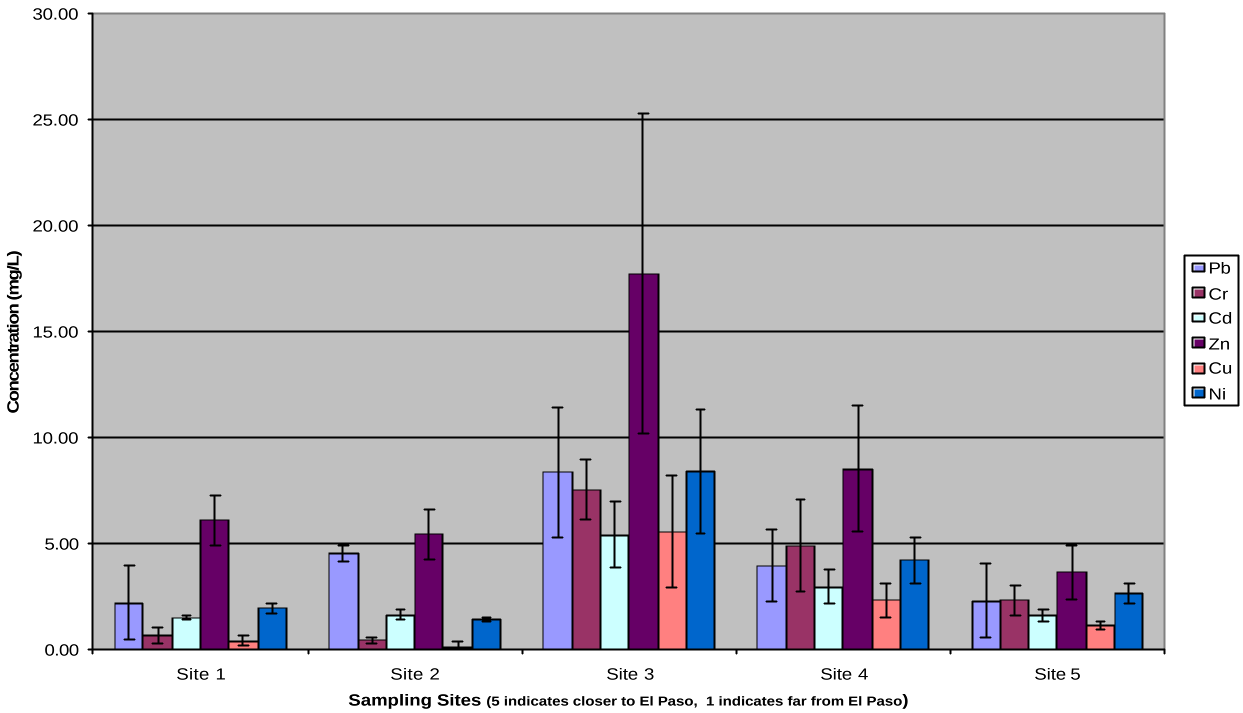


Figure 4. Total recoverable metals from sediments obtained in October. Bars indicate mean ± SD.

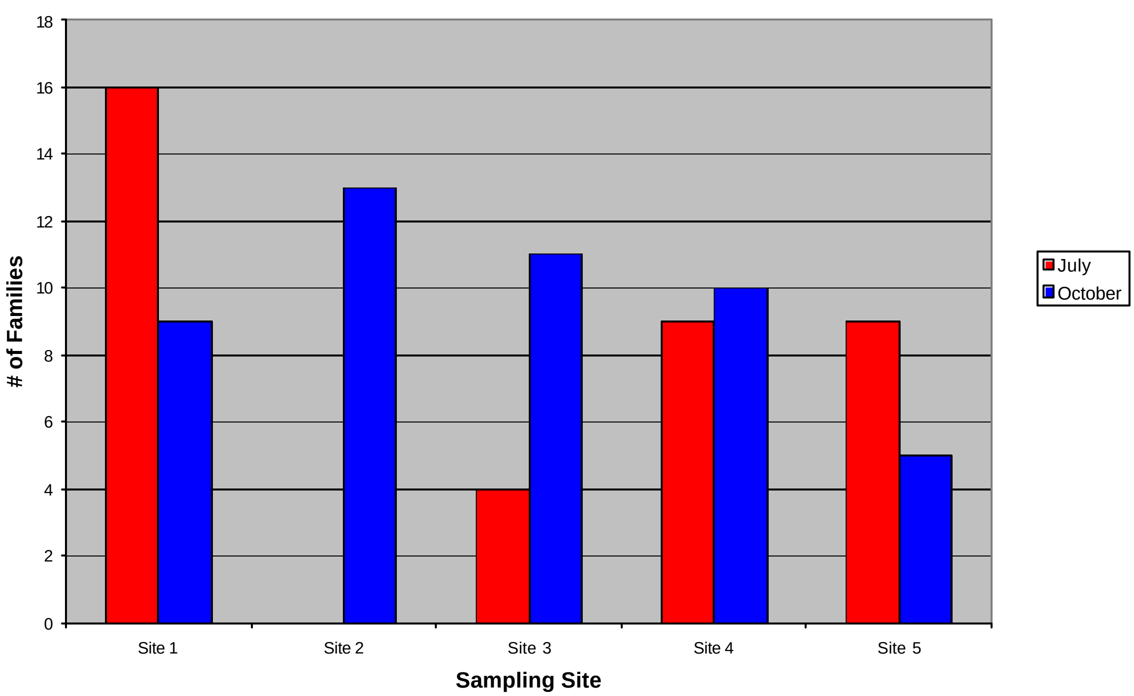


Figure 5. Total number of families of benthic macroinvertebrates present at each site in July and October.

The funds that were provided by this grant were used for the sampling times previously mentioned. A third sampling time will be taking place during February 20th and 21st using the rest of the funds. Also funds were used for supplies such as nets, bottles, nitric acid, and tubes.

Thanks to this grant I was able to gather data to have a solid dissertation proposal presentation which I will defend at the end of this semester. The funds provided were essential in carrying out the activities mentioned in this report, and have left me with an incredible satisfaction and enthusiasm for what comes next; wrapping up the study and hopefully provide a baseline study to develop a restoration plan for the river which is much needed.

Measuring Infiltration Using a Rainfall Simulator to Comparing Shrub and Water Interactions of Brush Species

Basic Information

Title:	Measuring Infiltration Using a Rainfall Simulator to Comparing Shrub and Water Interactions of Brush Species
Project Number:	2003TX95B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	5
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Water Quantity, Surface Water
Descriptors:	Brush Control, Hydrology, Rainfall Simulators
Principal Investigators:	Shane Porter, Clyde L. Munster

Publication

1. Porter, S., Munster, C. L. "Development of a Portable Rainfall Simulator for Large Plot Brush Control Hydrology Studies." In Proceedings of the International Meeting of the American Society of Agriculutral Engineers in Las Vegas, NV. Riviera Casino during July 27-30, 2003.
2. Porter, S., Munster, C. L. "Rainfall Simulation Study of a Hillslope Covered in Dense Juniper." In Proceedings at the 2003 American Geophysical Union. San Freancisco, California at the Moscone Center West during December 8-12, 2003. The poster highlighted preliminary results of a filed study at Honey Creek State Natural area in Bulverde, TX.

Progress Report to Texas Water Resources Institute

This report is to update the Texas Water Resources Institute about progress made on research funded by the institute through a USGS grant awarded in 2003. The grant was awarded for Measuring Infiltration using a Rainfall Simulator for Comparing Shrub and Water Interactions of Brush Species**.** *This progress report will present discussion on the following issues: Research – related activities, Insights on information learned during the research, Experiences of shared information related to the project, Progress made in expanding funds, Progress on graduate degree, and Related activities of the committee chairman as a result of this grant.*

Research Related Activities

Funding from other Texas Water Resources Institute grants in the past have allowed the rainfall simulator to be developed and constructed. Money was used to support salaries for student workers, purchase necessary materials and equipment, and was used to purchase an equipment trailer. Once the simulator was constructed and tested, it was set up at the Texas Agricultural Experiment Station in Sonora, TX. This initial study took place from October 2002 to June 2003. The rainfall simulator was installed around a 3 m by 12 m plot which was covered with heavy brush. The plot was instrumented to collect information such as soil moisture, surface runoff, and stemflow within trees. Unique to this site was the addition of a trench at the base (down slope) of the plot. The trench assisted in visually monitoring and quantifying lateral subsurface flow within this system. Artificial rain events were applied to the plot at varied intensity and duration (4 in per hour for 45 minutes to 1 in per hour for seven hours). At the conclusion of the initial simulations, the brush was removed from the plot, and simulations commenced. An "open canopy," or grass plot was installed in close proximity to the brush plot to be used as a control in the experiment.

At the conclusion of work at the Sonora Experiment Station, the rainfall simulator was relocated to Honey Creek State Natural Area, close to Bulverde, TX. There the simulator was installed on a 7 m by 14 m plot containing heavy brush. Knowledge gained from tests conducted in Sonora allowed the research team to scale up the plot studies without compromising the integrity of the basic design on the rainfall simulator. To accomplish simulating rainfall on this larger plot size, the unit would require slight modifications to conserve water while applying water on the area.

The plot at Honey Creek was instrumented similarly to the plot at Sonora. The brush species was notably different there when compared to Sonora, which made certain instrumentation difficult. The Honey Creek site had a larger trench dug at the base of the plot, again to visually observe and quantify subsurface flow. Similar intensities of water were applied to this plot site.

Figure 1. Rainfall Simulator Deployed at Honey Creek State Natural Area

This study is currently in progress. A second grass plot is being installed at the area and experiments will start in the near future. The brush on the original Honey Creek plot will be removed, and simulations will resume once the area is cleared. Future applications of the rainfall simulator include setting the unit above a cave and quantifying recharge through the soil and rock structures. This study will be conducted at Camp Bullis in San Antonio, TX, and will commence in the near future.

Insights on Information Learned

The addition of the trench to the research site at the base of the plot has proved to be invaluable. We are able to get a basic idea of lateral subsurface flow from the plot. This flux can be related back to the amount of water that was applied to the plot of exact dimension. An appreciable amount of water applied at the surface reappears as lateral subsurface flow in the trench (as much as 10%). A dye tracer test was conducted in conjunction with the Edwards Aquifer Authority. The results of this test are still being analyzed. Preliminary information from this study suggests that dye that was applied at the base of a tree 7 m from the trench appeared as subsurface flow from the trench face. This suggests that a relationship may exist between the roots of brush species and potential water recharge.

Figure 2. Water Sampling During a Dye Tracer Test at
Honey Creek State Natural Area

Experiences of Shared Information

During the previous year, we gave a presentation on a conference paper at the International Meeting of the American Society of Agricultural Engineers in Las Vegas, NV. The conference was held at the Riviera Casino during July 27 – 30, 2003. The presentation covered the paper written for this international meeting entitled, *Development of a Portable Rainfall Simulator for Large Plot Brush Control Hydrology Studies.* This paper discussed the development of the simulator and knowledge learned from a field campaign using the unit at the Texas Agricultural Experiment Station in Sonora, TX. The conference was attended by Agricultural, Biological, Forestry, and Food Engineers world wide.

We also gave a poster presentation at the Fall Meeting of the American Geophysical Union. This meeting was held in San Francisco, California at the Moscone Center West during December 8 – 12, 2003. The poster was titled *Rainfall Simulation Study of a Hillslope Covered in Dense Juniper.* The poster highlighted preliminary results of a field study at Honey Creek State Natural area in Bulverde, TX.

The main rainfall simulation study to date is established at the Honey Creek State Natural Area. The current research site is a collaborative effort of researchers from the Department of Biological and Agricultural Engineering and Department of Rangeland Ecology Management at Texas A&M University, from the Texas Agricultural Experiment Station in Uvalde, TX, and researchers from the University of Texas and Duke University. Many distinguished guests to the research site, including world – renowned scientists from many universities. In addition, many agencies that support this research have brought their own employees and their colleagues.

Progress Made in Expanding Funds

Money from this generous grant is still available to purchase additional research equipment. We have been very fortunate to have the cooperation of many entities that can provide services and support at no cost. Texas Parks and Wildlife has allowed us access to their land to conduct research. Bexar Met Water District is providing water essential to this research.

Progress on Graduate Degree

The majority of my research has comprised field work at Sonora and Bulverde, TX. My thesis is in the process and I am planning to defend it in time to graduate in May 2004. I am finished with the class requirements of my degree program.

Related Activities of Chairman

Information learned from initial tests conducted with the rainfall simulator have allowed collaborators of this research project to secure additional funding to continue this research. As mentioned, future work will soon commence at Camp Bullis. This project will add valuable insight to the overall picture of water recharge, since actual recharge will be documented within a cave that exists below the research plot. Future plans are to take this research to the next scale by installing a series of rainfall simulators at the hillslope scale (rather than just the large plot scale) in an effort to look at watershed issues of brush control.

Spatial and Temporal Characterization of the Radon Distribution in a Region of the Hickory Aquifer in Central Texas: Assessment of Stratigraphy and Groundwater Dynamics on Radon Concentrations

Basic Information

Title:	Spatial and Temporal Characterization of the Radon Distribution in a Region of the Hickory Aquifer in Central Texas: Assessment of Stratigraphy and Groundwater Dynamics on Radon Concentrations
Project Number:	2003TX96B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	21
Research Category:	Ground-water Flow and Transport
Focus Category:	Radioactive Substances, Groundwater, Water Quality
Descriptors:	Groundwater Quality, Radionuclides, Geohydrology
Principal Investigators:	Leslie Randolph, Bruce Hebert

Publication

1. None

Leslie Randolph **TWRI Progress Report** **February 20, 2004**

I. Activities in chronological order

- Extensive research on best instrument to purchase to measure radon in groundwater led to decision to try to purchase a liquid scintillation detector (LSC). Discovered these are expensive instruments, but we have one on campus, in the Environmental Health and Safety Office (EHSO), that could be upgraded to do radon analyses. The manager of the EHSO agreed to let me upgrade their instrument, but the bid came in at ~$5,500.00, which was more money than I had/wanted to spend since I also need money for analyses of other chemical constituents in the Hickory groundwater.

- Networked through colleagues and friends, spoke with representatives of companies that sell other radon monitoring instruments and contacted government scientists involved in radiochemical analyses (including people at USGS, TAMU Department of Nuclear Engineering, TAMU Nuclear Science Center, Environmental Chemistry Lab at the Texas Department of Health). This effort led to the fortuitous discovery that a personal friend had two radon monitoring instruments that he wanted to sell. It also provided me with some useful contacts at TAMU and TDH.

- Completed a comprehensive literature search on studies of U and Th radionuclides in groundwater and the aqueous chemistry of U, Th, Ra and Rn. This document already has proven to be a very useful resource.

- Purchased the radon monitoring instruments (Pylon AB-5; details on the instrument provided below) and accessories from my friend. These instruments measure radon in air only, so I purchased a Water Degassing Unit (WG1001) from Pylon designed to be used with the AB-5 instruments. This apparatus allows one to strip radon from a water sample so that the radon concentration can be analyzed with the AB-5. An added benefit of using these instruments is that the water sample can be entirely stripped of radon, and then held for about 30 days while radon grows in as the radium in the groundwater sample decays. The sample is then degassed again, and the concentration of radium in the groundwater can be calculated from the radon concentration in the sample. For reasons discussed below, the ability to measure radium concentrations, in addition to radon concentrations, will greatly enhance what can be learned from this study.

- Calibrated Pylon AB-5 with help from Pylon representative. Pylon normally recommends that their technicians calibrate their instruments. Doing this independently helped save the project some money.

- Studied detailed stratigraphy at my field site, layout of monitoring wells and locations of monitoring zones in the wells, as part of the planning for the field efforts.

- Made preliminary measurements of the ^{222}Rn concentration in Hickory groundwater in four monitoring zones in one of the wells and the ^{226}Ra concentration in groundwater collected from a house well. This field work familiarized me with what to expect, when I undertake the first sampling effort, in terms of collecting water samples from the monitoring wells, degassing the samples, and analyzing them with the Pylon AB-5.

- I presently am preparing to do the initial field work for the project, which will take place during this spring semester. I am designing the groundwater sampling scheme, i.e. which zones will be sampled and which chemical constituents will be included in the analyses. I also am learning to use field analytical instruments, learning about appropriate sample containers, sampling methods, analytical labs and costs of analyses .

II. Analytical instruments

The Pylon AB-5 uses a photomultiplier tube (PMT) coupled with a Lucas style scintillation cell to count the scintillations (light pulses) produced when alpha particles from decay of radon and it's two daughter products strike the zinc sulfide coating on the inside of the cell. The scintillator (zinc sulfide) is insensitive to beta and gamma radiation, temperature and humidity. The lowest activity detectable (LAD) by the cells that I purchased is 0.74 pCi/L (27.4 Bq/m^3) (LAD is with a 95% probability of being distinguished from background).

Pylon AB-5

Water Degassing Unit

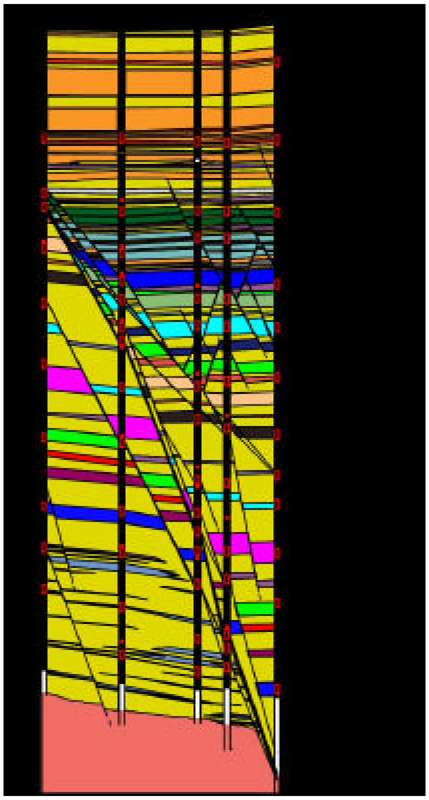
III. Literature Search

The extensive literature search revealed a variety of approaches to studying U- and Th-decay chain radionuclides in rock and groundwater (including field geochemical studies, lab studies, and analytical and numerical models). The take-home message from the literature is that the occurrence of these radionuclides in groundwater is controlled by the concentration and location of the radionuclides in the rock, the complex water/rock interactions that are a function of the aqueous chemistry, and of course the hydraulic characteristics of the aquifer and surrounding rock units.

Radon gas is chemically inert but can become mobile if it is "ejected" into the groundwater during decay of its parent radium. Since ^{222}Rn's half-life is relatively short, 3.82 days, it does not migrate far from its source before it decays. Hence, the concentration of radon in the groundwater reflects the concentration of radium in the rock that is close enough to the water/rock interface such that radon can escape to the water via alpha recoil. The concentration of radium in the groundwater will reflect the concentration of radium in the rock that is close enough to the water/rock interface such that radium can be dissolved (if conditions are suitable), and/or the concentration of it's parent, thorium, in the rock that is close enough to the water/rock interface such that radium can escape to the water via alpha recoil. The aqueous chemistry controls whether radium that enters groundwater will stay in solution or sorb to mineral surfaces or colloids.

I keep coming back to aqueous chemistry. It is clear that knowledge of the groundwater chemistry is critical to understanding the dynamics of radium, and therefore to some degree radon, in the aquifer. It also is clear from the literature that radionuclide concentrations and groundwater chemical concentrations rarely can be correlated.

IV. Study Site Stratigraphy, Structure and Hydraulics



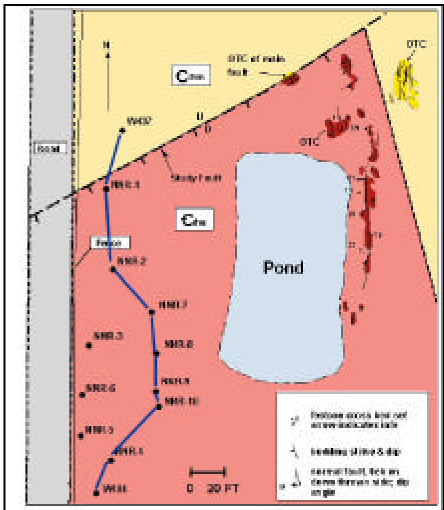
Wilson (2000?) compiled detailed cross sections of the site stratigraphy and geologic structure (faults) and Zhurina (2000) modeled the groundwater flow regime, under the guidance of Professor Brann Johnson. Johnson installed eight Westbay monitoring wells at the site. A total of ninety-four stratigraphic zones are isolated in the wells. Pressures in the zones can be monitored continuously, and groundwater samples can be collected.

The figure at left is a cross section showing the aquifer stratigraphy and five monitoring wells installed in the aquifer. The vertically oriented rectangles represent the location of packers, which are inflated against the borehole wall and impede vertical flow. Many are situated in low permeability clay layers, and therefore isolate more permeable zones in the aquifer.

During the initial field effort, at a minimum all zones in one borehole will be sampled and analyzed for a host of chemical constituents and radon and radium. This data will allow me to characterize the chemistry of the aquifer as it relates to the stratigraphy.

V. Preliminary Measurements

The table below shows the concentrations of ^{222}Rn in Hickory groundwater in four of the monitoring zones in well NNR-4, and the ^{226}Ra concentration in Hickory water collected from a house well near the field area. The site map is provided to show the location of NNR-4. The zones in each well are numbered from the bottom of the well to the top. These preliminary measurements lend confidence to my analytical methods, and suggest that the radon concentration does vary with the stratigraphic units. The detectable radium concentration is not a surprise, since radium has been detected in groundwater from many Hickory water wells.

	**Zone**	**^{222}Rn concentration (pCi/l)**
	11	344
	9	388
	7	473
	2	274

In conclusion, I believe I have made considerable progress with this research. Though the delay in funding for the project (received the end of July 2003) set back plans for sample collection and analyses, it gave me time to conduct other research critical to the project. Groundwater samples will be collected and analyzed this spring for a host of chemical constituents. The initial sampling effort will identify and quantify the chemical constituents in the water in the various rock layers. This information will be used to plan and undertake a more extensive groundwater sampling and analysis effort.

Groundwater Data Modeling for Arc Hydro

Basic Information

Title:	Groundwater Data Modeling for Arc Hydro
Project Number:	2003TX97B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	10
Research Category:	Engineering
Focus Category:	Groundwater, Models, Methods
Descriptors:	Computer Models, Geographic Information systems
Principal Investigators:	Gil Strassberg, David R. Maidment

Publication

1. Strassberg, G., Maidment, D. R. Arc Hydro groundwater data model. AWRA May 2004 Spring Specialty Conference on GIS and Water Resources (Paper accepted).
2. Strassberg, G., Maidment, D. R. Arc Hydro groundwater data model. AGU fall meeting 2003.

Arc Hydro groundwater data model – Progress report June 2004
David R. Maidment and Gil Strassberg

a) ***research-related activities [i.e., tests or experiments you conducted]:***

We are in the process of designing a data model to represent groundwater systems within GIS. Activities related to the data model development are:

- **Review of available data models**: The review helps to understand how to conceptually describe three dimensional phenomena dealing with subsurface properties and how to represent measurements at wells and boreholes. Data models reviewed included the Petroleum Public Data Model, The EarthFX data model, the North American data model and the marine science data model.
- **Design of a data model interface for MODFLOW**: A draft data model interface was designed for MODFLOW. MODFLOW is the most common software package used in groundwater modeling. The data model interface is a database design for storing MODFLOW inputs and outputs within GIS.
- **Integration of GAM models from the TWDB with the MODFLOW data model interface**: model inputs and outputs from the TWDB Groundwater Availability Models (GAM) were integrated with the MODFLOW data model interface. Information from GAM models of the Carrizo Wilcox and the Northern Edwards aquifers were integrated into GIS using the MODFLOW interface data model.
- **Experiments on how to construct three dimensional objects within ArcGIS**: Experiments with the three dimensional objects within ArcGIS are conducted to assess the possibilities of using three dimensional objects for describing groundwater features. Features such as cross sections, well hydrostratigraphy, and volumetric objects are being stored in a spatial database, and tools are being developed to create these features.
- **Design of a draft data model:** A draft data model has been designed, and a document presenting the data model is being circulated among groundwater professionals for review. Once the review process is complete a more detailed design will be completed from the draft data model.

b) ***insights to what you learned during the research [i.e., preliminary results]***

The experiments and design processes described above expanded our knowledge and understanding of groundwater systems and how they are conceptually described and modeled. We learned how MODFLOW is constructed, and what are the parameters needed to model groundwater. We also gained a better understanding on the use of GIS to represent three dimensional phenomena.

c) Experiences where you shared information about the project [i.e., scholarly accomplishments, and citations of presentations, papers, abstracts, etc.]

Papers:

- Gil Strassberg and David R. Maidment. Arc Hydro groundwater data model. AWRA May 2004 Spring Specialty Conference on GIS and Water Resources (Paper accepted).

Presentations:

- Gil Strassberg and David R. Maidment. Arc Hydro groundwater data model. AGU fall meeting 2003.

d) Progress you made in expending funds [were all the funds spent?]

Out of the $4,182 granted, $3,500 was used for the following purposes:

- Purchase of a computer hardware.
- Purchase of technical books.
- Computer software license.

e) progress on your graduate degree program

All the following are at the University of Texas at Austin department of Civil Engineering:

- Graduated from the Masters program in May 2003.
- Passed qualifier exam in September 2004.
- Formally accepted as a ph.D candidate in January 2004.
- Defended dissertation proposal in May 2004.
- Expected graduation in May 2005.

f) Related activities that your Chairman may have involved in as a result of this grant [i.e., did this grant lead to follow-up funding or did it support other projects?]

Bridging the Gap Between Plankton Dynamics and Spatial Variability in Water Quality in the Guadalupe Estuary (Texas): The Importance of Freshwater Pulses

Basic Information

Title:	Bridging the Gap Between Plankton Dynamics and Spatial Variability in Water Quality in the Guadalupe Estuary (Texas): The Importance of Freshwater Pulses
Project Number:	2003TX112G
Start Date:	9/1/2003
End Date:	8/31/2004
Funding Source:	104G
Congressional District:	8
Research Category:	Water Quality
Focus Category:	Ecology, Water Quality, Water Quantity
Descriptors:	Estuary, Freswater Inflows, Salinity
Principal Investigators:	Stephen Edward Davis, Daniel L. Roelke

Publication

1. Will present preliminary findings of research in Estuarine & Tidal Wetlands Session at the 2004 Annual Meeting of the Society of Wetland Scientists, Seattle WA. Abstract entitled: Determining the Importance of Freshwater Inflows to Ecological Structure and Function in the Bays and Marshes of the Guadalupe Estuary (TX)

BRIDGING THE GAP BETWEEN PLANKTON DYNAMICS AND SPATIAL VARIABILITY IN WATER QUALITY IN THE GUADALUPE ESTUARY (TEXAS):
THE IMPORTANCE OF FRESHWATER PULSES

First Semi-Annual Research Progress Report
Year 1

March 18, 2004

Submitted to:

National Institutes of Water Resources

Through:

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USGS Project ID# 2003TX112G
TAMU Account No. 57136800

INTRODUCTION

In accordance with the reporting policies established by the National Institutes of Water Resources, this report describes the activities undertaken by researchers at Texas A&M University throughout the first six months of funding (September 1, 2003 through March 18, 2004) for project ID # 2003TX112G.

TASKS COMPLETED

After resolving confusion over the accounting and location of funds transferred from the U.S. Geological Survey, we had access to our account on October 9, 2003. At that point, we began the process of acquiring necessary field and lab equipment to initiate our study in the Guadalupe Estuary. This involved updating necessary quotes for items and submission purchase order requests. The major equipment purchases supported by this project are a Dataflow unit—to be used for high resolution spatial sampling of water quality in the Guadalupe Estuary—and an incubator array—to conduct experiments on the effects of water residence times and salinity on plankton community dynamics.

Due to purchasing delays and bidding problems, the university has only recently released a purchase order for the construction and delivery of the Dataflow unit. Much of the problem was due to the unit's necessary parts being acquired and then assimilated by a private consultant—the developer of the technology (Dr. Christopher Madden). All of these problems have been resolved. We expect to have the Dataflow unit on hand (i.e. at Texas A&M University) in early to mid-April and fully functional before our May sampling. The unit we are purchasing will have built-in and integrated sensors for simultaneous measurement of surface water temperature, pH, salinity/conductivity, chlorophyll a fluorescence, DOM fluorescence, turbidity, ambient PAR, and water depth. Figure 1 is a photo of the sensor housing for the type of unit currently being built for this study.

Figure 1: Photo illustrating design and layout of Dataflow being built for this study.

This project supports the establishment of an automated water sampler to be based in the Lower Guadalupe River, near the saltwater barrier (see site #8 in Figure 2). Working with representatives of the Guadalupe-Blanco River Authority (GBRA), we have recently received authorization to establish our sampler under an equipment shed near the saltwater barrier. This shed houses a USGS gauging station (station # 08188800 Guadalupe River near Tivoli, TX). Flow data generated from this station will be used in conjunction with nutrient data derived from analyses on the water collected by our sampler to estimate nutrient loading into the estuary. GBRA has also extended an electrical conduit from this equipment shed and installed an electrical outlet (110 volt) to power our sampler for the duration of the project.

This project also has funds to build a plankton incubator array. One third of this array is built and fully functional. The first plankton community experiment will commence in April 2004. Construction of the remaining array will be completed by mid-summer of 2004. The limiting factor at this moment is the schedule of a glassblower with expertise necessary to make the specialized plankton chambers.

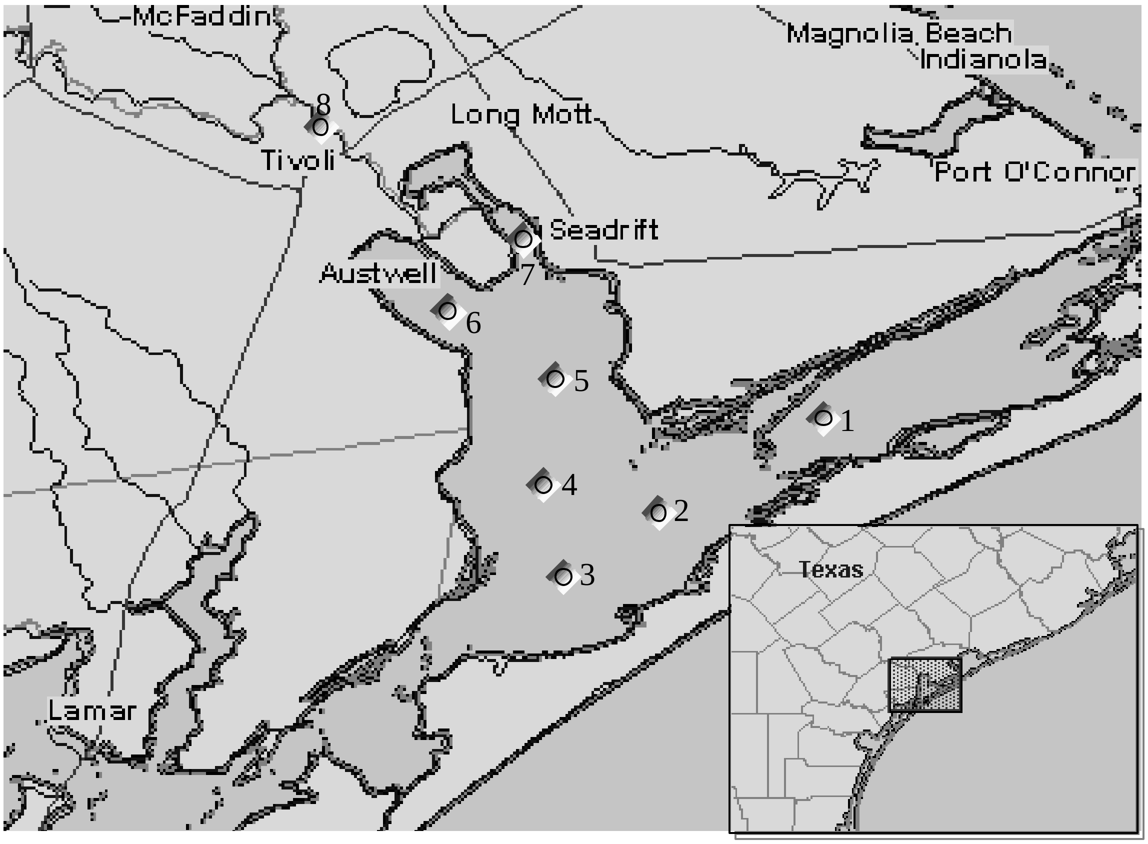

Figure 2: Map of Guadalupe Estuary (Texas) created using EPA's Enviromapper. Site locations are indicated and correspond to site information presented in Table 1.

We also began an active search for a graduate student to conduct work on and be supported by this project. This project has funds to support one graduate at the Master's level. This past year we recruited for this position by posting announcements on the ASLO and ERF society web pages. We also actively pursued promising students on campus and at other institutions. We have successfully recruited a student for this position who will officially start on this project in June 2004. Carrie Miller, an undergraduate at Millersville University, PA, and runner-up for "Best Undergraduate Research Presentation" at the recent international ERF conference in Seattle will be working directly with both PIs and will be involved with all aspects of the project.

Thus far, we have completed two monthly sampling trips (February and March 2004) in which we have identified our fixed sampling stations (n=8) and, at each, collected surface water and net tows for nutrient analyses and plankton identification and enumeration. We also measured water column productivity and respiration at these stations. The sites and their approximate locations are included in Figure 2 and Table 1. Our salinity data from our March sampling clearly indicate the spatial variability we expect to see along the salinity axis of this estuary throughout the study.

We will continue to perform our samplings each month for the duration of the study, but we also intend to repeat samplings on consecutive days during high inflow events as described in our proposal. This phase of the study will not begin until we have all aspects (Dataflow, incubator array, etc.) of the project functioning (anticipated May 2004).

Table 1: GPS coordinates, location description, and surface salinity data (from March 2004 sampling) for all eight sites to be sampled monthly in this study.

ID	Latitude	Longitude	Salinity (‰)	General Location Description
1	28°19.00'	96°36.00'	27.5	Espiritu Santo Bay
2	28°16.00'	96°41.00'	22.1	San Antonio Bay
3	28°14.00'	96°44.00'	23.6	San Antonio Bay
4	28°18.00'	96°45.00'	16.3	San Antonio Bay
5	28°21.00'	96°44.00'	14.3	San Antonio Bay
6	28°23.00'	96°48.00'	9.8	Hynes Bay
7	28°26.00'	96°46.00'	2.2	Guadalupe Bay
8	28°30.20'	96°53.04'	0.4	Lower Guadalupe River

SUMMARY OF PLANNED ACTIVITIES

- We are in the process of planning our April 2004 sampling trip and completing construction of the incubator array.
- We plan to initiate plankton incubations immediately after this sampling trip.
- We expect to have the Dataflow in hand and operational by the May 2004 sampling.
- Carrie Miller will begin her graduate work on this project in June 2004.
- Will present preliminary findings of research in Estuarine & Tidal Wetlands Session at the 2004 Annual Meeting of the Society of Wetland Scientists, Seattle WA. Abstract entitled: Determining the Importance of Freshwater Inflows to Ecological Structure and Function in the Bays and Marshes of the Guadalupe Estuary (TX)

Information Transfer Program

Texas Water Resources Institute Information Transfer Program FY 2003-04

Information transfer activities in 2003 focused on developing new publications, videotapes and fact sheets and updating newsletters, Web sites, and brochures, as well as supporting conferences, workshops, and demonstration projects associated with programs of Texas Cooperative Extension.

During 2003, TWRI created fact sheets about U.S. Geological Survey-supported grants program as well as individual projects supported by external funds and private endowments. In addition, TWRI revised its Web site, developed a new brochure outlining the Institutes expanded mission and focus, and developed strategies to refine the scope, purpose, and distribution of TWRI newsletters. The Institute was also engaged in capturing the results and achievements of projects supported by the USGS-NIWR program through technical reports, scientific papers, posters, and other means and making these materials available to the public through the TWRI Web site.

The Institute played a key role in transferring technology and disseminating information about timely issues in water resources through involvement and support of conferences, workshops, and seminars. For example, TWRI was a co-sponsor of the Texas Water Summit and developed policy papers for this event. The Institute co-sponsored the International Conference on Agricultural Science and Technology, which devoted a session to water resources issues. In addition, TWRI sponsored a regular series of seminars in which USGS-funded graduate students and researchers presented results of their research and outreach activities. TWRI also supports ongoing Extension programs to educate groundwater district managers and the general public about policies and emerging issues they need to know about, and assisted in efforts to create videotapes and DVDs describing water law and policy issues.

Substantial efforts in information transfer and information dissemination are associated with the TWRI Rio Grande Basin Initiative (RGBI). This program includes substantial research and Extension work along the Texas-Mexico border. Information transfer programs associated with RGBI include newsletters, conferences, special publications, demonstrations, and outreach and education activities.

Other significant externally funded programs that TWRI communicated through information transfer activities include efforts to utilize composted dairy manure to remove a source of nonpoint source pollution from Central Texas watersheds; protecting water quality in North Central Texas through modeling and education activities; stabilizing military training areas on Fort Hood that are subject to heavy erosion losses by applying compost to revegetate disturbed lands; and identifying the potential to treat naturally saline groundwaters and brackish waters that may result from oil and gas production and to then make this resource available to rural communities. Each of these programs involves significant opportunities for information transfer.

Through 2003 TWRI operated/moderated Watertalk, an electronic mailing list. This list provides an opportunity for person in the water resources community to ask questions, receive feedback, publicize conference, and share information.

TWRI has developed individual fact sheets, brochures, and Web sites for these projects and is working to develop specific bulletins on research resulting from these efforts.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	12	0	0	0	12
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	15	0	0	0	15

Notable Awards and Achievements

Jason Afinowicz was honored with the Outstanding Achievement in Master's Research in 2004 by the Association of Former Students at Texas A&M University.

Roger Havlak won 2nd place at the Texas Water Summit Poster Competition.

Yoko Masu has been awarded a graduate Fellowship at Stanford University,(Department of Geological and Environmental Sciences) to pursue her Ph. D. Degree. We have a User proposal approved for beam time at the National Synchrotron Light Source (NSLS), Brookhaven National Laboratory, for spectroscopy (EXAFS and XANES) that does relate directly to this project.

Publications from Prior Projects