Water Resources Research Institute
Annual Technical Report
FY 2009

Introduction

This program report provides the required information for projects funded with the 2009 base grant and mandatory non-federal matching funds. Please note that there may be some overlap in information with our 2008 report because data collection is based on a July-June fiscal year rather than the March-February USGS Grant Award period.

The New Mexico Water Resources Research Institute (NMWRRI) was established in 1963 by the New Mexico State University Board of Regents, becoming one of the first of the 54 state institutes approved nationwide under the authorization of the 1964 Water Resources Research Act. It is considered to be the statewide nucleus for coordinating water resources research. Using the expertise of researchers in a variety of disciplines at state-supported universities, the institute is able to respond to the critical water needs of New Mexico and the region. It operates under the general advice of a Program Development and Review Board, whose membership includes faculty representatives as well as state and federal agency personnel.

The mission of the NMWRRI is to develop and disseminate knowledge that will assist the state, region, and nation in solving water resources problems. Specifically, the institute encourages university faculty statewide to pursue critical areas of water resources research while providing training opportunities for students who will become our future water resources scientists, technicians, and managers. It provides an outlet for transferring research findings and other related information to keep water managers and the general public informed about new technology and research advances. In addition, the institute maintains a unique infrastructure that links it with many federal, state, regional, and local entities to provide expertise and specialized assistance.

The institute maintains a dynamic program to transfer technical information from the producer to the user and the public. Technical publications, newsletters, conferences, press announcements, and presentations keep practitioners aware of new technology and research advances. The NMWRRI homepage (wrri.nmsu.edu) provides online information about the institute, newsletters, technical report series, requests for proposals, upcoming conferences and symposia, links to related entities, and the research reference library.

New Mexico is one of the driest states in the nation, averaging no more than 20 inches of precipitation a year, varying from about 6.5 inches in the Four Corners area to more than 30 inches in the high mountains. The relative humidity is low, resulting in a high rate of evaporation. Summer rain accounts for almost half of the annual precipitation other than in the high mountains. Widely varied precipitation contributes as much to a water allocation problem as water scarcity itself. To compound the situation, New Mexico, like much of the West, continues to suffer from the worst drought in 100 years or longer. Water conservation measures continue to expand in municipalities throughout New Mexico to help ensure adequate public water supplies for residential and industrial use. Drought ordinances are in place in cities across the state, and county and municipal governments are working together to limit water use and reduce demand. The Drought Task Force, established in April 2002 by New Mexico's governor after declaring a state of emergency because of the drought, continues to monitor the situation.

During the past year, New Mexico experienced a reprieve from the drought conditions of previous years. The 2009 monsoon season brought average rainfall and the winter saw above average snowfall. Reservoirs throughout the state are generally at normal levels. Streamflow data indicate normal flows throughout the state with below normal flows in the far northwestern corner of the state. Still worrisome is that another drought will have harsh repercussions on the state.

Water problems in New Mexico, like in other western states, continue to revolve around three key issues: quality, quantity, and management. Because water resources are so limited, water quality and water resources

management have taken on increasing importance. These concerns are interrelated and sufficiently complex so that the highest quality research is essential to solving them.

Research Program Introduction

The primary objective of the New Mexico Water Resources Research Institute is to maintain a balanced program of research that addresses water issues and problems critical to New Mexico, the region, and the nation. In administering this program, the institute relies on financial support from state appropriations, federal and state agencies, and the USGS Water Resources Research Institute Annual Base Program (USGS 104B).

To make the best use of limited resources, the institute has targeted four areas as high priority for funding: water conservation, planning and management; atmospheric, surface and groundwater relationships; water quality; and utilization of saline and other impaired waters. During the reporting period, three projects received funding from the 2009 Annual Base Program. These projects fit into the water conservation, planning and management category: "WRRI Information Transfer Program," "Land Application of Industrial Effluent on a Chihuahuan Desert Ecosystem: Impact on Soil Physical and Hydraulic Properties," and "Geographic Information System for Water Resources Planning." The NMWRRI also administered a USGS 104G award categorized in the atmospheric, surface and groundwater relationships category: "Validation, Calibration and Improvement of Remote Sensing ET Algorithms in Mountainous Regions." In addition, two projects received special funding through the USGS, "Transboundary Aquifer Assessment Program" (PL 109-448) and "Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan."

During the reporting period, the NMWRRI administered a total of 24 projects dealing primarily with water quality and conservation issues. The total value of these projects was almost $1.3 million, including required cost sharing. Awards were made by various federal and state agencies and from the institute's annual state appropriations. Dollar amounts per project award ranged from $4,920 to nearly $263,398. During the reporting period, 18 projects were conducted at New Mexico State University, two at New Mexico Tech, three at the University of New Mexico, and one at New Mexico Highlands University. Faculty members were principal investigators on 16 projects and NMWRRI staff managed eight projects. The institute maintained frequent contact with its researchers through periodic progress updates, site visits, and expenditure tracking.

Research projects administered by the NMWRRI utilized at least 71 students during the year including undergraduates, masters, PhD candidates, and two post-doctoral students in the disciplines of agricultural economics, animal and range science, biology, biochemistry, chemical engineering, chemistry, civil engineering, computer engineering, computer science, earth and environmental science, economics, environmental engineering, environmental geology, environmental science, general studies, genetics, geography, geology, horticulture, hydrology and hydro-geology, mathematics, mechanical engineering, natural resource management, plant and environmental science, soil science, and water resources engineering.

Projects administered by the NM Water Resources Research Institute during the reporting period are listed below. Note that total award value is shown and includes both agency and cost sharing when appropriate, and includes multiyear funding.

Uranium and Heavy Metals in Macroinvertebrates in the Santa Fe River on the Cochiti Reservation. WRRI Student Research Grant 06 (Carlos R. Herrera, New Mexico Highlands University) $0 (reporting only)

New Mexico Water Rights Prices Database Development. WRRI Student Research Grant 07 (Shawn Landfair, New Mexico State University) $0 (reporting only)

Sustainable Recovery of Potable Water from Saline Waters. New Mexico state appropriations $0 (reporting only)

Utilization of Saline and Other Impaired Waters for Turfgrass Irrigation. New Mexico state appropriations; 104B program $0 (reporting only)

Assessment of a Novel Source-Tracking Protocol for Evaluating the Significance of Municipal Wastewater Sources on the Microbial Contaminant Levels of Discharged Wastewaters. WRRI Student Research Grant 09 (Jesus Sigala, New Mexico State University) $4,920

The Dependency of Anomalous Transport Behavior on Flow Path Orientation. WRRI Student Research Grant 09 (Nicholas B Engdahl, University of New Mexico) $4,952

Effects of Copper Sulfate Treatment on Benthic Macroinvertebrates in Peterson Reservoir Sediments. WRRI Student Research Grant 09 (Daryl Williams, New Mexico Highlands University) $4,953

Evaluation of Multi-stage Solar-powered Desalination System. WRRI Student Research Grant 09 (Akash Mummaneni, New Mexico State University) $4,991

Designing a Combined Piezometric and Gravity Monitoring Network in Lower Rio Grande Basin. WRRI Student Research Grant 09 (B. V. N. P. Kambhammettu, New Mexico State University) $5,000

Residence Time Distribution in Dynamically Changing Hydrologic Systems. WRRI Student Research Grant 09 (Jesus D. Gomez, New Mexico Tech) $5,000

From Stormwater Management to Stormwater Integration: The Use of Low Impact Development Techniques in the Albuquerque Region. WRRI Student Research Grant 09 (KT LaBadie, University of New Mexico) $5,000

Aqueous Geochemistry of the Springs and Wells of the Sevilleta National Wildlife Refuge: Evaluating Hydrochemical Pathways and Microbiology. WRRI Student Research Grant 09 (Amy J. Williams, University of New Mexico) $5,000

Composite Membrane for Membrane Distillation Desalination Process. WRRI Student Research Grant 09 (Sai Reddy Pinappu, New Mexico State University) $5,000

Investigation of Improved Operational Streamflow Forecasting in the Rio Grande Basin. WRRI Student Research Grant 09 (Shalamu Abudu, New Mexico State University) $5,000

Uranium Abatement in Water. WRRI Student Research Grant 09 (Nicholas G. Beltran, New Mexico State University) $5,000

New Mexico Pesticide Management Plan 2008-2009. Memorandum of Agreement with the New Mexico Department of Agriculture $30,000

Information Transfer Program (Catherine Ortega Klett) 104B $38,835

Geographical Information System for Water Resources Research Planning (Bobby J. Creel) 104B $40,500

Land Application of Industrial Effluent on a Chihuahuan Desert Ecosystem: Impact on Soil Physical and Hydraulic Properties. New Mexico state appropriations $29,240; 104B $30,000

Estimating Water Use through Satellite Remote Sensing. New Mexico state appropriations $20,000; 104B $40,000

Salinity Management Program and Rio Grande Project Salinity Assessment. Texas A&M University, $63,036

Water Information Websites Phase II. SCERP $66,523

Validation, Calibration and Improvement of Remote Sensing ET Algorithms in Mountainous Regions. 104G $74,795

Transboundary Aquifer Assessment Program. USGS $82,000

Gila Settlement Act Planning. New Mexico Interstate Stream Commission $109,000

Continued Development of a RiverWare Model of the Rio Grande Flow and Coordinated Database. Texas A&M University $162,602

A Joint Investigation of Evapotranspiration Depletion of Treated and Non-Treated Saltcedar at the Caballo Dam, New Mexico. U.S. Bureau of Reclamation $170,608

Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan. USGS $263,398

Validation, Calibration, and Improvement of Remote Sensing ET Algorithms in Mountainous Regions

Basic Information

Title:	Validation, Calibration, and Improvement of Remote Sensing ET Algorithms in Mountainous Regions
Project Number:	2006NM63G
Start Date:	9/1/2006
End Date:	8/31/2009
Funding Source:	104G
Congressional District:	Second
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Water Quantity, Models
Descriptors:	
Principal Investigators:	Jan M.H. Hendrickx, Jan Kleissl

Publications

1. Hendrickx, J.M.H., J. Kleissl, J.D. Gomez-Velez, S.-h Hong, J.R. Fabrega-Duque, D. Vega, H.A. Moreno-Ramirez, and F.L. Ogden. 2007. Scintillometer networks for calibration and validation of energy balance and soil moisture remote sensing algorithms. Proc International Society for Optical Engineering (SPIE). 6565:65650W.
2. Gomez, J.D., J. Kleissl, J.M.H. Hendrickx, and O.K. Hartogensis. 2008. Large aperture scintillometers for hydrology. Water Resources Research,submitted.
3. Hong, S.-h., J. Kleissl, J.M.H. Hendrickx, R.G. Allen, W.G.M. Bastiaanssen, R.L. Scott, and A.L. Steinwand. 2008. Validation of SEBAL for mapping sensible and latent heat fluxes in arid riparian areas from remotely sensed optical imagery. Water Resources Research. In preparation.
4. Kleissl, J., S.-h. Hong, and J.M.H. Hendrickx. 2008. New Mexico scintillometer network in support of remote sensing, and hydrologic and meteorological models. Bulletin American Meteorological Society. In press.
5. Kleissl, J., J. Gomez, S.-h. Hong, J.M.H. Hendrickx, T. Rahn, and W.L. Defoor. 2008. Large aperture scintillometer intercomparison study. Boundary Layer Meteorol. 128:133-150, DOI 10.1007/s10546-008-9274-1.
6. Gomez, J.D., J. Kleissl, J.M.H. Hendrickx, and O.K. Hartogensis. 2009. Large aperture scintillometers for hydrology. Water Res. Res.: resubmitted.
7. Hendrickx, J.M.H., J. Kleissl, J.D. Gómez-Vélez, S.-h. Hong, J.R. Fábrega-Duque, D. Vega, H.A. Moreno-Ramírez, and F.L. Ogden. 2007. Scintillometer networks for calibration and validation of energy balance and soil moisture remote sensing algorithms. Proc. International Society for Optical Engineering, SPIE 6565:65650W.
8. Hong, S.-h., J. Kleissl, J.M.H. Hendrickx, R.G. Allen, W.G.M. Bastiaanssen, R.L. Scott, and A.L. Steinwand. 2009. Validation of SEBAL for mapping sensible and latent heat fluxes in arid riparian areas from remotely sensed optical imagery. Water Res. Res. submitted.
9. Kleissl, J., S.-h. Hong, and J.M.H. Hendrickx. 2009. New Mexico scintillometer network in support of remote sensing, and hydrologic and meteorological models. Bulletin American Meteorological Society: 90:207-218.

10. Kleissl, J., J. Gomez, S.-h. Hong, J.M.H. Hendrickx, T. Rahn, and W.L. Defoor. 2008b. Large aperture scintillometer intercomparison study. Boundary Layer Meteorol. 128:133-150, DOI 10.1007/s10546-008-9274-1.
11. Hendrickx, J.M.H., 2010, Validation, Calibration and Improvement of Remote Sensing ET Algorithms in Mountainous Regions, New Mexico Water Resources Research Institute technical completion report. In preparation.

Problem and Research Objectives

Accounting of key reservoirs and fluxes associated with the global water cycle, including their spatial and temporal variability, are crucial goals of water resource managers. Advancements in satellite optical remote sensing have resulted in the development of several operational remote sensing evapotranspiration (ET) algorithms. While these algorithms typically give accurate ET predictions over flat terrain, significant difficulties have been encountered in mountainous regions which are characterized by heterogeneous soil and topography and high elevation changes. However, mountain runoff represents more than 90% of the total runoff in the semi-arid basins of the Rio Grande, Oranje, Colorado, and Rio Negro rivers. Thus improving ET estimates in the mountains is crucial for determining the regional water balance in the southwestern U.S. and in many mountainous regions worldwide.

Methodology

Most remote sensing algorithms obtain ET as the residual of the energy balance after measuring and/or modeling net radiation, ground heat flux, and sensible heat flux H. Among these fluxes, H is the most complex to estimate and its value is associated with the greatest uncertainty. We will use novel measurement techniques, such as scintillometers, together with spatially dense meteorological measurements and archived ETA numerical weather model data to measure H and determine how it is related to temperature lapse rate, wind speed, water vapor deficit, and boundary layer height. Two protected sites with idealized topographical shape will be considered in the field study: the Magdalena Ridge and the Valles Caldera National Park in New Mexico. First, the measured H will be used to validate estimates derived from the Surface Energy Balance over Land (SEBAL) algorithm applied on data from synchronous ASTER and MODIS satellite overpasses. Second, techniques for calibration of the SEBAL algorithm in near-real time using surface measurements of H will be developed. Third, parameterizations in the SEBAL algorithm for mountain lapse rates, wind speeds, and surface roughnesses will be critically reviewed and improved by considering meteorological measurements and archived numerical weather model data. Through this work we will make a lasting contribution to ET estimation from SEBAL and other remote sensing algorithms for current and future satellite missions.

Principal Findings

The support of this USGS/NMWRRI project together with support of other sponsors has allowed us to investigate and develop procedures for the validation and calibration of remote sensing ET algorithms in mountainous regions in New Mexico. Our research work on ET algorithms started well over eight years ago. However, due to the extremely complex nature of combining the physics of momentum, mass, and energy transport in the atmospheric boundary layer with the radiation physics of remote sensing imagery, it took over five years to prepare our first publications. The USGS/NMWRRI support is critical to complement our progress to date and to develop new knowledge to expand our remote sensing algorithms to more challenging conditions.

For the validation of SEBALNM we have used the new technology of scintillometry. Since no other research group had established a network of six scintillometers over an area of 315,000 km2 we have spent considerable effort to test the performance of scintillometers under the mountainous conditions of New Mexico.

We performed first two field studies with six large aperture scintillometers (LASs) using horizontal and slant paths. The accuracy of this novel and increasingly popular technique for measuring sensible heat fluxes was quantified by comparing measurements from different instruments over nearly identical

transects. Random errors in LAS measurements were small, since correlation coefficients between adjacent measurements were greater than 0.995. However, for an ideal set-up differences in linear regression slopes of up to 21% were observed with typical inter-instrument differences of 6%. Differences of 10% are typical in more realistic measurement scenarios over homogeneous natural vegetation and different transect heights and locations. Inaccuracies in the optics, which affect the effective aperture diameter, are the most likely explanation for the observed differences (Kleissl et al., 2008b). The quantification of the instrument error of large aperture Kipp & Zonen scintillometers is critical information for all hydrologists using scintillometer worldwide. These results are relevant for Objective One.

We also established in New Mexico a first-of-its-kind network of seven Large Aperture Scintillometer (LAS) sites to measure sensible heat fluxes over irrigated fields, riparian areas, deserts, lava flows, and mountain highlands. Wireless networking infrastructure and auxiliary meteorological measurements facilitate real-time data assimilation. LAS measurements are advantageous in that they vastly exceed the footprint size of commonly used ground measurements of sensible and latent heat fluxes (~100 m2), matching the pixel-size of satellite images or grid cells of hydrologic and meteorological models (~0.1-5 km2). Consequently, the LAS measurements can be used to validate, calibrate, and force hydrologic, remote sensing, and weather forecast models. We have published initial results for: (1) variability and error of sensible heat flux measurements by scintillometers over heterogeneous terrain and (2) the validation of the Surface Energy Balance Algorithm for Land (SEBAL) applied to MODIS satellite imagery (Hendrickx et al., 2007; Kleissl et al., 2008a). The findings from this study are relevant for Objectives One and Two.

In another recently submitted publication we present our experiences with the emerging method of scintillometry for hydrologic studies include the use of SEBALNM. Large aperture scintillometers are employed to derive the sensible heat flux over irrigated fields, riparian areas, deserts, lava flows, and mountain highlands in New Mexico. The theory and technical aspects of the setup, operation, and analysis of LAS data are discussed. The advantages of a larger flux footprint, compared with other measurement techniques for the sensible heat flux, are explained, particularly in the context of the calibration and validation of remote sensing surface energy balance algorithms, and hydrologic and meteorological models. The scintillometer transects were used to explore this measurement technique as a potentially useful tool in hydrological applications. Evapotranspiration rates for hydrologic applications can be obtained at scales of the pixel-size of satellite images or grid cells of hydrologic and meteorological models (0.1-10 km2) (Gomez et al., 2008). The findings from this study are relevant for Objectives One and Two.

Finally, in another recent publication we discuss why scintillometer measurements cannot be used directly for the calibration and validation of SEBALNM since the sensible heat flux determined by SEBALNM absorbs biases caused by its assumptions and atmospheric conditions (Hong et al., 2008). This was somewhat of a surprise to us and is very relevant for practitioners worldwide; it is relevant for Objective Two.

We have already taken many measurements relevant for Objective Three such as air temperature and humidity measurements along elevation gradients and scintillometer measurements over snow in the Valles Caldera. These measurements are being analyzed. Since a new PhD student withdrew from the project in the fall semester of 2007, this work has been delayed and, therefore, we requested a no-cost extension of one year.

Much progress has been made with the development of methods to derive ET in mountainous regions using SEBAL and METRIC. Hendrickx's group in now involved with three projects that involve mountain ET: ET mapping in the Salt Basin for the Interstate Stream Commission, ET mapping in the Sacramento Mountains for the Bureau of Geology, and ET mapping in the Green River Basin of Wyoming for the Wyoming State Engineer's Office. We have derived and are testing new approaches to estimate the lapse rate in the mountains as well as reference ET as a function of elevation, slope, and aspect. Without this project we never could have done this.

The researchers are preparing their final report, which will be published as part of the New Mexico Water Resources Research Institute's technical completion report series.

Award No. 08HQAG0146 Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan

Basic Information

Title:	Award No. 08HQAG0146 Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan
Project Number:	2008NM114S
Start Date:	9/22/2008
End Date:	9/21/2013
Funding Source:	Supplemental
Congressional District:	2
Research Category:	Climate and Hydrologic Processes
Focus Category:	None, None, None
Descriptors:	Afghanistan, crop growth, agriculture, economics
Principal Investigators:	M. Karl Wood, Frank Ward

Publications

1. Gregory Torell, 2010, Economic analysis for improved water management, food security, and rural livelihoods in Afghanistan's Balkh Basin, M.S. Thesis, NMSU Department of Agricultural Economics and Agricultural Business.
2. Gregory Torell, Balkh River Canal System, Afghanistan Decision Support (excel spreadsheet), posted on the web at http://agecon.nmsu.edu/fward/water/

Description of problem and research objectives

This is the second year of a cooperative agreement with NMSU and USGS in support of the Afghanistan Water, Agriculture and Technology Transfer Program. Activities have focused on the application and development of techniques for monitoring the physical variables governing crop growth, such as timing and level of precipitation, evapotranspiration and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators.

These data have been integrated into an analysis of policy options for improving farm income, rural food security, and improved livelihoods. Recent work has developed and applied a framework to inform water decision makers on profitable and food secure uses of land and water resources in the Balkh River Basin.

Description of methodology

Funding under Agromet has supported the following activities:

Installation of 113 weather observation sites: 1) all of the 113 observation sites are recording daily rain and snow; 2) 80 out of 113 sites are reporting in addition to rain and snow on crops (wheat, rice, barley and maize) and pasture and grazing twice a month (fortnightly forms) including crop condition (all the weather adverse factors, shortage of inputs, weed, pests and diseases infestations) and crop phonological stages (including land preparation) in addition to areas planted (% of the total by agricultural zone), planting and harvesting dates in addition to the expected yields during the agricultural year and final obtained yields after the harvesting; and 3) out of 113 sites, 21 sites are complete agrometeorological stations (three observations daily), with 19 classical stations recording 7 weather parameters and 5 automatic stations that can report on up to 20 weather parameters at daily step.

Using weather, hydrologic, agronomic, and economic data, several arrangements for allocating water through an existing network of irrigation canals were analyzed for their impacts on land and water use, farm profitability and food security at both the canal and basin levels.

Description of principal findings and significance

Findings show that total water supply and institutional arrangements for allocating water during periods of shortages have important influences on farm income and food security. The methods used and results found provide a framework for informing decisions on the sustainable use of land and water for improved food security and rural livelihoods in the world’s irrigated areas.

Award No. 08HQAG0117 Transboundary Aquifer Assessment Program

Basic Information

Title:	Award No. 08HQAG0117 Transboundary Aquifer Assessment Program
Project Number:	2008NM115S
Start Date:	4/1/2008
End Date:	3/31/2013
Funding Source:	Supplemental
Congressional District:	2
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	aquifer assessment, Mesilla Basin, Hueco Bolson, GIS, database,
Principal Investigators:	M. Karl Wood

Publications

1. Hawley, John W. and Alfredo Granados-Olivas, 2008, Progress Report on Development of an Annotated Bibliography for Transboundary Aquifer Systems of the Mesilla Basin-Paso del Norte Area, New Mexico, Texas (USA), and Chihuahua (MEX), poster presented at the 2008 New Mexico Water Research Symposium, Socorro, NM, August 2008, Symposium Program and Abstracts.
2. Hawley, J.W., B.J. Creel, and B.V.N.P. Kambhammettu, 2009, Digital hydrogeologic-framework model of the San Francisco River basin, west-central New Mexico and east-central Arizona [abstract], Geological Society of America. Abstracts with Programs, 41(7) Session 58-T21 on CD ROM. ISSN 0016-7592.
3. Hawley, J.W., J.F. Kennedy, A. Granados-Olivas, and M.A. Ortiz, 2009, Hydrogeologic framework of the binational western Hueco Bolson-Paso del Norte area, Texas, New Mexico, and Chihuahua. NM Water Resources Research Institute, NM State University, Technical Completion Report 349. 45 p., with 2 plates on CD ROM. ftp://wrri.nmsu.edu/pub/hueco
4. Monger, H.C., L.H., Gile, J.W. Hawley, and R.B. Grossman, 2009, The Desert Project: an analysis of aridland soil-geomorphic processes New Mexico State University Agricultural Experiment Station Bulletin 798. 76 p., http://aces.nmsu.edu/pubs/research/weather-climate/
5. Creel, B.J., 2010, Research Needs in the U.S. Portion of the Rio Grande Watershed, E.M. Ward and E.A. Barrantes (eds), Journal of Transboundary Water Resources, 01:31-42.
6. Schmid, W., J.P. King, and T. Maddock III, 2010, Conjunctive Surface-Water/Groundwater Model in the Southern Rincon Valley Using Modflow-2005 with the Farm Process, NM Water Resources Research Institute, New Mexico State University, Technical Completion Report No. 351, 65 pp.
7. Hawley, J.W., B.J. Creel, and B.V.N.P. Kambhammettu, 2009, Digital hydrogeologic-framework model of the San Francisco River basin, west-central New Mexico and east-central Arizona. Contract report for New Mexico Interstate-Stream Commission, NM Water Resources Research Institute, New Mexico State University, with CD ROM. In preparation as NMWRRI Technical Completion Report. ftp://water.nmsu.edu/pub/gila/hydrogeologic.

Description of problem and research objectives

Rapid population growth in the United States-Mexico border region over the last decade has placed major strains on limited water supplies in the region. Rapid growth rates are expected to continue for at least several more decades. Water quantity and quality issues are likely to be the determining and limiting factors affecting future economic development, population growth, and human health in the border region. Increasing use of groundwater resources in the border region by municipal and other water users has raised serious questions concerning the long-term availability of the water supply.

Cooperation between the United States and Mexico in assessing and understanding transboundary aquifers is necessary for the successful management of shared groundwater resources by state and local authorities in the United States and appropriate authorities in Mexico, including management that avoids conflict between the United States and Mexico. While there have been some studies of binational groundwater resources along the United States-Mexico border, additional data and analyses are needed to develop an accurate understanding of the long-term availability of useable water supplies from transboundary aquifers.

The objectives of the Transboundary Aquifer Assessment Program is to collect and evaluate new and existing data to develop high-quality, comprehensive groundwater quantity and quality information and groundwater flow models for the Mesilla Basin aquifer in New Mexico, Texas, and Mexico.

Description of methodology

A review of all previously developed groundwater flow models was conducted last year. This year field studies were used to develop any additional data that are needed to define aquifer characteristics to the extent necessary to enable the development of groundwater flow models. Additional evaluations of all available data and publications relevant to the aquifer and produce a binational bibliography were conducted. The project utilized the geographic information system database that was created last year to better characterize the spatial and temporal aspects of the aquifer, with emphasis on a digital model of the hydrogeologic framework. The project also continued to expand existing agreements, as appropriate, between the authorities in the United States and Mexico to (1) conduct joint scientific investigations; (2) archive and share relevant data; and (3) carry out any other activities consistent with the program. A basin steering committee of local stakeholders was established to provide review and feedback on tasks and products.

Description of principal findings and significance

A bibliography of previous studies that was compiled in 2008 has been updated and reviewed by the USGS, New Mexico, and Texas team. This is an ongoing process as more literature is found and new literature is written. The basin-scale hydrogeologic framework model that was produced in 2005, including cross sections and model layer maps, was reviewed and updated with recent information and a new compilation of well-control data. Expansion of this model into Mexico

has been proposed and is pending finalization of the binational agreement for conducting joint investigations and basic-data sharing. Mesilla Basin groundwater flow models developed in the last 20 years have been reviewed and evaluated for their possible future use and modification. This evaluation still needs collaborative input from the Mexican authorities before selection of the most appropriate flow model(s) for expansion into Mexico.

The basic binational-agreement documents related to conduct of joint investigations and data sharing were signed in August 2009; and specific final arrangements for agreement implementation are planned for completion in March-April 2010.

Land application of industrial effluent on a Chihuahuan Desert ecosystem: Impact on soil physical and hydraulic properties

Basic Information

Title:	Land application of industrial effluent on a Chihuahuan Desert ecosystem: Impact on soil physical and hydraulic properties
Project Number:	2009NM103B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Acid Deposition, Solute Transport, Acid Deposition
Descriptors:	industrial effluent, soil physics, Chihuahuan Desert
Principal Investigators:	Manoj Shukla, John G. Mexal, Theodore Wallace Sammis

Publications

1. Adhikari P. 2008. Chihuahuan Desert Ecosystem: Geomorphology, Physical and Chemical Properties of Soil Irrigated with Industrial Effluent. New Mexico State University. Master's Thesis.
2. Babcock, M, M.K. Shukla, G. Picchioni, J. Mexal, and D. Daniel. 2009. Chemical and physical properties of Chihuahuan desert soils irrigated with industrial effluent. J. Arid land Research and Management. 23:47-66.
3. Shukla M.K., J.G. Mexal, G. Pichioni, T.W. Sammis, D. Daniel, P. Adhikari and M. Babcock, 2010, Land application of industrial effluent on a Chihuahuan Desert ecosystem: Impact on soil physical and hydraulic properties. WRRI Technical Completion Report No. 351, 75 pp.
4. Adhikari P., M.K. Shukla, J.G. Mexal, and P. Sharma, 2010, Identification of Soil Properties Based Indicators Using Principal Component Analysis for Desert Soils Irrigated with Treated Wastewater, J Environ Sciences. (Under Review)
5. Adhikari P., M.K. Shukla and J.G. Mexal, 2010, Spatial Variability of Electrical Conductivity in the Land Application Site Irrigated with Treated Wastewater. (In preparation)
6. Adhikari P., M.K. Shukla, J. Mexal, G. Picchioni, and D. Daniel, 2010, Physical and chemical properties of desert soil irrigated with aerated lagoon water. (In preparation)

Description of problem and research objectives

Urban and industrial wastewater treatment is complex, expensive, and requires energy and technology. The safe disposal of the treated wastewater is also a challenge because effects of wastewater to the soil and plant environment are complex and depend upon the amount of harmful elements present in the wastewater. Reuse of industrial effluent could be beneficial especially in areas where water stress is a major concern primarily due to limited water resources, higher water demands and limited economic resources. Suspended solids present in effluents are also reported to accumulate in the soil voids and physically block water-conducting pores leading to sharp decline in soil hydraulic properties. Soil physical properties such as texture, structure, porosity, hydraulic conductivity, and soil moisture retention can influence soil chemical properties like salinity and sodicity. Similarly physical and chemical properties may have strong influence on the thermal properties of soil. Other factors such as irrigation method and wastewater distribution uniformity can also change soil properties. Little data are available on the use of native terrestrial ecosystems for wastewater treatment, especially in arid and semi-arid regions of the southwestern U.S. and Mexico. Further, little is known about the impacts of wastewater irrigation on soil physical and thermal properties in native terrestrial ecosystems, and whether changes in soil chemical properties alter soil physical properties and plant growth (Babcock et al., 2009).

Soil characteristics vary with time and space and variability in the application of treated effluent and can exacerbate depending on the variability of soil properties. Accurate information on the spatial variation of soil properties within the fields is very useful for site specific management of land application site. Overall objectives of the research are to expand knowledge of West Mesa soil chemical properties to include physical and thermal properties to schedule effluent irrigation more effectively. The specific objectives of this study are to (i) to determine the variability of soil chemical and hydraulic properties in the land application site (ii) to determine the variability of infiltration rate and unsaturated hydraulic conductivity soil, (iii) identify hot and cold spots with respect to soil properties, and (iv) to determine the thermal properties of soil irrigated with and without treated industrial effluent. The hypothesis for the study is that the spatial variability of wastewater application will increase the spatial variability of soil properties.

Description of methodology

The West Mesa is dominated with annual shrubs like creosote and mesquite and perennial forbs and grasses. To make the area a perfect rectangle and ease to construct a transit line, some area beyond the land application was also included. Six horizontal and nine vertical transit lines will be drawn that will result in 54 grids in the entire 17.5 ha plot. Soil sampling was performed in the centre of each gird. Five additional girds were chosen for lag sample. Lag sample were taken at distances of 2m, 7m, and 22m from the centre of grid sampling point in two directions. Infiltration tests were performed at the centre of each gird using a tension infiltrometer. All together, 74 infiltration test were conducted in all sampling and lag points at -30, -20, -10 and -5 cm tension. A sprinkler distribution uniformity assessment was carried out in the irrigated plot, following the

American Society of Agricultural Engineers standard #S330.1 (ASAE Standards, 1993). Sprinkler heads (Senninger model #3012-1-3/4) installed on irrigation lines were placed on a 12 x 12 m grid. In addition, 30 nonrecording rain gauges were also installed to determine the variability of rainfall and effluent application.

About 168 bulk soil samples were collected from each sampling point including lag points at 0-20 and 20- 40 cm depth. In addition, 84 core samples were collected from each grid including lag locations from 0-20 cm depth. All cores were trimmed and the soil bulk density (p_b) was obtained by the core method (Blake and Hartge, 1986). All cores were immediately saturated in tap water by slowly raising the water level. Saturated hydraulic conductivity (K_s) was determined by the constant head method (Klute and Dirksen, 1986). Volumetric moisture content (θ) of each soil core was measured at 0 kPa (saturation), 3 kPa, and 6 kPa suctions using a tension table (Leamer and Shaw 1941), and at 30 kPa, 100 kPa, 300 kPa, 500 kPa, 1000 kPa and 1500 kPa suctions (h) using a pressure plate apparatus (Klute, 1986). The θ at 1000 kPa and 1500 kPa suctions were determined on bulk soil samples <2mm in diameter. The difference in θ at 0 kPa and 6 kPa was calculated to estimate drainable porosity (θ_d), or soil macroporosity, the difference in θ at 0 kPa and 30 kPa was used to estimate effective porosity (θ_e), and the difference in θ at 30 kPa (Field capacity; FC) and 1500 kPa (Wilting point; WP) was used to estimate plant available water capacity (AWC). Brooks and Corey (1964) model was fitted to the measured $h(\theta)$ curves to obtain the air entry value ($1/\alpha$) and the pore size distribution parameter (λ) by using the retention curve (RETC) program of van Genuchten et al. (1991).

Soil collected from each depth was air dried, mixed thoroughly, and passed through a 2 mm sieve. Soil pH was measured in the saturated paste extract and concentrations of Na^+, Ca^{2+}, and Mg^{2+} used to calculate SAR, and ESP were measured by the solution conductivity method (USDA Staff, 1954). Chloride was measured by the colorimetric method (USEPA, 1979). Soil particle size analysis for determining sand, silt, and clay content was performed by the hydrometer method (Gee and Bauder, 1986).

Descriptive statistics parameters like mean, median, standard deviation, standard errors, coefficient of variation (CV), kurtosis, skewness, and minimum and maximum were calculated for each measured infiltration rate using Microsoft Office Excel (Microsoft Corporation, 2007). The mean and median is used as primary estimates of central tendency, and standard deviation, standard errors, CV, kurtosis, skewness, minimum and maximum were used to describe the degree of variability in soil infiltration rate. The Shapiro-Wilks normality test was conducted to test the normal distribution of the dataset (SAS Institute Inc., 2002-2003).

Spatial variability for each variable was determined by using a geostatistical method using semivariograms. Semivariograms for each variable were obtained by using GS^+ software ver. 9. The semivariogram functions were calculated by using spherical, exponential, linear and Gaussian model. A semivariograms was determined for each variable to ascertain the degree of spatial variability between neighboring observations, and the appropriate model function was fit to the semivariograms.

Spatial autocorrelation was used to express spatial changes in the soil property and degree of dependence among neighboring sampling locations. Information on autocorrelation helps to identify the soil sampling interval for which observations

remains spatially correlated and can be used for designing soil-sampling schemes. Moran's *I* statistics was used to calculate the coefficient at selected lag distance.

Description of principal findings and significance

Part of the study was conducted to determine the spatial variability of electrical conductivity ($EC_{1:1}$) and suggest suitable management strategy to reduce the detrimental effect to the soil and plant environment. Each EC dataset was classified into five classes where there was a relatively big jump in the EC values and the numbers of counts were nearly equal in each class; class I contained $EC_{1:1} \leq 1$, class II $1.1 < EC_{1:1} \leq 2$., class III $2.1 < EC_{1:1} \leq 4$, class IV $4.1 < EC_{1:1} \leq 5$ and, class V $EC_{1:1} > 5$. According to the CV, class II and V were moderately variable ($0.15<CV<0.35$) and class I, III and IV were least variable ($CV<0.15$) at 0-20 cm depth during 2009. At 20-40 cm depth, EC class I, II, III and V were moderately variable. Semivariograms showed that $EC_{1:1}$ for both depths and years were moderately spatially dependent and correlograms showed significant autocorrelation at 25 m lag distances for 0-20 cm depth, and 50 m lag distances for 20-40 cm depth during 2009 and 2010. Area coverage of classes I and II were much higher than classes III, IV and V during 2009. However, during 2010 area coverage by class II decreased from 26% to 14.91% and class four increased from 12.11% to 22.97% and class V increased from 10.95% to 20.55%. So management steps are necessary to control the increase of area under higher EC classes (>4 dS/m). Soil EC map showed EC classes IV(> 4.1-5 dS/m) and V (> 5.1 dS/m) were concentrated at northeast and southwest side of the field and classes I and II were at the center of the study plot. The predominant vegetations of the study site are creosote, mesquite and perennial and annual weeds. The tolerance limit of EC of soil saturation paste extract (EC_e) for creosote was up to 7.51 dS/m and EC_e for mesquite was up to 9.36 dS/m. During 2009 and 2010, mean $EC_{1:1}$ for class IV and V was > 4.50 dS/m, which was beyond the tolerance limit of mesquite and creosote. So it is necessary to change the wastewater application pattern, in such a way that higher wastewater in the middle and lower in the northeast and southwest direction of the land application site.

Soil physical properties analyzed were field capacity (FC), wilting point (WP), available water content (AWC), hydraulic conductivity (K_s), soil texture, bulk density (BD) and chemical properties; pH, nitrate (NO_3^-), chloride (Cl^-), sodium (Na^+), sodium adsorption ratio (SAR), organic matter (OM) and exchangeable sodium percentage (ESP). Initial results showed that ESP, SAR, Cl^-, WP, K_s,Na^+, NO_3^- were most variable with CV>0.35. FC, AWC, silt and OM were moderately variable where as sand; clay, BD, and pH were least variable. FC, WP, AWC, Na^+, OM, Cl^-, pH, and K_s exhibits strong spatial dependence where as sand, silt, $N0_3^-$ indicated moderate spatial dependence and ESP, SAR, BD and clay showed weak spatial dependence. Kriged spatial distributions maps showed that most of the higher chemical properties were concentrated in the northeast side of the experimental field. The analysis of other soil physical and chemical properties is on-going and results will be included in the final report.

Information Transfer Program Introduction

The New Mexico Water Resources Research Institute maintains an active program to transfer technical information from the producer to the user and the public. Technical publications, newsletters, conferences, symposia, press announcements, and presentations keep practitioners aware of new technology and research advances. The WRRI homepage (wrri.nmsu.edu) provides online information about the institute's newsletters, technical report series, requests for proposals, upcoming conferences and symposia, and the research reference library. All 54 past annual water conference proceedings have full-text viewing via the institute's homepage. Other federal and state servers, such as the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, USGS, and National Weather Service are linked to the WRRI homepage.

Geographic Information System for Water Resources Research Planning

Basic Information

Title:	Geographic Information System for Water Resources Research Planning
Project Number:	2002NM1B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	Second
Research Category:	Not Applicable
Focus Category:	Management and Planning, Conservation, Water Quality
Descriptors:	
Principal Investigators:	Bobby J. Creel

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Problem and Research Objectives

The New Mexico Water Resources Research Institute has become the focal point for geographic information system (GIS) data and information concerning water resources in New Mexico. It combines database management with digital mapping into spatial-tabular data models. These models are powerful tools for representing and manipulating earth-science information.

As use of geographic information systems has grown and presented new opportunities, it also has raised a number of new issues and problems. Of increasing concern is the management of a growing collection of spatial data sets and applications programs. These data sets and programs are very expensive to produce but relatively easy to share, so there is a great incentive to avoid duplicating production efforts. The trend clearly is toward managing these elements in distributed spatial libraries.

The primary objective of the project is to increase availability and accessibility of water resource information to support water resource planning and management in the state. The first task provides spatial data library accessibility. This task maintains arrangements and establishes those necessary to provide access to spatial data maintained by other agencies and organizations. The second task, spatial data development, evaluates needs, establishes priorities, and undertakes development of spatial data that is otherwise unavailable. These efforts will be coordinated with cooperating agencies and organizations to ensure no duplication of effort and to establish guidelines for coverages and priorities. The principal investigators maintain, update as necessary, and make the data available to cooperating agencies and organizations through both formal and informal arrangements to facilitate water resource planning activities.

Methodology

A number of cooperative data sharing agreements have been entered into with state, federal, and local agencies and organizations to facilitate access and to develop spatial data. Others will be pursued as necessary. Research funded by the NMWRRI in many cases results in the development of data that can be represented in a spatial form and thus can contribute to the state data pool. Projects that have such a potential are adjusted as necessary to meet this secondary purpose.

The NMWRRI maintains a GIS laboratory consisting of computer workstations; data storage devices; input/output devices (color plotter, digitizer, etc.); software for mapping and analysis (ARC/Info); database development and visualization; and network systems. The laboratory is connected via fiber to the New Mexico State University computer network and thereby to the Internet. The NMWRRI also maintains an Internet web server site through which both spatial and tabular water resource data can be provided.

Principal Findings

Various research activities are supported by the system for water resources planning in the state. The New Mexico Interstate Stream Commission provides grants to regional groups to support water resources planning. NMWRRI continues to be utilized by the NM Interstate Stream Commission to provide GIS mapping products for use in their plans and in public outreach. NMWRRI has helped many regional groups with GIS mapping products for use in their plans and in public outreach efforts.

Additionally, support has been given to the New Mexico/Texas Water Commission and various public entities of southern New Mexico for their planning activities. GIS mapping support is also provided to the Lower Rio Grande Water Users Organization.

This sophisticated mapping and geo-spatial database management system, originally designed to support WRRI-funded research activities, is now being used for external research grants (e.g., Creation of a Digital Hydrogeologic Framework Model of the Mesilla Basin and Southern Jornada del Muerto Basin; creation of maps for the purpose of water planning funded by the New Mexico Interstate Stream Commission; and pesticide management planning in the state funded by the New Mexico Department of Agriculture) by water resources management and planning agencies in the state. A research grant resulted in the creation of a regional geographic information system to support water planning in the Paso del Norte borderland area of the southwestern United States.

This is an ongoing project with new data continually being added to the database and assistance being given to produce specific GIS products upon request. Continued funding is anticipated from annual state appropriations as well as pending agency awards.

Information Transfer Program

Basic Information

Title:	Information Transfer Program
Project Number:	2002NM3B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	Second
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	
Principal Investigators:	Cathy T. Ortega Klett, Bobby J. Creel

Publications

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Statement of Critical Water Problem

The New Mexico Water Resources Research Institute's Information Transfer Program is designed to bring the results of its research projects to the public and to educate New Mexicans on the critical water issues of the state, region, and nation. Different sectors of the public are targeted for each of its activities.

Statement of Results and Benefits

The program goal is to provide people with water information appropriate to their level of training and interest. Information transfer activities are funded primarily from non-federal sources. Responsibilities for different segments of the program have been assigned to various professional and support staff at the institute.

Nature, Scope, and Objectives

The primary methods for information transfer are conferences, publications, audio/visual presentations, and available information on the institute's website. For the past 54 years, the NMWRRI has sponsored the Annual New Mexico Water Conference focusing on a topic of importance to the New Mexico water community, usually policy oriented. The annual conference is held in different locations around the state in the fall. Most of the conference participants are water resources practitioners working for state, federal, or local agencies, although some members of the general public and of academia also attend. Average attendance ranges between 200 and 350 people, depending on the location and topic of the conference. Last year, the New Mexico State Engineer called the WRRI annual conference the premier water meeting in the state. The WRRI began hosting a technical research symposium in 2002 and the annual event has become the focal meeting for researchers from around the state and region to share their water-related research and demonstration projects. Many students attend the symposium and present posters and oral presentations.

Publications include technical completion reports resulting from NMWRRI-sponsored projects, special in-house publications, and conference proceedings. The institute has published more than 380 technical and miscellaneous reports. The peer reviewed technical completion reports are directed toward water professionals working in disciplines related to the research projects. All technical reports are now available via the NMWRRI website in full text. Those interested in a particular report are able to print off the Internet instead of ordering a hard copy of the report. WRRI water conference proceedings for the past 54 years are also available online in full text.

A quarterly newsletter, *The Divining Rod,* focuses on research and current water issues. It is emailed to approximately 1,600 readers and hard copies are sent to about 300 readers. The newsletter is available on the WRRI homepage.

A reference room, housed at the institute, contains over 11,000 documents and is used frequently by faculty, students, and others. A complete catalog of holdings can be

searched through the NMWRRI homepage on the Internet, along with an extensive water resources and information system database.

WRRI's homepage (http://wrri.nmsu.edu) provides online information about the institute's newsletters, technical report series, requests for proposals, upcoming programs, and the research reference library. All WRRI reports are available for viewing online via the institute's website. The website, created in 1995, is updated on a regular basis and continues to be a focal point of information on New Mexico's water resources with many links to other related sites such as the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, USGS, and National Weather Service. In recent years, the WRRI website received an average of over 6,000 inquiries per month.

WRRI has developed a state-of-the-art geographic information system on water resources in New Mexico and has become the focal point for GIS data and information concerning water resources in the state. It combines database management with digital mapping into spatial-tabular data models. These models are powerful tools for representing and manipulating earth-science information. The primary objective of the system is to increase availability and accessibility of water resource information to support water resource planning and management in the state. Efforts are coordinated with cooperating agencies and organizations to ensure no duplication of effort and to establish guidelines for coverages and priorities. The staff maintains, updates as necessary, and makes the data available to cooperating agencies and organizations through both formal and informal arrangements to facilitate water resource planning activities.

The institute director and associate director are invited frequently to speak at local, regional, and national conferences and workshops in addition to serving on a number of committees that focus on water resources.

Accomplishments

The 54th Annual New Mexico Water Conference was held in October at the Isleta Casino and Resort, on the Isleta Pueblo, just south of Albuquerque. The conference theme was, "Water Planning in a Time of Uncertainty" and was attended by about 180 participants. A full proceedings of the conference is in production and will be available on the WRRI website. All conference participants will receive a copy on CD.

The NMWRRI coordinated the 2009 Water Research Symposium on the campus of New Mexico Tech, in Socorro. The one-day "2009 New Mexico Water Research Symposium" was co-sponsored by Sandia National Laboratories, Los Alamos National Laboratory, New Mexico's three state universities, the Office of the State Engineer, New Mexico Interstate Stream Commission, and the AWRA-New Mexico section. Thirty-six oral presentations were given and 35 posters displayed. This year a special session on *Southwest Modeling and Forecasting for Resource Management* was organized as requested by the New Mexico Interstate Stream Commission. Over 162 participants including 84 students from throughout New Mexico, Arizona, and west Texas attended. Fifteen students gave oral presentations and 31 students presented posters.

In May 2009, the WRRI coordinated a one-day workshop that brought together eight experts to present an array of economic tools and techniques in conjunction with the New Mexico portion of the 2004 Arizona Water Settlement Act. The Gila Settlement Economic Forum was co-sponsored with U.S. Bureau of Reclamation and stakeholders groups, and was attended by 65 participants. The forums final report is available via the institute's webpage at ftp://water.nmsu.edu/pub/gila/economic_forum/FinalReport.pdf.

The WRRI co-sponsored the Spring and Fall 2009 New Mexico State University Water Lecture Series, a monthly seminar with attendance averaging about 100.

Institute staff judged science projects at the April 2009 High School Science Fair and presented several awards to middle and high school students for their water-related projects. The WRRI student assistant took part in the May 2009 Water Festival and presented a game to several dozen elementary students that taught students about the hydrologic cycle.

The institute's publications for the period included four technical reports: "Land Application of Industrial Effluent on a Chihuahuan Desert Ecosystem: Impact on Soil Physical and Hydraulic Properties"; "Conjunctive Surface-Water/Groundwater Model in the Southern Rincon Valley Using Modflow-2005 with the Farm Process"; "Hydrogeologic Framework of the Binational Western Hueco Bolson-Paso del Norte Area, Texas, New Mexico, and Chihuahua: Overview and Progress Report on Digital-Model Development"; and "The Development of a Coordinated Database for Water Resources and Flow Model in the Paso Del Norte Watershed (Phase III)," a three part report published jointly with the Texas Water Resources Institute. The 54th Annual New Mexico Water Conference proceedings is being produced in hardcopy and on CD. NMWRRI technical completion reports are available at no charge while supplies last. A copy charge is assessed if the report is out of print or has been reprinted.

The institute's website averages over 45,000 webpage hits each month. It averages nearly 400 online requests for publications from its technical and miscellaneous report series and about an average of 100 hits per month of its proceedings series each month. Because of the ability to view and print all institute publications online, the WRRI is averaging only a few requests for hard copies of specific publications each month via postal mail or visits to the institute. Requests online have more than quadrupled in the past three years.

The institute's quarterly newsletter, *The Divining Rod*, is an eight- to sixteen-page newsletter that focuses on research projects administered by the NMWRRI and on current water issues in New Mexico. It provides information on upcoming conferences, seminars, and workshops; describes new grants and newly released publications; and provides general information on new developments in water resources research and management. Each issue is available on the NMWRRI's homepage. Hard copies of the newsletter are distributed to approximately 300 readers and about 1,600 readers receive it via email with a pdf of the newsletter attached. To become more cost-effective and to save resources, the institute recently moved to distributing the newsletter primarily via email. During the

reporting period, the institute published one 8-page issue and three 12-page issues of *The Divining Rod*. The newsletter received an average of 120 hits per month online during the reporting period.

Online usage of the WRRI's reference room averages 400 requests per month. During the reporting period, approximately 30 publications were checked out of the library.

The institute's director and assistant director participate in local, state, and national conferences and workshops and speak before many groups. For example, during the reporting period, Director Karl Wood delivered the address "They Are Going to Miss Me When I'm Gone: The Loss of Knowledge and Institutional Memory Due to Retirement" at the 54th Annual New Mexico Water Conference. The director also spoke before the NMSU University Pioneers on "Futuristic Ways to Increase Water Supplies." Wood gave a lecture to an NMSU class on New Mexico water law, and to another NMSU class on ecosystem succession. The associate director presented numerous technical presentations in conjunction with the U.S. Transboundary Aquifer Assessment Program. These presentations were given jointly with students, agency staff, and international faculty members.

The institute's director is an active member of the National Institute of Water Resources. The Universities Council on Water Resources has asked the New Mexico WRRI to help coordinate their 2012 national meeting. The WRRI assisted with the 2006 UCOWR meeting and it was one of their most successful. The NMWRRI staff also regularly provides expertise for solving specific problems and general concerns. They play a central role in planning for the water future of the region by cooperating with a host of water resources entities throughout the state and region, particularly in the Paso del Norte area.

The Information Transfer Program is an ongoing program with no particular timelines.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	3	0	6	13
Masters	3	0	0	2	5
Ph.D.	2	1	0	1	4
Post-Doc.	0	1	0	0	1
Total	9	5	0	9	23

Notable Awards and Achievements

Dr. Manoj Shukla, principal investigator on USGS 104b project, "Land application of industrial effluent on a Chihuahuan Desert ecosystem: Impact on soil physical and hydraulic properties" has incorporated research from his project into a new graduate course taught at New Mexico State University, Contaminant Transport Modeling (SOIL 655). Two students working on the project completed their master's degrees and produced theses from the project.

Dr. Bobby J. Creel, principal investigator on a supplemental award entitled, "Transboundary Aquifer Assessment Program" received the New Mexico Geographic Information Council, Inc. Green Chile award for Lifetime Service in the field of geographical information.

New Mexico State University College of Agricultural, Consumer, and Environmental Sciences Dean's Award for Research Excellence, 2010, was awarded to Gregory Torell, a master's degree student working on the supplemental award entitled, "Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan." Principal investigator, Professor Frank Ward, will teach a related course in Valencia, Spain from May-June 2010 entitled, "Water Policy Analysis through Hydroeconomic Models."

Publications from Prior Years

1. 2006NM41B ("Mitigation of Membane Biofouling by Harnessing Bacterial Cannibalism (Huang)") - Articles in Refereed Scientific Journals - Huang, F.Y.C., and P. Natrajan, 2006, Feasibility of using natural zeolites to remove sodium from coal bed methane-produced water, Journal of Environmental Engineering, 132(12) 1644+.
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3. 2000NM7G ("Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin") - Articles in Refereed Scientific Journals - Brinegar, H.R. and F.A. Ward, 2009, Basin impacts of irrigation water conservation policy, Ecological Economics, 69(2) 414-426.
4. 1999NM102B ("Detection of Groundwater through Ultra-Sensitive Magnetic Measurements with Ultra-short Pulse Lasers") - Articles in Refereed Scientific Journals - Kubecek, V., M. Jelinek, M. Cech, P. Hirsl, A. Stintz, and J.-C. Diels, 2009, Pulse shortening by passive negative feedback in mode-locked train from highly-doped Nd:YAG in a bounce geometry, Proceedings of SPIE - The International Society for Optical Engineering, 7354.
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8. 2006NM60G ("Impacts of Land Use Change on Water Resources, Water Quality, and Acequia Culture in Northern New Mexico/Southern Colorado") - Articles in Refereed Scientific Journals - Matthews, O. P., 2010, The Dominant Water Estate and Water Reallocation, Journal of Contemporary Water Research & Education, 144, 75-83.
9. 2006NM60G ("Impacts of Land Use Change on Water Resources, Water Quality, and Acequia Culture in Northern New Mexico/Southern Colorado") - Articles in Refereed Scientific Journals - Brookshire, D.C., D. Goodrich, M.D. Dixon, L A. Brand, K. Benedict, D. Lansey, J. Thacher, C.D. Broadbent, S. Stewart, M. McIntosh, and D. Kang, 2010, Ecosystem services and reallocation choices: A framework for preserving semi-arid regions in the Southwest, Journal of Contemporary Water Research & Education, 144, 60-74.
10. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Gochis, D.J., E.R. Vivoni, and C.J. Watts, 2010, The impact of soil depth on land surface energy and water fluxes in the North American Monsoon region, Journal of Arid Environments, 74(5), 564-571.
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30. 2008NM89B ("Utilization of Saline and Other Impaired Waters for Turfgrass Irrigation (Leinauer)") - Articles in Refereed Scientific Journals - Leinauer, B., M. Serena, M. Schiavon, and D. Singh, 2010, Seed Coating and Seeding Rate Effects on Turfgrass Germination and Establishment, HortTechnology, 20(1), 179-185.
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