Division of Hydrologic Sciences
Annual Technical Report
FY 2007

Introduction

Research Program Introduction

Award No. 05HQAG0069 – Water Resources of the Basin and Range Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah

Basic Information

Title:	Award No. 05HQAG0069 – Water Resources of the Basin and Range Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah
Project Number:	2005NV125S
Start Date:	6/1/2005
End Date:	5/31/2008
Funding Source:	Supplemental
Congressional District:	Nevada 2
Research Category:	Not Applicable
Focus Category:	Water Quantity, Groundwater, Hydrogeochemistry
Descriptors:	
Principal Investigators:	James Thomas

Publication

1. Cablk, Mary E., Kratt, Christopher, A Methodology for Mapping Shrub Canopy Cover in the Great Basin Desert using High Spatial Resolution Satellite Imagery. Desert Research Institute Publication No. 41236, 28 p.

Water Resources of the Basin and Range Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah

The U.S. Geological Survey is conducting a cooperative study with the Desert Research Institute to evaluate geohydrologic characteristics of ground-water flow systems in selected basins in White Pine County, Nevada, and adjacent basins in Lincoln County, Nevada, and Utah. The main objectives of the proposed study are to evaluate the following geohydrologic characteristics within the study area:

(1) the extent, thickness, and hydrologic properties of aquifers,
(2) the volume and quality of water stored in aquifers,
(3) the delineation of subsurface geologic structures controlling ground-water flow,
(4) determining ground-water flow direction and gradients,
(5) the distribution of recharge and discharge areas, and
(6) determining representative rates of recharge and discharge.

Geologic, hydrologic, and supplemental geochemical information will be integrated to determine basin and, if possible, regional ground-water budgets. All geohydrologic data will by synthesized and evaluated to develop a three-dimensional conceptual model of the ground-water flow system in the proposed study area.

Information Transfer Activities: The research team has traveled to several communities, within the study area, to deliver progress reports to local residents. Topics of discussion include status of the various projects, identification and discussion of relevant findings, and question and answer sessions with the audience.

The complete report is posted on http://nevada.usgs.gov/barcass/pubs.htm

Soil Heterogeneity and Moisture Distribution Due to Rainfall Events in Vegetated Desert Areas: Potential Impact on Soil Recharge and Ecosystems

Basic Information

Title:	Soil Heterogeneity and Moisture Distribution Due to Rainfall Events in Vegetated Desert Areas: Potential Impact on Soil Recharge and Ecosystems
Project Number:	2006NV100B
Start Date:	3/1/2006
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Geomorphological Processes, Drought
Descriptors:	
Principal Investigators:	Michael Young, Li Chen

Publication

1. Chen, L., J. Yin, J. Miller and M. H. Young. Hydrologic impact of the clast layer in desert pavements, Brownbag Seminar, DHS, DRI, June, 2008.
2. Yin, J., M. H. Young, L. Chen and Z. Yu (2008) Modeling the effect of spatial variability of soil hydraulic properties on the rainfall−runoff process in a rangeland watershed using a diffusion wave model. Water Resour. Res. (submitted).
3. Chen, L. and M. H. Young (2008) A Physically−Based, Two−dimensional Hillslope Rainfall−Runoff Modeling Approach. Water Resour. Res. (submitted).
4. Yin, J., M. H. Young, L. Chen and Z. Yu, (2008) Modeling surface runoff on a semi−arid watershed using a physically based model. World Environmental and Water Resources Congress. Honolulu, Hawaii.
5. Yin, J. 2008 Spatio−temporal variation in soil moisture and hydraulic properties and their impacts on rainfall−runoff and infiltration processes. Ph.D. Dissertation. University of Nevada Las Vegas, Department of Geosciences.

Soil Heterogeneity and Moisture Distribution Due to Rainfall Events in Vegetated Desert Areas: Potential Impact on Soil Recharge and Ecosystems

Annual Report
2008

Michael Young and Li Chen
Division of Hydrologic Sciences
Desert Research Institute, Las Vegas, NV

Problem and research objectives

Strong interactions exist between desert soils and plants, and these interactions will potentially control the overall movement and distribution of water, which are critical for water resources and desert ecosystems. The high level of spatial and temporal heterogeneities of near-surface soil and plant environments creates significant difficulty for quantifying, understanding and simulating how climate, soil properties and ecological resources interact with one another. Heterogeneities are attributed to physical, geomorphological, and biological variations across the landscape and soil surface; many of these attributes directly influence soil hydraulic properties and thus hydrological processes. The overriding objective of this research is to observe and simulate the contribution of surface feature heterogeneity to the landscape response from precipitation events, particularly as they relate to recharge and surface runoff in desert environments.

Methodology

Field Measurements

The proposed methodology for this study is to apply both field experimental and numerical approaches to examine the impact of the heterogeneity of soil surface introduced by microtopography, plant canopies, and soil hydraulic properties on rainfall-infiltration-runoff processes. In the experimental portion of the study, we set up three experimental plots (20 m by 30 m) on 3 geomorphic surfaces with ages that range from 500 to 100,000 years old (McDonald et al, 2003; Young et al 2004) at the Mojave National Preserve, CA, and then conducted high-resolution elevation and plant surveys within each plot. On each plot, a surface elevation survey was conducted using a Laser Total Station. Surface elevations were first measured on 5 m X 5 m control grid to represent overall topographic trends. Significant topographic structures such as channels, ridges and mounds were measured in more detail. A vegetation survey was also conducted in each plot. The quantity of plant in each category was counted and characteristic scales (long and short axes and hight) of selected individual plants were measured, generating the spatial distribution of the plants. Topographic mounds under plants were also measured to investigate the micro topographic features.

Hydraulic properties (i.e., hydraulic conductivity function) were measured using a tension infiltrometer (TI) in every experimental plot for both interspace and under canopy soils. The soil hydraulic properties obtained from the TI data similar to the method described by Young et al. (2004). Soil samples were collected from each TI location and analyzed for soil texture (i.e., gravel, sand, silt and clay contents) and bulk density. Spatial distribution and correlation of the texture and hydraulic property parameters were analyzed. Experimental results were imported to a numerical model (described below) to simulate runoff the experimental plots under a variety of different precipitation events.

Leveraging an internally-funded DRI project, rainfall simulation experiments were conducted at the plot located on the oldest (Qf3) surface. This study aims to investigate the impact of the clast (upper rock) layer found on many desert pavement surfaces on runoff and infiltration rates. We used a portable rainfall simulator on adjacent plots on surfaces with and without the clasts. In the case where clasts were removed, the underlying Av material was kept intact to the extent possible; thus, the difference between the two plots is the presence of the clast layer. Seven pairs of experiments (14 plots total) were conducted. In each experiment, characteristic times for runoff generation were recorded (i.e., time to ponding, initial runoff, runoff observed in all quadrant, full runoff connection and runoff to the trough) and the runoff volume was measured by collecting water in a downstream trough at specific time intervals. Changes in soil water content were also monitored continuously during the experiment using a Water Content Reflectometer (WCR, model 616, Campbell Scientific Inc., Logan UT). The soil cumulative infiltration curves obtained from the WCR measurements were used in a parameter estimation scheme to obtain the Green-Ampt infiltration parameters.

Numerical Modeling

The numerical model used for this research is known as CeRIRM (Cell-Based Rainfall Infiltration Runoff Model), a physically-based distributed model for rainfall-runoff modeling (Chen and Young, 2008). The model is capable of simulating surface runoff and infiltration using a very high-resolution distributed modeling approach. CeRIRM was originally developed by the co-PI for his dissertation and was further modified through funding from the U.S. Army Corp of Engineers. The model applies a two-dimensional surface runoff routing approach to account explicitly for topographic impact on overland flow movement, and it incorporates the Green-Ampt model to simulate infiltration. This comprehensive modeling technique addresses the interaction between the infiltration and surface runoff routing that is greatly complicated by heterogeneity of soil hydraulic properties and topography. The model has been modified to accommodate the plot scale rainfall-runoff simulation for this project. In addition, scripts have been created to randomize the hydraulic properties across the field site. The randomization accounts for uncertainty in our knowledge of soil hydraulic properties, and opens the use of Monte Carlo simulation techniques.

A primary issue in rainfall-runoff modeling is how to efficiently represent the spatial variability of parameters in hydrologic models. Thus, the numerical modeling work for the past year was focused on the fundamental impact of spatial variability of soil hydraulic properties on runoff and infiltration, given specific storm distributions. The model was applied to the Walnut Gulch Experimental Watershed, near Tombstone, AZ, to investigate how different spatial patterns of watershed characteristics (e.g., vegetation coverage) and soil hydraulic properties (e.g., hydraulic conductivity and saturated water content) could impact runoff and infiltration in a semi-arid environment (Yin, 2008; Yin et al., 2008). In these studies, the model was used to examine how parameter generation – uniform versus random versus co-kriged– could affect the accuracy of runoff predictions at a small (approximately 44,000 m^2) watershed known as Lucky

Hills 104. Parameter fields for this modeling study were generated using a pedotransfer function, using soil textural data obtained from samples collected at 33 locations across the watershed. Samples were collected at both interspace and undercanopy microsites (66 samples total) using a stratified sampling technique. Saturated hydraulic conductivity (K_s), saturated water content (θ_s), and wetting front capillary pressure for the Green-Ampt model (S) were then derived from the estimated hydraulic properties. Three different methods were used to generate the parameter field: geometric mean for K_s and arithmetic mean for θ_s and S; Latin Hypercube Sampling (LHS); and, cokriging using all three parameters. For each method, the parameter fields were generated using only interspace samples, only undercanopy samples, and the entire population (nine combinations of averaging and sample origin). The numerical model was then run for eight recorded rainfall events during the last 50 years that produced measurable runoff at LH104, using each parameter field respectively (72 simulations total). The runoff generation results were compared to find the best approach for representing soil heterogeneity.

Principal findings and significance

Results from the field studies and numerical modeling studies have shown:

- Soil surfaces are features with various scales of topographic elements, which mainly include channels, topographic mounds, under canopy soil mounds (Fig.1). These features can dominate the runoff routing dynamics and significantly affect the lateral water distribution and nutrient movement toward or away from ecological niches.
- Soil hydraulic properties have significant variability across the surface, as seen by a qualitative review of the TI experimental results. Quantitative analyses of the results are undergoing and will show more details of the heterogeneity and spatial correlation.
- In the rainfall simulation experiment, results of both runoff and soil moisture did not show significant difference between plots with and without clasts (Fig.2), which implies that the rock surface does not impact runoff generation by itself. In addition, the measured soil moisture curves were used to develop an optimization method for estimating Green-Ampt infiltration parameters (Yin, 2008). The new method can be useful for directly estimating G-A parameters for practical applications.
- Numerical simulation results showed that impacts of spatial variability depend on flood characteristics such as runoff coefficients (Fig.3). In general, the diffusion wave model captured the runoff characteristics for most storm events. Simulation results also showed that the best performance occurred for parameters fields generated using cokriging. Also the results showed that effects of vegetation on interception loss and increased roughness coefficient cannot be neglected. Results also indicated that small-scale spatial variability dominates the runoff generation mechanism when storm events are small.

Information Transfer Activities

Papers:

Yin, J., M. H. Young, L. Chen and Z. Yu (2008) Modeling the effect of spatial variability of soil hydraulic properties on the rainfall-runoff process in a rangeland watershed using a diffusion wave model. *Water Resour. Res.* (submitted).

Chen, L. and M. H. Young (2008) A Physically-Based, Two-dimensional Hillslope Rainfall-Runoff Modeling Approach. *Water Resour. Res.* (submitted).

Yin, J., M. H. Young, L. Chen and Z. Yu, (2008) Modeling surface runoff on a semi-arid watershed using a physically based model. World Environmental and Water Resources Congress. Honolulu, Hawaii.

Yin, J. 2008 Spatio-temporal variation in soil moisture and hydraulic properties and their impacts on rainfall-runoff and infiltration processes. Ph.D. Dissertation. University of Nevada Las Vegas, Department of Geosciences.

Presentations:

Chen, L., J. Yin, J. Miller and M. H. Young. Hydrologic impact of the clast layer in desert pavements, Brownbag Seminar, DHS, DRI, June, 2008.

Student Support:

This grant funded the research endeavors (time, instruments and travel) during Jun Yin's Ph.D. degree study.

Reference

McDonald, E.V., L.D. McFadden, and S.G. Wells. (2003) Regional response of alluvial fans to the Pleistocene-Holocene climatic transition, Mojave Desert, California. p. 189–206. *In* N. Lancaster et al. (ed.) Paleoenvironments and paleohydrology of the Mojave and Southern Great Basin Deserts. GSA Spec. Pap. 368. GSA, Boulder, CO.

Young, M. H., McDonald, E. V., Caldwell, T. G., Benner, S. G., Meadows, D. G. (2004) Hydraulic Properties of a Desert Soil Chronosequence in the Mojave Desert, USA. *Vadose Zone J.* 3: 956-963

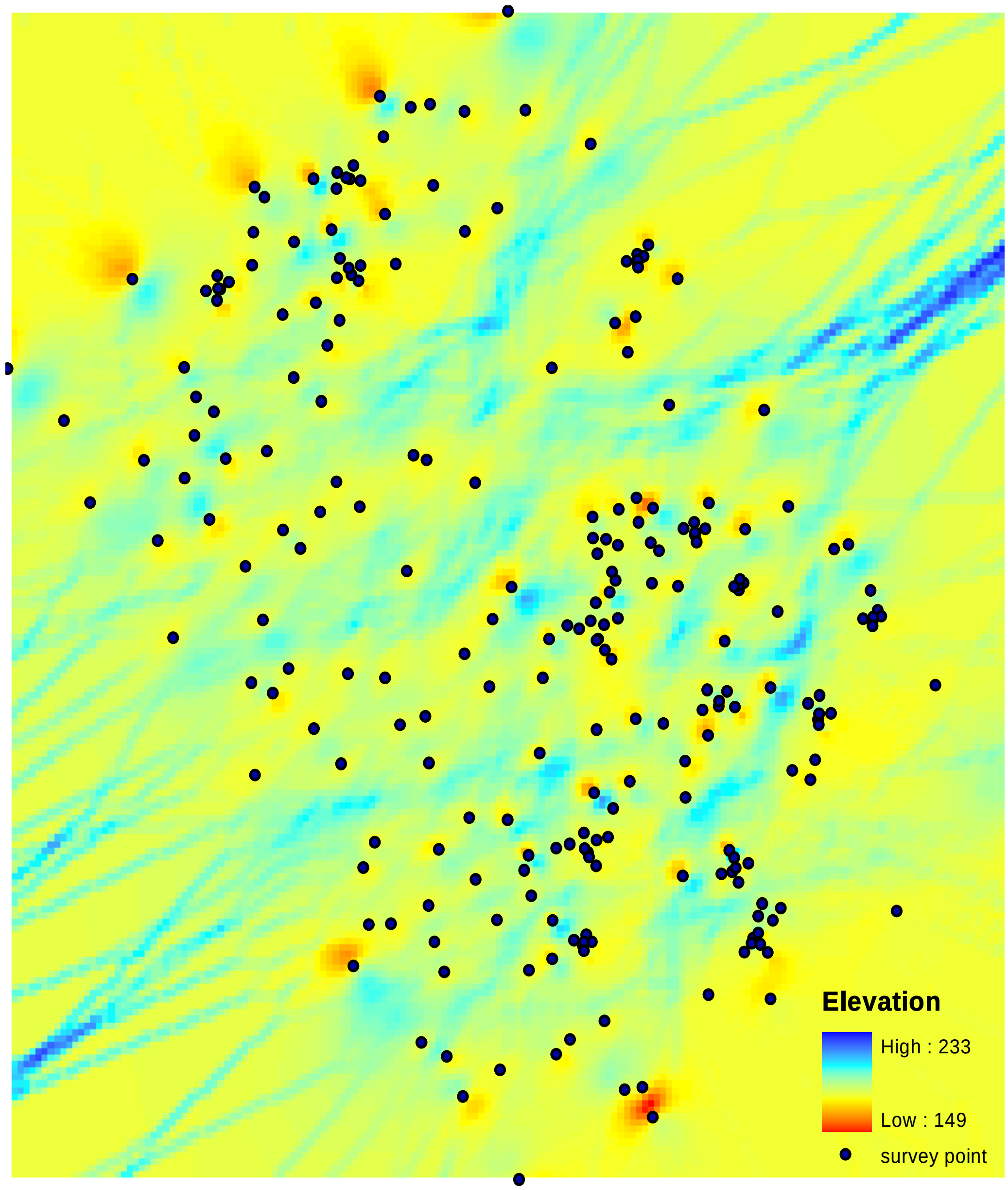
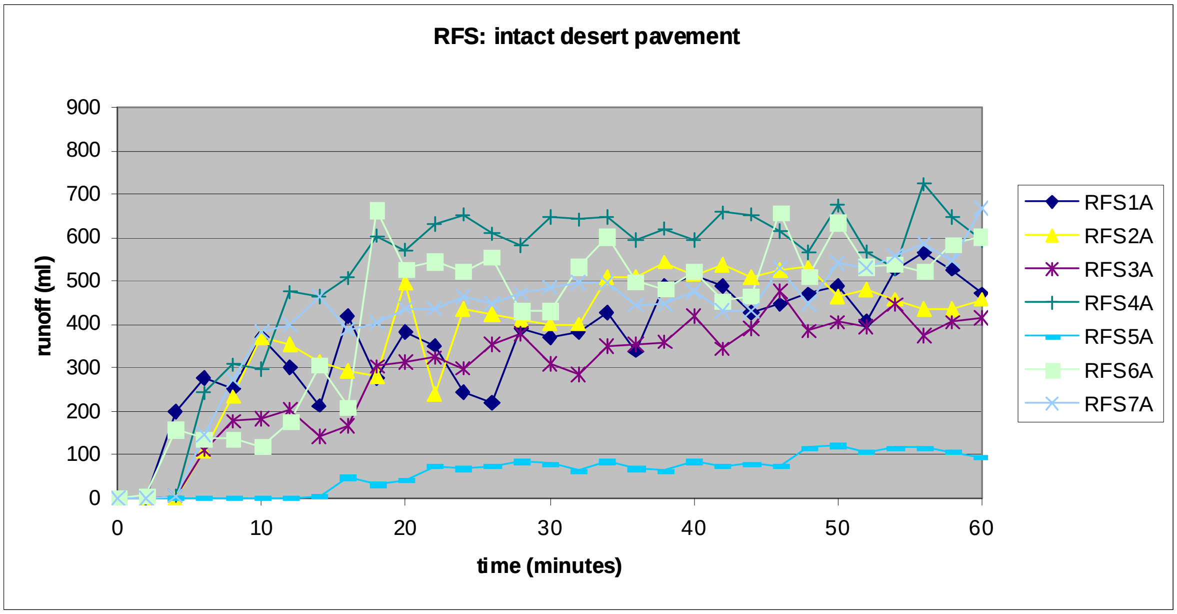


Fig. 1 The elevation survey points in one plot and the generated elevation map.



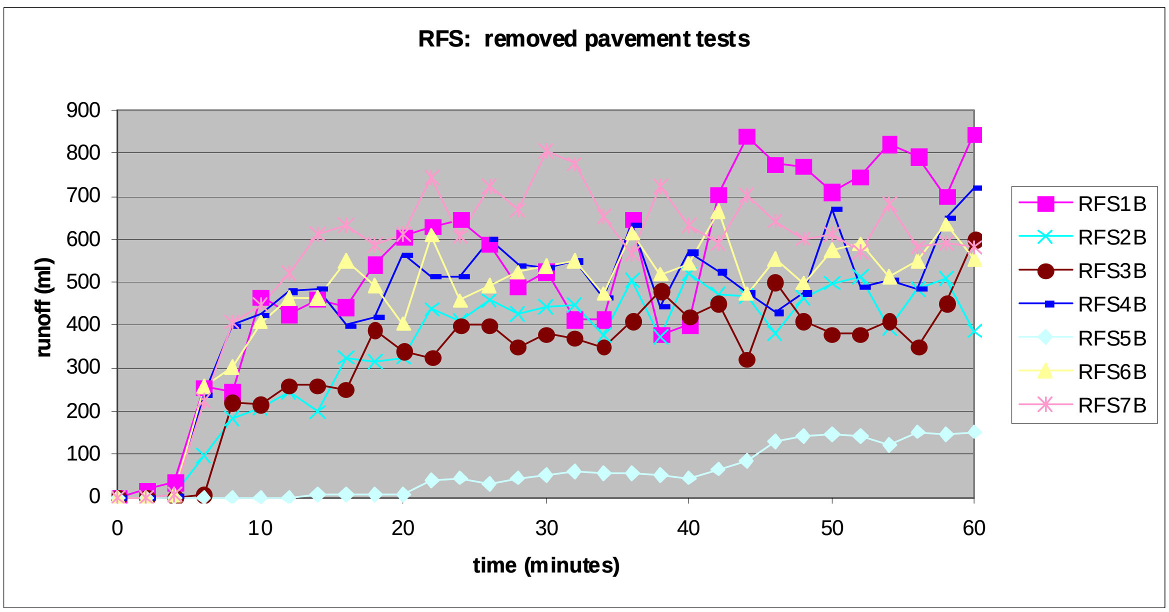


Fig. 2 Experimental results of rainfall tests on the older (Qf3) surface at Mojave National Preserve, CA. RFS indicates rainfall simulation test. Upper graph (tests denoted with A) are for surfaces with clasts intact and lower graph (tests denoted with B) are for surfaces with clasts removed.

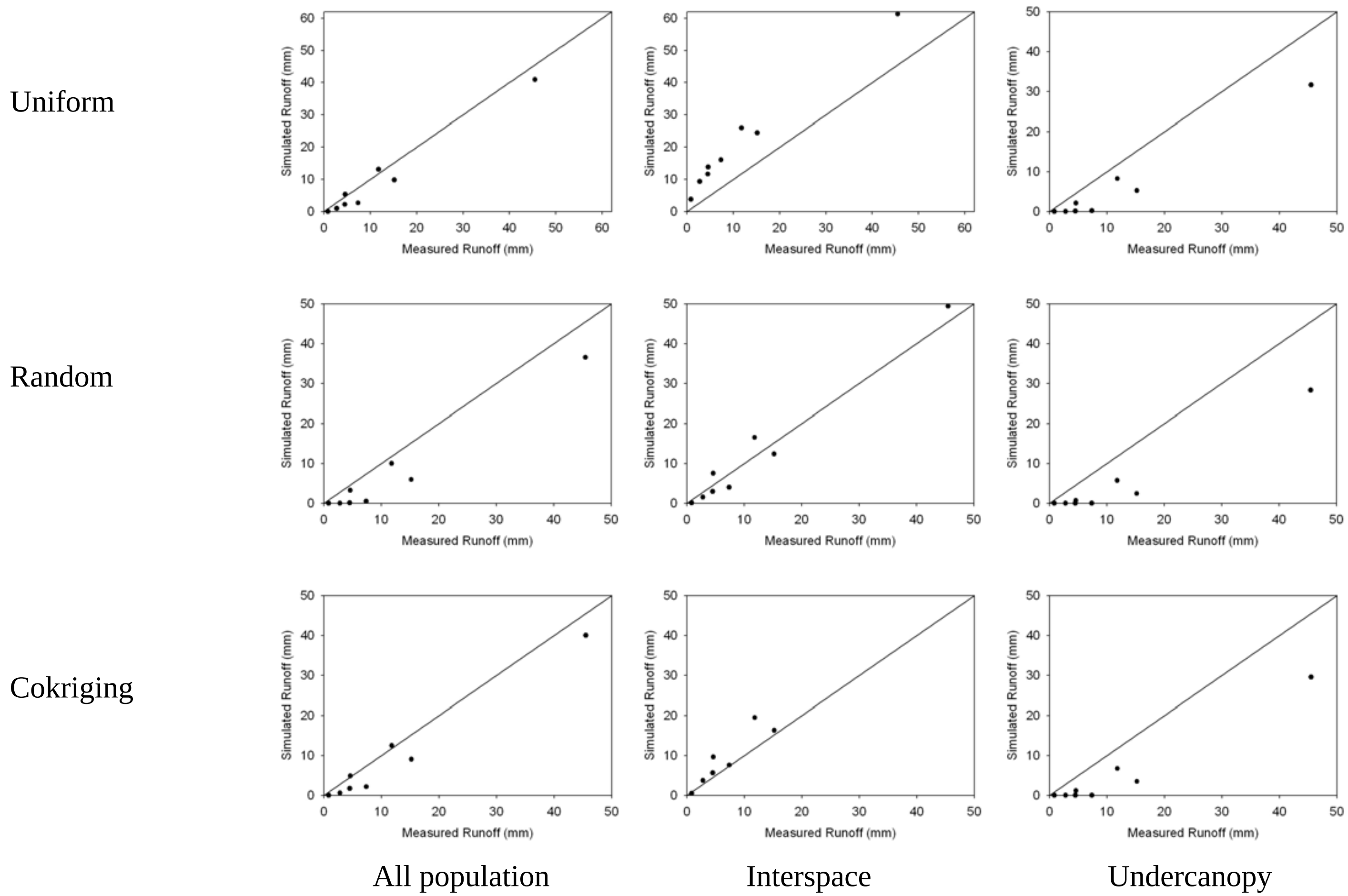


Fig. 3. Simulated runoff depth versus the measured runoff depth for the eight storm events recorded at the Lucky Hills 104 watershed.

Modeling Biotic Uptake of Mercury in the Lahontan Resevoir System

Basic Information

Title:	Modeling Biotic Uptake of Mercury in the Lahontan Resevoir System
Project Number:	2006NV101B
Start Date:	3/1/2006
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	Nevada 02
Research Category:	Water Quality
Focus Category:	Models, Toxic Substances, Ecology
Descriptors:	
Principal Investigators:	Rosemary Woods−Hart Carroll, Rosemary Woods−Hart Carroll

Publication

1. Warwick, J.J., and Carroll, R.W.H. 2007. Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada. 23rd Annual International Conference on Soil, Sediment and Water. Oct 15−18, 2007. University of Massachusetts, Amherst. Published in conference proceedings, Contaminated Soils, Sediment and Water, vol 13.

Modeling Biotic Uptake of Mercury in the Lahontan Reservoir System

Synopsis

Year Two Progress Report – Not Final Report Due to No-Cost Extension

Problem and research objectives

The timing of maximum growth of phytoplankton relative to that of mercury loading could matter greatly if the loading signal varies strongly over time. Therefore, accurate prediction of mercury bioaccumulation may depend upon understanding mercury loading mechanisms and associated uncertainty to the system as well as the interaction between this loading and phytoplankton growth at sub-annual time scales (i.e. days to weeks). Also, using a well defined and strongly varying mercury signal may help to elucidate important bioaccumulation features (e.g., bioavailable forms of mercury and the rate of mercury transfer through different trophic levels).

The geologic and geochemical controls on THg and methylmerncy (MeHg) transport through the Carson River have been successfully modeled with a linked and modified version of RIVMOD (Hosseinipour and Martin, 1990) and WASP5/MERC4 (Ambrose et al., 1991) by Carroll et al. (2004), Carroll and Warwick (2001), Carroll et al. (2000) and Heim and Warwick, (1997). Proposed research will better quantify physical parameters impacting mercury transport into/through Lahontan Reservoir as well as quantify uncertainty associated with geomorphologic and biogeochemical controls influencing mercury loading into the Carson River and subsequently into Lahontan Reservoir. Results will be evaluated in their relationship to a varying mercury signal within the lower trophic levels occupying Lahontan Reservoir.

Methodology

Proposed research has been divided into two distinct phases based on site location. First, a detailed uncertainty analysis looks at geomorphic controls, bank moisture history, as well as methylation-demethylation on mercury loading into the Carson River and subsequently into Lahontan Reservoir. Hypothetical best management practices will address mitigation of fluvial loads into the reservoir and results will be incorporated into proposed bioaccumulation modeling. Second, Lahontan Reservoir will be investigated in greater detail. Detailed cross sections and stage modeling will ensure a correctly moving delta region which dictates sediment and mercury deposition at the mouth of the Carson River. With proper hydrodynamic modeling of the reservoir established, it is proposed to observe and model a temporally varying mercury signal in the lower food web, specifically within the phytoplankton communities. Collected data will parameterize/drive a bioaccumulation model (e.g. Bioaccumulation and Aquatic System Simulator – BASS by the US EPA (Barber, 2004)) to simulate mercury pulse loading on bioaccumulation of MeHg in generalized/hypothetical trophic levels in Lahontan Reservoir. A verified model will allow model prediction of bioaccumulation based on hypothetical flow and mercury loading scenarios. Finally, a coupled uncertainty analysis of fluvial inputs and BASS model parameters will provide a quantitative assessment of the expected accuracy of model predictions. This will allow a determination of significant differences between simulated scenarios

Principal findings and significance

This project was granted a no-cost extension through February 2009 and therefore the listed findings will not meet all objectives listed above. Observed phytoplankton mercury concentrations as related to mercury loading were discussed in the progress report from year 1.

- Uncertainty related to modeled geomorphic processes of bank erosion and overbank deposition describe observed variation in Hg water column concentrations prior to and during the 19978 flood.
- The model places relatively greater uncertainty in modeled behavior on earlier over-bank discharge events than for later events. This is most evident in river reaches that have shallow channel slopes which experience the greatest increases in channel widths during the earliest modeled overbank flow events.
- A change in the system appears to occur at Fort Churchill during the 1997 flood that is not adequately modeled since uncertainty in modeled parameters alone cannot explain Hg variation following the 1997 flood.
- MeHg loading appears dominated by diffusion processes as opposed to geomorphic channel changes.
- Diffusion from river banks is included (indirectly) in the uncertainty analysis via the amount of MeHg in the banks and it is an important mechanism for MeHg loading. However, its influence diminishes with time due to increased channel widths.
- Uncertainty in geomorphic channel change and MeHg bank concentrations are not enough to capture observed variation in MeHg water column concentrations at Fort Churchill.

Information Transfer Activities

Papers:

Warwick, J.J. and Carroll, R.W.H. (accepted). Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada. International Journal of Soil, Sediment and Water.

Carroll, R.W.H., Memmott, J., Warwick, J., Fritsen, F.H., and J.C. Bonzongo. draft. Biotic sorption of mercury in Lahontan Reservoir phytoplankton: Implications of dynamic loading. *In the process of being re-written and re-submitted*.

Conference Abstracts:

Warwick, J.J., and Carroll, R.W.H. 2007. Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada. 23rd Annual International Conference on Soil, Sediment and Water. Oct 15-18, 2007. University of Massachusetts, Amherst. Published in conference proceedings, Contaminated Soils, Sediment and Water, vol 13.

Awards:

Adventus Americas Student Award for Platform Presentation, October 19, 2007, 23rd Annual International Conference on Soils, Sediment and Water for paper presentation: Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada.

Student Support

This grant funds doctoral research for Rosemary Carroll who attends the University of Nevada, Reno graduate program of Hydrologic Sciences. The papers listed above serve as the first two chapters in her dissertation. The first paper was presented by Ms. Carroll at University of Massachusetts, Amherst and earned her the Adventus Americas student award for best platform presentation. Addition papers written by the close of funding in 2009 will also be used in her dissertation. John Warwick serves as her advisor on her Ph.D. committee and provides technical assistance and oversight.

References Cited

Ambrose, R.B., T.A. Wool, J.L. Martin, J.P. Connolly, and R.W. Schanz (1991). WASP5.X: A Hydrodynamic and Water Quality Model: Model Theory, Users Manual and Programmer's Guide. U.S. Environmental Protection Agency, Athens, Georgia.

Barber, M.C. 2004. Bioaccumulation and Aquatic System Simulator (BASS). User's manual version 2.2. Ecosystem Research Division, U.S. Environmental Protection Agency. EPA Report No. 600/R-04.

Carroll, R.W.H., J.J. Warwick, K.J. Heim, J.C. Bonzongo, J.R. Miller, and W.B. Lyons (2000). Simulation of Mercury Transport and Fate in the Carson River, Nevada. Ecological Modelling, 125, 255-278.

Carroll, R.W.H. and J.J. Warwick (2001). Uncertainty analysis of the Carson River mercury transport model. Ecological Modelling, 137, 211-224.

Carroll, R., James, A., Warwick, J. and J. Miller. (2004). Modeling Erosion and Overbank Deposition During Extreme Flood Conditions on the Carson River, Nevada. Journal of Hydrology. 297(1-4): 1-21.

Heim, K.J. and J.J. Warwick (1997). Simulating Sediment Transport in the Carson River and Lahontan Reservoir, Nevada, USA. Journal of the American Water Resources Association, 33(1), 177-191.

Hosseinipour, E.Z. and J.L. Martin (1990). RIVMOD, A One-dimensional Hydrodynamic and Sediment Transport Model: Model Theory and User's Guide, U.S. Environmental Protection Agency, Athens, Georgia.

Flood Warning System for the Clark County Wetlands Park

Basic Information

Title:	Flood Warning System for the Clark County Wetlands Park
Project Number:	2006NV102B
Start Date:	3/1/2006
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Not Applicable
Focus Category:	Floods, Hydrology, Models
Descriptors:	
Principal Investigators:	Thomas Piechota, Thomas Piechota

Publication

1.

Synopsis

Progress Report (Year 2)

Title: Flood Warning System for the Clark County Wetlands Park

Investigators: Thomas C. Piechota and Jim Pollard

Problem and research objectives:

This research project will develop an integrated flood warning system for the Clark County Wetlands Park located in the Las Vegas Valley. The Clark County Wetlands Park is located adjacent to the Las Vegas Wash and is an invaluable environmental resource. The facility is open to the public with various walking trails; however, there is potential for the facility to be inundated with flood waters during significant rainfall events. The proposed research project seeks to integrate the rich sources of data (rainfall and GIS) available in Clark County to develop the Wetlands Advanced Inundation Threat System (WAITS) that will be able to (1) predict when the Wetlands Park may flood using real time and historical rainfall data; (2) be used to make assessments of flooding at the Wetlands Park for various hypothetical storms; (3) and can be used for future development into Las Vegas Valley wide flood forecasting system.

Methodology:

The basis for the system will be a series of hydrologic and hydraulic models that will be integrated within a Geographic Information System (GIS) to provide seamless exchange of data and the flood inundation mapping. The research will accomplish the goals through 5 tasks.

- Task 1: Compile existing rainfall and topographic data
- Task 2: Adopt the Clark County Master Plan Hydrology Model
- Task 3: Develop a hydraulic model for the Las Vegas Wash
- Task 4: Develop a decision support system (WAITS)
- Task 5: Expansion of the decision support system

Principal findings and significance:

Minimal resources were available in Year 2 of the project, so the research was limited to Task 3 where a preliminary hydraulic model was developed for the Las Vegas Wash which drains the entire Las Vegas Valley. Modeling results were obtained for steady flow and unsteady flow conditions. This was research developed as part of a Masters Project by David Betley at UNLV (Master of Science in Civil Engineering, May 2007).

Anil Acharya continued some of this work in Fall 2007 and Spring 2008. He will be fully supported on this project during Year 3 of the project.

Information Transfer Activities

a) **Meeting with Stakeholders**

- **March 28, 2008: Clark County Parks and Recreation (Elise Sellars) and Jim Pollard.**

b) **Conference Presentations:**

c) **Publications**

Student Support: No students supported in Year 2. Anil Acharya will be working on the project and was funded on a state-supported assistantship in the Fall 2007 and Spring 2008.

Hydrodynamic Modeling of Lake Mead

Basic Information

Title:	Hydrodynamic Modeling of Lake Mead
Project Number:	2006NV103B
Start Date:	3/1/2006
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Water Quality
Focus Category:	Models, Surface Water, Water Supply
Descriptors:	
Principal Investigators:	Mark Stone, Mark Stone

Publication

1. None

Progress Report for Hydrodynamic Modeling of Lake Mead (2006NV103B)

PI: Mark Stone
June 16, 2008

Problem and Research Objectives

Lake Mead is one of the most important water bodies in the United States; providing recreational opportunities, fish and wildlife habitat, and drinking, irrigation, and industrial water for approximately 25 million people. Consequently, it is crucial that the quality of this water be maintained to provide a reliable and safe source of water for its many uses. Rapid urban development in Southern Nevada, combined with modified upstream land use and extended drought, has gradually degraded Lake Mead water quality. This problem was demonstrated by an intense algal bloom throughout Boulder Basin in the spring of 2001. Concerns over water quality were the impetus for intensive sampling efforts conducted by the U.S. Bureau of Reclamation (USBR), the Southern Nevada Water Authority (SNWA), the U.S. Geological Survey (USGS), and others in Lake Mead over the past 15 years. Although the monitoring efforts have provided an outstanding record of spatial and temporal circulation and water quality trends, this data has not been incorporated into a unifying tool to support management and research efforts. *The goal of this research is to develop a hydrodynamic model of Lake Mead to investigate circulation and eutrophication of the lake*. The model will integrate previous water monitoring efforts, improve understanding of lake circulation, and provide the framework for a robust adaptive management tool for Lake Mead.

Methodology

The final product of this research will be a hydrodynamic model capable of investigating the influence of dropping lake levels on circulation patterns and water quality. The following tasks are underway to produce the model.

1. Review existing models and data

We conducted an extensive review of the models available for this purpose and compared their capabilities and data requirements with the objectives of this project and available data.

The Bureau of Reclamation, USGS, and SNWA have been collecting a wide range of environmental data on Lake Mead over the past 15 to 20 years. As one of the first stages of this research, we reviewed the reports and publications resulting from these monitoring efforts. We have requested the available data necessary for developing the ecological model.

2. Select hydrodynamic model

We initially planned to base our model on a Structurally Dynamic Models (SDM) focusing on exchange from the near surface, deep, and sediment regions of the lake, but have changed course to use a spatially explicit numerical model; Environmental Fluid Dynamics Code (EFDC). EFDC has been developed through a collaborative effort between the U.S. Environmental Protection Agency and Sandia National Laboratories.

3. Parameterize the model

A preliminary model has been successfully parameterized using topographic and flow information gathered by the USGS. Additional data describing thermal forcing has been collected from the WRCC and NCDC.

4. Calibrate the ecological model based on historical data

Fortunately, the extensive monitoring activities in Lake Mead provide an excellent calibration dataset. We will use 5 to 10 years of the historical dataset to calibrate the model. We will then use the additional historical data to validate the model under different environmental conditions (i.e. lower water levels).

5. Evaluate system response to environmental conditions

Following model calibration and validation, we will be able to evaluate how the model responds to various environmental conditions. We will focus on high water (around 2001) and low water (current) conditions.

Principal Findings and Significance

As the model is currently still in it's developmental stages, there are no significant findings at this point it time. The research is now in full motion and we expect to complete the project on time. Thus, findings will be given in the final report.

Information Transfer Activities

The project is still underway and therefore has not yet been published in any fashion. Outcomes from the initial data review have been discussed with limnologists at SNWA and with resource managers at the Bureau of Reclamation. We expect to publish the final study results in at least one peer-reviewed journal paper and to present the results at one or more professional conferences. We also hope to present the results to the Lake Mead Water Quality Forum.

Student Support

This project was initially delayed by the inability to recruit a graduate student. Consequently an undergraduate student, *Mahsa Amirsarhangpour*, was hired to work on the project in October of 2006 until her graduation in December of 2007. A early career researcher, Dr. Dong Chen, is now assisting with the research.

Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV

Basic Information

Title:	Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV
Project Number:	2006NV104B
Start Date:	3/1/2006
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Biological Sciences
Focus Category:	Toxic Substances, Water Quality, Acid Deposition
Descriptors:	
Principal Investigators:	Duane Moser

Publication

Synopsis

Annual Report

March 1, 2007 through February 28, 2008

Problem and research objectives

Las Vegas Wash, a tributary which enters the Boulder Basin of Lake Mead, NV, is primarily supplied by tertiary treated wastewater. Various endocrine disrupting chemicals (EDCs), with the potential to adversely affect the reproductive systems of fish and other aquatic life, have been found in water and sediment from Las Vegas Wash and Las Vegas Bay. Common carp, a surrogate for endangered species such as the razorback sucker, have been collected from this system and found to contain high concentrations of synthetic organic chemicals and altered levels of endocrine disrupting biomarkers. During this and the prior contract period, I have developed a relationship with a research team of USGS and USFWS researchers investigating EDC-related phenomena in Lake Mead. Members of this team (e.g. Michael Rosen, USGS, Carson City, NV) are pursuing a "cradle to grave" approach and indicate a growing interest in the role of natural microorganisms for mediating the environmental fate of these and other persistent organic chemicals. Las Vegas Wash, functionally a river of treated wastewater, provides a unique environment to study the impacts of microorganisms upon the fate of EDCs. As stated in our initial proposal, a major objective of our project has been to develop a sustainable research program at DRI focused on the role of environmental microorganisms in mediating the persistence of emerging contaminants. The aforementioned relationship with USGS and more recently a collaboration with Southern Nevada Water Authority are detailed below.

Methodology

Aerobic cultivation-based approaches have been utilized to date to begin to assess the physiological and phylogenetic range of bacteria that impact these contaminants. Enrichment cultures and quantitative dilutions using the estrogens (ethinylestradiol, estradiol and estrone, EE2, E2, and E1) as sole carbon sources were prepared using a defined artificial surface water medium and samples from various sites along the Las Vegas Wash. High performance liquid chromatography (HPLC) and Gas Chromatography/Mass Spectrometry (GC/MS) was used to quantitatively analyze the consumption of EE2, E2 and E1 in cultures. Most probable number (MPN) methods were used to determine abundance of estrogen-degrading microorganisms in Las Vegas Wash and several isolates have been identified using rRNA-based molecular approaches.

Principal findings and significance

Preliminary work has focused on identifying microorganisms within Las Vegas Wash with estrogen-degrading capabilities:

- A collection of aerobic EDC-degrading microorganisms is being developed and characterized.

- One morphologically distinct (pink) microorganism (*Methylobacterium* sp.) was shown to grow with E2 as a sole carbon source and is able to oxidize E2 to E1, leading to eventual complete degradation of E1.

- Degradation was quantified using HPLC and GC/MS methods in selected ion monitoring mode.

- Further quantification methods involving extremely low, environmentally relevant concentrations (ppt) are currently under development in collaboration with the Southern Nevada Water Authority.

- A Yeast Estrogen Screening (YES) Assay is being developed in order to measure microbial degradation of additional estrogenic compounds (nonylphenols, alkylphenols) at ppt concentrations.

Information transfer activities

Presentations:

Moser, D.P., Blunt, S.M. 2007. Microbial degradation of endocrine disrupting contaminants in Las Vegas Wash and Lake Mead. Principle Investigator Meeting. NPS Aquatic Safety Center in Boulder City. Nov. 09, 2007

Blunt, S.M., D.P. Moser. 2008. Microbial degradation of endocrine disrupting contaminants in Las Vegas Wash. Interagency Water 2025 Meeting. Las Vegas, NV. Mar. 21, 2008

Moser, D.P. 2008. Environmental microbiology lab at DRI. Introductory talk given to Applied Research and Development Group, Southern Nevada Water Authority. Henderson, NV. Apr. 10, 2008

Student support

UNLV School of Life Sciences Masters' student Susanna Blunt has been supported on this grant at a rate of 50% (the other 50% from NPS/USGS SNPLMA funds). Susanna is now entering her second year. We have subsequently obtained additional funds for Susanna's continued training from Southern Nevada Water Authority.

Return on investment

This initial award was treated as seed money to establish a program in endocrine disruptor microbiology at DRI. My initial funds we used in FY 2006 to supplement an undergraduate research project (NSF EPSCoR) to Karen Levy of UNLV focused on microbial EDC microbiology. Ms Levy has subsequently gone on receive a prestigious Amgen fellowship at Columbia University and most recently a Goldwater scholarship. Karen's data was utilized to leverage a cooperative agreement with USGS for $57,000 in 2007. This funding was utilized to supplement Susanna Blunt's Masters' NIWR-funded studies at UNLV and to further develop EDC microbiology at DRI. Early successes in this work were used to forge a relationship with Southern Nevada Water Authority (Shane Snyder and Ben Sanford, Appled Research and Development Group) that continues today. This relationship was recently formalized (June of 2008) in the form of a student internship at SNWA where Susanna is receiving state of the art analytical chemistry training focused on low concentration measurements of estrogen-like compounds essential for the continuation of our initial study.

Hydraulic Property Correspondence and Upscaling for Arid and Semi−Arid Hydrologic Processes

Basic Information

Title:	Hydraulic Property Correspondence and Upscaling for Arid and Semi−Arid Hydrologic Processes
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Descriptors:	
Principal Investigators:	Jianting Julian Zhu

Publication

1. Zhu, J., Mohanty, B. P., and Das, N. N., On the Effective Averaging Schemes of Hydraulic Properties at the Landscape Scale, Vadose Zone Journal, 5, 308−316, 2006.
2. Zhu, J., and Mohanty, B. P., Effective Soil Hydraulic Parameters for Land−atmosphere Interaction, Journal of Hydrometeorology, in press, 2007.
3. Zhu J., Young, M. H., van Genuchten, M. Th., Upscaling Schemes for Gardner and van Genuchten Hydraulic Functions for Heterogeneous Soils, Vadose Zone Journal, 6, 186−195, 2007.
4. Zhu, J., Mohanty, B. P., and Das, N. N., Effective Soil Hydraulic Properties at the Landscape Scale and Beyond, 18th World Congress of Soil Science, Philadelphia, PA, July 9−15, 2006.
5. Zhu, J., Sun, D., and Young, M. H., Aggregating Hydraulic Property Measurements to Large Scale Hydrologic Processes, Western Pacific Geophysics Meeting, Beijing, China, July 24 – 27, 2006
6. Zhu, J., Young, M. H., and van Genuchten, M. Th., Upscaling Schemes for Hydraulic Functions at the Landscape Scale, AGU Joint Assembly, Baltimore, MD, May 23 – 26, 2006.
7. Zhu, J., Young, M. H., van Genuchten, M. Th., Sun, D., Upscaling Schemes of Hydraulic Properties and Characterizing Hydraulic Parameter Variability Using Cokriging and Artificial Neural Network for Heterogeneous Soils, W1188 Multistate Research Project Annual Meeting, Las Vegas, NV, January 2 – 4, 2007.

HYDRAULIC PROPERTY CORRESPONDENCE AND UPSCALING FOR ARID AND SEMI-ARID HYDROLOGIC PROCESSES

Statement of Critical Regional or State Water Problems

Water resources issue is a major problem facing Nevada. Because of the ever-increasing population in Nevada and in the West, in addition to federal environmental regulations, water troubles may be a source of major headaches for a long time to come. Groundwater is the main source of water supply in much of Nevada and the Great Basin. The vadose zone determines the partitioning of precipitation over surface runoff and infiltration and the partitioning of infiltrated water over evapotranspiration and the recharge of groundwater.

In order to quantify flow and transport in the vadose zone, the soil hydraulic properties of have to be specified. The soil hydraulic properties include the relationships of unsaturated hydraulic conductivity versus capillary pressure head and capillary pressure head versus water content (water retention characteristics). Hydraulic property data are often characterized using various forms of functions. The Gardner exponential model [Gardner, 1958] and the van Genuchten model [van Genuchten, 1980] are two of the more widely used hydraulic conductivity functions. Conditions for which alternative forms of the hydraulic functions give the same or similar hydrologic responses for a given hydrologic scenario are essential in many applications, such as soil-vegetation-atmosphere transfer (SVAT) schemes in general circulation models (GCMs). While the equivalence relationships from previous investigations [Morel-Seytoux et al., 1996; Lenhard et al., 1989] are potentially useful for establishing parameter correspondence among the different hydraulic property models, all are in essence mathematical manipulations based on matching of hydraulic property curves, and as such may lack physical meaning in hydrologic applications. In this study we propose two conceptually new equivalence criteria, based on hydraulic behavior equivalence. Our approach forces the predicted moisture flux across the land-atmosphere boundary and the soil surface moisture to be the same for the different hydraulic conductivity functions, rather than matching the hydraulic property functions themselves. Warrick [1995] pointed out that hydraulic behavior equivalence depends on the hydrologic scenario being considered. We selected the moisture flux across the land-atmosphere boundary and the soil surface moisture for this purpose since these two quantities are critically important in GCMs.

A related important issue of concern for heterogeneous field soils is the upscaling of hydraulic parameters. Based on a point-scale or local scale measurements and characterizations, those parameter models of hydraulic functions are applicable only at the point or local scale. When those models are used in larger (plot, field, watershed or regional) scale processes, major questions remain about how to average the spatially variable hydraulic properties over a heterogeneous soil volume [e.g., Russo, 1992; Desbarats, 1998; Govindaraju et al., 2001] and what averages of hydraulic parameters to use for these models [e.g., Green et al., 1996]. An obstacle to practical applications in the field, catchment, watershed, or regional scale is the difficulty of quantifying the "effective" soil hydraulic functions $\theta(h)$ and $K(h)$, where θ is the soil moisture content, h

is the pressure head and K is unsaturated hydraulic conductivity. Proper evaluation of the water balance near the land-atmosphere boundary depends strongly on appropriate characterization of soil hydraulic parameters under field conditions and at the appropriate process scale. Hydrologists have recognized the critical role of soil hydraulic properties and soil moisture and tried to develop models that extend the point scale or local scale physics of soil hydrology to the larger domains of meso-scale meteorological GCMs.

Benefits and Results

The novelty of the proposed research is to use two new critically significant process equivalence criteria to establish correspondence between different hydraulic property models and to adopt p-norm averaging schemes that will be better defined and less variable in relation to heterogeneities of soil hydraulic properties and other environmental conditions.

The expected outcomes from this project will be various important optimal averaging schemes for the hydraulic parameters for a variety of hydrologic processes and the effective parameter averaging scheme relationships between the Gardner and van Genuchten models with an emphasis on the evaporation and infiltration scenarios typical for arid and semi-arid regions in western United States.

The concepts developed in this project can be extended to a broader range of scenarios, which include vegetation, climate heterogeneities etc. The outcomes of this project have potential benefit for water budget studies in Nevada. For example, evapotranspiration is the principal, and in some areas the sole mechanism of groundwater discharge in the Great Basin and can be a significant method of groundwater consumption in other areas of the arid and semi-arid western United States [Nichols, 1994]. The similar approach combined with proper characterizations of land cover and soil heterogeneities can be used in upscaling of evapotranspiration process. The proposed activities are based on successful past/ongoing research effort by PI Zhu and colleagues and promise to have significant impact on large scale water budget analysis that has important societal benefit in Nevada and beyond.

Nature, Scope, and Objectives of Research

Soil hydraulic properties (hydraulic conductivity, water retention) are by far the most important land surface parameters to govern the partitioning of soil moisture between infiltration and evaporation fluxes at a range of spatial scales. Spatial variability of soil hydraulic properties has significant impacts on desert hydrologic processes and ecosystems. In meso-/regional-scale SVAT schemes used in hydro-climatic models, pixel (gird) dimensions may range several hundred square meters to several hundred square kilometers. Grid-scale soil hydraulic parameters and their accuracy are critical for the success of hydro-climatic and soil hydrologic models.

Our research project seeks to address two important issues in hydrologic processes: (1) hydraulic property function correspondence and (2) hydraulic property upscaling to large scale hydro-climate modeling. The main objective of this study is to investigate how the hydraulic parameters of commonly used hydraulic functions correspond, and what the correspondence implies in terms of averaging schemes of the hydraulic properties for heterogeneous soils at the larger scale. More specifically, we focus on establishing relationships of effective averaging schemes (in terms of *p*-norms as discussed below) among the parameters of those hydraulic functions.

The proposed research is a continuing effort toward the overall goal of having a better quantitative understanding of the vadose zone hydrologic processes and controls (such as soil, topography, climate, vegetation etc.) at different space and time scales responsible for subsurface and atmospheric interaction and its dynamics. This goal is also one of PI Zhu's long term career objectives.

Methods, Procedures, and Facilities

(1) *Averaging Schemes and p-norm Averages*

The *p*-norm for a set of *N* parameter values ζ is defined as [e.g., Korvin 1982; Ababou and Wood, 1990; Gomez-Hernandez and Gorelick, 1989; Green et al., 1996]

$$\hat{\zeta}(p)=\left[\left(\frac{1}{N}\right)\sum_{i=1}^{N}\zeta_i^p\right]^{1/p} \quad (1)$$

The arithmetic (p=1), geometric ($p\to 0$), and harmonic (p=-1) means are all particular cases of the *p*-norm average. "Effective" soil hydraulic properties must yield the same water budget as the mean water budget corresponding to a random field of controlling parameters. It is obvious that the extent of deviation of various effective parameters from arithmetic means is mainly dictated by the environmental and parametric variability. We envision that *p*-norm value is less sensitive to the variation of ζ field since the larger parameter variance will offset the variability of the *p*-norm values. We hypothesize that if the effective parameter averaging schemes are expressed in terms of *p*-norm, the variability of *p*-norm will be smaller and the effective averaging schemes can be better defined with less variability for various hydrologic scenarios. Figure 1 shows some of our results of effective Miller-Miller soil scaling factor δ [Miller and Miller, 1956] for transient infiltration in terms of the *p*-norm value for the δ field as function of the coefficient of variation of the ponding depth, $CV(h_{surf})$. For large uncertainties in the scaling factor δ, relatively insignificant change has been found for the *p*-norm value for the δ field when the *CV* of the ponding depth varies from 0 to 1. In the figure, *rho* indicates the correlation between the δ field and the ponding depth, which goes from nearly uncorrelated (0.02) and almost fully correlated (0.92). In view of the large range of hydraulic properties for silty clay and sand and the large variabilities of the scaling factor considered in this study, a relatively small range in the *p*-norm values is somewhat encouraging with regard to effective parameter estimation for large land areas encompassing various soil textures, large/small topographic structures and other hydrologic scenarios.

Two important issues regarding soil hydraulic properties will be addressed in this project, (1) hydraulic parameter correspondence and (2) and its implications in hydraulic parameter upscaling for large scale hydrologic process modeling.

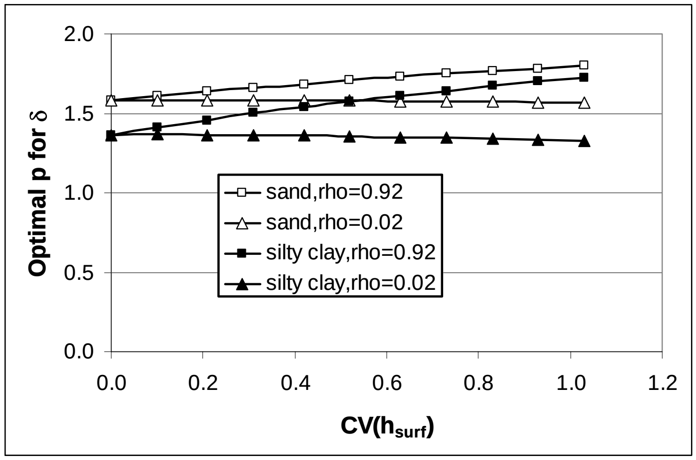

Figure 1: Optimal *p*-norm for the effective soil scaling factor δ vs. coefficient of variation of ponding depths [after Zhu and Mohanty, 2005]

(2) *Hydraulic Parameter Correspondence*

Soil hydraulic behavior is characterized by the soil water retention curve which defines the water content as a function of pressure, and the hydraulic conductivity function which establishes the relationship between the hydraulic conductivity and the water content or pressure. A brief review of hydraulic conductivity models used in this study is given below. Interested readers are referred to Leij et al. [1997] and Warrick [2003] for more comprehensive reviews and discussions of various closed-form expressions for the soil hydraulic properties, including the hydraulic conductivity models used here.

Gardner Model: The hydraulic properties used by Gardner [1958] and Russo [1988] are given by

$$S_e = \left[e^{-0.5\alpha_G h}\left(1 + 0.5\alpha_G \,|\, h \,|\right)\right]^{0.8} \quad (2)$$

$$K = K_S e^{-\alpha_G |h|} \quad (3)$$

van Genuchten Model: van Genuchten [1980] combined his proposed S-shaped soil water retention function with the theoretical pore-size distribution model of Mualem [1976] to obtain the following hydraulic property functions

$$S_e = \frac{1}{\left[1 + \left(\alpha_{vG} \,|\, h \,|\right)^n\right]^m} \quad (4)$$

$$K = \frac{K_S \left\{1 - \left(\alpha_{vG} \,|\, h \,|\right)^{mn}\left[1 + \left(\alpha_{vG} \,|\, h \,|\right)^n\right]^{-m}\right\}^2}{\left[1 + \left(\alpha_{vG} \,|\, h \,|\right)^n\right]^{0.5m}} \quad (5)$$

In (2) – (5), $S_e = (\theta-\theta_r)/(\theta_s-\theta_r)$ is the effective degree of saturation, θ is the volumetric water content, θ_r is the residual volumetric water content, θ_s is the saturated volumetric water content, h is the pressure head, K is the hydraulic conductivity, K_s is the saturated hydraulic conductivity, α, m and n are empirical hydraulic shape parameters, and m=1-

1/*n*. The subscript "*G*" denotes Gardner model parameters, and "*vG*" means van Genuchten model parameters.

DRI researchers have conducted research on field measurements and characterization of hydraulic properties [Young et al., 2005]. The hydraulic property data was measured from the Corn Creek Fan Complex located on the Desert National Wildlife Refuge north of Las Vegas, Nevada. The hydraulic properties were characterized for both Gardner and van Genuchten models, giving us a great opportunity that the conceptual ideas of hydraulic property correspondence and its implications in upscaling for large scale modeling can be investigated. The obtained hydraulic parameter data has been used to characterize statistics of the parameter fields.

In this project, we propose two *conceptually new criteria* to investigate the correspondence of the Gardner model and the van Genuchten model. Our criteria are based on important hydrologic process equivalence and require two models producing same surface soil moisture and predicting same vertical water flux across land-atmosphere boundary. The two new criteria result in the following relationships:

$$q_{sG} = q_{svG} \tag{6}$$

$$\left[e^{-0.5\alpha_G h_0}\left(1+0.5\alpha_G\,|\,h_0\,|\right)\right]^{0.8} = \left[1+\left(\alpha_{vG}\,|\,h_0\,|\right)^n\right]^{-m} \tag{7}$$

where q_s is the flux across the land-atmosphere boundary, h_0 is the pressure head at the soil surface. Equation (5) indicates that the predicted flux across the soil surface is required to be the same for the Gardner and van Genuchten functions. Equation (7) forces two models to produce same effective degree of saturation at the soil surface. Our new criteria focus on these two quantities since predicting flux rate across land-atmosphere boundary and soil surface moisture is usually a main concern in most practical SVAT models.

First we will consider relatively simple scenarios of steady state evaporation and infiltration to establish parameter correspondence and then cast the correspondence into hydraulic property upscaling framework for the effective averaging scheme relationships between the two hydraulic property models.

(2) *Implications of Hydraulic Parameter Correspondence in Hydraulic Property Upscaling*

With the exception of very steep areas, a good initial assumption is that variably-saturated flow in the vadose zone at the field or larger scale occurs one-dimensionally in the vertical direction. Developed at the George E. Brown, Jr. Salinity Laboratory, HYDRUS-1D [Simunek et al., 1998] is a comprehensive deterministic numerical model which simulates the movement of water and heat in one-dimensional variably-saturated porous media. The Richards equation for variably-saturated flow and transport is solved with user-defined initial conditions and constant or time-variable boundary conditions. The modular program uses fully implicit, Galerkin-type linear finite element solutions of the governing equations. For a variably-saturated rigid porous medium, the governing equation for one-dimensional vertical flow is [Richards, 1931]:

$$C\frac{\partial h}{\partial t}=\frac{\partial}{\partial z}\left(K\frac{\partial h}{\partial z}-K\right)-S(z,t) \quad (8)$$

where $C=d\theta/dh$ is the soil water capacity (L^{-1}), $S(z, t)$ represents the volumetric root water uptake rate (LT^{-1}), z is soil depth defined positive downward (L), and t is time (T). The water holding capacity is determined by the water retention curve, $\theta(h)$, while water transmission is governed by conductivity function $K(h)$.

Using the randomly generated hydraulic parameters based on the target statistics from the field measurement data set by DRI researchers [Young et al., 2005; Zhu and Young, 2005], many realizations of local scale HYDRUS-1D runs will be carried out to define fluxes and moisture state based on local scale parameter values and then the results will be aggregated into large scale ensemble behavior. The effective soil hydraulic parameters of the heterogeneous soil formation are then calculated by conceptualizing the soil formation as an equivalent homogeneous medium, assuming that the equivalent homogeneous soil will discharge same ensemble-mean flux across the land-atmosphere boundary and produce same ensemble-mean surface moisture in the formation. An inverse procedure [e.g., Marquardt, 1963] along with the HYDRUS-1D [Simunek et al., 1998] will be used to find the effective hydraulic parameters and the associated optimal *p*-norm values for the effective hydraulic parameters.

Related Research

We briefly discuss two major themes of previous investigations that are related to the proposed research, i.e., hydraulic parameter correspondence and upscaling of hydraulic parameters for large scale hydrologic process modeling applications.

Morel-Seytoux et al. [1996] proposed two criteria for equivalence of the hydraulic parameters for various hydraulic property models. Their primary criterion was to preserve the macroscopic capillary lengths. Their secondary criterion was to preserve the asymptotic behavior of the retention curve at low water contents. Lenhard et al. [1989] obtained other relationships by equating the specific moisture capacity halfway between the saturated (θ_s) and residual (θ_r) water contents and minimizing the difference between the water retention curves. Warrick [1995] investigated the correspondence of hydraulic functions and discussed some of the features that need to be preserved in order for different types of hydraulic functions to correspond. Zhu et al. [2004] established parameter equivalence among the conductivity functions based on preserving the macroscopic capillary lengths and predicting the same vertical water flux. Results show that the hydraulic parameters correspond very well when predicting evaporation rates from heterogeneous soils having a relatively large suction at the soil surface (e.g., a dry surface condition and/or a shallow groundwater table). Zhu and Young [2005] obtained some preliminary results of hydraulic correspondence and its applications in hydraulic property upscaling based on two above mentioned new equivalence criteria. The results show that when predicting maximum evaporation rate, variation in *p*-norm relationship were relatively small for a wide range of correlation lengths and variances and that *p*-norm relationships severely deviated from 1:1 line, indicating optimal averaging schemes for Gardner and van Genuchten models are quite different. We will continue to explore and extend similar ideas to a wide range of evaporation and infiltration scenarios in this project.

Within the context of effective hydraulic parameters, Sharma and Luxmoore [1979] revealed the complexities of soil-plant-atmospheric interactions in evaluating the influence of soil variability on water balance. They indicated that the results were highly dependent on the coefficient of variation and the frequency distribution function of the Miller-Miller scaling factor, and the soil-plant-weather combination. Kim and Stricker [1996] employed Monte Carlo simulation to investigate the separate and simultaneous effects of horizontal heterogeneity of soil hydraulic properties and rainfall intensity on various statistical properties of the components of the one-dimensional water budget. Their results showed that the heterogeneity of soil hydraulic properties on the components of the annual water budget has a stronger effect for loam than for sand. Kim et al. [1997] further investigated the impact of heterogeneity of the soil hydraulic property on the spatially averaged water budget of the unsaturated zone based on an analytical framework [Kim et al., 1996].

PI Zhu and colleagues have been quite active in developing averaging schemes for the hydraulic parameters for various flow scenarios for the past few years [Zhu and Mohanty, 2002a; 2002b; 2003a; 2003b; 2004; Zhu et al., 2004; Zhu and Mohanty, 2005; Zhu et al., 2005; Zhu and Young, 2005]. We investigated several hydraulic parameter averaging schemes and their appropriateness in describing the ensemble behavior of heterogeneous formations. We examined and compared effective parameters obtained by conceptualizing the heterogeneous soil formation as an equivalent homogeneous medium that will discharge same flux as the ensemble flux of the heterogeneous formations with a few simple averaging schemes for the hydraulic parameters and addressed their effectiveness and uncertainties.

Partly benefited from the funding support by this program last year, we have been able to continue and extend our previous study of soil hydraulic property upscaling. Brief description of some of our results is given below to help the panel evaluate this proposal in the context of creativity, totality and complementarities. The study of Zhu and Mohanty [2005] investigated the effective hydraulic parameters for transient infiltration in terms of the optimal averaging schemes for the input hydraulic and environmental parameter fields. The derived optimal effective powers for the random (input) parameters define an optimal averaging scheme for the random input fields, which can be used in large scale hydrologic and GCMs. Specifically, we discuss the effects of microtopography (as reflected in surface ponding depth), and hydraulic parameter correlation on the ensemble-mean behavior as well as on the optimal effective schemes. For a large range of hydraulic properties from silty clay to sand with large uncertainties in the Miller-Miller scaling factor, the saturated water content, and the surface ponding depth, relatively small range of optimal effective power values has been found. Among the three, variability of the Miller-Miller scaling factor has the most significant effect on the ensemble flux behavior. The correlation among the Miller-Miller scaling factor, the saturated water content and the surface ponding depth increases the effects of soil heterogeneity. Zhu et al. [2005] examined the impact of the skewness (third-order moment) of hydraulic parameter distributions on "effective" soil hydraulic parameter averaging schemes for heterogeneous soils in a flat landscape. The focus was to study the influence of higher (the third) order moment of the hydraulic parameter distribution on the effective parameters that are able to produce ensemble flux in the heterogeneous soils. Using three widely used unsaturated hydraulic conductivity functions and various types of probability distribution functions to represent spatial variability for the nonlinear shape factor in the hydraulic conductivity function, we derived the effective parameter values. Numerical/field experimental results show that distribution skewness is also important in determining the upscaled effective parameters in addition to the mean and variance. Negative skewness enhances heterogeneity effects, which make the effective parameter values deviate more significantly from the arithmetic mean. In the case of negative skewness, a few small hydraulic parameter values make the heterogeneous soil more permeable (with larger flux), which hence causes the effective heterogeneous system to deviate more from the homogeneous formation with arithmetic mean parameters.

Training Potential

The funding is mainly requested to directly support student training. We anticipate that the funding will support MSc student Michelle Harris at the University of Nevada Las Vegas for her to carry out her master thesis work. Michelle Harris just started her MSc program in September 2005 and we feel that the continuing funding through this program is essential for her to finish the thesis project. Michelle's thesis will be mainly related to the optimal hydraulic parameter averaging schemes and HYDRUS-1D simulations proposed in this project.

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Zhu, J., B. P. Mohanty, and N. N. Das, On the effective averaging schemes of hydraulic properties at the landscape scale, *Vadose Zone J*., 2005, in press.
Zhu, J., and Young, M. H., Correspondence of hydraulic functions and its implication on upscaling for large scale flux and surface soil moisture in heterogeneous soils, Poster Presentation, *AGU Fall Meetings*, December 5 – 9, San Francisco, California, 2005.

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A. Vitae

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Education

1996-1998	NSERC Postdoc Fellow, Civil Eng., Univ. Waterloo, Waterloo, Canada
1996	Ph.D., Environmental Hydrology, Dalhousie University, Halifax, Canada
1985	M.Sc., Fluid Mechanics, Beijing (Peking) University, Beijing, China
1982	B.Sc, Engineering Mechanics, Zhejiang University, Hangzhou, China

Appointments

Oct 2004 -	Assistant Research Professor, Desert Research Institute, Nevada
2002- Oct 2004	Assistant Research Scientist, Biological and Agricultural Engineering Dept., Texas A&M University, College Station, Texas
2000- 2001	Visiting Researcher, Environmental Sciences Department/ U. S. Salinity Laboratory, University of California at Riverside, Riverside , U. S. A.
1998- 2000	Assistant Professor, Dept. Geological Sci., University of Saskatchewan, Saskatoon, Canada
1996- 1998	Postdoctoral Fellow, Dept. Civil Eng., Univ. of Waterloo, Waterloo, Canada
1995-1996	Research Associate, Civil Eng., Dalhousie University, Halifax, Canada
1993- 1995	Graduate Research Assistant, Civil Engineering, Dalhousie University Halifax, Canada
1991-1993	Visiting Scholar, Civil Engineering, Dalhousie University, Canada
1988-1991	Research Engineer, Chinese Academy of Sciences, Beijing, China
1985- 1988	Research Associate, Dept. of Mechanics, Beijing University/Institute of Chemistry, Academia Sinica, Beijing, China

Professional Affiliations and Activities

Member: Association of Professional Engineers of Ontario of Canada (Professional Engineer), American Geophysical Union, Soil Science Society of America.

Reviewer: Water Resources Research, Transport in Porous Media, Royal Society, *Proceedings A*, Canadian Journal of Chemical Engineering, Vadose Zone Journal, Geophysical Research Letters.

Selected Honors and Awards

1996-1998	NSERC Postdoctoral Fellowship Award, Canada.
1994, 1995	Bruce and Dorothy Rosetti Scholarship, Dalhousie University, Canada.

B. 5 Refereed Publications Mostly Related to the Project

Zhu, J., and Mohanty, B. P., Effective Scaling Factor for Transient Infiltration in Heterogeneous Soils, *Journal of Hydrology*, in press.

Zhu, J., Mohanty, B. P., and Das, N. N., On the Effective Averaging Schemes of Hydraulic Properties at the Landscape Scale, *Vadose Zone Journal*, in press.

Zhu, J., Mohanty, B. P., A. W. Warrick, and M. Th. van Genuchten, Correspondence and Upscaling of Hydraulic Functions for Heterogeneous Soils, *Vadose Zone Journal*, 3, 527-533, 2004.

Zhu, J., and Mohanty, B. P., Soil Hydraulic Parameter Upscaling for Steady State Flows with Plant Root-water Uptake, *Vadose Zone Journal*, 3, 1464-1470, 2004.

Zhu, J., and Mohanty, B. P., Effective Hydraulic Parameters for Steady State Flows in Heterogeneous Soils, *Water Resources Research*, 39(8), 1227, doi:10.1029/2002WR001831, 2003.

C. 5 Other Selected Significant Publications (out of 40 journal publications)

Zhu, J., and Mohanty, B. P., Spatial Averaging of van Genuchten Hydraulic Parameters for Steady State Flow in Heterogeneous Soils: A Numerical Study, *Vadose Zone Journal*, 1, 261-272, 2002.

Zhu, J., and Mohanty, B. P., Upscaling of Hydraulic Properties for Steady State Evaporation and Infiltration, *Water Resources Research*, 38(9), 1178, doi:10.1029/2001WR000704, 2002.

Zhu, J., Transport and Fate of Nonaqueous Phase Liquid in Variably Saturated Porous Media with Evolving Scales of Heterogeneity, *Stochastic Environmental Research and Risk Assessment*, 15, 447-461, 2001.

Zhu, J., and Sykes, J. F., The Influence of NAPL Dissolution Characteristics on Field-scale Contaminant Transport in Subsurface, *Journal of Contaminant Hydrology*, 41, 133-154, 2000.

Zhu, J., A Note on Statistical Analysis of Rate Coefficient of Non-Aqueous Phase Liquid Dissolution in Porous Media, *Water Resources Research*, 36(5), 1347-1352, 2000.

D: Collaborators in Last 48 Months

Cooper, C. (DRI)	Koehne, J. (Univ. Rostock, Germany)
Miller, D. (Penn State Univ.)	Milne, D. ((Univ. Saskatchewan, Canada)
Mohanty, B. P. (Texas A&M Univ.)	Munster, C. (Texas A&M Univ.)
Pohlmann K. (DRI)	Rahman, M. (Dalhousie Univ., Canada)
Reeves, M. (Univ. Saskatchewan, Canada)	Sada, D. (DRI)
Satish, M. G. (Dalhousie Univ., Canada)	Schaap, M. (UC Riverside)
Simunek J. (UC Riverside)	Sun, D. (Hardin-Simmons Univ., Texas)
Sykes, J. F. (Univ. Waterloo, Canada)	van Genuchten, M. Th. (US Salinity Lab)
Vaughan, P. (US Salinity Lab)	Warrick, A. (Univ. Arizona)
Ye, M. (DRI)	Young M. (DRI)

Information Transfer Program Introduction

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR−USGS Internship	Supplemental Awards	Total
Undergraduate	4	0	0	0	4
Masters	2	0	0	0	2
Ph.D.	3	0	0	0	3
Post−Doc.	2	0	0	0	2
Total	11	0	0	0	11

Notable Awards and Achievements

Adventus Americas Student Award for Platform Presentation, October 19, 2007, 23rd Annual International Conference on Soils, Sediment and Water for paper presentation: Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada.

Publications from Prior Years