Division of Hydrologic Sciences
Annual Technical Report
FY 2006

Introduction

Research Program

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. Lundmark, K.W., 2007, Regional Water Budget Accounting and Uncertainty Using a Deuterium-Calibrated Discrete State Compartment Model: White Pine County, Nevada, and Adjacent Areas in Nevada and Utah. University of Nevada-Reno, Masters thesis, 186 p.
2. Welch, A.H. and D.J. Bright (eds.), 2007, Water Resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and UtahDraft Report. U.S. GEOLOGICAL SURVEY Open-File Report 2007-1156.
3. Hershey, R.L., L. Justet, V.M. Heilweil, P. Gardner, B.F. Lyles, S. Earman, J.M. Thomas, and K.W. Lundmark, 2007, Ground-water Chemistry Interpretations Supporting the Basin and Range Regional Carbonate-rock Aquifer System (BARCAS) Study, Eastern Nevada and Western Utah. Desert Research Institution Publication No. 41230, 106 p.
4. Mizell, S.A., C.E. Russell, and T.L. Kluesner, 2007, Reconnaissance Estimation of Groundwater Recharge to Selected Hydrographic Basins of Eastern Nevada and Western Utah using the Chloride Mass-Balance Method. Desert Research Institution Publication No. 41232, 35 p.
5. Zhu, J., M. Young, and M. Cablk, 2007, Uncertainty Analysis of Estimates of Groundwater Discharge by Evapotranspiration for the BARCAS Study Area. Desert Research Institution Publication No. 41234, 36 p.
6. Lundmark, K., G.M. Pohll, and R.W.H. Carroll, (in press), A Steady-State Water Budget Accounting Model for the Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah. Desert Research Institution Publication.

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.

A summary report was completed for the project and is available for public comment for 90 days starting June 1st. This summary report is a collaborative effort with USGS researchers in Nevada and Utah and DRI researchers in Nevada. The summary report is a USGS Open-File Report written by USGS and DRI researchers. In addition to the Summary report, DRI has published five reports with more detailed analyses and interpretations that support the summary report and has four more reports in review or preparation that evaluate some of the methods used in the summary report in more detail.

A list of the Summary report and DRI reports follows:

Welch, A.H. and D.J. Bright (eds.), 2007, Water Resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah—Draft Report. U.S. GEOLOGICAL SURVEY Open-File Report 2007-1156.

Lundmark, K.W., 2007, Regional Water Budget Accounting and Uncertainty Using a Deuterium-Calibrated Discrete State Compartment Model: White Pine County, Nevada,

and Adjacent Areas in Nevada and Utah. University of Nevada-Reno, Masters thesis, 186 p.

Hershey, R.L., L. Justet, V.M. Heilweil, P. Gardner, B.F. Lyles, S. Earman, J.M. Thomas, and K.W. Lundmark, 2007, Ground-water Chemistry Interpretations Supporting the Basin and Range Regional Carbonate-rock Aquifer System (BARCAS) Study, Eastern Nevada and Western Utah. Desert Research Institution Publication No. 41230, 106 p.

Mizell, S.A., C.E. Russell, and T.L. Kluesner, 2007, Reconnaissance Estimation of Groundwater Recharge to Selected Hydrographic Basins of Eastern Nevada and Western Utah using the Chloride Mass-Balance Method. Desert Research Institution Publication No. 41232, 35 p.

Zhu, J., M. Young, and M. Cablk, 2007, Uncertainty Analysis of Estimates of Groundwater Discharge by Evapotranspiration for the BARCAS Study Area. Desert Research Institution Publication No. 41234, 36 p.

Lundmark, K., G.M. Pohll, and R.W.H. Carroll, (in press), A Steady-State Water Budget Accounting Model for the Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah. Desert Research Institution Publication.

Cablk, M. and C. Kratt, (in review), A Methodology for Mapping Shrub Canopy Cover in the Great Basin Desert using High Spatial Resolution Satellite Imagery, Desert Research Institution Publication.

Cablk, M. and C. Kratt, (in prep), Precision mapping of shrub canopy cover in the Great Basin Desert, USA to improve estimates of phreatophyte groundwater draw.

Cablk, M. et al., (in prep), A quantitative assessment of Evapotranspiration (ET) unit mapping of the Great Basin Desert, USA. Desert Research Institution Publication.

Arnone, J.A. III et al., (in prep), Seasonal and annual estimates of evapotranspiration from [representative?] low elevation basin plant communities of Spring Valley and White River Valley, Nevada using eddy covariance.

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

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

Annual Report

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 heterogeneity of the near-surface soil/plant environment creates significant difficulty for understanding and simulating these interacting processes. These heterogeneities are attributed to all of the physical, geomorphological and biological variations across the surface; many of these attributes have direct influences on soil hydraulic properties and thus hydrological processes. The overriding objective 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

In this study, we applied both field experimental and numerical approaches to study the impact of the heterogeneity of soil hydraulic properties on rainfall-infiltration-runoff processes. In the experimental study, we have scheduled a tension infiltrometer (TI) study in three experimental plots located at the Mojave National Preserve, CA. The TI study will be conducted at 20 locations in each plot, on both under canopy and interspace surfaces. Measurements will be taken during the TI experiments to augment the data set; these measurements will include soil texture, bulk density, and an estimate of the initial capillary pressure of the soil. The soil hydraulic properties will be back calculated from the TI data, and spatial distributions of the hydraulic conductivity and capillary pressure will be analyzed. These experimental results will be imported to a numerical model that simulates hydrological processes (surface runoff and infiltration) on the experimental plots.

The numerical model to be used for this research is known as CeRIRM (Cell-Based Rainfall Infiltration Runoff Model), a physically-based distributed model for rainfall-runoff modeling, to study the plot scale hydrological process using very high-resolution distributed modeling approach. CeRIRM is originally developed by the co-PI for his dissertation and is 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 a more physically-based approach (Green-Ampt infiltration 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 randomizing accounts for uncertainty in our knowledge of soil hydraulic properties, and open the use of Monte Carlo simulation techniques.

Due to the departure of one of the PIs (Meadows), the research procedures of the project have been adjusted to first emphasize the development of the numerical modeling approach, and to second emphasize the field studies. To date, the numerical work is essentially completed and the field work has been scheduled.

Preliminary Modeling Studies

We have conducted preliminary modeling studies to examine the general trends of the impact of heterogeneous topography and soil hydraulic parameters on the rainfall-runoff process. The simulation cases are conducted on a hypothetical plot with the scale of 50m by 50m and the modeling cell size is 1m by 1m. The lowest 50 grids are considered as open boundary where runoff is calculated and measured. Other three boundaries are set as no flow boundaries. Both deterministic and random simulations are conducted. The deterministic simulation adopts the homogeneous parameters for the whole domain and the random simulation employs the randomly distributed parameters. In the random simulation study, we are currently using Latin Hypercube Sampling (LHS) to generate the random fields for the Monte Carlo simulations, where statistical characteristic of surface runoff is evaluated by running the model repeatedly when sampling four input parameters 2,500 times each. The parameters include initial soil moisture (θ_i), saturated soil moisture (θ_s), saturate hydraulic conductivity (K_s) and wetting front capillary pressure head (Ψ_f). The number of realizations is equal to the total number of cells in the study domain. In the LHS method, the probability axis (Y axis) of each variable X_i is evenly divided into 2,500 non-overlapping intervals. Therefore, the *n* non-overlapping bandwidths of the parameter axis (X axis) are determined by using the cumulative probability curve. One value from each X interval is selected at random according to the probability density for this interval. The advantage of this selection is that the entire distribution is covered. Each X_i value is randomly paired to a X_j value. Therefore the 2500 groups of 4-variable compose the Latin-Hypercube samples. In this study, we assume that these four parameters are not correlated.

Different topographic and rainfall settings are examined, which are listed as follows:

- ***Planar slope***: A simple planar slope with the slope degree of 6º.
- ***Uneven slope***: A slope with randomly generated microtopography with the average slope being 6º.
- ***Steady rainfall*****:** Precipitation series is constant with an intensity of 5 cm/hr.
- ***Unsteady rainfall*****:** Precipitation series is selected from a storm in '90 monsoon season recorded at the Walnut Gulch Experimental Watershed, Arizona, which is a research site in a related project.

Soil texture in all homogeneous cases is set close to a rangeland soil found at the Walnut Gulch Watershed. We used the following textural breakdown: 66% sand, 24% silt and 10% clay. Initial and saturated moisture contents are 0.1 $cm^3\ cm^{-3}$ and 0.37 $cm^3\ cm^{-3}$, respectively. Saturated hydraulic conductivity is set as 8 cm/hr and wetting front capillary pressure head is set as 10 cm. Fig.1 shows the simulated results. Heterogeneous soils are examined with the Monte Carlo simulation approach. A total of 30 random fields are generated from the LHS method for 30 Monte Carlo simulation runs. The modeling procedures are listed as follows

1. θ_s is considered to be uniform and equal to 0.37 $cm^3\ cm^{-3}$.throughout the simulation area in all cases.

2. According to Meyer et al. (1997) and a parallel study conducted at the Walnut Gulch Experimental Watershed, Arizona, we can safely make the assumption that in most of the fields, K_s follows a lognormal distribution and Ψ_f follows a normal distribution.
3. The LHS method (Iman and Shortencarier, 1984) is used to generate 2,500 θ_i with the assumption that θ_i follows a normal distribution. The generated θ_i field then is used in all simulation cases.
4. The LHS method (Iman and Shortencarier, 1984) is used to generate 2,500 sets of K_s and Ψ_f based on their distributions at Walnut Gulch and with the assumption that these two parameters are independent.
5. We thus randomly distributed these 2,500 sets of K_s and Ψ_f as well as the uniform θ_s into 2,500 computational cells.
6. Steps 4 and 5 are repeated 30 times to generate 30 random fields for K_s and Ψ_f.
7. The CeRIRM model is then run using the dataset to evaluate the behavior of surface runoff.

Only planar slope and unsteady rainfall are considered for the heterogeneous soil, which are described in the previous section. Fig. 2 shows the simulated results.

Principal findings and significance

Preliminary results from the numerical modeling studies have shown:

- The distributed topography has strong impact on the runoff generation process (Fig. 1), which implies that the 'runon' plays an important role in the rainfall-runoff process. Compared with the pure rainfall-infiltration case, runon will increase local infiltration by means of the lateral surface flux, and in turn, will influence the total runoff amount on the domain scale.
- The spatial variability of soil hydraulic properties can greatly affect the connection between rainfall, infiltration, and runoff. Assuming the same mean hydraulic conductivity, a homogeneous parameter field and a heterogeneous parameter field produce significantly different runoff (Fig. 2), which indicates that simple averaging is not sufficient for estimating parameter in this highly non-linear hydrologic situation. However, according to the Monte Carlo simulation, randomly generated soil hydraulic properties affect the runoff similarly (Fig, 2). Thus, as long as the generated input parameters cover the entire statistical distribution (lognormal and normal in this study), almost identical simulated runoff are produced no matter how these parameters are distributed across the plot. Nevertheless, more studies are needed to determine if similar runoff can be generated when larger scale cells are used.
- Using the findings from the bullet above, it follows that spatially distributed models can better handle spatial heterogeneity of soil hydraulic properties. Lumped parameter models are unable to deal with spatial variability, because the interactions between areas on the watershed with different hydraulic conductivities are not accounted for. Further studies will focus on whether a deterministic heterogeneous field (e.g. derived from Kriging) and random heterogeneous field (e.g. derived from LHS) will produce the same improvement of the surface runoff simulation.
- We recognize that very high resolution simulations are often not realistic. In these cases, upscaling approaches (i.e., averaging) are necessary. However, existing upscaling approaches may not be sufficient for complicated rainfall-runoff processes, especially for

unsteady rainfall events and domains with contributing areas. The data that will be collected in this research will become natural tie-ins to future research in this technical area.

Information Transfer Activities

Papers:
Yin, J., L. Chen, M. H. Young. Influence of heterogeneous surface on rainfall-runoff process in desert environment. (Under preparation)

Presentations:
Yin, J., L. Chen, M. H. Young. High resolution rainfall-runoff simulation for heterogeneous surface. AGU Fall Meeting, 2007 (Under preparation)

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

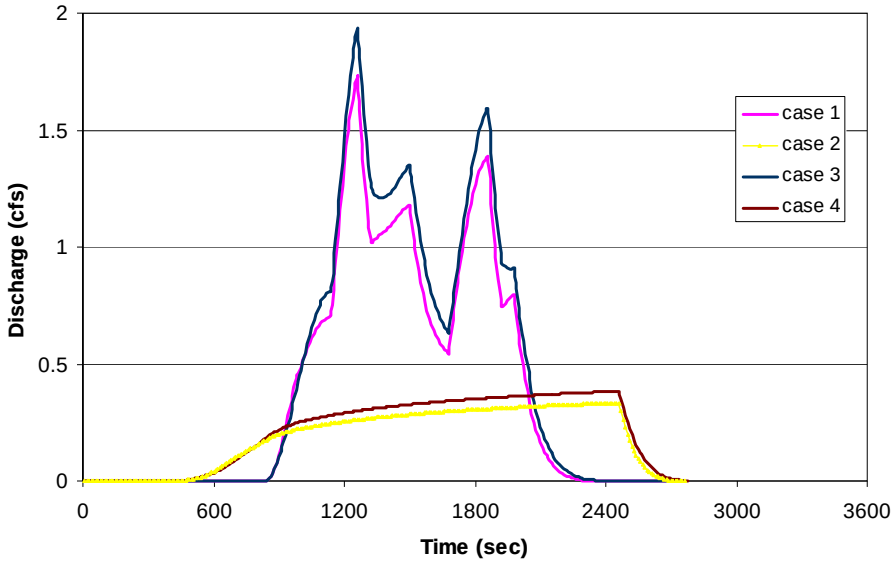

Fig. 1. Preliminary modeling results of rainfall-runoff process for hydraulically homogeneous plots with single valued hydraulic parameters across the surface.

Case 1: Uneven slope with random microtopography, unsteady rainfall
Case 2: Uneven slope with random microtopography, steady rainfall
Case 3: Planar slope surface, unsteady rainfall
Case 4: Planar slope surface, steady rainfall

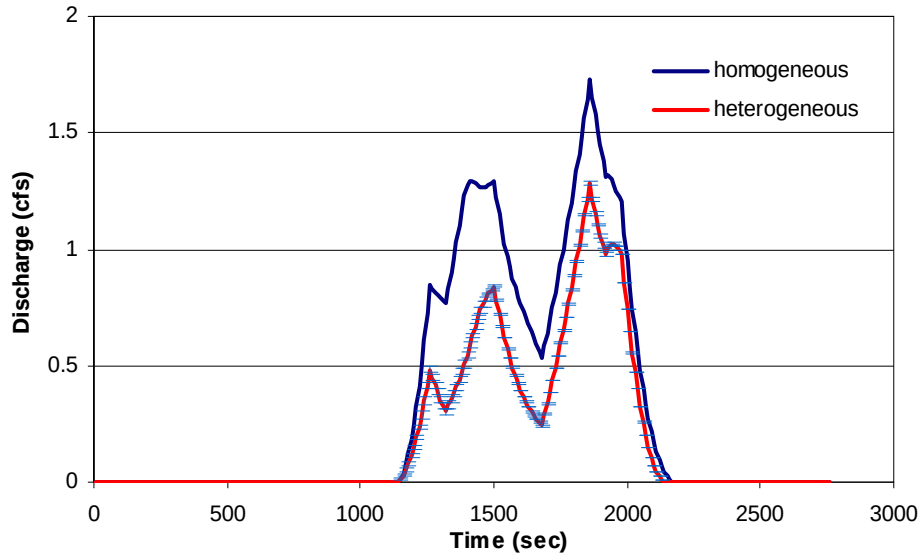

Fig. 2. Preliminary modeling results of rainfall-runoff process for heterogeneous surfaces with randomly distributed hydraulic conductivities. The homogeneous case is for a planar surface with unsteady rainfall, using averaged values of K_s, Ψ_f and θ_s. The heterogeneous line represents the mean of 30 realizations for the Monte Carlo simulation on the same slope and with the same rainfall, and the error bars represent the standard deviation of the discharge in the 30 realizations.

References

Iman, R. L., and Shortencarier, M. J. 1984, A FORTRAN 77 C Program and User's Guide for the Generation of Latin Hypercube and Random C Samples for Use With Computer Models. NUREG/CR-3624, SAND83-2365. C Albuquerque, NM: Sandia National Laboratories.

Meyer, P.D., Rockhold, M.L., Gee, G.W., 1997, Uncertainty analyses of infiltration and subsurface flow and transport for SDMP sites, Pacific Northwest National Laboratory, NUREG/CR-6565.

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:	2/28/2008
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. Carroll, R.W.H., Memmott, J., Warwick, J., Fritsen, F.H., and J.C. Bonzongo. in review. Biotic sorption of mercury in Lahontan Reservoir phytoplankton: Implications of dynamic loading. Science of the Total Environment.

Modeling Biotic Uptake of Mercury in the Lahontan Reservoir System

Synopsis

Year One Progress Report

Problem and research objectives (year 1):

Most mercury bioaccumulation modeling efforts assume a constant loading of mercury through time and space. These are justifiable assumptions where atmospheric mercury loading is the dominant phenomenon. However, 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 the interactions of mercury loading and phytoplankton growth at sub-annual time scales (i.e. days to weeks). It was hypothesized that the strong temporally varying signal of mercury loading to Lahontan Reservoir will cascade, albeit with expected dampening, up through the reservoir foodweb with significantly different non-linear responses depending upon the relative timing and duration of peak mercury loading and the rates of phytoplankton and zooplankton growth. The primary objective of the proposed study for the first year of funding was to observe a temporally varying mercury signal in the lower food web, specifically the phytoplankton and zooplankton communities.

Problem and research objectives (year 2):

Note that funding for the second year is contingent on results presented in this progress report. The proposed objectives for the second year of funding include using collected data to 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 uptake of several trophic levels in Lahontan Reservoir. A verified model will allow model prediction of bioaccumulation based on hypothetical flow/Hg-loading scenarios. Finally, an uncertainty analysis (Monte Carlo simulation) will provide a quantitative assessment of the expected accuracy of model predictions. This will allow a determination of significant differences between simulated scenarios.

Methodology (year 1)

Water column sampling occurred every six weeks at Fisherman's Point, a narrow section separating the southern and middle basins of Lahontan Reservoir. Sampling began in March 2006 to ensure the capture of peak spring runoff from the Carson River and continued until late September 2006 in hope of capturing a secondary zooplankton peak and to witness possible impacts of internal mercury cycling on biotic uptake. Using a YSI 6600 profiler, measurements of temperature, pH, oxidation-reduction potential, specific conductivity, in vivo fluorescence, photosynthetically-active radiation, turbidity, and dissolved oxygen occurred at three equidistant locations across the lake. Water samples were collected at the same three points along the transect. When the lake was stratified, depth integrated samples were collected above and below the thermocline for mercury (total and dissolved), methylmercury (total and dissolved) and phytoplankton

mercury concentrations and biomass (ash free dry mass (AFDM) and chlorophyll-a (chla)), as well for as nutrient analysis (NO_3^-, NO_2^-, NH_4^+,TKN and PO_4^3, TP, DOC). When the lake was not stratified, depth integrated samples representing the entire vertical profile (lake bottom to surface) were collected. Nutrient analysis was conducted at the Desert Research Institute water quality lab while mercury samples (water and biota) were analyzed at the University of Florida by J.C. Bonzongo. Zooplankton were collected at each location along the reservoir transect with vertical drags of an 86 μm Nitex net. Collected zooplankton were combined into a single representative sample. Mercury associated with different-sized algal groups was measured to assess if different sizes showed different patterns of mercury affiliation. Differentiating by size is a rough method to designate functional groups such that the smaller-sized algal fraction (in this case, less than 35 μm) was assumed more palatable and more easily consumed by higher trophic levels (Horne and Goldman, 1994). On the other hand, the larger-sized algal fraction (greater than 35 μm) was assumed not as palatable, and any mercury sorption could represent a sink of mercury, or a mechanism for depositing mercury onto the reservoir bed for later cycling in the system.

Mercury loading into Lahontan Reservoir was separated by source: the Carson River, and diffusion from reservoir benthic sediments. Two mercury loading mechanisms were considered: (1) the Carson River, and (2) the diffusion from the benthic sediments. While the former contributes large quantities of Hg-laden sediment, only the dissolved fraction is considered bio-available and discussed in conjunction with dissolved benthic loads. Carson River mass loading into the reservoir was computed as discharge (USGS, 2007) multiplied by USGS concentrations measured at Weeks Bridge (Karen Thomas, USGS, written communication, 2006). Loading of mercury species from reservoir benthic sediments was computed with a constant rate of diffusion from May and June 2001 flux experiments with sediment from the southern lobe of the reservoir (Kuwabara *et al*., 2002). The amount of surface area available for active diffusion was assumed to equal the surface area of the reservoir as computed from the U.S. Bureau of Reclamation rating curve. The area of active diffusion upstream of FPO was assumed to equal one-third the total area of the reservoir. While assumptions used to compute benthic loads were crude, calculations helped illustrate the time-varying nature of benthic loading and relative importance when compared to Carson River loads.

Data analysis included adjusting mercury concentrations on GF/F filters by subtracting out the mercury content found in a blank filter then normalized by the volume of composite reservoir water used in the filtering process. This established concentrations of phyto-Hg and phyto-MeHg per unit volume of reservoir water. Phyto-mercury concentrations for particles greater than 35 μm were derived by subtracting concentrations less than 35 μm from the total concentration. This calculation maintains mass balance if one assumes no error in the sub-sampling process from the 14-L, Teflon, USGS Water Quality Modified Churn Splitter. Similar calculations were done for all biomass indices (Chla, AFDM) to obtain biomass per volume reservoir water. If one assumes that AFDM increases proportionately to phytoplankton Chla, then any change in the ratio of AFDM to Chla, or the autotrophic index (AI), becomes an indicator of change in either variable relative to the other. Biomass-specific concentrations (mass mercury per biomass) were established by dividing phyto-mercury concentrations (ng/L) by either Chla or AFDM concentrations (μg/L). Significance of correlation between all

measured/derived parameters was conducted using the *t*-statistic given two degrees of freedom, and assuming highly significant at $p \leq 0.05$ and moderately significant at $p \leq 0.10$.

Bio-concentration factors (BCF) were computed with Equation (1)

$$BCF = \log\left(\frac{C_b}{C_w}\right) \quad (1)$$

where C_b is the concentration of mercury (ng/L) of a given phytoplankton size fraction and C_w is the concentration of dissolved mercury in the water column (ng/L). Negative values imply dilution, while positive values signify increased concentration .

A Monte Carlo uncertainty analysis was conducted to establish 95-percent confidence intervals in mercury and biomass concentrations. One thousand realizations were run in Monte Carlo. Random sampling from Hg and MeHg assumed a normal distribution while random sampling from biomass indices assumed a uniform distribution. Ranked results provided median (no distribution assumed) and 95-percent upper and lower confidence intervals.

Principal findings and significance (year 1)

- The total annual load of dissolved Hg into Lahontan Reservoir was 54,680 g, with the Carson River, on average, contributing 30-percent. Dissolved Hg loads are highest during the Carson River spring discharge (425 g/d) in late May, with fluvial contributions spiking to 75-percent of the total during this period. Late summer dissolved Hg loads to the reservoir drop nearly an order of magnitude with river contributions making up only 1-percent of the total load.
- Fluvial contributions dominate loading of dissolved MeHg such that nearly 90 percent of the annual MeHg load (416 g) comes from the river. Contributions of MeHg from the river are 99 percent during periods of high river discharge with peak loads occurring in late May (5.72 g/d). Only in late August, when loading is two orders of magnitude less than the May peak, does the river contribution diminish to 30 percent.
- The highest phyto-Hg concentrations coincide with peak loading from the Carson River and the spring algal bloom in March and May. Late summer phyto-Hg concentrations are low for phytoplankton less than 35 μm despite linear growth. Large phytoplankton (>35 μm) show no Hg sorption during the massive late summer bloom of filamentous blue-green algae. Correlation analysis confirms that fluvial loads had the greatest impact on phyto-Hg concentrations.
- Efficiency of Hg sorption, as expressed as Hg per unit mass phytoplankton, decline throughout the summer months, suggesting that growth dilution may be, in part, responsible for blue-green algae's inability to concentrate Hg. Dilution is supported by increasingly negative BCF values throughout the summer season with large particles having more negative values than small particles.
- Phyto-MeHg concentrations and biomass specific MeHg concentrations in small phytoplankton were bimodal. A first peak occurred in the spring during high loading from the Carson River and a secondary, more substantial, peak occurred in the late summer when diffusion from benthic sediments may dominate the system.

- Phyto-MeHg concentrations and biomass-specific MeHg concentrations increase directly with phytoplankton growth and are more dependent on benthic loading.
- Given small phytoplankton are more efficient pathways of Hg sorption during the summer months, compared to larger phytoplankton, one might assume the same holds true for MeHg sorption. Therefore, it is hypothesized that the smaller, and more palatable phytoplankton become an important mechanism for the transfer of both inorganic and the more toxic organic mercury species to higher trophic levels.
- Methylmercury becomes more concentrated in the algal population compared to water column concentrations during March, August, and September, but more diluted during May and June. The ability of cells to concentrate MeHg during peak algal blooms shows that MeHg is more transferable through the food web than inorganic mercury, which tends to become diluted in the algal masses when loading is small.
- The percent MeHg in small phytoplankton is low during the spring and early summer, with values near 2-percent, but increase dramatically during the late summer to 30 to 40-percent and compounds any assumption of a temporally constant fraction of bio-available mercury.
- Zooplankton results were not considered due to large uncertainty in results. Future work will need to minimize uncertainty in collection and measurement to address the relationship between phytoplankton mercury concentrations with respect to zooplankton growth and uptake.
- This study suggests that Hg sorption is driven by fluvial inputs to Lahontan Reservoir timed with the spring algal bloom. Fluvial inputs of MeHg are also important during the spring, but benthic loading appears more important during the late summer when MeHg concentrations accumulate in greater and greater percentages. Therefore, it is necessary to address the benthic community and the eventual transfer of MeHg from this community into the upper trophic levels in the reservoir.

Information transfer activities (year 1)

Paper:

Carroll, R.W.H., Memmott, J., Warwick, J., Fritsen, F.H., and J.C. Bonzongo. in review. Biotic sorption of mercury in Lahontan Reservoir phytoplankton: Implications of dynamic loading. *Science of the Total Environment*.

Conference (anticipated):

Carroll, R.W.H., Memmott, J., Warwick, J., Fritsen, F.H., and J.C. Bonzongo. in review. Biotic sorption of mercury in Lahontan Reservoir phytoplankton: Implications of dynamic loading. *American Geophysical Union (AGU) Fall meeting (December 2007), San Francisco*.

Student support (year 1)

Rosemary W.H. Carroll is a doctoral student at the University of Nevada, Reno and this project may serve as a component of her dissertation. John Warwick serves on her committee and acts as her primary advisor on Hg-related projects. Funding allowed Ms.

Carroll to manage her first project, direct laboratory staff and learn analytical techniques. Funds also helped support technical staff at DRI and several undergraduate students at the University of Nevada, Reno who aided Ms. Carroll in field preparation, data collection and laboratory analysis of phytoplankton and zooplankton.

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:	2/28/2008
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. Chataut, S., 2006. Development of Flood Forecasting Model for the Flamingo Tropicana Watershed in the Las Vegas Valley. M.S. Thesis, University of Nevada Las Vegas.
2. Betley, D. 2007. HEC-RAS Steady and Unsteady Flow Model Analysis for the Las Vegas Wash. M.S. Project, University of Nevada, Las Vegas.

Synopsis

Progress Report (Year 1)

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:

The first year of the research project focused on Tasks 1, 2, and 3. All of the rainfall data from Clark County has been compiled and specific storms have be identified for modeling. The Clark County Master Plan Hydrology Model was obtained from the Clark County Regional Flood Control District and imported into HEC-HMS. The first trial subbasin that was evaluated for model performance was the Flamingo/Tropicana watershed. The Master Plan model was tested for three (3) storms: November 21-22, 2004; December 28-29, 2004; and July 24, 2005. For all the storms, the time to peak runoff captured in the model; however, the magnitude of the peak flow was overestimated.

In addition to the gage precipitation data obtained from the Clark County Flood Threat Recognition System, radar data (at 1 km and 2 km resolutions) was obtained from OneRain Inc. A comparison was made between the two data sets and it was found that when the radar precipitation was used in the model, the estimate of the peak flow rate was improved. Lastly, there was not a significant

improvement from using 1 km radar data as compared to the 2 km radar data. This research was by Satya Chataut Masters Thesis at UNLV (Masters of Science in Civil Engineering, December 2006).

For Task 3, 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).

Information Transfer Activities

a) Meeting with Stakeholders

- **May 9, 2006: Clark County Regional Flood Control District (Tim Sutko) and Clark County Parks and Recreation (Bruce Sillitoe and Elise Sellars)**

b) Conference Presentations:

c) Publications

- Chataut, S., 2006. Development of Flood Forecasting Model for the Flamingo Tropicana Watershed in the Las Vegas Valley. M.S. Thesis, University of Nevada Las Vegas.

- Betley, D. 2007. HEC-RAS Steady and Unsteady Flow Model Analysis for the Las Vegas Wash. M.S. Project, University of Nevada, Las Vegas.

Student Support: Funding two MS students at UNLV (Satya Chataut and David Betley)

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

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

PI: Mark Stone
June 15, 2007

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 an ecological 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 an ecological model capable of investigating the influence of abiotic parameters on eutrophication and algal blooms. The following tasks are underway to produce the model.

1. Review existing models and data

A number of ecological models exist which are capable of simulating eutrophication processes ranging from complex biogeochemical models, which are often coupled with 2- or 3-D hydrodynamic models, to simple empirical relationships based on observations. 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 ecological model

We initially planned to base our model on a biogeochemical approach, but have changed courses to use a structurally dynamic approach. Structurally Dynamic Models (SDM) are based on an evolutionary framework in which the productivity and community composition are determined through goal functions of optimal biomass or exergy. For this project, we will be customizing the SDM PAMOLARE (Planning And Management Of Lakes And Reservoirs focusing on Eutrophication) developed by the United Nations Environmental Program.

3. Parameterize the model

We have received a portion of the requested data necessary for parameterizing the PAMOLARE model. This data has been incorporated into the model for several short time spans. We are expecting to receive several additional datasets in the near future from the USGS and Bureau of Reclamation. Further, several parameters necessary for the model are not available through existing models. We plan to collect the additional field data from Lake Mead by the end of this summer.

4. Calibrate the ecological model based on historical data

Like other environmental models, the PAMOLORE model has a large number of parameters which can be adjusted within a suitable range to better reproduce historical datasets and improve overall model performance. 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. For example, we will evaluate the impact of increased nutrient loads and lower water depth on primary production.

6. Identify environmental thresholds for algal blooms

A priority for Lake Mead managers is to prevent the reoccurrence of a major algal bloom like the one that occurred in 2001. Algal blooms occur as a response to appropriate environmental conditions in which lead to exponential algal growth rates. We will attempt to identify such environmental thresholds.

Additionally, in January of 2007 the invasive quagga mussel was identified for the first time in Lake Mead. This aggressive invasive species can have severe environmental

consequences including short-circuiting by overgrazing algae. We will also attempt to evaluate the potential ecological consequences of this emerging issue.

Principal Findings and Significance

The only finding of this research to date has come as a result of reviewing data from previous monitoring activities. We have determined that the lake is P limited and that a threshold concentration for severe algal blooms appears to be at approximately .05 mg/L. We also have found that the lake fully mixed in approximately 60% of the years of record. As data from the past 4 years is not yet available, we have not been able to identify the impacts of dropping water levels.

The ecological model is still in its developmental stages and therefore we have no findings to report. We anticipate having an operational model by this fall.

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. Mahsa has performed at a very high level and I'm hopeful that she will continue this project as a Masters student in the spring of 2008.

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:	2/28/2008
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

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

Synopsis: Only recently has it become known that microorganisms metabolize endocrine degrading compounds (EDCs), mediating processes including biodegradation, bioaccumulation, and deconjugative activation. Organisms at the bottom of the food web may thus the control the fate, persistence, and activity of agents whose greatest impacts are at the highest trophic levels. This award has been used to develop a preliminary dataset and facilitate program development at DRI focused on the role of natural microorganisms in controlling EDC ecology in the Las Vegas Wash. Highlights to date include the securing of roughly matching funding through USGS/SNPLMA for the funding a graduate student at UNLV and the development of preliminary results and techniques through the contributions of several undergraduate researchers. Tools developed in association with this project to date have revealed that EDC-degrading microorganisms are present in Las Vegas Wash and can be obtained in pure culture. Numerical abundance of EDC-degraders in the Wash appears to increase from about 10^2 in the upper Wash to 10^4 below the major wastewater discharges, representing about $1/100^{th}$ of the total microbial bioburden. The availability of techniques and collaborations developed to date will enable very quick progress with the enrollment of a graduate student dedicated solely to this project in September of 2007.

Annual Report

Problem and research objectives: Lake Mead serves as the principal water supply for much of the southwestern US. Extending 15 miles from Las Vegas proper to Las Vegas Bay of Boulder Basin, the Wash contributes in excess of 100 million gallons per day of treated wastewater to Lake Mead. Among the contaminants inadvertently delivered to the Wash via wastewater, endocrine disrupting chemicals (EDCs) represent a class of growing concern. Most notably, EDCs alter the structure of the vertebrate endocrine system, leading to reproductive impairment of wildlife. The most potent are medical EDCs such as 17β-estradiol (E2), and ethinylestradiol (EE2, the main ingredient in birth control pills). These compounds have been detected in basin water samples (Snyder, 1999) and fish blood plasma (Goodbred, 1999). Evidence, including tissue abnormalities and reproductive effects (Goodbred, 1999, Snyder, 1999), that these contaminants are bioactive is mounting. For example, male carp (*Cyprinus carpio*) in the Wash and Las Vegas Bay display low gonadosomatic index values, low sperm counts, gonadal macrophage aggregates, and elevated concentrations of egg yolk protein, vitellogenin (Goodbred, 1999, Snyder, 1999).

Certain microorganisms, through the activity of 17β-hydroxysteroid dehydrogenase (Lanisnik, 1992) have the ability to deconjugate EE2 to its bioactive intermediate E2 (Weber, 2005), although very little is known concerning the abundance and diversity of ECD-degraders. Thus, microbial communities may play a role in determining the environmental fate and persistence of these compounds and research into microbial mechanisms underlying EDC-degradation is timely. We propose that the fortuitous experiment embodied by Las Vegas Wash, a river composed mostly of treated wastewater, represents an outstanding resource for the elucidation of mechanisms underpinning the environmental processing of EDCs. The work described here details initial methods development towards these ends and provides some of the first information concerning the abundance, activity, and diversity of EDC-degrading microorganisms from the Southwest U.S.

Methodology: Water samples were collected from five sites along the Las Vegas Wash: including an upstream site (East Desert Inn road) lacking exposure to any wastewater source, the outfalls for the Las Vegas Pollution Control Facility and the Henderson Wastewater Treatment Plant, and a downstream site at Pabco Road. A sample of opportunity was also collected from the Tronox Inc. discharge (perchorate bioremediation).

For microbial cultivations, the basal freshwater medium, M1 (Myers and Nealson, 1988) was used with estrogens added as the sole carbon and energy source. To this, 10 ppm of EE2, E2, or a combination of both was added from a 5 mg/mL stock solution in HPLC grade methanol. Alternative carbon source controls included a mixture of formate, acetate, lactate, and glucose, each at 5 mM. Enumerations of aerobic heterotrophs were obtained by serial ten-fold dilution and plate counting on solid R2A medium (Reasoner 1985). Densities of aerobic estrogen-degrading microorganisms were estimated by serial ten-fold dilution in liquid M1. Growth was assessed by optical density (OD_{600}, Spectronic 20 spectrophotometer, Bausch & Lomb). Enrichment cultivations were performed using shake flask technique with weekly transfers. Growth curves were performed over a 4-day period in shake flasks at 25°C and sampled every 6 hours for optical density and estrogen concentrations. Microscopic examinations were performed using a Zeiss Axioskop 2 Plus fitted with phase contrast and an

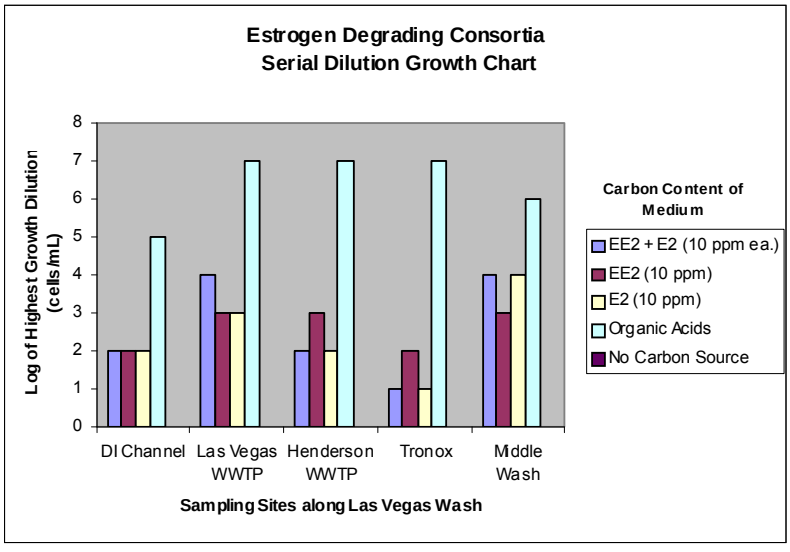

FIG. 2. Media containing multiple types of carbon sources were used to assess the trends in EE2 and E2 degradation at each site. The Middle Wash by far produced the most growth on both all media types. The negative control, which lacked a carbon source, failed to produce growth at any of the sites.

Axiocam MRC digital camera.

Quantitative analysis of EE2 and E2 was performed after filtration (0.2 μm, Millipore Acrodisc) using high performance liquid chromatography (HPLC). (HPLC-UV, Agilent Technologies, 1200 series). Separation was achieved on a Zorbax ODS 4.6 mm ID x 250 mm C-18 reverse phase column with a 70Å pore size and a mobile phase of 40% acetonitrile and 60% water with a flow rate of 1 mL/min. The injection volume was 150 μL, and signals were detected at 220 nm. Retention times for EE2 varied between 13 and 14 min, and that for E2 was steady at 9 min.

Principal findings and significance: A collaboration was established with the USGS SNPLMA-funded endocrine disruptors project under the management of Drs. Steven Goodbred and Michael Rosen of USGS (Objective 1). The 1:1 match and the collaborative infrastructure provided by this team will facilitate the support of a Masters's student at UNLV. A strong candidate from Denver Colorado, Susanna Blunt was recruited and will commence her program in September of 2007. In addition, we were able to recruit one of UNLV's top biology students (Karen Levy, 4.0 GPA) to apply for an receive an NSF EPSCoR undergraduate fellowship, which was used during the academic 2006/2007 year to supplement these funds and initiate methods development that will be required to complete the tasks outlined here. Her success in this project, was instrumental in her receiving a prestigious AMGEN fellowship at Columbia University this summer. Karen will be rejoining the project in the fall of 2007 where this research will be the basis for her undergraduate thesis work in the UNLV Honors College. Thus, the infrastructure and educational goals from this proposal have already exceeded expectations. Research-wise, we have obtained significant preliminary results and these are detailed under Objects 2 and 3 below.

Objective 1: Founding of a joint DRI/USGS/USFWS relationship focused on Lake Mead. This project was designed to dovetail with SNPLMA-funded water quality research being performed by the USGS and USFWS. In this regard, we were able to use this award to leverage a roughly 1:1 match from the USGS SNPLMA project for the support of our graduate student. Final contracting for the supplemental USGS funding is now underway. Delays in the delivery of the SNPLMA funding and the availability of a graduate student have necessitated pushing the start-date for major project activities back to September of 2007 (when Susanna Blunt commences her program).

Objective 2: Identification of major EDC-degrading microoganisms and algae. The first necessary steps were the development of culture media, sampling approaches, and analytical techniques to enable the cultivation of and measurement of E2 and EE2 degradation in microbial cultures. Enrichment cultures and quantitative dilutions using EE2, E2, or combination of the two as the sole carbon source were prepared using M1 medium. Whereas, typically an initial enrichment took about 5 days to reveal significant growth and estrogen

degradation, subsequent transfers grew up in as little 12 hrs, suggesting a conditioning of the microbial community. Individual isolates were obtained from the flask or tube enrichments by streaking for isolation onto solid estrogen-containing medium in purified agar and have been archived at -80^{o}C.

These experiments confirmed that significant bacterial growth was possible with EE2 and/or E2 and that from 10^2 and 10^4 culturable degraders were present in Las Vegas Wash, increasing in abundance moving down stream. These numbers were ca. 3 orders of magnitude lower than total cell counts, suggesting that about 1/1000th of environmental microorganisms in the Wash are estrogen degraders (a significant proportion). Several locations (Tronox and the Henderson plant sites) produced a conspicuous pink colonial estrogen-degrading culture type, visible as clumps to the naked eye and nearly clonal microscopically. We have also observed what appeared to be the same colonial organism free-floating in Las Vegas Wash. The identification of these and isolates yet to be recovered will be a future objective of the project.

Objective 3: Measurement of potential EDC degradation and metabolite generation rates. Using high performance liquid chromatography (HPLC) to quantitatively analyze the consumption of EE2 an E2 and a spectrophotometer to measure bacterial growth, we were able to track estrogen degradation and coincident growth. Growth curves from isolates and aquatic enrichments revealed significant, although sometimes incomplete, degradation of 10 ppm estrogen after an initial lag phase of ca. 48 hrs. Although future experiments must be performed at lower (e.g. more environmentally relevant) concentrations, the results of this work indicate that per-cell degradation rates will be achievable using adaptations of the techniques developed here.

Objective 4: Determination of the possible impacts of proposed deep wastewater delivery to mid Boulder Basin. Not addressed at this time.

Information Transfer Activities : The preliminary methods and approaches tested to date should provide the basis for publication-quality work in the near future. For this to occur, more samples will be required and additional characterization of the isolates will be required, which will become the main focus of our graduate student. Undergraduate, Karen Levy presented her results at the NSF EPSCoR student conference, held at DRI in Las Vegas in April of 2007.

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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
Project Number:	2006NV105B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Water Supply, Methods
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

Final Report

Problem and research objectives

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). In this study, we mainly addressed two issues related to soil hydraulic properties as described below.

Hydraulic property data are often characterized using various forms of 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 schemes in general circulation models. In this study we applied 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. Using the field hydraulic property measurements by researchers at the Desert Research Institute in Nevada from across various locations of arid and semi-arid western United States, our objective is to developed conceptual guidelines to establish equivalence relationships when different hydraulic property models are used to simulate a variety of large scale hydrologic processes [Zhu *et al.*, 2007].

Another 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 and what averages of hydraulic parameters to use for these models. An obstacle to practical applications in the field, catchment, watershed, or regional scale is the difficulty of quantifying the "effective" soil hydraulic property function. 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. Our main goals related to this issues are to investigate 1) how the effective hydraulic parameter schemes are sensitive to the time scale of hydrologic process, 2) how the hydraulic parameter correlation and variability significantly impact effective hydraulic parameter schemes, and 3) how the effective schemes can be better expressed in relation to variability [Zhu and Sun, 2007].

Methodology

The soil hydraulic functions consist of the soil water retention function which defines the water content as a function of the suction head, and the hydraulic conductivity function which relates the hydraulic conductivity with the water content or suction head.

Using either the field-measured data sets or the re-generated data, we calculate the effective hydraulic parameters using the two critical criteria (i.e., preservation of the surface flux and the surface moisture content). From these two important criteria, we calculated the effective hydraulic parameters of Ks and α for both Gardner-Russo and van Genuchten models. We hence use the effective hydraulic parameters to predict the mean flux exchange between the subsurface and the atmosphere and to preserve the mean effective degree of saturation at the land surface. The effective degree of saturation was used because it reflects (and preserves) the prevailing effective moisture content important for many global water cycle applications, as well as for other large-scale problems.

An inverse procedure along with the HYDRUS-1D model is used to find the effective hydraulic parameters for infiltration process that are able to predict overall average infiltration flux. The developed effective parameters are further expressed in terms of p-norm values as described below.

The *p*-norm or *p*-order power average $\hat{\xi}(p)$ for a set of any *N* random parameter values ξ_i is given by,

$$\hat{\xi}(p) = \left[(1/N) \sum_{i=1}^{N} \xi_i^p \right]^{1/p}$$

Based on these effective parameter values and the original input parameters that were used to obtain the effective parameter values, we can calculate the corresponding *p*-norms for the hydraulic parameters iteratively.

Using various boundary pressure head and depth to water table we illustrated effect of ponding and depth to water table on the effective hydraulic parameters at different time scales. By comparing the effective hydraulic parameters of field-measured and re-generated hydraulic parameters data sets, we investigated the sensitivity of effective hydraulic parameters to the correlation of *Ks* and α.

Principal findings and significance

The main results of Zhu et al. [2006a] can be summarized as follows. For the steady-state flow problem considered in this study, we showed that *p*-norms and their relationships were similar using 84 field-measured hydraulic parameter values and 10,000 randomly regenerated hydraulic parameter realizations when upscaling the flux across the land–atmospheric boundary and the surface effective degree of saturation. The upscaling schemes were in general better defined, and had less variability, in terms of *p*-norms than when effective parameter values were used. In general, *p*-norms for the Gardner model were less well defined than for the van Genuchten model, and may in fact be more difficult to use than the van Genuchten model in the upscaling context. For deep water tables (at least equivalent to 10 m), *p*-norms for van Genuchten parameters were relatively constant, while *p*-norms for Gardner parameters varied significantly, especially as flow scenarios shifted from evaporation to infiltration. As the water table became shallower, *p*-norms for the van Genuchten model became also less well defined and more sensitive to changes in the

pressure head at the soil surface. Correlations between the hydraulic parameters within a given hydraulic property model was important for determining *p*-norm relationships between the Gardner and van Genuchten models.

The main findings of Zhu and Sun [2007] are as follows. Effective hydraulic parameters change with infiltration time scale initially, and then approach nearly constant values, indicating an equivalent homogeneous medium is a more viable alternative for large spatial and temporal scale transient infiltration process. Effective hydraulic parameters are sensitive to the correlation between Ks and α.The effective parameter schemes are more variable at early stage of infiltration.

Information Transfer Activities

Papers:

Zhu, J., Macroscopic Parallel and Perpendicular Unsaturated Hydraulic Conductivities for Layered Soils: Arithmetic Mean or Harmonic Mean?, Ware Resources Research, submitted, 2007.

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.

Zhu, J., and Mohanty, B. P., Effective Soil Hydraulic Parameters for Land-atmosphere Interaction, Journal of Hydrometeorology, in press, 2007.

Zhu, J., and Sun, D., Effective Hydraulic Parameters for Transient Flows in Heterogeneous Soils, to be submitted to Vadose Zone Journal, 2007.

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.

Abstracts and Presentations:

Mohanty, B. P., Ines, A. V. M., Das, N. N., Jana, R., and Zhu, J., Effective Soil Hydraulic Parameters – State-of-the-Art!**,** Soil Science Society of America Annual Meetings, New Orleans, LA, November 4 – 8, 2007, submitted.

Sun, D., and Zhu, J., Saturation-Dependent Hydraulic Conductivity Anisotropy in Unsaturated Soils, Soil Science Society of America Annual Meetings, New Orleans, LA, November 4 – 8, 2007, submitted.

Zhu, J., Parallel and Perpendicular Unsaturated Hydraulic Conductivities for Layered Soils, Soil Science Society of America Annual Meetings, New Orleans, LA, November 4 – 8, 2007, submitted.

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.

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.

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.

Zhu, J., Young, M. H., van Genuchten, M. Th., Sun, D., Zhao, Y., and Hassan, A., 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.

Student Support

This grant was largely used to fund student training. Yanxia Zhao and Alexander Baron, MS students at University of Nevada Las Vegas (UNLV), Department of Mathematics and Department of Geosciences, respectively were funded partially from this grant during the past year.

Quantify Wash Load and Fractional Suspended Load Transport in Lake Tahoe

Basic Information

Title:	Quantify Wash Load and Fractional Suspended Load Transport in Lake Tahoe
Project Number:	2006NV114B
Start Date:	3/1/2006
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	Nevada 02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Sediments, Surface Water, Non Point Pollution
Descriptors:	
Principal Investigators:	Guohong Jennifer Duan

Publication

1. Rotter, S. and Duan, J.G. (2005). Fine-sized sediment load prediction by Artificial Newton Network approach. Lake Tahoe Science Consortium 2005, June.
2. Rotter, S. (2006) Predicting fine-sized sediment load in Lake Tahoe tributaries. ASCE EWRI 2006 World Water Congress.
3. Rotter, S. and Duan, J. G. (2006) Statistical properties of fine sediment time-series from Lake Tahoe tributaries, Submitted to Lake Thaoe Basin 3rd Biennial Conference.

Synopsis

Final Report

Project Objective

The objective of the project is to quantify fine sediment load from 10 primary streams directly discharging into Lake Tahoe. Integrated sediment samples were collected at the Long Term Interagency Monitoring Program (LTIMP) stations. DRI Soil Lab has analyzed fine particles of silt and clay from the measured suspended load. The project is in collaboration with USGS Carson City office. USGS scientists are Nancy Alevax, Bob Burrow, and Tim Rowe.

This funded research project is important to the LTIMP program. It provides additional data of fine-grained sediment by size fractions at ten primary LTIMP sites, develops statistical and analytical methods to predict fine-grained sediment load, and establishes foundations for DRI and USGS continue their collaboration in strengthening LTIMP program in Lake Tahoe.

Study Site

Due to the focus on Lake Tahoe as the terminal point for suspended sediment transport in all of the tributaries to the lake, the sampling sites of greatest concern are those in the closest proximity to the lake on any individual tributary. The study chose ten primary LTIMP sites, which located at Third Creek near Crystal Bay, Incline Creek near Crystal Bay, Glenbrook Creek at Glenbrook, Edgewood Creek at Stateline, Trout Creek at South Lake Tahoe, Upper Truckee River at South Lake Tahoe, General Creek near Meeks Bay, Blackwood Creek near Tahoe City, Ward Creek at Hwy 89 near Tahoe Pines. The ten tributaries that are monitored each have a gauging site located near their entrance to the lake with several of the streams having additional sites further upstream. The eight additional sites located higher within the watersheds are of less importance to this study because we are most concerned with the final output to the lake from any one tributary. Thus, the ten gauging stations located closest to the lake provide the most relevant data and are the only LTIMP sites used for this study.

Results

Measurements were taken weekly or bi-weekly depending on high or low flows since May 2005. At each site, we measured air and water temperature, and collected water samples. These samples were analyzed using DRI Saturn Laser Digitizer for turbidity, suspended sediment concentration, and conductivity. Preliminary conclusions from samples collected from May 2005 to Jan. 2006 are summarized as follows.

1) Over 96% of suspended sediments is finer than $62.5\,\mu m$, and over 82% of suspended sediment is less than $31\mu m$ at the ten streams. The averaged D_{50} for the ten streams is $25.85\mu m$. This result clearly indicated that fine particles less than $62.5\,\mu m$ are the majority of sediment load to the lake.
2) The highest sediment concentration (503 mg/L) was measured at the Glenbrook Creek. Sediment concentrations at Logan House and Edgewood Creek are around 100mg/L. Other Creeks including Blackwood, General, Upper Truckee, Incline, Ward, Third, Trout Creek has SSC varying from 30 to 90 mg/L.
3) Suspended sediment concentration (SSC) does not directly relate to flow discharge. Streams (e.g. Third Creek, Upper Truckee) having high values of SSC associate with low discharges. However, the total fine sediment volume closely correlates with flow discharge. High flows carry more fine sediment load to the lake because flow discharge is

high.

In summary, fine sediment load is the primary suspended sediment load discharging directly into the lake. The contributions from different streams vary depending on climate and watershed characteristics. High suspended sediment concentration does not always associate with high sediment load volume.

Current Research Activity

Since we have not completed data collection for an entire season, field data collection is currently on-going. More sediment samples are analyzed at DRI soil laboratory. SSC showed no direct correlation with flow discharge, so that we are employing statistical method to analyze these field data. Currently, we are generating time-series of discharge, SSC, sediment percentages by size fraction for data collected from May 2005 to June 2006. Statistical characteristics (e.g. mean, variance, skewness) are calculated for these time-series. Correlations between time-series for the same variable (e.g. discharge) at different watersheds or time-series of different variables for the same watershed will be analyzed.

Training Accomplishment

Funding one MS student, Shane Rotter, from the Hydrologic Sciences Program at the University of Nevada, who has successfully defended his proposal, and expected to graduate in Dec 2006.

Publications

Rotter, S. and Duan, J.G. (2005). "Fine-sized sediment load prediction by Artificial Newton Network approach." *Lake Tahoe Science Consortium 2005*, June.

Rotter, S. (2006) "Predicting fine-sized sediment load in Lake Tahoe tributaries." *ASCE EWRI 2006 World Water Congress.*

Rotter, S. and Duan, J. G. (2006) "Statistical properties of fine sediment time-series from Lake Tahoe tributaries", Submitted to Lake Thaoe Basin 3rd Biennial Conference.

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	5	0	0	0	5
Ph.D.	2	0	0	1	3
Post-Doc.	2	0	0	4	6
Total	11	0	0	5	16

Notable Awards and Achievements

Publications from Prior Projects