

# Report as of FY2010 for 2008NV139B: "Uncertainty and Sensitivity of Ground-Water Discharge Estimates for the Shrublands in the Great Basin Area"

## Publications

- Articles in Refereed Scientific Journals:
  - ◆ Pan, F., J. Zhu, M. Ye, Y. A. Pachepsky, and Y.-S. Wu. 2010. Sensitivity analysis of unsaturated flow and contaminant transport with correlated parameters. *Journal of Hydrology*. doi:10.1016/j.jhydrol.2010.11.045.
- Conference Proceedings:
  - ◆ Zhu, J., K. Pohlmann, J. B. Chapman, C. E. Russell, R. W. H. Carroll, and D. S. Shafer. 2010. Sensitivity to Formation Porosity of Contaminant Transport from Nevada Test Site to Yucca Mountain, *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, ASCE, 2010. doi:10.1061/(ASCE)HZ.1944-8376.0000047.
  - ◆ Zhu, J., and M. Young. 2009. Sensitivity of evapotranspiration estimates for semi-arid shrublands, 94th ESA Annual Meeting, Albuquerque, New Mexico, U. S. A., August 2&#8211;7, 2009.

## Report Follows

# Uncertainty and Sensitivity of Ground-Water Discharge Estimates for the Shrublands in the Great Basin Area

Final Report

## Problem and Research Objectives

The current limited water supply to Las Vegas area mainly from Colorado River is not likely enough to support its potential future growth. With future needs of water resources in mind, local water authorities are looking northeast to the Great Basin. One plan – among many others – proposes to pump water from the Great Basin aquifers. Before such action can be taken, it is necessary to investigate the way in which the aquifers are influenced and the potential for long-term pumping to affect water availability to phreatophytic vegetation. Federal legislation (Section 131 of the Lincoln County Conservation, Recreation, and Development Act of 2004) was enacted to conduct a water resources study of the alluvial and carbonate aquifers in Nevada and Utah. The study was known as the Basin and Range Carbonate Aquifer System Study, or BARCAS study. The study area includes 30 sub-basins in 12 valleys. Of particular focus in the BARCAS study was the amount of ground water lost through evapotranspiration (ET). While groundwater ET as an overall water budget component has been estimated in other studies, including BARCAS, the sensitivity and uncertainty of groundwater ET estimates have not been systematically analyzed.

Given the large size of the study area and the dearth of previous studies of the valleys, groundwater discharge through ET was estimated using a rather sparse dataset. As a result, the ET rate and area uncertainty have significant influence on the groundwater discharge estimates. It is therefore beneficial to quantify the uncertainty associated with these estimates in order to help maximize future data collection efforts. This project seeks to develop an integral approach to quantify the uncertainty and sensitivity of groundwater discharge estimates.

## Methodology

We first present the general steps for quantifying fractional contributions of uncertainties in individual variables to the estimation uncertainty of groundwater discharge by ET, when large numbers of independent variables are involved:

1. Establish model(s) to estimate groundwater discharge that relate independent variables to the calculations of groundwater discharge.
2. Estimate uncertainty ranges and probability density functions for the independent variables based on field characterization, professional judgment, etc.
3. Randomly select realizations from the prescribed probability distributions of the independent variables, and calculate groundwater discharge values based on the selected model(s) in Step 1 for all realizations.

4. Select influential independent variables, based on the physical characteristics and model structure of the considered problems. The main goal of this step is to reduce the number of independent variables included in the subsequent sensitivity analysis.

5. Conduct sensitivity analysis to quantify the uncertainty contributions from individual independent variables.

To quantify how parameter-level uncertainty affects groundwater discharge estimates, we conduct Monte Carlo simulations that represent independent variables as statistical distributions rather than as single values. Each independent variable is assumed to be characterized by a probability density function, with the mean ET rate estimated either through remote sensing analyses, values taken from the literature, or from existing data. To examine the sensitivity of the total groundwater discharge estimate to the three independent variable categories in general (i.e., ET rate, acreage, and precipitation rate), we also systematically vary the standard deviations for the independent variables. The Monte Carlo simulations based on the estimated standard deviations are considered as the Base Case. By comparing the results relative to the Base Case, we can assess how uncertainty from each independent variable category contributes to the uncertainty of the total groundwater discharge estimate. For this purpose, we investigate two main themes: (1) varying the standard deviations of one individual independent variable category, while holding constant the standard deviations of the other two categories at the Base Case levels; and (2) varying the standard deviations of one individual independent variable category while using the mean of the other two independent variable categories (i.e., standard deviations equal zero). By investigating theme (2), we can explore how uncertainties in individual variable categories propagate to the uncertainty in the total groundwater discharge. After the Monte Carlo simulations, we develop regression models that relate total groundwater discharge to individual independent variables, and we use these models to assess overall sensitivity of the total groundwater discharge estimate to the individual independent variables. The squared values of standardized regression coefficients simply represent the fractional contributions from the individual independent variables to the total variance of the groundwater discharge.

### Principal Findings and Significance

The principal findings are:

- Although the independent variables in this study typically have small CVs, the CV of groundwater discharge estimates in some sub-basins can be quite large.
- The uncertainty of ET rates is the most significant contributor to the uncertainty of groundwater discharge estimates. We find that a total of 630 variables affect the estimates of total groundwater discharge, but that only seven variables account for almost all of the variability in the discharge estimates. We demonstrate that groundwater discharge estimates using the simplified regression relationship and the full relationship correlate very closely (correlation coefficient is 0.982).
- Quantitatively, the variability in ET rates for the moderately dense desert shrubland contributes to 75% of the variance in the total groundwater discharge estimates. The results indicate that field data collection to reduce overall uncertainty should focus primarily on this ET unit, and less on other units.

## Information Transfer Activities

### Journal Papers:

Zhu, J., and M. H. Young. 2009. Sensitivity and uncertainty of ground-water discharge estimates for semi-arid shrublands. *Journal of the American Water Resources Association (JAWRA)*. 45(3):641-653, doi:10.1111/j.1752-1688.2009.00312.x.

Pan, F., J. Zhu, M. Ye, Y. A. Pachepsky, and Y.-S. Wu. 2010. Sensitivity analysis of unsaturated flow and contaminant transport with correlated parameters. *Journal of Hydrology*. doi:10.1016/j.jhydrol.2010.11.045.

Zhu, J., K. Pohlmann, J. B. Chapman, C. E. Russell, R. W. H. Carroll, and D. S. Shafer. 2010. Sensitivity to Formation Porosity of Contaminant Transport from Nevada Test Site to Yucca Mountain, *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management, ASCE*, 2010. doi:10.1061/(ASCE)HZ.1944-8376.0000047.

### Abstracts and Presentations:

Zhu J., and Young, M. H. 2008. Uncertainty and sensitivity of evapotranspiration estimates for semi-arid shrublands, Nevada Water Resources Association Annual Conference, Mesquite, Nevada, March 5 – 6, 2008.

Zhu, J., and M. Young. 2009. Sensitivity of evapotranspiration estimates for semi-arid shrublands, 94th ESA Annual Meeting, Albuquerque, New Mexico, U. S. A., August 2–7, 2009.

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