Within the hyper-arid to semiarid areas of Israel are three experimental drainage basins. They are the Nahal (stream in Hebrew) Yael, subdivided into five subbasins, Rahaf-Qanna'im (main and tributary, respectively) and Eshtemoa. These basins vary in drainage area and climate, and in monitoring duration and type. All are drained by gravel-bed channels. As the size of monitored drainage area is limited, 3-4 additional representative basins covering areas of 300, 1000, 2000 and 8000 square kilometers will likely be implemented in the next decade. The basins have precipitation, runoff, sediment and fluviomorphological records. Each was conceived for differing purposes, but all share the common two objectives for the continuous monitoring:

1. Many hydrological issues may be approached if, and only if, there are prototype databases on a wide spectrum of hydrological processes; and
2. There is a need for long-term records to assess large floods and subsequent hydrologic and geomorphic recovery.

Lessons derived from a large number of research projects on these experimental basins focus on characteristics of runoff in arid climates. For example, the effect of the spatial distribution of rainfall on runoff generation becomes increasingly important with aridity. Rainfall angle on hillslopes and storm intensity and direction derived from rainfall recorders and radar backscatter are crucial for explanation of runoff response. Runoff hydrographs tend to have more bores, shorter-duration peaks, briefer recessions, longer dry periods, and are more variable in terms of flood volume and peaks with increased aridity. Suspended-sediment fluxes, yields and concentrations are relatively large in the semiarid realm, reaching maxima at the beginning of a flood season and after long dry spells. Bedload fluxes are exceptionally high from dryland basins in which hillslopes are minimally vegetated and where bedload transport takes place in channels lacking an armor layer.

Bedload/suspended-sediment load ratios increase with aridity. Bedload yield may represent up to 70% of the total load. Hillslope to channel connectivity is high in drylands. In the hyperarid region suspended-sediment sources are hillslopes and the coarser, sandy fraction of the channel bedmaterial. The depth of channel bed activity is indicated by a fluvio-pedogenic unit beneath the channel surface.

National and regional hydrological research needs will dictate future global monitoring in experimental basins. International collaboration may bring about considerable cost reduction by exclusion of monitoring aspects that can be evaluated based on the monitoring in other, similar conditions. Advanced international collaboration on validation and calibration of and consistency in monitoring means, as well as syntheses of lessons derived from international collaboration, such as from an International Watershed Research Network, are required for maximizing our understanding of water and sediment responses in varied global regions.

H51C MCC: 120 Friday 0830h

Using Groundwater Models to Guide Field Data Collection I

Presiding: **C Tiedeman,** U.S. Geological Survey**; B Wagner,** U.S. Geological Survey

H51C-01 0835h INVITED

Use of Flow and Transport Models for Experimental Design for Model Calibration and Monitoring Network Design

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Groundwater flow and contaminant transport in subsurface are governed by partial differential equations. With appropriate initial and boundary conditions specified, the governing equations are solved by either the finite-difference or the finite-element method. Groundwater models can be used for prediction as well as for guiding field data collection. This paper reviews the use of such models for experimental design for model calibration and monitoring network design for plume characterization. In general, experimental design concerns with the selection of a set of experimental conditions, including data collection strategies, such that the information collected will minimize either the parameter uncertainty in the parameter space or the prediction uncertainty in the prediction space. The minimization is subject to a set of constraints, most importantly, the budgetary constraint. To estimate the uncertainty in either the parameter or the prediction space, it requires the use of the flow and transport models to derive the covariance matrix of the model parameters. To improve the efficiency and reliability of a remediation design, the spread of a contaminant plume in time and space must be predicted by the flow and transport models and monitored accurately. Experimental design techniques have been applied to construct groundwater quality monitoring networks that maximize plume characterization while minimizing the construction and sampling costs.

H51C-02 0900h INVITED

Optimization Modeling to Guide Field Data Collection

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As part of on-going efforts to demonstrate the applicability and advantages of the simulation-optimization approach for reducing groundwater remediation costs under general field conditions, a series of optimization modeling projects was recently conducted at several Superfund sites in Massachusetts, Oregon, Utah and Nebraska. The optimization modeling at each site provides a logical framework for assessing the data gaps and guiding further data collection. This is done by evaluating the sensitivity of the cost function to various model parameters, and moreover, by incorporating the decision variables associated with a sampling network directly into the optimization formulation. In this presentation we will provide an overview of the optimization modeling efforts, demonstrate the use of the simulation-optimization model to guide field data collection, and discuss the challenges and research needs in field-scale optimization modeling.

URL: http://hydro.geo.ua.edu

H51C-03 0925h INVITED

Using Ground-Water Models to Guide Field Data Collection: Management Decisions Impacted by Groundwater-Surface Water Interactions

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Groundwater models provide a mechanism for linking management options with field data collection activities. This linkage allows cross-disciplinary integration of management and technical decisions. Models used in this framework must meet unique objectives in terms of tradeoffs between complexity and transparency. Management decision models provide constraints and guidelines related to the complexity and data requirements for the groundwater models. Issues related to groundwater-surface water interactions spawned by salmon recovery activities in the Pacific Northwest are used to illustrate these objectives and model applications.

H51C-04 0950h

Ground-water modeling and the installation of deep multiple-well monitoring sites in the Central and West Coast Basins, Los Angeles County, California

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An ongoing regional study of the geohydrology and geochemistry of the Central and West Coast Basins in Los Angeles County, California has iteratively combined the drilling of deep multiple-well monitoring sites with groundwater modeling. The monitoring sites are generally between 1,000 and 1,500 ft in depth and consist of 4-6 piezometers installed within a single borehole that provide depth-dependent geohydrologic data. The U.S. Geological Survey (USGS) and the Water Replenishment District of Southern California (WRDSC) drilled four monitoring sites at the beginning of the cooperative study. The data from these sites, along with data compiled from existing wells, formed the basis for developing a preliminary multi-aquifer groundwater simulation model. Initial model simulations were then used to help prioritize new drilling locations where additional geohydrologic data were needed to more accurately simulate the complex system. Additional drilling, updating the regional simulation model, and new modeling-including development of particle tracking, simulation-optimization, and solute transport models-have proceeded iteratively. As of September, 2002, 34 multiple-well monitoring sites (162 piezometers) have been constructed.

The new modeling, which focuses on seawater intrusion, has identified the need for more detailed data on sequence stratigraphy, geometries of confining beds and high permeability zones, and pore-water chemistry. In response to this need, continuous coring has been conducted cooperatively by the USGS, WRDSC, and Los Angeles County Department of Public Works at six of the monitoring sites completed thus far.

H51C-05 1030h

The Use of Genetic Algorithms as an Inverse Technique to Guide the Design and Implementation of Research at a Test Site in Shelby County, Tennessee

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The Shelby Farms test site in Shelby County, Tennessee is being developed to better understand recharge hydraulics to the Memphis aquifer in areas where leakage through an overlying aquitard occurs. The site is unique in that it demonstrates many opportunities for interdisciplinary research regarding environmental tracers, anthropogenic impacts and inverse modeling. The objective of the research funding the development of the test site is to better understand the groundwater hydrology and hydraulics between a shallow alluvial aquifer and the Memphis aquifer given an area of leakage, defined as an aquitard window. The site is situated in an area on the boundary of a highly developed urban area and is currently being used by an agricultural research agency and a local recreational park authority. Also, an abandoned landfill is situated to the immediate south of the window location. Previous research by the USGS determined the location of the aquitard window subsequent to the landfill closure. Inverse modeling using a genetic algorithm approach has identified the likely extents of the area of the window given an interaquifer accretion rate. These results, coupled with additional fieldwork, have been used to guide the direction of the field studies and the overall design of the research project. This additional work has encompassed the drilling of additional monitoring wells in nested groups by rotasonic drilling methods. The core collected during the drilling will provide additional constraints to the physics of the problem that may provide additional help in redefining the conceptual model. The problem is non-unique with respect to the leakage area and accretion rate and further research is being performed to provide some idea of the advective flow paths using a combination of tritium and ^{3}He analyses and geochemistry. The outcomes of the research will result in a set of benchmark data and physical infrastructure that can be used to evaluate other environmental tracers and modeling techniques.

URL: http://web.utk.edu/~rgentry/research/research.html

H51C-06 1045h

Inverse Modeling to Quantify Recharge in Unconfined Aquifers

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There are several approaches to quantifying recharge, or water-table accretion, in unconfined aquifers. Quantitative approaches include analyzing baseflow recession, estimating flow through the unsaturated zone using tracer studies or modeling, and modeling water-table response. The last of these approaches requires temporal monitoring of the water-table response and, in many cases, requires that transient inverse models be solved for the unknown time-varying recharge function.

We quantify recharge in a water-table aquifer using a time-dependent model for the one-dimensional Boussinesq Equation. In our model the unknown time-dependent recharge function is represented as a Fourier series in which the number of Fourier coefficients is limited by the frequency of water-table elevation measurements via the Nyquist frequency. We developed a Monte Carlo inverse model in which we randomly generate Fourier coefficients and compare the resulting modeled water-table fluctuations to observed water-table elevations. The model assumes Dupuit flow and allows lateral variations in hydraulic conductivity.

We applied our model to simulate water-table hydrograph data collected at Hatteras Island, North Carolina, USA. Irregularly sampled water-table elevation data require that the recharge function contain only low frequency components. These simulations suggest that (1) recharge and precipitation diverge in spring and summer; (2) recharge increases with precipitation in fall and winter; and (3) the precise timing of the minimum recharge rate may be tied to ENSO conditions. They suggest further that water-table response data should be collected at much shorter time scales.

H51C-07 1100h

Model Structure Identification: From the Reliability of Model Prediction to the Robustness of Experimental Design

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The paper introduces a new methodology for identifying a distributed parameter system when the structure of the system is complex and unknown. The basic idea of the new methodology is to solve a generalized inverse problem (GIP) to find the simplest model structure for given model applications. In the theoretical part of the presentation, the identifiability of model parameters, the reliability of model applications, and the sufficiency of observation data are rigorously defined for the case of existing model structure errors. Some quantitative relationships of them are derived. Sufficient conditions for assuring the reducibility of a model structure are given.

When model structure is unknown, to find a robust experimental design for model calibration is a very challenging problem because a more complex structure needs more data to identify. The worst-case-parameter (WCP) of a model structure is defined as such a parameter that produces the largest structure error when the model structure is simplified. We can prove that if a design is sufficient for identifying the WCP, it must be a robust one.

Based on these theoretical results, the paper gives the following algorithms: (1) Using GA to Find the WCP, and (2) Judging the robustness of an experimental design before it is actually conducted in the field. A numerical example shows how this methodology is used for identifying the structure of hydraulic conductivity of a heterogeneous aquifer.

H51C-08 1115h

Designing Groundwater Monitoring Networks for Regional-Scale Water Quality Assessment: A Bayesian Approach

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The design of groundwater monitoring networks is an important concern of regional-scale water-quality assessment programs because of the high cost of data collection. The work presented here addresses regional-scale design issues using ground-water simulation and optimization set within a Bayesian framework. The regional-scale design approach focuses on reducing the uncertainty associated with a fundamental quantity: the proportion of a subsurface water resource which exceeds a specified threshold concentration, such as a mandated maximum contaminant level. This proportion is hereafter referred to as the threshold proportion. The goal is to identify optimal or near-optimal sampling designs that reduce the threshold proportion uncertainty to an acceptable level.

In the Bayesian approach, there is a probability density function (pdf) associated with the unknown threshold proportion before sampling. This function is known as the prior pdf. The form of the prior pdf, which is dependent on the information available regarding the distribution of water quality within the aquifer system, controls the amount of sampling needed. In the absence of information, the form of the prior pdf is uniform; however, if a ground-water flow and transport model is available, a Monte Carlo analysis of ground-water flow and transport simulations can be used to generate a prior pdf which is non-uniform and which contains the information available regarding solute sources, pathways and transport.

After sampling, the prior pdf is conditioned on the sampling data. The conditional distribution is known as the posterior pdf. In most cases there is a reduction in uncertainty associated with conditioning. The reduction in uncertainty achieved after collecting samples can be explored for different combinations of prior pdf distribution and sampling method. Three scenarios are considered: (i) uniform prior pdf with random sampling; (ii) non-uniform prior pdf with random sampling; and (iii) non-uniform prior pdf with non-random sampling. Optimization is used in case (iii) to find near-optimal monitoring locations for reducing the uncertainty of the proportion pdf. The reduction in uncertainty is compared for all three cases. Hypothetical examples are presented to demonstrate the value of incorporating modeling information and non-random sampling strategies into the design of regional-scale networks.

H51C-09 1130h

Optimal Long-term Groundwater Quality Monitoring Network Design

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A groundwater quality monitoring network design is developed in this work. The method combines a Kalman filter and a genetic algorithm to determine when and where to take groundwater samples to reduce the uncertainty that is associated with this concentration field at least cost. The proposed method is applied to a field problem. At each sampling period current sampling locations are determined using the proposed method, and the groundwater quality data are sampled. Then the collected data are used to update the statistical information regarding the concentration field. The sampling locations at the next sampling period are determined using the updated information. Results show the degree to which collection and utilization of the actual field data impact the decision making process and result in a better estimate.

H51C-10 1145h

Numerical Modeling for Integrated Design of a DNAPL Partitioning Tracer Test

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Partitioning tracer tests (PTTs) are commonly used to estimate the location and volume of nonaqueous-phase liquids (NAPLs) at contaminated groundwater sites. PTTs are completed before and after remediation efforts as one means to assess remediation effectiveness. PTT design is complex. Numerical models are invaluable tools for designing a PTT, particularly for designing flow rates and selecting tracers to ensure proper tracer breakthrough times, spatial design of injection-extraction wells and rates to maximize tracer capture, well-specific sampling density and frequency, and appropriate tracer-chemical masses. Generally, the design requires consideration of the following factors: type of contaminant; distribution of contaminant at the site, including location of hot spots; site hydraulic characteristics; measurement of the partitioning coefficients for the various tracers; the time allotted to conduct the PTT; evaluation of the magnitude and arrival time of the tracer breakthrough curves; duration of the tracer input pulse; maximum tracer concentrations; analytical detection limits for the tracers; estimation of the capture zone of the well field to tracer ensure mass balance and to limit residual tracer concentrations left in the subsurface; effect of chemical remediation agents on the PTT results, and disposal of the extracted tracer solution. These design principles are applied to a chemical-enhanced remediation effort for a chlorinated-solvent dense NAPL (DNAPL) site at Little Creek Naval Amphibious Base in Virginia Beach, Virginia. For this project, the hydrology and pre-PTT contaminant distribution were characterized using traditional methods (slug tests, groundwater and soil concentrations from monitoring wells, and geoprobe analysis), as well as membrane interface probe analysis. Additional wells were installed after these studies. Partitioning tracers were selected based on the primary DNAPL contaminants at the site, expected NAPL saturations. Partitioning coefficients were measured in the laboratory in water and in solutions containing expected post-remediation residual concentrations of the chemical remediation agent, which was shown to influence the partitioning coefficients. The numerical model was used to optimize the injection-extraction rates and distribution to most efficiently sweep the NAPL hot spot, to enable hydraulic capture of the tracers, and to predict the peaks and arrival times of the tracer breakthrough curves. Field results are presented to evaluate the effectiveness of the PTT design approach.

H51D MCC: 103 Friday 0830h

Linking Hydrology and Biogeochemistry I *(joint with B, GC)*

Presiding: **M Gooseff,** Oregon State University**; B Newman,** Los Alamos National Laboratory**; D DeWalle,** Pennsylvania State University**; J McDonnell,** Oregon State University

H51D-01 0835h

Interaction of Strontium-90 in Sediment and Porewater in a Stream Near Chernobyl

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We investigated the interaction of ^{90}Sr in sediments and pore waters of wetlands and stream hyporheic zones at a stream near Chernobyl. A non-dimensional activity ratio was formulated, the ratio of ^{90}Sr in the pore waters compared with exchangeable ^{90}Sr in the sediment on a volume basis. The average activity ratio for the wetland and channel sediments was 0.028 +/- 0.005. The activity ratio decreased when the sediment and porewaters were not in equilibrium. The change in the activity ratio was documented during two observational periods in a wetland: initially during a time when groundwater was discharging to the wetland (snowmelt, 2000) and subsequently at a time of near-stagnant groundwater flow (late fall in 2001 after a dry three month period). In both the discharge and stagnant periods, the exchangeable ^{90}Sr concentration in sediment increased with depth by a factor of five to a peak concentration at 10 cm. In contrast, the ^{90}Sr concentration in porewater differed significantly in the two observational periods. During the groundwater discharge period, the porewater concentration was relatively constant over the 30 cm depth of observation (120 +/-12 Bq/L) and surface water concentrations were similar. During the near-stagnant period, the porewater concentration increased with depth from 20+/-2 Bq/L in surface waters to 400 +/-40 Bq/L at a depth of 10 cm. We hypothesize that during discharge periods, the porewaters in the wetland represent the ^{90}Sr concentration of advecting groundwater while during stagnant periods, the porewaters represent the concentration of ^{90}Sr in equilibrium with the sediment. This proposed explanation is supported using PHREEQC in a dual porosity mode. Using independent estimates of the model parameters, the con-