H52B MCC: Hall C Friday 1330h

Recent Advances in Groundwater Hydrology Posters

Presiding: **C Welty,** Drexel University**; P T Imhoff,** University of Delaware

H52B-0849 1330h POSTER

LNAPL Displacement in a Porous Medium by Flushing with a Humic Acid Solution

David A. Steffy (256-782-5966; dsteffy@jsucc.jsu.edu)

Jacksonville State University, Dept. Physical Earth Sciences 700 Pelham Rd. N, Jacksonville, AL 36265, United States

A series of laboratory tests and numerical model simulations were conducted to evaluate the use of humic acid (HA) as a surfactant to mobilize simulate low-density, non-aqueous phase liquid (LNAPL) in a sand aquifer. The laboratory tests were conducted with homogenous fine-grained sand, packed in a 50-cm borosilicate tube with a diameter of 3 cm. The LNAPL was a mineral oil dyed with Sudan IV. The tests were initiated by establishing a water table condition in a vertical sand-packed column that becomes contaminated by the LNAPL. The column is then rotated horizontal and pumped with the surfactant at a constant rate. The amount and rate of LNAPL displaced was measured. Laboratory tests found that at higher the pump rates the more LNAPL was recovered (displaced). However, in terms of pumping efficiency (amount of LNAPL recovered / amount of fluid pumped) - a moderate pump rate of 127 cc/hr (0.6 pore volumes/hr) was the most efficient. HA at its critical micelle concentration of 3.5 mg/ml was then used to increase LNAPL mobilization. When a humic acid solution was used, recovery was increased from 60% to 81%, and efficiency was improved by over 180%. A dynamic model using STELLA software was then used to evaluate the delivery systems of surfactant and characteristics of the surfactant itself to enhance LNAPL recovery. This dynamic one-dimensional model was first calibrated using laboratory derived LNAPL displacement measurements. The calibrated model found no difference between a continuous and cyclic delivery of the surfactant.

H52B-0850 1330h POSTER

Electro-enhanced Permeable Reactive Barrier : Optimal Design of PRB System With External Current for Effective TCE Removal From Groundwater

Ji-Won Moon[1] (82-2-2123-2665; jwmoon@yonsim.yonsei.ac.kr)

Hi-Soo Moon[1] (82-2-2123-2669; hsmoon@yonsei.ac.kr)

Yul Roh[2] (1-865-576-9931; rohy@ornl.gov)

Heonki Kim[3] (heonki@sun.hallym.ac.kr)

Yungoo Song[1] (82-2-2123-2671; yungoo@yonsei.ac.kr)

[1]Yonsei University, Department of Earth System Sciences 134 Shinchon-dong, Seodaemun-ku, Seoul 120-749, Korea, Republic of

[2]Oak Ridge National Laboratory, Environmental Sciences Division Bldg 1505, Room 336, MS-6038 P.O. Box 2008, Oak Ridge, TN 37831-6038, United States

[3]Hallym University, Department of Environmental System Engineering Okchon-dong 1, Chunchon Kangwon-do, Chunchon 200-702, Korea, Republic of

The objective of this study was to design an optimal electro-enhanced permeable reactive barrier (E2PRB) system for remediation of trichloroethylene (TCE)-contaminated water using zero valent iron (ZVI) and direct current (DC). A series of column experiments were conducted to evaluate the location of Fe0 permeable reactive barrier (PRB) and the effects of electrode arrangement in the column on the TCE removal efficiency and iron corrosion processes. In twelve different combinations of ZVI and/or DC application in the test columns, the rate of reductive dechlorination of TCE was improved with simultaneous application of both ZVI and DC compared to that used ZVI only to evaluate the synergistic effect (SE). The most effective arrangement of electrode and ZVI for TCE removal from simulated groundwater was a column set with ZVI and cathode installed at the down gradient (outlet side). Based on the electrochemical study in the E2PRB system, application of direct current provided external electrons to the system so that the system did not depend entirely on the oxidation of the medium for the reductive dechlorination of TCE. The enhanced dechlorination rate of TCE in ZVI-DC systems is considered to attributed to more generation and fast formation kinetic of electron by following reactions: (1) direct supply of electrons from external DC source (2) the electrolysis of water generating additional electrons at the vicinity of the anode (3) the electro-reduction of the compound by released electrons on the ZVI surfaces by oxidation (4) released electron through oxidation of dissolved ferrous iron, and (5) oxidation of atomic hydrogen at the cathode. The competition between five different electron sources generated from five sources evidently influenced on the TCE removal efficiency, valid lifetime of E2PRB system, and reduction of energy expenditure in both of electrochemical and electrokinetic aspects. The results from a series of experiments with twelve columns showed a trend that removal efficiency was more related to the electrode arrangement, but longevity of ZVI PRB and reduction of energy expenditure to location of ZVI installation.

H52B-0851 1330h POSTER

An Outer Approximation Based Time-Varying Methodology

Maria P. Papadopoulou[1,2] (802-656-7789; mpapadop@emba.uvm.edu)

George F. Pinder[1,2] (pinder@emba.uvm.edu)

George P. Karatzas[2,3] (karatzas@mred.tuc.gr)

[1]Dept. of Civil and Environmental Engineering University of Vermont, 213 Votey Building, Burlington, VT 05405, United States

[2]Research Center for Groundwater Remediation Design, 114 Votey Building University of Vermont, Burlington, VT 05405, United States

[3]Dept. of Environmetal Engineering Technical University of Crete, Polytechnoupolis, Chania 73100, Greece

An Outer Approximation based time-varying methodology to obtain a least-cost groundwater remediation design based upon a multiple-stage pump-and-treat strategy is introduced. Various concentration constraints are defined at the end of each management period to ensure maximum mass removal and to prevent further off-site migration of the contaminant plume.

In this analysis, the effectiveness of a remediation scheme beyond the end of its design period is also considered. A penalty term is added to the objective function to evaluate the performance of the proposed remediation-pumping scheme at a pre-selected time beyond the end of the design period. Finally, a discount coefficient that incorporates the changes in the present value of money during the overall period of the remediation has been added to the objective function.

The method has been applied to a field site in Toms River New Jersey, with very promising results.

H52B-0852 1330h POSTER

Multi-Objective Optimization of Groundwater Remediation System Design

Chinnathambi Esakkiperumal[1] ((205) 348-3015; esakk001@bama.ua.edu)

Chunmiao Zheng[1] ((205) 348-0579; czheng@ua.edu)

Pu Patrick Wang[2] ((205) 348-5302; pwang@ua.edu)

[1]University of Alabama, Department of Geological Sciences, BOX 870338,, Tuscaloosa, AL 35487-0338, United States

[2]University of Alabama, Department of Mathematics, BOX 870350,, Tuscaloosa, AL 35487-0350, United States

In recent years, the use of multi-objective optimization techniques in designing groundwater remediation systems has increased because of their computational efficiency for solving problems with two or more objectives, such as minimizing the remediation costs while maximizing the design reliability. For any given multi-objective problem, there exists a set of Pareto-optimal solutions or nondominated solutions. The purpose of this study is to identify those sets of non-dominated solutions using a multi-objective optimization technique, Non-dominated Sorting Genetic Algorithm (NSGA). NSGA is coupled in this study with the commonly used groundwater flow and transport models MODFLOW and MT3DMS, to design pump-and-treat systems that achieve the dual objectives of minimum cost and minimum mass remaining. The coupled code is demonstrated to work well for both 2-D hypothetical test problems and 3-D real-world design problems, leading to efficient identification of the Pareto optimal solutions (tradeoff curves).

H52B-0853 1330h POSTER

Effect of constraint severity on pumping rate and remediation time in optimal design of groundwater remediation

Nak-Youl Ko[1] (fuu@netian.com)

Kang-Kun Lee[1] (kklee@snu.ac.kr)

[1]School of Earth and Environmental Sciences, Seoul National University, School of Earth and Environmental Sciences, Seoul National University, Seoul 151-742, Korea, Republic of

Variation of decision variables for optimal remediation using the pump-and-treat method are examined to identify the effect of the degree of concentration constraint. The decision variables include pumping rates for each extraction well and time for remediation, which are used to calculate the total pumping volume. Simulation-optimization method is applied to minimize the total pumping volume. The simulation model solves flow and transport equations using MODFLOW and MT3DMS under the decision value yielded from the optimization model, and the optimization model evaluates the design through the result of the simulation model and optimizes the decision variables using genetic algorithm. Change of the concentration constraint causes change in decision values. If the contaminant concentration becomes severer, both the pumping rate and time for remediation are increased. However, the increase rates and patterns are different. In total volume minimization strategy, the remediation time increases rapidly prior to significant increase in pumping rates. The number and position of main extraction wells are also changed. As the constraint is set severer, the more wells are required and the well on the down-gradient direction of the plume hot-spot shows more efficient remediation performance than that on the hot-spot position. These results show that the more profitable strategy for remediation can be achieved by increasing the required remediation time than raising the pumping rate until the time reaches a certain limitation level. So, the remediation time has to be considered as one of the essential decision variables for optimal remediation design.

H52B-0854 1330h POSTER

Simulation of Vertical Displacement of Hydrocarbons Coupled with Aerobic Biodegradation in Porous Media.

Maria del Carmen Hernandez-Rendon (55-56-22-41-31; carmenhr@tonatiuh.igeofcu.unam.mx)

Instituto de Geofisica, UNAM, Circuito de la Investigacion S/N, Ciudad Universitaria, Mexico, D.F., D.F 04510, Mexico

A mathematical and numerical model for simulate transport of hydrocarbons in porous media is presented. Since only a few components of these fluids are slightly soluble in water, a multiphase approach is adopted. The model takes into account hydrodynamic, chemical and biological phenomena that are important during subsurface transport and fate of contaminants. Three phases are considered: water, gas and immobile oil. The model takes into account the transport of the organic contaminant as well as oxygen in water and gas phases. A system of nonlinear, coupled, parabolic, mass balance partial differential equations (PDE's) and a set of constitutive equations govern the whole process. Darcy's law is incorporated and Fick's first law governs diffusion. It is assumed that the residual organic phase does not affect the movement of the aqueous and gas phases. In this way, a two phase hysteretic model is used for capillary pressure and relative permeabilities. Non equilibrium relationships are employed for dissolution and volatilization, and linear equilibrium is assumed for sorption. Monod type constitutive equations are included to account for biodegradation. A sequential solution algorithm that decouples the system of PDE's is employed. While using a fractional flow formulation for the flow system, an elliptic water pressure equation and a nonlinear parabolic water saturation equation are obtained. For the transport equations and, in order to avoid stiff matrices, an operator splitting method is applied in such a way that, the advection-diffusion part is solved apart. Standard Picard linearization is applied and the spatial advection-diffusion part is discretized by Trefftz-Herrera collocation method. It has some advantages in comparison with standard Galerkin finite element method.

H52B-0855 1330h POSTER

Scaling DNAPL Migration From the Laboratory to the Field

Paul T Imhoff[1] (302-831-0541; imhoff@udel.edu)

Amy S. Mann[1] (302-323-4542; polkadottie@yahoo.com)

Mark Mercer[2] (703-308-8652; mercer.mark@epamail.epa.gov)

Michael Fitzpatrick[2] (703-308-8411; fitzpatrick.mike@epamail.epa.gov)

[1]University of Delaware , Department of Civil and Environmental Engineering, 301 DuPont Hall, Newark, DE 19716, United States

[2]U.S. EPA Office of Solid Waste , Hazardous Waste Corrective Action Program, 401 M Street SW, Washington, DC 20460, United States

When dense nonaqueous phase liquids (DNAPLs) are released into the subsurface, an important problem is identifying where the DNAPL is and if it is still moving. This question is perhaps most important at sites where thousands of cubic meters of DNAPL were released over decades. While large DNAPL releases are outnumbered by smaller DNAPL spills, the most significant risk to the environment and human health may be associated with large DNAPL spill sites.

To our knowledge no laboratory studies have examined DNAPL migration over the length and time scales associated with large DNAPL releases. In this investigation a laboratory tank experiment was conducted to examine DNAPL migration over these scales. Modified inspectional analysis was used to develop relationships for scaling observations from the laboratory model to four hypothetical spill scenarios in the field, all of which had large DNAPL releases. One scenario was compared to an actual DNAPL spill site. The length and time scales of DNAPL movement predicted from our analysis were consistent with those predicted from a numerical model of this site. The methodology developed in this work may prove useful for scaling results from other laboratory investigations of DNAPL migration to field-scale systems. Our results also challenge the common conceptual model of a stationary DNAPL source with only a migrating aqueous phase plume when large DNAPL volumes are released.

H52B-0856 1330h POSTER

Single Degree of Freedom Calculation of Multi-dimensional Multiphase Porous Medium Flow and Transport

Melissa C. McKay[1] (802/656-7789; mcmckay@emba.uvm.edu)

George F. Pinder[1] (802/656-8697; pinder@emba.uvm.edu)

Franco Fedele[1] (802/656-8140; ffedele@emba.uvm.edu)

Joseph Guarnaccia[2] (732/914-2516; joseph.guarnaccia@cibasc.com)

[1]Department of Civil and Environmental Engineering University of Vermont, 213 Votey Bldg., Burlington, VT 05405, United States

[2]Ciba Specialty Chemicals Corp., Oak Ridge Parkway PO Box 71, Toms River, NJ 08754, United States

Classical collocation methods utilizing Hermite basis functions have been widely used to accurately solve multi-phase groundwater flow and transport problems in both two and three dimensions. However, due to inefficiencies inherent in the classical collocation method, the computational time required to solve large-scale problems limits its widespread use. However, when this complex model is modified to utilize a new numerical concept based upon a localized collocation formulation, the computational efficiency of the code is significantly enhanced. The new approach first approximates the equations using standard collocation methods with cubic Hermite functions. The resulting derivative functions are then represented using Lagrangian functions. This reduces the number of nodal unknowns from 4 to 1 in 2D, and from 8 to 1 in 3D. Solutions to the multiphase groundwater flow and transport equations obtained using the classical and new formulation were compared for accuracy as well as efficiency.

H52B-0857 1330h POSTER

A Computationally Cost Effective Approach to Modeling Transport of Multicomponent VOC mixtures in the Vadose Zone. Validation With Field Data

Petros Gaganis[1] (30-0610-965-220; pgaganis@iceht.forth.gr)

Vasilis N. Burganos[1] (30-0610-965-215; vbur@iceht.forth.gr)

[1]Institute of Chemical Engineering and High Temperature Chemical ProcessesFoundation for Research and Technology, Hellas (ICE/HT-FORTH), P.O. Box 1414, Stadiou Str, Patras 265 04, Greece

A major difficulty that is typically encountered when real contamination problems are investigated is the typically large number of constituents in the actual VOC mixture compared to the number of species that can be handled numerically. An approach to dealing with complex mixtures of individual hydrocarbons while reducing the computational cost is to define a small number of effective composite constituents to simulate the average behavior and fate of groups of individual hydrocarbons in the subsurface. However, there are two additional sources of uncertainty associated with this technique that may influence the reliability of model predictions, namely, the time dependence of the effective properties of a composite constituent due to temporal composition changes, and the approximation in determining their effective property values. An approach to limit these sources of uncertainty was developed recently by the authors based on experimental data from a lysimeter study that involved artificially mixed kerosene. The minimization of the time dependence of the effective thermodynamic properties of the composite constituents is achieved through a methodology for optimizing component grouping, based on the minimization of an objective function. Simple arithmetic averages are found to provide poor approximations to the effective group properties and alternative algorithms are proposed to express the effective property values of composite constituents in terms of property values of the member components. The applicability of this approach to large-scale contamination problems is demonstrated here using data from field studies. Compared to the case of simulating all organics as individual compounds, our approach offers the advantage of a greatly reduced computational cost, reduced data requirements, as well as a smaller impact of the uncertainty in the compound properties on modeling results because effective values are used for each composite constituent, which follow a pdf with reduced variance compared to that of the individual values.

H52B-0858 1330h POSTER

Validation of the Multiscale Thermohydrologic Model for the Yucca Mountain Repository

Thomas A. Buscheck[1] (925-423-9390; buscheck1@llnl.gov)

Lee G. Glascoe[1] (925-423-2922; glascoe@llnl.gov)

Kenrick Lee[1] (925-422-8492; lee23@llnl.gov)

James Gansemer[1] (925-422-2716; gansemer1@llnl.gov)

Yunwei Sun[1] (925-422-1587; sun4@llnl.gov)

[1]Lawrence Livermore National Laboratory, Mailstop L-646, Livermore, CA 94551, United States

Design evaluation and performance assessment of the repository at Yucca Mountain require a thermohydrologic (TH) modeling tool that simultaneously accounts for TH processes occurring at a scale of a few tens of centimeters around individual waste packages and emplacement drifts, and for heat flow at the multi-kilometer scale of the mountain. The MultiScale ThermoHydrologic Model (MSTHM) is a computationally efficient alternative to a monolithic TH model by virtue of its breaking the problem into smaller tractable pieces. For a complete MSTHM realization, four families of NUFT-submodel calculations, of varying detail and scale, are conducted. The final MSTHM output is obtained by superposition of 3-D mountain-scale and 3-D drift-scale thermal-conduction-submodel results onto those of 2-D drift-scale TH-submodel results. The MSTHM has been previously validated against a monolithic TH model that uses a nested mesh. Excellent agreement was observed between the MSTHM and the monolithic TH model in the predictions of temperature, relative humidity and liquid saturation. Presented here is a continuation of the prior validation effort, including additional variables such as liquid-phase flux and evaporation rate. This study also addresses the validation of key assumptions utilized in the MSTHM approach, such as that of negligible vapor flow along emplacement drifts. This validation exercise also addresses waste packages emplaced at the outer edges of the repository. Using the monolithic TH model, a sensitivity study is conducted to determine the threshold bulk-permeability value for which buoyant gas-phase convection begins to significantly influence TH conditions in emplacement drifts. The results of the bulk-permeability sensitivity study demonstrate the reasonableness of using thermal-conduction submodels to represent mountain-scale heat flow at Yucca Mountain.

H52B-0859 1330h POSTER

Thermohydrologic modeling of the large-block test in partially saturated fractured tuff at Yucca Mountain, Nevada

Kenrick Lee[1] (925-422-8492; lee23@llnl.gov)

Thomas A. Buscheck[1] (925-423-9390; buscheck1@llnl.gov)

Lee G. Glascoe[1] (925-423-2922; glascoe@llnl.gov)

James Gansemer[1] (925-422-2716; gansemer1@llnl.gov)

Yunwei Sun[1] (925-422-1587; sun4@llnl.gov)

[1]Lawrence Livermore National Laboratory, Mailstop L-646, Livermore, CA 94551, United States

In support of the characterization of Yucca Mountain as a potential site for as a geologic repository for high-level nuclear waste, the US Department of Energy conducted the Large Block Test (LBT) at nearby Fran Ridge. The LBT was conducted in an excavated 3x 3x 4.5m block of partially saturated, fractured nonlithophysal Topopah Spring tuff, which is one of the host-rock units for the potential repository at Yucca Mountain. The LBT was one of a series of field-scale thermohydrologic tests conducted in the repository host-rock units. The LBT was heated by line heaters installed in five boreholes lying in a horizontal plane 2.75 m below the upper surface of the block. The field-scale thermal tests were designed to help investigators better understand the coupled thermohydrologic-mechanical-chemical processes that would occur in the host rock in response to the radioactive heat of decay from emplaced waste packages. The tests also provide data for the calibration and validation of numerical models used to analyze the thermohydrologic response of the near-field host rock and Engineered Barrier System (EBS).

Using the NUFT code and the dual-permeability approach to representing fracture-matrix interaction, we simulated the thermohydrologic response of the block to a heating and cooling cycle. The primary goals of the analysis were to study the heat-flow mechanisms and water redistribution patterns in the boiling and sub-boiling zones, and to compare model results with measured temperature and liquid saturation data, and thereby evaluate two rock property data sets available for modeling thermohydrologic behavior in the rock. Model results were also used for model calibration and validation. We obtained a good to excellent match between model and observed temperatures, and found that the distinct dryout and condensation zones modeled above and below the heater level agreed fairly well with the liquid-saturation measurements. We identified the best-fit data set by using a statistical analysis to compare model and field temperatures, and found that heat flow in the block was dominated by conduction.

H52B-0860 1330h POSTER

A Mountain Scale Model of Hydrothermal and Geochemical Processes

William E. Glassley[1] (925-422-6499; glassley1@llnl.gov); James Gansemer[1] (925-422-2716; gansemer1@llnl.gov); Thomas A. Buscheck[1] (925-423-9390; buscheck1@llnl.gov); Yunwei Sun[1] (925-422-1587; sun4@llnl.gov); Lee G. Glascoe[1] (925-423-2922; glascoe@llnl.gov); Kenrick Lee[1] (925-422-8492; lee23@llnl.gov)

[1]Lawrence Livermore National Laboratory, Mailstop L-646, Livermore, CA 94551, United States

When conducting numerical simulations of interactions between thermal, hydrological and geochemical processes in porous rock systems, the system of nonlinear partial differential equations describing mass balance, energy balance, and equilibrium and kinetic reactions is usually solved by complex numerical procedures. For this reason, the coupled modeling of hydrothermal and geochemical processes is computationally expensive and often limited to strict assumptions regarding system properties and complexity, simple chemical and mineralogical systems, or small scale problems. In this presentation we provide a mountain scale model which includes a wide range of subsurface hydrothermal and geochemical processes using a multi-scale modeling approach. Hydrothermal and geochemical variables are fully described in "low-level" models and information from these low-level models is abstracted and upgraded to the mountain scale model. We use this model to evaluate the consequences of different design alternatives on the performance of a geological repository for high level nuclear waste in fractured, porous volcanic tuffs, such as those at Yucca Mountain, Nevada.

H52B-0861 1330h POSTER

Development Of Groundwater Model For Western Barind Of Bangladesh

Syeda Fahliza Begum[1] (81-52-789-2523; fahliza@eps.nagoya-u.ac.jp)

Mohammad Rezwanul Islam[1] (81-52-789-2523; m_r_islam2000@yahoo.com)

Katsuro Ogawa[1] (81-561-61-3410; ogawa@hm.aitai.ne.jp)

[1]Nagoya University, Department of Earth and Planetary Sciences Graduate School of Sciences Nagoya University Chikusa-ku,, Nagoya 464-8602, Japan

Hydraulic parameters and spatial and temporal distribution of hydraulic heads of a confined aquifer underlying in a sedimentary basin situated in western Barind of Bangladesh has been evaluated by using a three-dimensional ground water flow model. The unconsolidated sand aquifer of this area is experiencing gradual declination of ground water level due to over pumping. The average declination rate from 1986 to 1997 is 0.3 m/year and from 1993 to 1997 it is 0.54 m/year. The model incorporates the movement of ground water with constant density through heterogeneous porous media with constant head boundary condition. These phenomena, expressed by partial differential equations, are solved by using a finite difference method is in a three dimensional cartesian coordinates. Alternating Directional Implicit (ADI) method combined with Thomas algorithm is used to shorten the computational time. The model program is written in auto compiler type Future Basic 3 (Release 4) for Macintosh. By using this model a numerical solution of pumping test data has been performed. Simulation is carried out for multi (four) layered aquifer system. Validation are carried out by comparing the model predictive results with field measurements.Simulated water heads satisfactorily match with observed ones. In the calibration, hydraulic head is strongly controlled by the values of storativity. Considering distance between two pumping wells with capacity of 0.056 m^3/sec in the study area, spatial distribution of simulated hydraulic head shows that well interference may occur within 10 to 20 minutes of pumping started. The simulated values of diffusivity (122400 to 1995200 m^2/day), transmissivity (402 to 4520 m^2/day), permeability (22 to 200 m/day) and storativity (5times10^4 to 0.01) can play an important role in proper management and development of ground water resource in the study area.

Key words Ground water flow model, Pumping test, Hydraulic head, Hydraulic properties, Barind, Bangladesh.

H52B-0862 1330h POSTER

Development and Application of a Multilevel - Multitracer Test Method for Subsurface Investigation and Testing of Stochastic Models for the Delineation of Wellhead Protection Zones in Heterogeneous Porous Aquifers

Eugeniu Martac[1] (+49-7071-2974691; eugeniu.martac@uni-tuebingen.de)

Thomas Ptak[1] (+49-7071-2775238; thomas.ptak@uni-tuebingen.de)

[1]University of Tuebingen, Center for Applied Environmental Geoscience, Sigwartstrasse 10, Tuebingen D-72076, Germany

Used as measures against polluted drinking water, wellhead protection zones are assigned based on the residence time concept. A prerequisite for the application of this concept is the investigation of subsurface properties. In order to assess the solute transport behavior in highly heterogeneous alluvial aquifers, which are very often exploited for drinking water needs, a multitracer test method has been developed and tested at the "Lauswiesen" experimental field site close to the city of Stuttgart in Germany. The observed aquifer heterogeneity generally confirms the need for a 3D investigation approach. Therefore the design and implementation of the tracer test instrumentation involves an improved multilevel setup. To reproduce the flow situation of a well field and to shorten the duration of the experiments, the tracer tests are run under convergent flow forced gradient conditions. To consider multiple flow directions, different tracers are injected instantaneously into fully penetrating groundwater monitoring wells across the saturated aquifer thickness at the same time. The injection wells are positioned around a pumping well, and multilevel breakthrough curves are measured within the pumping well itself using a flow separation technique. To obtain a high temporal and spatial resolution, on-line measurement equipment is used (multilevel fiber optic fluorimeters for fluorescent tracers). At the "Lauswiesen" experimental field site, one salt tracer and five fluorescent tracers were used, with different transport distances of up to 250 m in order to obtain data at multiple transport scales. The recorded multilevel-multitracer breakthrough curves can serve to estimate aquifer transport parameters, to characterize subsurface heterogeneity, to directly delineate protection areas as well as to test transport predictions obtained from deterministic or stochastic model approaches, which are used to quantify the uncertainty in the delineation of wellhead protection zones. This paper presents the method, the experimental setup, and first results from the application.

H52B-0863 1330h POSTER

Electrical Imaging of Tracer Migration at the Massachusetts Military Reservation, Cape Cod

Kamini Singha[1] (ksingha@pangea.stanford.edu)

Andrew M. Binley[2] (a.binley@lancaster.ac.uk)

Steven M. Gorelick[1] (gorelick@pangea.stanford.edu)

[1]Stanford University, Dept. of Geological and Environmental Sciences, Building 320, Geology Corner, Stanford, CA 94305, United States

[2]Lancaster University, Institute of Environmental and Natural Sciences, Lancaster LA1 4YQ, United Kingdom

Accurately characterizing flow and solute transport in groundwater systems is a critical problem in hydrology. Given the large volume of data required to develop an accurate model of subsurface flow, and the cost of direct sampling, the use of geophysical methods can contribute significantly to information about the subsurface. Electrical resistance tomography (ERT) is examined as a method to provide spatially continuous information about aquifer properties. The primary goal of this study is to use ERT to map subsurface flow paths in detail. High-resolution images of the movement of a tracer in two- and three-dimensions help delineate aquifer heterogeneity. Field data were acquired at the U.S. Geological Survey research site at the Massachusetts Military Reservation, Cape Cod during the summer of 2002. ERT was used to track the flow and transport of an electrically conductive sodium chloride tracer introduced over 9 hours during a two-well tracer test. Three hundred and fifty 2-D data sets were collected between four corner-point wells for 20 days following the injection, combining to form approximately sixty 3-D data sets. Concentrations were measured at a multilevel sampler centrally located within the ERT array and at the production well.

The tomograms indicate the movement of the saline tracer that correspond well with measured concentration data, and the resistivity inversions serve as an appropriate surrogate for concentration measurements that are otherwise impossible to obtain. Under reasonable assumptions, groundwater velocity estimates and hydraulic conductivity can be obtained by tracking the tracer.

H52B-0864 1330h POSTER

Hydrostratigraphy of the Westside Groundwater Basin, San Francisco and San Mateo Counties, California

Erdmann H Rogge[1] (650-363-4355; erogge@co.sanmateo.ca.us)

Matthew J LaForce[1] (415-338-6869; laforce@sfsu.edu)

[1]San Francisco State University - Department of Geosciences, 1600 Holloway Ave, San Francisco, CA 94132, United States

The Westside Groundwater Basin is a coastal aquifer system located on the San Francisco Peninsula between Golden Gate Park and Burlingame. Since the beginning of the 20th century groundwater from the Basin has been used for drinking water and irrigation purposes. Unfortunately, the Basin wide potentiometric surface has gradually declined and saltwater intrusion from the Pacific Ocean is threatening this fragile aquifer system. Several studies have looked at groundwater movement within the Basin (Boone, Cook and Associates (1987), Yates et al. (1990), Applied Consultants (1991), Geo/Resources Consultants (1993), Phillips et al. (1993), CH2Mhill (1997)); unfortunately, all of the studies assumed horizontal layering of the hydrostratigraphic units. However, recent studies indicate that tectonic deformation and intense folding has altered the stratigraphy of the Westside Basin close to the Pacific Ocean (Bonilla (1998), Barr (1999)). Accordingly, the purpose of this study is to delineate hydrostratigraphic units within the Westside Basin by using tritium, helium, and oxygen isotopes in conjunction with general mineral water quality data, water level data, and geologic cross-sections to depict the subsurface hydrogeology of the system. Our results indicate that the upper part of the Merced Formation (sequences P through Z of Clifton and Hunter (1991, 1999)) forms the major hydrostratigraphic units where groundwater is extracted, and that the Serra Fault separates the upper part of the Merced from the lower part (below sequence P) along most of its extent. In addition, thick clay layers, observed in well logs and identified in cross sections, were tentatively correlated with sequences W and S2. These clay layers, although discontinuous at places, work as aquitards between the hydrostratigraphic units as the difference in water chemistry and age indicates.

H52B-0865 1330h POSTER

The Geophysical Investigation of Drinkable Water at Shkodra Region

Idriz B Jata[1] (+355-42-3758; Ijata@yahoo.com)

Vladimir S Kavaja[1] (+355-42-33758; Kavajav@yahoo.com)

Armand N Kotori[2]

[1]Geophysical Center, Blloku Vasil Shanto,Qendra Gjeofizike, Tirana 0000

[2]Mining and Processing Technology institute, Blloku Vasil Shanto, Tirane 0000

The drinkable water has been and is a great problem for the population of Shkodra region , NW of Albania. Many studies have been widely used in this domain by Geophysical Center of Tirana.Two case histories are presented in this paper.One, the Drini river terraces and other example near coast line.Actually, the need from fresh water are increasing due to the high demand for water supply. In compliance with geographical and geological classification the survey is in a narrow sense belongs to marginal part of the Nenshkodra plain. Geological situation of survey area consists on diverse geological make up.The stratigrafic section begins with carbonate formations (Cr2) have a monoclyne structure, nearly NW-SE trending. Paleogene formations is composed mainly: by carbonatic flysch (Pg2), alevrolitic-sanstone formation(Pg31 Pg32) and Oligocene deposits with alevrolitic-clay-sandston formation (Pg13). Quaternary formation interbeded by silt, clay, sand and gravel layers. In survey area the thickness of concerned younger deposits does not surpass 50-70m, therefor we were able to draw up a picture of the thickness and depositional conditions of the Quaternary accumulations as corresponding in precision to given scale. The aim of the study is been delineation of aquifers and aquicludes soils extension within terrace profile based in the resistivity parameter as well as zone of aeration and water table. In the paper are described all the phases from field measurements, data processing and interpretation, as well as the soil thickness and resistivity maps, the thickness and resistivity maps of gravel terraces was build up. The high resistivity values show best aquifers gravel deposits. But when the gravel terrace companies with large thickness of the layers it is practical to multiply these two parameters, Hi x *i = S. In the other hand, one and more important maps are the correlation of rocks permeability T (sq.m/day) with transversal resistivity (S) parameters. In preparing such maps the descriptive logs of latest survey boreholes and resistivity data of field have been provided by vertical electric soundings extending over whole area was fundamental.Histories of terrestrial erosion,near shore sediment and land-sea interaction are obvious now. For a gravel deposition, in addition to the usual parameter maps as resistivity and thickness maps, combined multiparametric characterization maps have been plotted. These maps are more application on hydrogeologic domain than conventional parameter maps. Based in above maps are shown prospective areas in Quaternary deposits, in which the drillings have the positive results for fresh water.

H52B-0866 1330h POSTER

A new Flow-Log Technique Suitable for Small Flow Rates in Deep Drillings

Werner Grasle[1] (++49-511-643-3467; W.Graesle@gga-hannover.de)

Winfried Kessels[1] (++49-511-643-3547; W.Kessels@gga-hannover.de)

Haifa Rifai[1] (++49-511-643-3537; H.Rifai@gga-hannover.de)

[1]Leibniz Institute for Applied Geosciences (GGA), Stilleweg 2, Hannover 30655, Germany

In the pilot borehole of the German deep continental drilling project (KTB) a new flow-log technique was tested to assess the permeability distribution for the open hole section (3850m to 4000m). Because of the extremely low permeabilities usually found in the crystalline crust at this depth only small flow rates are achievable when applying an injection pressure of 0.1 to 0.3 MPa. The corresponding flow velocities in the drilling are to low to be measured with most of the conventional flow-log techniques. Within an injection test lasting seven days the downward movement of a freshwater to saltwater transition in the borehole was monitored using a borehole tool measuring mud resistivity, temperature and fluid pressure. These observations were used to derive a permeability distribution for the open hole section. Whereas the technical expense required for this technique is fairly moderate, the data processing involves some major problems caused by errors of depth measurement, temporal variations of the injection rate and the changes of the fluid density distribution during the injection process.

The calculation of flow velocities is based on differential quantities. Therefore, differential errors of the depth recording which usually occur when starting or stopping the movement of a borehole tool can not be

neglected as can be done for most other logging purposes. A method of depth correction based on high resolution fluid pressure data had to be developed to overcome this problem.

The conditions of the injection process are heterogeneous with respect to time and to depth. At the beginning of the injection process the vertical fluid pressure gradients in the formation and in the borehole were identical for the whole open hole section. While the freshwater to saltwater transition moves downward an increasing part of the open hole section is filled with a lower density fluid resulting in a smaller vertical pressure gradient within the borehole. Thus the horizontal pressure gradient between borehole and formation that governs the injection process decreases faster in the upper part of the open hole section than in its lower part. Consequently semi-analytical solutions valid for simple boundary conditions are not applicable for this injection test. This results in the necessity to employ numerical modeling techniques to determine the vertical distribution of hydraulic parameters.

H52B-0867 1330h POSTER

A numerical analysis on the applicability of the water level fluctuation method for quantifying groundwater recharge

Min-Ho Koo[1] (+82-41-850-8515; koo@kongju.ac.kr)

Dae-Ha Lee[2] (+82-42-868-3078; renee@kigam.re.kr)

[1]Kongju National University, Dept. of Geoenvironmental Sciences 182 Shin Kwan-dong, Kongju 314-701, Korea, Republic of

[2]Korea Institute of Geoscience and Mineral Resources, Environmental Geology Division, 30 Gajeong-dong, Yuseong-gu, Daejon 305-350, Korea, Republic of

The water table fluctuation(WTF) method is a conventional method for quantifying groundwater recharge by multiplying the specific yield to the water level rise. Based on the van Genuchten model, an analytical relationship between groundwater recharge and the water level rise is derived. The equation is used to analyze the effects of the depth to water level and the soil properties on the recharge estimate using the WTF method. The results show that the WTF method is reliable when applied to the aquifers of the fluvial sand provided the water table is below 1m depth. However, if it is applied to the silt loam having the water table depth ranging 4∼10m, the recharge is overestimated by 30∼80%, and the error increases drastically as the water table is getting shallower. A 2-D unconfined flow model with a time series of the recharge rate is developed. It is used for elucidating the errors of the WTF method, which is implicitly based on the tank model where the horizontal flow in the saturated zone is ignored. Simulations show that the recharge estimated by the WTF method is underestimated for the observation well near the discharge boundary. This is due to the fact that the hydraulic stress resulting from the recharge is rapidly dissipating by the horizontal flow near the discharge boundary. Simulations also reveal that the recharge is significantly underestimated with increase in the hydraulic conductivity and the recharge duration, and decrease in the specific yield.

H52B-0868 1330h POSTER

Estimation of Relative Recharge Sequence to Groundwater with Minimum Entropy Deconvolution

Taehee Kim[1] (82-2-522-6116; thkim@nexgeo.com)

Kang Keun Lee[2] (82-2-880-8161)

[1]Nexgeo Ltd, Seung-Jung Building 401, 1485-3, Secho-Dong, Seocho-Gu, Seoul, South Korea, Seoul 137-070, Korea, Republic of

[2]Seoul National University, School of Earth and Environmental Sciences, Seoul National University, Shillim-Dong, Kwanak-Gu, Seoul, South Korea, Seoul 151-742, Korea, Republic of

Groundwater is widely used as natural resources for the drink, spa, etc., and a supplement to the official and/or natural water supply. In these cases, the establishment of water balance model can provide a safe and effective usage of resources. To establish the appropriate water balance model and the design of water usage, recharge rate must be estimated with an allowed accuracy. For these purposes, many methods were suggested to estimate recharge rate. One of most popular methods in recent years is measuring groundwater age with environmental tracer(Solomon et. al., 1993; Leduc et. al., 1997; Bromley et. al., 1997; Williams, 1997; Ayalon et. al. 1998). Using the distributed environmental tracer, the vertical profile of groundwater age can be composed, and recharge rate can be estimated with the composed profile. Water budget analysis can be the other one of available method(Bradbury and Rushton, 1998; Finch, 1998; Bekesi and McConchie, 1999). However, to explain the expansion of contaminant with temporal variation of unsaturated flow, sequential estimation of recharge must be needed. Unfortunately, it is a very hard work to find out some studies on sequential approaches to estimate the recharge rate to groundwater. Even predictive deconvolution technique was rarely. In general, minimum phase condition, preposition of classical predictive deconvolution, can hardly be satisfied in nature. On the contrary, the input signal in natural system can be considered as a random signal. To avoid the strong restriction of minimum phase condition, Wiggins(1978) proposed minimum entropy deconvolution(MED) with varimax norm. However, solution process with varimax norm is non-linear. For the linearization of MED problem, Carbrelli suggested another criterion, D norm(1984). In this study, MED with D norm was applied to the estimation of the sequence of relative recharge rate, and the applicability of MED to evaluation of recharge sequence was investigated. To check out the applicability of MED to the estimation of relative recharge sequence, synthesized data set and two real data set were applied. To compare the estimated results with source wavelets, cross-correaltion coefficient was adopted. Cross-correaltion in synthesized cases are over 0.9, and in real case with rainfall sequence is 0.73 0.8. The cross correlations in both of two cases indicate that results from MED are the appropriate estimations of recharge sequences.

H52B-0869 1330h POSTER

Investigation of the nitrogen isotope chemistry of an urban aquifer: a case study of the Nottingham Sherwood sandstone, UK

Kevin M Hiscock[1] (K.Hiscock@uea.ac.uk); Teppei Fukada[1] (T.Fukada@uea.ac.uk); Richard G Taylor[2] (r.taylor@geog.ucl.ac.uk); Aidan A Cronin[3] (a.a.cronin@surrey.ac.uk); Jason D Fairbairn[1] (jason.fairbairn@environment-agency.gov.uk); Paul F Dennis[1] (P.Dennis@uea.ac.uk)

[1]University of East Anglia, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom

[2]University College London, Department of Geography, University College London, London WC1H 0AP, United Kingdom

[3]University of Surrey, Robens Centre for Public and Environmental Health, University of Surrey, Guildford GU2 7XH, United Kingdom

The potential for exploitation of urban aquifers is dependent on understanding the distribution and fate of surface-derived contaminants. Land application of inorganic fertilisers and organic manure as well as leaking sewer lines are likely sources of NO3- that can affect the use of groundwater for public supplies. In providing some of the first measurements of 18O-NO3- in an urban aquifer, we measured dual-isotopic and hydrochemical parameters at two multi-level piezometers and eleven shallow boreholes in the layered Triassic sandstone aquifer below Nottingham in the English Midlands. Measurements of 15N-NO3- in the range +9.16 to +42.21 for depth samples from the piezometers and NO3- concentrations from 7.6 to 66.7 mg/L are evidence for sewage-derived inputs. By comparing 15N-NO3- and 18O-NO3- data, it was shown that groundwater in one of the piezometers (the Meadows) is experiencing denitrification to explain the most enriched isotopic signatures. The predominantly sewage-derived source for the dissolved NO3- is corroborated by total B and microbiological parameter values. The contrasting, generally lower nitrogen and oxygen isotope compositions for the second piezometer (Old Basford) are influenced by a nearby groundwater abstraction that draws less contaminated groundwater (15N-NO3- = +9.16 , 18O-NO3- = +8.21) into a coarse sandstone horizon.

H52B-0870 1330h POSTER

Dispersion Measurements in Highly Heterogeneous Laboratory Scale Porous Media

Steven P Sternberg (1-218-726-6165; ssternbe@d.umn.edu)

University of Minnesota Duluth, Department of Chemical Engineering, Duluth, MN 55812-2496, United States

Laboratory experiments and numerical simulations investigate contaminant transport in a heterogeneous porous medium. The laboratory experiments were performed in cylindrical columns 1-meter long and 3.5 cm inside diameter filled with spherical glass beads. Concentration breakthrough curves are measured at a scale much finer than the size of the heterogeneity. Numerical simulations are based on a random walk in a known constant velocity field. The heterogeneity is a distinct, discontinuous change in the local permeability field. Fluid flow is miscible, flowing in a saturated porous medium. Previous work has shown this to be a very poorly understood phenomenon. The measurements reported here help to better understand how dispersion evolves through and past a heterogeneity.

H52B-0871 1330h POSTER

Analytical Modeling of Contaminant Transport with Convergent Reactions

Yunwei Sun[1] (925-422-1587; sun4@llnl.gov)

Thomas A. Buscheck[1] (925-423-9390; buscheck1@llnl.gov)

Xinjian Lu[2] ((510) 885-4276; xlu@csuhayward.edu)

[1]Lawrence Livermore National Laboratory, Mailstop L-646, Livermore, CA 94551, United States

[2]Department of Computer Information Systems, CSU Hayward, Hayward, CA 94542-3067, United States

In this presentation, we provide analytical solutions for reactive transport with convergent reactions using the singular value decomposition approach. We consider a reaction network in which a compound reacts to form multiple daughter products, which further react to a single granddaughter. This reaction scheme is illustrated by the dechlorination of tetrachloroethylene (PCE) and trichloroethylene (TCE). PCE reacts to produce TCE and TCE reacts to form three daughter products, cis-1,2-dichloroethylene (cis-1,2-DCE), trans-1,2-dichloroethylene (trans-1,2-DCE), and 1,1-dichloroethylene (1,1-DCE). Three DCEs will further react to form the same product, vinyl chloride (VC). Finally, VC reacts to produce ethene (ETH). In achieving the analytical solution, all reactions are assumed to be first-order. Because the partial differential equation describing the reactive transport of a compound may be coupled by multiple reactant concentrations, currently the problem must be solved numerically. We analytically conduct the singular value decomposition and decouple the system of transport equations with convergent reactions into orthogonal (independent) subsystems. Previously published analytical solutions become the basic solutions in the transformed domain for each independent subsystem. The solutions in real concentration domain are obtained using the inverse transform.

H52B-0872 1330h POSTER

Reducing Dependence upon "the Grid": A Framework for Contaminant Transport Modeling using Analytic Flow Solutions

James R Craig[1] ((716)-645-2839 x2508; jrcraig2@acsu.buffalo.edu)

Alan Rabideau[1] ((716)-645-2114 x2327; rabideau@eng.buffalo.edu)

[1]State University of New York at Buffalo, Dept. of Civil, Structural & Environmental Engineering Jarvis Hall Rm. 207, Buffalo, NY 14260-4400, United States

The development of localized reactive remediation strategies (i.e. reactive barriers, bioremediation, chemical oxidation, etc.) has progressed rapidly in recent years. With such progress, there is a distinct need for contaminant transport models that simulate complicated reaction phenomena at much finer scales than the extent of hydrodynamic transport. These systems are currently difficult to model at the desired local resolution due to the computational burden of cell size constraints. One of the tactics for adequately representing such systems is to reduce the dependence on grid-based flow models. Operator splitting allows transport models to be integrated into analytic, grid-free flow solutions such as those provided by the analytic element method (AEM). Modeling contaminant advection via AEM combined with Eulerian-Lagrangian methods or streamline techniques removes many of the constraints placed upon transport models by grid cell size. In addition, AEM provides the benefit of continuous, analytic velocities, thus freeing the model from inaccuracies attributable to velocity interpolation techniques.

The analytic element method models groundwater flow via the superposition of analytic functions ("elements") that represent hydrogeologic features. Each of these functions (and therefore the final velocity field) is continuous. The computational burden associated with a model is dependent upon the number of features, rather than the scale, of the system. Therefore, while the analytic element method represents the flow field in an entirely grid-free manner, it also is quite efficient in modeling the mixed-scale hydraulic systems associated with many remediation techniques.

A framework is developed for incorporating advection-dominated contaminant transport into AEM. The random walk method, the method of characteristics, and streamline methods are revised to operate within a continuous flow domain and exploit the analytic nature of the velocity field. The benefits of these revised methods are described in the context of systems with complex chemical behavior at short length scales

and significant hydrodynamic transport behavior at long length scales (i.e. remediation systems). The development of this new framework for mechanical contaminant transport will allow for the computational burden of complex reactive transport models to lie almost entirely within the reactive portion of the transport simulation.

URL: http://www.groundwater.buffalo.edu

H52B-0873 1330h POSTER

Iterative Split-Operator Approaches for Approximating Advection Dominated Nonlinear Reactive Transport Problems

Joseph F Kanney[1] ((919) 966-7892; joe_kanney@unc.edu)

Matthew W Farthing[1] ((919) 966-7892; matthew_farthing@unc.edu)

Cass T Miller[1] ((919) 966-1024; casey_miller@unc.edu)

[1]University of North Carolina, Department of Environmental Sciences and Engineering, CB 7431, Chapel Hill, NC 27599-7431, United States

Split-operator (SO) approaches are often used to compute numerical solutions to nonlinear reactive solute transport problems. SO methods are timestep-splitting methods that separate the reactive transport problem into transport and reaction sub-problems, thus avoiding many costly matrix operations and allowing the best numerical method to be used for each process. But this uncoupling also introduces an additional source of numerical error, known as the splitting error. In standard (non-iterative) SO approaches, the splitting error is reduced at the expence of reducing the timestep. By contrast, the iterative split-operator (ISO) algorithm removes the splitting error through iteration. But standard ISO methods can converge quite slowly. In recent work, we have proposed several techniques to accelerate ISO convergence for nonlinear reactive transport problems. These convergence acceleration techniques include solution projection methods and interpolation of lagged operator estimates over a timestep. Theoretical analysis and numerical experiments indicate that a second-order convergence rate can be achieved for problems which are sufficiently smooth. In this presentation we report on efforts to extend the above mentioned techniques to advection dominated transport problems, which are characterized by sharp concentration fronts. We will discuss our efforts to combine the convergence acceleration techniques with several high-resolution finite difference schemes for advective transport.

H52B-0874 1330h POSTER

Coupled Groundwater and Heat Flow in the Tahoe Basin Region

James C Trask[1] ((530)756-3244; jctrask@ucdavis.edu)

Graham E Fogg ((530)752-6810; gefogg@ucdavis.edu)

[1]Hydrologic Sciences Program, UC Davis, Hydrologic Sciences Office Veihmeyer Hall University of California, Davis, Davis, CA 95616, United States

We propose that recent developments in available temperature probe technology and improvements in appropriate modeling software, together with the advent of desktop high-speed computing, have enabled the thermal analysis approach to be an inexpensive, robust, and practical way to constrain groundwater flow fields in a wide variety of environments. We present field measurements and numerical models of coupled heat and groundwater flow in the Tahoe Basin region.

In montane regions such as the Tahoe Basin, steep topography provides a driving force for deep groundwater flow. Deep groundwater flow re-routes subsurface heat flow, impacting temperature gradients to depth, including the shallow subsurface (<100m depth). In the Tahoe Basin region, the magnitude of deep groundwater flow on the areal or regional scale has been largely unknown. We present examples of borehole temperature profiles that constrain possible areal groundwater flow patterns, including the magnitude of flow beneath the bottom of boreholes probed.

H52B-0875 1330h POSTER

Potential for Lateral Flow Associated with Fractured, Nonwelded, Layered Tuffs in the Unsaturated Zone

Randall W Fedors[1] (2110-522-6818; rfedors@swri.org)

David A Ferrill[1] (210-522-6082; dferrill@swri.org)

[1]CNWRA-SwRI, 6220 Culebra Road, San Antonio, TX 78209, United States

The magnitude of lateral flow caused by permeability and capillary barriers associated with dipping, layered, nonwelded tuffs above the proposed repository horizon is an important issue for evaluating the amount and distribution of water potentially contacting high-level radioactive waste proposed for emplacement at Yucca Mountain, Nevada. Predictions of the distance over which lateral flow occurs vary from the meter scale to the kilometer scale. Numerical models using homogeneous properties and sharp stratigraphic boundaries overpredict the amount of lateral flow along stratigraphic contacts. Primary heterogeneity or secondary discontinuities (e.g., fractures and faults), however, could lead to preferential flow paths through the Paintbrush nonwelded tuff (PTn) and into the Topopah Spring welded tuff below. Heterogeneity of matrix properties, including primary depositional textures and vapor-phase alteration combined with later structural overprinting and mineralization, will affect the ability of permeability and capillary barriers to produce lateral flow.

The potential for lateral flow to occur is evaluated using observations of field hydrogeologic characteristics, laboratory measurements, and results of numerical models that simulate fluid flow in the unsaturated zone. These include (i) observations of field water content profiles; (ii) observations on the nature of stratigraphic contacts (e.g., unconformity or gradational); (iii) analysis of laboratory measurements of matrix permeability; (iv) analysis of unsaturated zone constitutive relations to assess potential for permeability and capillary barriers occurrence in dual permeability models; (v) analysis of fault and fracture sizes, orientations, and spacings; and (vi) expected matrix deformation in small and large faults. The available geologic and hydrologic information, in conjunction with intuitive knowledge of geologic and hydrologic factors, is used to assess the possible extent of lateral flow along stratigraphic contacts in and near the PTn. This information helps to support the Nuclear Regulatory Commission's reviews of unsaturated zone studies being performed at Yucca Mountain by the U.S. Department of Energy.

This abstract is an independent product of the CNWRA and does not necessarily reflect the views or regulatory position of the NRC.

H52B-0876 1330h POSTER

Effect of Non-Instantaneous Release of Air Pressure on Pneumatic Slug Tests

Carl D. McElwee (785-864-2728; cmcelwee@ku.edu)

Dept. of Geology, Univ. of Kansas, 1475 Jayhawk Blvd., Lawrence, KS 66045, United States

Pneumatic initiation of slug tests has been used for many years and is an efficient technique, since water is not added or withdrawn from the well and no mechanical slug is required. However, for very permeable aquifers the release of air pressure or vacuum can not be considered instantaneous, as is usually assumed. This paper investigates the response time at the lower end of an air column where the water interface would be by using a pressure transducer, which can measure both positive and negative pressures. As the valve at the upper end of the air column is opened the disturbance propagates through the air column and bounces off the bottom of the air column. The disturbance continues propagating and bouncing off the ends while the air escapes from the valve. The net result is an oscillatory air column response that decays exponentially with time. The step function release that is usually assumed is not obtained in practice. Detailed measurements show that the decay is an exponential function of the square root of time and a decay constant. The period of the oscillation is dependent on the length of the air column, with shorter lengths giving higher frequencies. The decay constant seems to vary inversely with the square root of the initial pressure and directly with the air column length for a given initial pressure. For configurations tested and typical field situations the air column goes to atmospheric pressure within about 2 seconds. This means that for slow responding aquifers the effect is minimal. However, for very highly permeable aquifers where the slug test lasts only a few seconds (we have tested many in this category), the deviation from step function release of air pressure or vacuum can have a significant effect on the data analysis using a specific model for slug test response. In particular, the aquifer response will be stretched out and the effective initial height of the slug will be less than expected. Where positive and negative pressures of the same magnitude are used to check for a directional dependence of aquifer response, there will be a difference in the response due to the difference in length of the air column, which is not related to any aquifer characteristic. For maximum accuracy in determining hydraulic conductivity of highly permeable aquifers from pneumatic slug tests, this effect of non-instantaneous release of air pressure or vacuum must be considered.

H52B-0877 1330h POSTER

An Analytical Model for Computing Ground Water Residence Times Near a Pumping Well

Matthew J Simpson[1] (+618 - 93801698; simpson@cwr.uwa.edu.au)

T Prabhakar Clement[2] (+1 - 334 - 8446268; clement@eng.auburn.edu)

Francis E Yeomans[3] (+618 - 93803384; frank@maths.uwa.edu.au)

[1]Centre for Water Research, Department of Environmental Engineering The University of Western Australia Western Australia Australia, Nedlands, WA 6009, Austria

[2]Department of Civil Engineering, 208 Harbert Engineering Centre Auburn University, Auburn, AL 36894 - 53, United States

[3]Department of Mathematics and Statistics, The University of Western Australia Western Australia Australia, Nedlands, WA 6009, Austria

A new analytical solution for calculating the residence time of fluid flowing towards a single pumping well in an unconfined aquifer is developed. The analytical solution was derived based upon a one-dimensional, steady state, Dupuit-Forchheimer flow model. The resulting integral expression involves computing the imaginary error function, for which a simple series expansion is successfully proposed. The validity of the expression is tested against the results from a numerical approximation for an example problem, which demonstrated a good correspondence between the numerical and analytical results. The applications and limitations of the new analytical solution are presented.

H52B-0878 1330h POSTER

Modeling experiments of fluid injection and the application of the inversion using the surface deformation

Kiyoshi Kishida[1] (81-75-753-5106; kishida@toshi.kuciv.kyoto-u.ac.jp)

Hidekazu Taniya[1] (taniya@toshi.kuciv.kyoto-u.ac.jp)

Kenzi Karasaki[2] (kkarasaki@lbl.gov)

Donald W Vasco[2] (DWVasco@lbl.gov)

Toshihisa Adachi[3] (adachi@geor.or.jp)

[1]Kyoto University, Dept. of Civil Eng., Kyoto University, Sakyo, Kyoto 606-8501, Japan

[2]Lawrence Berkeley National Laboratory, Earth Sciences Division Berkeley Lab 1 Cyclotron Road, Mailstop 90-1116, Berkeley, CA 94720

[3]Geo-Research Institute, 4-3-2 Itachibori, Nishi-ku, Osaka 550-0012, Japan

The authors had developed the inversion of the surface deformation and had estimated the subsurface volume change. The withdraw experiments in the field had been actually carried out and the subsurface volume had been calculated. Moreover, the coupled inversion of transient pressure observations and surface displacement measurements had been applied and the permeability distribution in a field had been estimated. In this research work, the modeling apparatus of the fluid injection is developed and the modeling experiments are carried out. In the experiments, the fluid is injected into the modeling ground under controlling the flux and the pressure. Then, the surface displacement, the earth pressure and the transient pressure can be measured continuously. Based on the obtained data, the inversion is carried out. Finally, as discussed the result, the validity of the inversion is discussed. And, the subsurface volume change and the distribution of the permeability are estimated.

H52B-0879 1330h POSTER

Development of Optimal Groundwater Management Model for a Multi-Layered Aquifer

Nien-Sheng Hsu[1] (011-886-2-2362-1840; nsshue@ccms.ntu.edu.tw)

Cheng-Chang Wei

[1]Dept. Civil Engrg., National Taiwan Univ., No.1, Sec.4, Roosevelt Road, Taipei 106, Taiwan

The purpose of this paper is to develop an optimization model for groundwater planning and management for a multi-layered aquifer system. The decision variables, i. e., the policy, are the number and locations of production wells as well as the pumping rate of each well. The objective function minimizes the sum

of the capital and the operational costs over the planning horizon. The constraints include: (1) meeting the specified demand during each stress period, (2) meeting the specified head value at each monitored location, and (3) the upper and lower bounds of pumping rate at each production well. MODFOLW is used to compute the hydraulic head distribution resulting from various extraction policies.

The formulated optimization model is a mix-integer nonlinear programming (MINLP) problem. An efficient iterative solution algorithm is developed by embedding MODFLOW in a genetic algorithm (GA). The procedure starts with a set of chromosomes, representing a set of feasible policies. An iterative procedure is then preceded to: (1) compute the hydraulic head distribution for each policy and check against constraint violation, (2) compute the fitness, i. e., the objective function value, of each feasible policy, (3) generate a new set of chromosomes by reproduction, crossover and mutation, and (4) check the stopping criterion and obtain the optimal solution.

A hypothetical three-layered aquifer system is used to demonstrate the applicability of the developed model and the solution algorithm. We consider a five-year planning horizon with 20 stress periods. The finite difference mesh consists of 675 blocks (15*15*3). Sixteen candidate extraction well locations are pre-determined. The upper and lower bounds of the pumping rates are 31,000 and 1,000 cubic meters per day, respectively. In the GA algorithm, the number of chromosomes in each generation is 300, the maximum number of generation is 150, and the reproduction and the mutation rates are 1.0 and 0.02, respectively. The results show that the developed model and algorithm is particularly suited for solving the formulated planning and management problem.

H52B-0880 1330h POSTER

Groundwater Management With Insufficient Data

Metin M Ozbek[1] (ozbek@emba.uvm.edu)

George F. Pinder[1] (pinder@emba.uvm.edu)

[1]University of Vermont, Civil and Environmental Engineering, 213 Votey Bldg., Burlington, VT 05401, United States

An optimization methodology is developed for groundwater management problems that incorporate imprecise (fuzzy) information on the groundwater-flow model parameters. The imprecision can be attributed to indirect measurements, subjective interpretation and expert judgment of limited information (e.g., the boundary of the model and location and strength of source/sink terms). In contrast to its stochastic counterparts, the resulting fuzzy flow model avoids a large number of realizations of the porous medium.

The output of the fuzzy simulation model is utilized herein for the least-cost design of a hydraulic-containment problem. Possibility theory is applied to the formulation of fuzzy-gradient and fuzzy-magnitude constraints to address the issue of proper selection of the containment boundary. The approach yields a set of feasibility indices for the constraints, which correspond to upper and lower probabilities (e.g., Dempster 1967) that the constraints will be satisfied, making the problem formulation especially suitable when a stochastic approach is not applicable because of lack of sufficient data.

H52B-0881 1330h POSTER

Declination of Groundwater Levels in Recharge Areas Within Active Tectonic Settings in Southern Taiwan

Ching-Huei Kuo[1] (ckuo@earth.sinica.edu.tw)

Chung-Ho Wang[1] (chwang@earth.sinica.edu.tw)

Jye-Jao Huang[2] (hjj@linx.moeacgs.gov.tw)

[1]Institute of Earth Sciences, Academia Sinica, P.O. Box 1-55, Nankang, Taipei, TWN 11529, Taiwan

[2]The Central Geological Survey, MOEA, 2 Lane 109, Hua-Hsin St., Chung-Ho, Taipei, TWN 235, Taiwan

The variability in time and space of groundwater levels in wells may be used as an indicator of environmental change in regions. Groundwater levels have declined in the recharge area since the last decade in the southern Taiwan. This decline not only occurs in the shallow wells (20-30 m) but also in the deeper wells (120-150 m) at the same site. Both shallow and deeper wells are actually located in the same hydrogeologic aquifer, unconsolidated gravel and coarse sand mainly, with the highest transmissivity reaching 5 m2/min. Yet, both wells belong to different recharge sources according to the values of δO18, ranging from around -8.0 to -10, respectively. The deeper wells have the lighter in the values of δO18 while the shallow wells have heavier δO18 values. This indicates that the deeper groundwater in the recharge area is supplied mainly from higher altitude mountains nearby with longer path and time while the shallow one is fed from adjacent hills and direct infiltration. The decrease of precipitation would easily become the primary contributor for this decline in groundwater level. In fact, the long-term observation of precipitation in the southern Taiwan has shown a decrease trend since 1950. However, a consecutive increase in precipitation has also been recorded in the recent years in the region. Thus, the decline of groundwater levels in the recharge regions in the southern Taiwan may not solely result from the decrease of precipitation. A preliminary study in the region has shown that the local tectonic tilting movements may also affect the decline of groundwater levels in the recharge areas. Therefore, understanding the geology of the region and choosing appropriate techniques become more important for quantifying groundwater recharge and understanding its variability.

H52B-0882 1330h POSTER

Water Fluctuations in Coastal Aquifers: Effects of Tidal Fluctuations, Alongshore Coastline Variations and Capillarity

D. A. Barry[1] (+44 (131) 650-7204; d.a.barry@ed.ac.uk)

D.-S. Jeng[2]

L. Li[3]

H. T. Teo[2]

P. Dong[4]

[1]Contaminated Land Assessment and Remediation Research Centre, Institute for Infrastructure and Environment, School of Engineering and Electronics, The University of Edinburgh, Crew Building, King's Buildings, West Mains Road, Edinburgh EH9 3JN, United Kingdom

[2]School of Engineering, Griffith University PMB 50, Gold Coast Mail Centre, Gold Coast 9726, Australia

[3]School of Engineering, The University of Queensland, Brisbane 4072, Australia

[4]Department of Civil Engineering, University of Dundee, Dundee DD1 4HN, United Kingdom

There are numerous analytical and numerical studies of tidally induced coastal aquifer fluctuations. For the most part, theoretical analyses typically include several simplifying assumptions, including that of a straight coastline, a vertical beach boundary, constant hydraulic conductivity and the Boussinesq assumption for flow in the aquifer itself. In a recent analysis, we relaxed the first assumption and investigated tidally induced fluctuations in an aquifer with a rhythmically varying coastline. Aquifer flow was modelled using the linearized two dimensional (vertically integrated) Boussinesq model, yielding the standard diffusion model for unconfined groundwater flow. This model was solved approximately for a sinusoidally varying coastline using a perturbation expansion, with the perturbation variable proportional to the ratio of the shoreline variation amplitude to the variation wavelength. The analytical approximation was used to generate solutions for "real" coastlines based on a Fourier series representation of the latter. Numerical modelling indicates the analytical approximation is satisfactory. Compared with a straight coastline, head fluctuations are enhanced at the embayment centers, and reduced at the headlands. Additionally, phase shifts in tidal signals are modified. The analysis is extended to include the effect of capillarity using an additional term in the governing linearized Boussinesq model. Again, we show differences in amplitude decay and phase of the tidal signal in the aquifer. The results further indicate errors that might be induced as a result of ignoring alongshore morphological variations in estimating aquifer transmissivity based on tidal signals.

H52B-0883 1330h POSTER

The Integrated Storage-Flux Model For Groundwater Storage and Baseflow Dynamics

Do Hun Lee[1] (82-31-201-2546; dohlee@khu.ac.kr)

Jooheon Lee[2] (82-41-750-6744; leejh@mail.joongbu.ac.kr)

[1]Kyung Hee University, Department of Civil Engineering, 1 Seocheon-Ri, Kihung-Eup, Yongin-city, Kyunggi-do, Yongin 449-701, Korea, Republic of

[2]Joong Bu University, Department of Civil Engineering, Chubu, Kumsan, Chungnam, Kumsan 312-702, Korea, Republic of

The integrated storage-flux model is proposed based on the storage-flux relations and tested against the Richards equation in the idealized stream-aquifer system. The groundwater storage-baseflow relation and soil water storage-effective infiltration relation are identified by numerical analysis of the Richards equation under the steady-state conditions. The relationship between groundwater and baseflow exhibits a linear relation, while the relationship between soil water storage and effective rainfall is appeared to be the inverse linear relation. This inverse linear relation agrees with the results of Duffy (1996) and Lee (1993) who investigated the storage-flux relations on the hillslope terrain.

The integrated storage-flux model is constructed by coupling the storage-flux relation with water balance equation. The coefficients of the integrated storage-flux model are based on the steady-state storage-flux relations and are calibrated against the response of the Richards equation. Under the step input condition, the dynamic response of the integrated storage-flux model agrees favorably with that of Richards equation. The development of the integrated storage-flux model has implication for predicting the groundwater storage and baseflow when the limited hydro-geologic data are available.

Acknowledgement This research was supported by a grant (2-2-1) from Sustainable Water Resources Research Center of 21st Century Frontier Research Program.

H52B-0884 1330h POSTER

Use of Ground-water Temperature Patterns to Determine the Hydraulic Conductance of the Streambed Along the Middle Reaches of the Russian River, CA

Grace W Su[1] (gracesu@usgs.gov)

James Constantz[1] (jconstan@usgs.gov)

James Jasperse[2] (jay@scwa.ca.gov)

Donald Seymour[2] (dseymour@scwa.ca.gov)

[1]U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025

[2]Sonoma County Water Agency, 2227 Capricorn Way, Santa Rosa, CA 95406

Along the Russian River in Sonoma County, the alluvial aquifer is the preferred source of drinking water because sediments and other constituents in the river water would require additional treatment. From late spring to early winter, an inflatable dam is erected to raise the river stage and passively recharge the alluvial aquifer. The raised stage also permits diversion of river water to a series of recharge ponds located near the dam along the river. Improved understanding of stream exchanges with ground water is needed to better manage available water resources. Heat is used as a tracer of shallow ground-water movement for detailed hydraulic parameter estimation along the middle reaches of the river. Water-levels and ground-water temperatures were measured in a series of observations wells and compared to the river stage and surface-water temperatures. Hydraulic conductivities were predicted by optimizing simulated ground-water temperatures using VS2DHI, a heat and water transport model, to observed temperatures in the aquifer. These conductivity values will be used in a stream/ground-water model of this region being developed using MODFLOW. Temperature-based estimates of streambed conductance will be inserted in the STREAM package of the model to constrain this parameter. Although temperature-based predictions of hydraulic conductivity vary significantly along the reach, the results generally suggest that an anisotropy of 5 to 1 (horizontal to vertical) provides the best hydraulic conductivity matches for predicted versus observed ground-water temperatures.

H52B-0885 1330h POSTER

Comparison of Heat and Bromide as Tracers of Stream Exchanges With Shallow Ground Water

James Constantz[1] (jconstan@usgs.gov)

Marisa H Cox[1] (mhcox@usgs.gov)

Grace W Su[1] (gracesu@usgs.gov)

[1]U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025

Heat and bromide were compared as tracers for examining stream/groundwater exchanges along the middle reaches of the Santa Clara River, CA, during a 10-hour surface-water sodium bromide injection. Three cross-sections comprised of 6 shallow (1 m) piezometers were installed at the upper, middle, and lower sections of a 17 km long study reach to monitor temperatures and bromide concentrations in the shallow ground water beneath the stream. The heat and ground-water transport simulation model, VS2DH, and a closely related solute and ground-water transport simulation model, VS2DT, were matched up for comparison of simulated and observed temperatures and bromide concentrations in the streambed. Simulated sediment temperature were fitted to observed temperature results

to yield apparent streambed hydraulic conductivities in each cross-section. Saturated hydraulic conductivities ranged from 1.39 x 10-5 m/s in the upper reach to 5.56 x 10-4 m/s in the lower reach. The temperature-based hydraulic conductivities were inserted into VS2DT to predict sediment bromide concentrations during the sodium bromide injection. The predicted bromide concentration curves in the sediments yielded an excellent match to the observed bromide concentrations, without adjustment of any model parameters. This indicates that for the spatial and temporal scales examined on the Santa Clara River, the use of heat and bromide as tracers provide comparable information with respect to apparent hydraulic conductivities and water fluxes in near-stream environments.

H52B-0886 1330h POSTER

Characterization of Surface-Water/Ground-Water Interaction Along the Spokane River, Idaho and Washington

Rodney R. Caldwell[1] (1-406-457-5933; caldwell@usgs.gov)

Craig L. Bowers[1] (1-406-457-5935; clbowers@usgs.gov)

Keith L. Hein[2] (1-208-263-4123; klhein@usgs.gov)

[1]U.S. Geological Survey, 3162 Bozeman Avenue, Helena, MT 59601, United States

[2]U.S. Geological Survey, 1500 Highway 2, Sandpoint, ID 83864, United States

Historical mining in the Coeur dAlene River basin of northern Idaho has resulted in elevated concentrations of some trace metals (particularly Cd, Pb, and Zn) in water and sediments of Coeur dAlene Lake and downstream in the Spokane River. On average during 1999 and 2000, about 20,000 kg/yr of whole-water lead (particulate plus dissolved), 2,100 kg/yr of whole-water cadmium, and 450,000 kg/yr of whole-water zinc flowed out of Coeur dAlene Lake into the Spokane River. These elevated trace-metal concentrations in the Spokane River have raised concerns about potential contamination of ground water in the underlying Spokane Valley/Rathdrum Prairie aquifer, the primary source of drinking water for the city of Spokane and surrounding areas. A study conducted as part of the U.S. Geological Surveys National Water-Quality Assessment Program examined the interaction of the river and aquifer using hydrologic and chemical data along a losing reach of the Spokane River. The river and ground water were extensively monitored over a range of hydrologic conditions at 3 stream gages and 25 monitoring wells (including 18 wells installed for this study) ranging from 8 to 1,000 m from the river. River stage, ground-water level, water temperature, and specific conductance were measured hourly to biweekly, and water samples were collected 8 times. Additional regional ground-water data were collected from more than 190 wells within 5 km of the study reach.

Hydrologic and chemical data indicate that the Spokane River recharges the Spokane Valley/Rathdrum Prairie aquifer along a 35-km reach between Coeur dAlene Lake and Spokane. Ground-water levels in near-river (<125 m from the river) wells responded rapidly to variations in river stage and indicated the presence of an unsaturated zone beneath the river and a ground-water flow gradient away from the river. Chemical data indicated that river recharge may influence ground-water chemistry as far as 900 m from the river. The chemistry and temperature of river water and ground water from near-river wells were similar and exhibited similar temporal trends, whereas ground water from wells located farther from the river had higher ionic strength and more stable temperature and chemistry. Lag time between variations of water temperature and water chemistry in the river and response of near-river wells may prove useful for estimating ground-water velocity and time of travel of chemical constituents to and through the aquifer.

Although concentrations of Cd and Pb were elevated in bed sediment, dissolved (<0.45 um) Cd and Pb were generally less than 1 ug/L in the river and ground water. Dissolved Zn concentrations were similar in near-river wells (17 to 71 ug/L) and the river (22 to 66 ug/L), but were less than detection levels in wells farther from the river. In 1999 and 2000, the dissolved Zn load in the Spokane River decreased by about 72,000 kg/yr, or 17%, within the losing reach from Post Falls to downstream from Spokane. Part of this Zn load likely is transported to and stored in the near-river zone of the aquifer because the Zn is not returned farther downstream near Spokane where the aquifer discharges to the river.

H52B-0887 1330h POSTER

Stream-Groundwater Interactions and Near-Stream Flow Systems: The Influence of Aquifer Heterogeneity and Stream Meandering on Three-dimensional Hyporheic Exchange Flows

Jorge Eurico Matos[1] ((215) 3875125 ext3536; sg96d729@drexel.edu)

Claire Welty[1] ((215) 8952281; weltyc@drexel.edu)

Aaron I Packman[2] ((847) 4919902; a-packman@northwestern.edu)

[1]Jorge Eurico Ribeiro Matos, School of Environmental Science, Enginering and Policy, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, United States

[2]Aaron I. Packman, Department of Civil and Environmental Engineering, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208, United States

This study examines the effects of aquifer heterogeneity and channel pattern on flow interactions between stream and groundwater systems. Previous efforts to model stream-groundwater interactions have generally used simplified, horizontal, two-dimensional domains and treated only one-dimensional vertical exchange between the river bed and the underlying aquifer layer. We have adopted a three-dimensional approach and used MODFLOW to evaluate the magnitude, direction and spatial distribution of stream-subsurface exchange flows induced by stream meanders. Our model includes vertical heterogeneity in hydraulic conductivity and analyzes exchange across the wetted perimeter of the stream. The numerical model consists of a 256 x 256 x 30 (x, y, z) grid with spatial dimensions determined both by the correlated scales used to generate the hydraulic conductivity random fields and by the scale of the stream meanders. Aquifer interactions with a straight river and a meandering river were simulated using four levels of heterogeneity (lnK variance equal to 0.25, 1.0, 2.5 and 4.0). Results of the straight-river simulations are compared to cases that incorporate a simple river meandering pattern in order to evaluate the interaction of degree of heterogeneity and hydraulic short-circuiting on the flow exchange pattern at the aquifer-riverbed interface. Comparison of model simulations with different stream geometries shows that flow variance of rows parallel to the river (longitudinal cross-section) and columns perpendicular to the river flow (transverse cross-section) increases as the lnK variance increases. For a longitudinal cross-section for the simulated meander pattern, the flow variance is greater for all levels of heterogeneity compared to the straight-river case. At a transverse cross-section the situation is the opposite: the flow variance is reduced for the meander case compared to the straight river case, for a given level of heterogeneity. Vertical penetration of water from the stream increases with increasing heterogeneity for both the straight-river and the meander cases.

H52B-0888 1330h POSTER

Groundwater Level Response to Precipitation in Catskill Formation Aquifers, Northern Pennsylvania

Gwendolyn B Rhodes (301-405-7328; rhodes@geology.umd.edu)

University of Maryland, Geology Department, 1119 Geology Building Zip 4211, College Park, MD 20740, United States

Evaluation of data from hydroclimatically sensitive ground water wells in northern Pennsylvania suggests drought recovery time can be as short as one week. The timing of groundwater depth below surface variation in three wells and precipitation occurrence were compared for water years 1999 to 2001 to determine average response time. Water-year 1999 was further scrutinized to detect the influence of Hurricane Floyd on drought culmination that year. The lag-time between peaks in precipitation amounts at the Williamsport-Lycoming Airport and water-table height based on data from Cameron, Lycoming and Sullivan County observation wells was tabulated and graphed. It was noted that the depth of the water table decreases with precipitation events delivering rainfall as low as 0.3 cm per day, water depth decreases last for approximately two days and increased rainfall volume effects the duration of decreases. For example, there is a drop in water table at the Cameron County Observation well between two rainfall dates when maximum rainfall is 0.6 and 0.8 cm on August 20 and 27, 1999 but there is no significant reduction in groundwater level between two later events where precipitation volume was higher (September 7 and September 16, 1999 rainfall totals were 17.4 cm and 6.9 cm respectively).

H52B-0889 1330h POSTER

ACTUALIZATION OF THE HYDROGEOLOGICAL MODEL OF THE OJOS NEGROS VALLEY´S AQUIFER

Jose-Ruben Campos-Gaytan[1] (01-52-646-177-6122; rcampos@cicese.mx)

Rogelio Vazquez Gonzalez[1] (01-52-646-174-5050; rvazquez@cicese.mx)

[1]Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, B.C. (CICESE), Km. 107, Carretera Tijuana-Ensenada, Ensenada, B.C 22860, Mexico

A regional groundwater flow model is actualized in order to study the water table behavior in the zone of the Ojos Negros valley, which is located in the state of Baja California, Mexico. In the actualization process of the Ojos Negros valleys hydrogeological model, is used all the information proportionate for the National Commission of Water, as well as that information obtained from academic and research works achieved in the study zone, about the hydrogeological conditions that present the Ojos Negros and Real del Castillo aquifers. In addition, a groundwater flow simulator is modified and improved from the numerical point of view. The actualized simulator solves numerically the Boussinesq equation, using centrals finite-differences techniques, the fully implicit approximation for the temporary variation, and the iterative method of successive over relaxation. Also it counts with the structure to considering the temporary variation of the different variables and geohydrologics conditions that has influence upon the groundwater system, and with programming subroutines in MATLAB (2000) for the graphic display of results. The simulation results are appropriate for determining the phreatic surface and the flow directions in different time intervals. The phreatic surface information can be used for studying the behavior (temporary evolution) of water table in the aquifers.

H52B-0890 1330h POSTER

Numerical Simulations of Road Salt Impact at a Municipal Water Supply

Michelle L. Bester[1] (519-888-4567 ext 2544; mlbester@uwaterloo.ca)

Emil O. Frind[2] (519-888-4567 ext 3959; frind@uwaterloo.ca)

John W. H. Molson[3] (519-888-4567 ext 3959; molson@uwaterloo.ca)

[1]Waterloo Hydrogeologic, Inc., 460 Philip Street, Suite 101, Waterloo, ON N2L 5J2, Canada

[2]University of Waterloo, 200 University Avenue, Waterloo, ON N2L 3G1, Canada

[3]Ecole Polytechnique Montreal, 2500 chemin de Polytechnique, Montreal, QB H3T1J4, Canada

Chloride concentrations at major water supply wells within the Regional Municipality of Waterloo in Ontario have been increasingly rapidly over the past 20 years. If present trends continue, drinking water limits may be reached within the next decade. Road salt has been identified as the prime source of the contamination, and various remediation strategies are being investigated.

As part of a overall comprehensive chloride reduction study, advanced numerical simulation tools are used to investigate the mechanisms of chloride transport from ground surface to water supply wells, and to assess the effectiveness of various remediation scenarios. Several options were simulated such as reducing chloride application by 25% over the entire study area, eliminating applications on secondary roads, and eliminating applications within the 5 and 10-year capture zones.

The numerical simulations include a 2D variably-saturated model and a fully 3D model of chloride transport from a growing road network. The results from the variably-saturated model show that chloride application to the water table can be assumed to be a steady state process where seasonal transients can be neglected. This assumption was used in the 3D model, which showed that the option of reducing salt application by 25% was sufficient to protect the water supply. Eliminating application on some secondary roads could further decrease concentrations at the wells with very little effort. Eliminating application from within the capture zones results in a dramatic decrease in chloride at the wells, however the chloride trends in the wells continue upward after time as chloride arrives from outside the capture zone.

H52B-0891 1330h POSTER

Constant Capacitance Model Prediction of Boron Speciation for Varying Soil Water Content

Peter J. Vaughan[1] (909 369-4875; pvaughan@ussl.ars.usda.gov)

Donald L. Suarez[1] (909 369-4815; dsuarez@ussl.ars.usda.gov)

[1]George E. Brown, Jr. Salinity Lab USDA-ARS, 450 W Big Springs Road, Riverside, CA 92507, United States

The aqueous speciation of boron and its partitioning to a tetrahedral surface species ($SH_3BO_4^-$) were studied using the constant capacitance model. Aqueous B species were boric acid (H_3BO_3) and the borate anion $B(OH)_4^-$. Adsorption of B on clay minerals is pH-dependent with $SH_3BO_4^-$ increasing with increasing pH in the range 7-9. Modeling of equilibrium among the B species in a drying soil thus requires that the pH be computed. We calculated equilibrium among major cations and anions for hypothetical soil solution chemistries using a matrix-based numerical solution that included cation exchange reactions and dissolution/precipitation of calcite. Numerical experiments were performed for 20 hypothetical soil textures with 10-60% clay content, generating a range of cation exchange capacities, and three soil solution compositions. The effective K_d ($SH_3BO_4^-$/total solution B) decreased with gravimetric water content (θ_g) over the range θ_g=1.5 to 0.01. This was due to a calculated decrease in $[H^+]$ concentration with decreasing θ_g for all soil textures and fluid compositions. A decrease in $SH_3BO_4^-$) is consistent with experimental work showing decreasing fractional adsorbed B with decreasing pH in the range 7-9. An application of this type of calculation would be prediction of adsorbed and solution B concentrations at field water content based on experimental determinations of adsorbed and solution B concentration for saturated paste extracts. Such predictions would be useful for generating initial conditions for solute transport modeling and for determining whether solution B concentrations at field water contents would be beneficial or harmful to plants.

H52B-0892 1330h POSTER

Heating Unsaturated Sediments Using Solar Energy to Enhance Passive Sediment Remediation Technologies

AJ Rossman[1,2] (802 656-0744; arossman@emba.uvm.edu)

[1]University of Vemont, 222 Votey Hall, Burlington, VT 05405, United States

[2]Draker Solar Design, PO Box 8346, Burlington, VT 05402, United States

Sediment heating has been shown to enhance passive sediment remediation technologies such as bioremediation and barometric pumping (passive soil venting). Sediment heating raises the slow remediation rates that often limit the widespread use of these technologies. In bioremediation applications, a 10 degree C increase in subsurface temperature is expected to double the microbial activity, and thus the remediation rate. The removal rate of tetracholorethylene (PCE - a common subsurface contaminant) by passive soil vapor extraction is expected to nearly double in low-permeable sediments when the subsurface is heated 10 degree C from ambient temperatures due to an increased vapor pressure in the PCE. When the sediment is heated using renewable energy sources, these thermally enhanced remediation technologies can be environmentally benign alternatives to conventional remediation techniques that rely on large external energy inputs. The thermally enhanced passive technologies may be particularly useful for remediating unsaturated, low-permeable lenses that are troublesome to most conventional remediation technologies such as conventional soil vapor extraction and co-solvent flushes.

The main objective of this work was to quantify subsurface sediment heating using a solar powered heat injection well. To do this, a pilot sediment heating system was installed in Vermont and high resolution meteorological and sediment temperature data were collected using a stand-alone data acquisition system. Unsaturated, silty sediments were heated in-situ by converting the direct and indirect solar energy available at the surface to heat energy in the subsurface using stand-alone renewable energy sources and a resistive element heat injection well. The heat injection well was powered by a 600-W passively tracking photovoltaic (PV) array and a small 1.2-m swept area wind turbine. It is envisioned that the heat injection well would be placed directly into an area of high subsurface contamination to speed up remediation efforts at a contaminated site.

H52C MCC: Hall C Friday 1330h

Using Groundwater Models to Guide Field Data Collection II Posters

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

H52C-0893 1330h POSTER

Modeling the Transport of Dissolved Contaminants Originating From a Rectangular Prism-shaped Multicomponent NAPL Source in Groundwater

Kenneth Y Lee ((732)445-2240; kenlee@rci.rutgers.edu)

Rutgers, The State University of New Jersey, Civil and Environmental Engineering, Piscataway, NJ 08854, United States

A three-dimensional, semi-analytical model for simulating the transport of contaminants originating from a dissolving rectangular prism-shaped, multicomponent nonaqueous phase liquid (NAPL) source in groundwater is developed. The NAPL dissolution process for each component is envisioned to occur in a series of continuous short intervals. The equilibrium aqueous concentration and the source dimensions are assumed to remain constant for the duration of each short interval. Individual component aqueous phase concentrations resulting from each dissolution interval are determined by an existing single component analytical solution. A synthetic two-component NAPL mixture is used for model simulation. Results show that for a dissolving multicomponent NAPL mixture, downstream aqueous phase concentrations may not always reflect source characteristics. The model is useful for an understanding of field data in homogeneous saturated porous media and for interpretation of bench-scale laboratory experiments.

H52C-0894 1330h POSTER

Salt Distribution in a Coastal Aquifer Determined From Geoelectric Soundings and From Numerical Groundwater Modeling

Thomas Willert[1] (49-511-643-3531; T.Willert@gga-hannover.de)

Winfried Kessels (49-511-643-3547; W.Kessels@gga-hannover.de)

[1]Thomas Willert, Stilleweg 2, Hannover 30655, Germany

To understand the interaction between salty sea water and non-salty groundwater it is essential to compare investigations of the salt content in the groundwater using numerical process modeling. The interaction of salt- and freshwater results in a 3D spatial pattern of the salt distribution in the aquifer. The paper discusses comparisons between geoelectric measurements and numerical calculations for a coastal aquifer in northern Germany. The large scale geoelectric model is based on a wide set of DC-soundings. The comparison uses results from medium scale numerical simulations of the density-influenced groundwater dynamics.

The area under investigation is situated between the estuaries of the rivers Elbe and Weser on the German North Sea coast. It covers an area of more than 1,000 square kilometres (400 square miles). The spatial pattern of the salt water distribution in the aquifers is investigated. The goal is to arrive at a characterization of the dynamics between salty and non-salty water to improve sustainable management of the groundwater resource. Numerical simulation is a tool suitable for management and forecasting purposes. The modeling must take into consideration the effect of salt on the density of water. Reliable simulations require extensive data to allow comparison of the numerical results with reality as well as providing a basis for good calibration of the numerical groundwater model.

Geoelectric soundings offers the possibility of establishing a closely meshed network of data on groundwater salinity. Our data base consists of over 1,000 soundings. Most reach a depth of 150 to 200 m (500 to 650 ft), sometimes more. Down to this depth we can determine the salt water distribution in the investigation area and build up a 3D spatial salinity model. The spatial interpretation of salinity is buttressed by salinity measurements at boreholes and pumping wells, by petrographic data and interpretations of high resolution AEM. In subregions of the investigation area, the resulting model is compared with numerical simulations of groundwater dynamics.

The results underline the applicability of comparisons between salt water distribution determined from geoelectric soundings and numerical groundwater simulations. This method is therefore suitable as a control of numerical simulations over the entire investigation area.

H52C-0895 1330h POSTER

Optimal Experimental Design for Inverse Problem in Groundwater Modeling

Li-Fang Chang[1] (lifang@ucle.edu)

Ne-Zheng Sun[1] (nezheng@ucla.edu)

William W-G. Yeh[1] (williamy@seas.ucla.edu)

[1]UCLA Civil Environmental Engineering Dept., 5731 Boelter Hall Box 951593, Los Angeles, CA 90095-1593

This research investigates experimental design in conjunction with the inverse problem of parameter structure identification in groundwater modeling. Despite the importance of model calibration, there exists only a few published works that systematically consider experimental design, model structure complexity and model application reliability. In this research, experimental design for parameter structure identification is formulated as a mixed integer nonlinear programming problem. To link the inverse problem with model application, the data sufficiency of a design is judged by solving a generalized inverse problem. The generalized inverse problem seeks to find the simplest parameter structure and its associated parameter values that satisfy the accuracy requirement in model application. To solve the inverse problem, it requires the calculation of sensitivity coefficients of state variables with respect to model parameters.

In this research, we use the adjoint state method to compute the sensitivity coefficients for all computation nodes. This method is superior because it only requires running the simulation model (L+1) times, where L is the number of observation wells. We use MODFLOW to simulate groundwater flow. Additionally, the developed adjoint state equations are solved by MODFLOW.

Since experimental design is predicated on the parameter values, which themselves are to be estimated before performing the experiments, prior information is combined with Monte-Carlo simulation to assess the reliability of data sufficiency. A globalVlocal optimization method is used to solve the generalized inverse problem. Finally, a genetic algorithm solves the optimal experimental design problem.

H52C-0896 1330h POSTER

Modeling Well-Bore Skin Effects at Pumping and Observation Wells Under Variable Pumping Rate

Timothy C. Johnson[1] (208-426-1397; tcj@cgiss.boisestate.edu)

Warren Barrash[1] (208-426-1229; wb@cgiss.boisestate.edu)

Tom Clemo[1] (208-426-1416; tomc@cgiss.boisestate.edu)

[1]Center for Geophysical Investigation of the Shallow Subsurface and Department of Geosciences, Boise State University, 1910 University Drive, Boise, ID 83725, United States

Well-bore skin effects have been recognized as a hydraulic influence at pumping wells during fully penetrating pumping tests with multiple observation wells conducted in the unconfined fluvial aquifer at the Boise Hydrogeophysical Research Site (BHRS). Because each well was constructed and completed in the same manner, skin effects are expected in both the pumping and the observation wells. Quantifying the effects of well-bore skin is important for accurate analysis and estimation of aquifer properties at the BHRS. For example, determinations of hydraulic parameters from fully penetrating pumping tests, tracer test injection behavior, and electromagnetic borehole flow-meter profiles are all sensitive to well-bore skin. Several lines of evidence indicate that well-bore skin effects at the BHRS are largely due to the presence of sand grains trapped in screen slots, with some fine material possibly left after cleaning. After construction, each well was cleaned to dissolve synthetic drilling mud and check for fine material. Pumping tests and geophysical logging were conducted before and after each cleaning to observe changes in skin effects and near-well physical properties. Video logging, laboratory tests, and modeling provide additional evidence that the skin effects are primarily caused by sand in the screen.

Well-bore skin is modeled here using modifications to the analytical model WTAQ of Moench (1997). We added capabilities to include the effects of well-bore skin at observation wells and also variable flow rate. In practice, analysis of well-bore skin effects may be complicated if the pumping rate takes some seconds to stabilize because skin effects occur at early time. With this in mind, we used a high-frequency measurement system in the field to collect flowrate and drawdown data during this period of variable flow rate. WTAQ and the parameter-estimation code UCODE were used