H21C-06 0915h

Use of TRMM Microwave Imager (TMI) to characterize soil moisture for the Little River Watershed

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Soil moisture plays a critical role in many hydrological processes including infiltration, evaporation, and runoff. Additionally, soil moisture has a direct effect on weather patterns. Satellite based passive microwave sensors offer an effective way to observe soil moisture data over vast areas, and there are currently several satellite systems that detect soil moisture. Long-term in situ (field) measurements of soil moisture are collected in the Little River Watershed (LRWS) located in Tifton, Georgia and compared with the remotely sensed data collected over the watershed. The LRWS has been selected by the United States Department of Agriculture (USDA) to represent the south eastern costal plains region of North America. The LRWS is composed primarily of sandy soils and has a flat topography with meandering streams. The in-situ measurements were collected by stationary soil moisture probes attached to rain gage stations throughout the LRWS for the period 2000-2002. The remotely sensed data was acquired by two satellites viz. - the Tropical Rainfall Measurement Mission Microwave Imager (TMI) for soil moisture and the Moderate Resolution Imaging Spectroradiometer (MODIS) for vegetation. The TMI is equipped with a passive vertically and horizontally polarized 10.65GHz sensor that is capable of detecting soil moisture. Soil moisture collected in the field is related to the TMI brightness temperatures. However, vegetation has a strong affect on the 10.65GHz brightness temperature. The Normalized Difference Vegetation Index (NDVI) data, provided by the (MODIS), are used to evaluate the effect of vegetation on soil microwave emission.

H21C-07 0930h

Evaluation of Data from the Multi-frequency Scanning Microwave Radiometer (MSMR) and Its Potential for Soil Moisture Retrieval

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The Multi-frequency Scanning Microwave Radiometer (MSMR) aboard the India Space Research Organization - Oceansat-1 (IRS-P4) platform measured land surface brightness temperature at low frequencies and provided an opportunity for exploring large-scale soil moisture retrieval during its two years period of observation. Several data issues had to be addressed before using the data. These included geolocation errors, data calibration and anthropogenic Radio-frequency Interference (RFI). Calibration was evaluated by comparisons to the Tropical Rainfall Measuring Mission/Microwave Imager (TRMM/TMI) measured brightness temperatures. A negative bias of 3.4 and 3.6 K were observed for the 10.6 GHz horizontal and vertical polarization bands respectively, negative differences of 14.0 and 10.1 K were found between the MSMR 6.6 GHz and TMI 10.6 GHz horizontal and vertical polarizations over land surface. These results suggested that additional calibration of the MSMR data was required. Comparisons between the MSMR measured brightness temperature and ground measured volumetric soil moisture collected during two field campaigns indicated that the lower frequency and horizontal polarization had higher sensitivity to the ground soil moisture. Using a previously developed soil emission model, multi-temporal soil moisture was retrieved for the continental United States. Comparisons between the MSMR based soil moisture and ground measured volumetric soil moisture indicated an uncertain error of 3.8 percent in the estimated soil moisture. This data may provide a valuable extension to the SMMR and AMSR instruments since it covers a portion of the time between the two missions. Keywords: passive microwave, brightness temperature, soil moisture, satellite remote sensing.

H21C-08 0945h

Measuring Large-Scale Changes in Water Storage from Space: First Results from GRACE

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The satellite Gravity Recovery and Climate Experiment (GRACE) provides data estimating monthly changes in the Earth's gravity field, which are in part due to changes in vertically integrated terrestrial water storage. Unlike conventional point or gridded hydrologic measurements, such as those from rain gauges, stream gauges, rain radars, and radiometric satellite images, GRACE data are comprised of the spectral coefficients describing the Earth's gravity field. These coefficients can be inverted to solve for spatially averaged changes in continental water storage. Because the data are more accurate at longer length scales, spatial averages become more accurate as the area of the region increases. Therefore, GRACE provides direct measurements which can be used to close the water budget at regional to global length scales. GRACE data can thus be used to assess modelled large-scale water-balance predictions. In addition, GRACE data combined with river gauge data can provide estimates of precipitation minus evapotranspiration spatially averaged over large river basins. We will present the first comparisons of GRACE water storage estimates with hydrologic models and gauge data.

H21D MCC: Level 2 Tuesday 0830h

Recent Advances in Groundwater Hydrology Posters

Presiding: **C Welty,** University of Maryland, Baltimore County**; J J Butler,** University of Kansas

H21D-0832 0830h POSTER

Determination of Time Dependent Virus Inactivation Rates

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A methodology is developed for estimating temporally variable virus inactivation rate coefficients from experimental virus inactivation data. The methodology consists of a technique for slope estimation of normalized virus inactivation data in conjunction with a resampling parameter estimation procedure. The slope estimation technique is based on a relatively flexible geostatistical method known as universal kriging. Drift coefficients are obtained by nonlinear fitting of bootstrap samples and the corresponding confidence intervals are obtained by bootstrap percentiles. The proposed methodology yields more accurate time dependent virus inactivation rate coefficients than those estimated by fitting virus inactivation data to a first-order inactivation model. The methodology is successfully applied to a set of poliovirus batch inactivation data. Furthermore, the importance of accurate inactivation rate coefficient determination on virus transport in water saturated porous media is demonstrated with model simulations.

H21D-0833 0830h POSTER

Contaminant transport in a variable aperture fracture in the presence of monodisperse colloids

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A three-dimensional particle tracking model is developed to characterize the spatial and temporal effects of advection, molecular diffusion, Taylor dispersion, fracture wall deposition, matrix diffusion, and co-transport on two discrete plumes (monodisperse colloids and aqueous phase contaminants) flowing through a variable aperture fracture. Contaminants travel by advection and diffusion and may sorb onto fracture walls and colloids, as well as diffuse into and sorb onto the surrounding porous rock matrix. Colloids also travel by advection and diffusion and may sorb onto fracture walls, but do not penetrate the rock matrix. A probabilistic form of the Boltzmann law is used to describe attachment of colloids and contaminants onto fracture walls. For colloids that have diffused into the matrix, a linear distribution coefficient governs their sorption; an irreversible kinetic isotherm is employed to describe contaminant sorption onto colloids. Ensemble averaged breakthrough curves of many fracture realizations are used to compare arrival times of colloid and contaminant plumes at the fracture outlet. Results show that the presence of colloids enhances contaminant transport (decreased residence times) while matrix diffusion and sorption onto fracture walls retard the transport of contaminants.

H21D-0834 0830h POSTER

Colloid Facilitated Transport of Radionuclides at the Field Scale: Model and Parameter Sensitivities

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The potential effect of naturally occurring inorganic colloids on field-scale transport of radionuclides is investigated using generic sensitivity studies and an example based on the alluvial aquifer near Yucca Mountain, Nevada. The linear, bi-linear, and Langmuir models are used to describe kinetically controlled sorption to mobile and immobile colloids. In the absence of colloid retardation and permanent removal, plutonium transport is greatly enhanced over the situation without colloids. Mass transfer between solution and immobile colloids makes colloid retardation relatively ineffective at reducing facilitated transport except when the retardation factor is large. Irreversible removal of colloids (filtration) is more effective than colloid retardation at reducing facilitated transport. For a fixed filtration rate, the degree of attenuation depends sensitively and non-monotonically on the rate of desorption from colloids. These results emphasize the need for accurate measurements of desorption rates as well as careful field studies of filtration rates for naturally occurring colloids. This paper is an independent product of the CNWRA and does not necessarily reflect the view or regulatory position of the NRC.

H21D-0835 0830h POSTER

Reactive Transport Model for Fracture and Matrix Geochemistry at Yucca Mountain, Nevada

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Reactive transport models for the potential nuclear waste repository at Yucca Mountain (YM) provide information on evolving water chemistries and

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secondary mineralogies, which may affect engineered barrier system performance, radionuclide releases, and radionuclide transport. Although reactive transport models permit explicit analysis of coupled thermal-hydrological-chemical processes important to predictions of long-term repository performance, these predictions have sources of uncertainty that are difficult to quantify. Confidence in reactive transport models of YM therefore requires demonstration of their capability to represent natural conditions. Site characterization studies at YM have revealed significant differences between the hydrogeochemical properties of fracture and matrix materials in the unsaturated zone (UZ) overlying the potential waste emplacement setting. A quantitative evaluation of the most significant hydrogeochemical processes that caused these differences is required to develop detailed estimates of the quantity and chemistry of water contacting engineered materials in a thermally-perturbed repository settingone of the most risk-significant components of performance assessment for YM. Developing a reliable explanation for observed differences between UZ matrix and fracture materials at YM thus provides a critical test for the reactive transport models that support performance assessments for a potential repository at YM. We developed a 1D, dual continuum, reactive transport model of the ambient UZ matrix/fracture system at YM in order to evaluate the origin and evolution of groundwater compositions and secondary minerals in fracture and matrix materials overlying the location of the potential repository. Sensitivity tests were conducted to gauge the importance of data and model uncertainties. This paper is an independent product of the CNWRA and does not necessarily reflect the view or regulatory position of the U.S. Nuclear Regulatory Commission.

H21D-0836 0830h POSTER

Effects of Drift Degradation on Environmental Conditions in Drifts

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Drift degradation is anticipated to significantly influence the environment inside waste emplacement drifts at the proposed repository for high level waste at Yucca Mountain, Nevada. This poster presents the calculated effects of drift degradation on the waste package and drip shield temperatures. Natural backfilling caused by degradation of the fractured tuff wallrock may occur gradually throughout the repository drifts, with all drifts estimated to be backfilled within 1,000 years after closure. Model results indicate prominent increases in waste package and drip shield temperatures due to the insulating effect of the backfill material. An algorithm linking drift degradation to estimates of waste package and drip shield temperature will be presented. Components of the different in-drift heat-transfer processesincluding, conduction, convection and thermal radiationare analyzed for relative importance. The results indicate that thermal radiation and convection dominate the in-drift heat transfer in the absence of drift degradation effects. In the case where drift degradation created a natural backfill, conduction through the backfill was the dominant heat transfer process. Furthermore, sensitivity analyses showed that the in-drift temperatures were very sensitive to the assumed thermal properties of the natural backfill. Ongoing numerical modeling that incorporates hydrologic effects on environmental conditions will also be discussed. This poster is an independent product of the CNWRA and does not necessarily reflect the view or regulatory position of the U.S. Nuclear Regulatory Commission.

H21D-0837 0830h POSTER

Yucca Mountain, a Likely Geologic Repository

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The Department of Energy is evaluating whether Yucca Mountain, Nevada, is likely to meet applicable radiation protection standards established by the Nuclear Regulatory Commission and the Environmental Protection Agency to become the geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. A number of engineered and natural barriers, among them the saturated zone (SZ), are expected to act as obstructions to the release of radionuclides from the potential repository. Radionuclides may move away from the potential geologic repository as either dissolved or colloidal constituents in groundwater. Although groundwater is the transport mechanism, the entire SZ is expected to delay the transport of radionuclides to the accessible environment and reduce the concentration of radionuclides before they reach the accessible environment. Along the flow path from the potential repository to the accessible environment, the water table transitions from fractured volcanic tuffs to alluvium. Transport processes in the more permeable volcanic tuffs include advective transport dominated by fracture flow, matrix diffusion, sorption in the matrix, and dispersion. Transport processes in the alluvium include advective transport, sorption, and dispersion. The site-scale conceptual model is a synthesis of what is known about flow and transport processes at the level of detail required for Total System Performance Assessment (TSPA). Its mathematical and the associated numerical approaches are designed to quantify the uncertainty in the permeability of geologic units and to accurately represent the flow and transport processes therein. Uncertainties are explicitly incorporated into the flow and transport abstractions through key parameters and conceptual models. An inverse approach is used to estimate the distribution of rock permeability that resulted in calculated values of hydraulic head that best match measured values. Inverse methods also yield rates of lateral flow across model boundaries compatible with results from the regional-scale flow model. Confidence in the model was built by comparing calculated to observed hydraulic heads, estimated to measured permeabilities, and lateral flow rates calculated by the site-scale model to those from the regional-scale flow model. In addition, it was confirmed that the flow paths leaving the region of the potential repository are consistent with those inferred from gradients of measured head and from water chemistry data. The results of the site-scale SZ flow and transport model analysis comprise breakthrough curves for radionuclides at the interface between the SZ and the biosphere (20 km from the potential repository). The importance of the breakthrough curves cannot be assessed independently of the TSPA because they do not contain information on the length of time between waste emplacement, the failure of waste packages, and the time until radionuclides reach the SZ. Nevertheless, for radionuclides not subject to sorption (e.g., carbon), simulated transport times generally were <1,000 yr. For radionuclides subject to minor sorption in the alluvium, simulated transport times were 1,000–2,000 yr. For radionuclides that irreversibly attach to colloids (actinides), simulated transport times in the SZ were somewhat <10,000 yr. Delay in the migration of colloids with attached radionuclides in the SZ results from filtration and resuspension processes. For radionuclides subject to moderate to high sorption, simulated transport times were in excess of 10,000 yr.

H21D-0838 0830h POSTER

Vapor-Phase Transport in the Near-Drift Environment at Yucca Mountain

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Yucca Mountain, located 160 km north of Las Vegas, Nevada, is currently being assessed as a potential site for disposal of spent nuclear fuel and high-level radioactive waste. A key issue regarding repository performance is the likelihood of precipitation percolating a vertical distance of 300 m through unsaturated rock into drifts containing the waste packages. The amount of water that flows into drifts is thought to control the corrosion rates of waste packages, and the mobilization and transport of radionuclides. Subsequently, much effort has been directed towards estimating seepage from the near-drift environment into underground openings. While no naturally occurring seepage has been observed in the excavated tunnels and cavities at Yucca Mountain, numerical studies show that seepage can occur at steady-state percolation fluxes of tens of millimeters per year. However, under current conditions, the potential for seepage to occur naturally is greatly reduced, because of increased evaporation in the drifts resulting from ventilation. This presentation includes observations made over a period of four years along the terminal 944 m of a 2.7 km long tunnel within Yucca Mountain, commonly referred to as the Enhanced Characterization of the Repository Block which was initially excavated to study seepage into unventilated drifts. This initial objective was expanded to include an evaluation of the near-drift microclimates after large sections of the nonventilated drift were observed to be damp, or coated with beads of water, or even occasionally puddled. Observations from this effort indicate that fractures in the unsaturated zone can be primary paths for vapor flow in the immediate vicinity of emplacement drifts which is contrary to conceptual models of liquid traveling through fractures before seeping into the drifts. This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between Bechtel SAIC Company, LLC, and the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab). The support is provided to Berkeley Lab through the U.S. Department of Energy Contract No. DE-AC03-76SF00098.

H21D-0839 0830h POSTER

Navier-Stokes Modeling of Gas, Moisture, Droplet, and Heat Flow in Yucca Mountain Project (YMP) Emplacement Drifts

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The performance of the engineered barrier system (EBS) within the emplacement drifts depends on coupled processes that involve the flow of moisture, gas and water droplets in large open cavities, liquid-film flow on the rock and engineered-material surfaces, fluid and gas migration in fractured, porous materials, and the chemical interactions between all in situ and emplaced materials. However, with the exception of recent heat-transfer analyses using the FLUENT code, virtually all of the in-drift modeling studies for the proposed repository at Yucca Mountain have used porous-medium Darcy-flow approximations. Conservative assumptions are thus required in Total System Performance Assessment (TSPA) to compensate for the abstracted, approximate representation of materials interactions and thermal-hydrological-chemical (THC) processes. This study is focused on achieving more rigorous representation of the in-drift environment with Navier-Stokes modeling of in-drift flow processes (natural convection, realistic gas/moisture movement, film/droplet formation and flow, reactive chemical transport, etc.). The simulations are carried out by finite-element version of the NUFT code, with full Navier-Stokes representation of humidity distribution, droplet and film flow, gas-chemistry evolution, and gas migration within the drifts and at the interface with the invert and host rock. The results of these simulations can be used to test the adequacy of the in-drift coupled-process models being used in the TSPA. This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

H21D-0840 0830h POSTER

Multiscale Model Simulations of Temperature and Relative Humidity for the License Application of the Proposed Yucca Mountain Repository

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For the proposed Yucca Mountain geologic repository for high-level nuclear waste, the planned method of disposal involves the emplacement of cylindrical packages containing the waste inside horizontal tunnels, called emplacement drifts, bored several hundred meters below the ground surface. The emplacement drifts reside in highly fractured, partially saturated volcanic tuff. An important phenomenological consideration for the licensing of the proposed repository at Yucca Mountain is the generation of decay heat by the emplaced waste and the consequences of this decay heat. Changes in temperature will affect the hydrologic and chemical environment at Yucca Mountain. A thermohydrologic-modeling tool is necessary to support the performance assessment of the Engineered Barrier System (EBS) of the proposed repository. This modeling tool must simultaneously account for processes occurring at a scale of a few tens of centimeters around individual waste

packages, for processes occurring around the emplacement drifts themselves, and for processes occurring at the multi-kilometer scale of the mountain. Additionally, many other features must be considered including non-isothermal, multiphase-flow in fractured porous rock of variable liquid-phase saturation and thermal radiation and convection in open cavities. The Multiscale Thermohydrologic Model (MSTHM) calculates the following thermohydrologic (TH) variables: temperature, relative humidity, liquid-phase saturation, evaporation rate, air-mass fraction, gas-phase pressure, capillary pressure, and liquid- and gas-phase fluxes. The TH variables are determined as a function of position along each of the emplacement drifts in the repository and as a function of waste-package (WP) type. These variables are determined at various generic locations within the emplacement drifts, including the waste package and drip-shield surfaces and in the invert; they are also determined at various generic locations in the adjoining host rock; these variables are determined every 20 m for each emplacement drift in the repository. The MSTHM accounts for 3-D drift-scale and mountain-scale heat flow and captures the influence of the key engineering-design variables and natural-system factors affecting TH conditions in the emplacement drifts and adjoining host rock. Presented is a synopsis of recent MSTHM calculations conducted to support the Total System Performance Assessment for the License Application (TSPA-LA). This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

H21D-0841 0830h POSTER

Saturated Zone Anisotropy Near the C-Wells Complex

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Understanding saturated flow and transport near the proposed high-level nuclear waste repository at Yucca Mountain is critical to a successful License Application. Because radionuclides released from the proposed repository at Yucca Mountain must travel through the saturated fractured tuff and the saturated alluvium before reaching the compliance boundary, it is important to characterize the hydrogeologic properties of the downgradient media. Since the completion of the C-wells complex in 1983, several single- and cross-hole tracer and pumping tests have been conducted to gain a better understanding of the hydrogeology of the region. A number of published studies have assigned transmissivities, storativities, and anisotropy ratios to the saturated zone in this area. In this analysis, reviews of several studies are used in conjunction with an independent re-analysis of the data to suggest a distribution of anisotropy ratios between 0.05 and 20 used in the Finite Element Heat and Mass Transfer stochastic flow model of the saturated zone.

H21D-0842 0830h POSTER

Film Flow Along Tunnel Walls

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Dripping of liquid water into tunnels or caves affects natural processes (such as formation of speleothems) and is important to engineering applications (such as mining and geologic disposal of nuclear wastes). Current computer models of these processes assume that liquid water drips immediately after entering the tunnel. In contrast, recent field observations showed that film flow and wetting of tunnel walls result in a temporal and spatial lag between liquid emergence and subsequent dripping, and reduces the amount of dripping. Moreover, spreading of water on the tunnel walls enhances the potential for evaporation. The objective of this study was to assess how film flow along rough tunnel walls affects seepage and to provide a framework for realistic modeling of seepage and evaporation. In this research, conceptual models are developed by capitalizing on recent advances in our understanding and modeling of (1) unsaturated flow near and around tunnels, (2) characterization of unsaturated flow on rough surfaces, and (3) dripping from pendant rivulets. We show that film flow has the potential for diverting a significant portion of the flux of liquid entry into a tunnel. We derived an analytical expression for the threshold flux that results in dripping (seepage) and analyzed the implications for various cavity sizes and tunnel wall roughness features. This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, Division of Chemical Sciences, Geosciences & Biosciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

H21D-0843 0830h POSTER

Analysis of Transport Through a Fault Using Transfer Functions

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Understanding flow and transport in unsaturated fractured rock (i.e., matrix and fracture flow, and fracture-matrix interactions) is important for performance assessment and the design of the proposed radioactive waste repository at Yucca Mountain, Nevada. A key factor affecting performance of the proposed repository is the transport of radionuclides through unsaturated fractured rock that lies between the repository horizon and water table located 300 m below. Of particular importance is the need for an understanding of diffusive mass transfer between high-permeability, advection-dominated domains and low-permeability domains. An in situ field experiment was conducted in the Exploratory Studies Facility at Yucca Mountain, Nevada to examine flow and transport in the vicinity of a fault located in unsaturated fractured rock. This experiment involved the release of 75,000 liters of ponded water over a period of 14 months directly into a near-vertical fault located in the fractured welded tuff of the Topopah Spring Tuff unit. Seepage rates were monitored in a large cavity (niche) excavated 20 m below where the water was released along the fault. Seven months after water was introduced, two conservative tracers (pentafluorobenzoic acid [PFBA] and bromide) were simultaneously released along the fault over a period of nine days. After the release of the tracers, seepage water was continuously collected from three locations in the niche and analyzed for the injected tracers. The results from this field experiment demonstrate that flow and transport near a fault located in unsaturated fractured rock is complex due to mechanisms such as dynamic flow behavior. Continuum-based models may not be applicable when these types of mechanisms affect flow and transport. Measured breakthrough curves from this field experiment are analyzed using transfer functions as an alternative to the continuum-based models, and the applicability of using transfer functions to describe transport in the vicinity of a fault is evaluated. This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between Bechtel SAIC Company, LLC, and the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab). The support is provided to Berkeley Lab through the U.S. Department of Energy Contract No. DE-AC03-76SF00098.

H21D-0844 0830h POSTER

Non-Aqueous Phase Liquid Drop Formation Within a Water Saturated Fracture

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This work focuses on the mechanisms for non-aqueous phase liquid (NAPL) drop formation within a single fracture. The fracture is assumed to be fully saturated, the relative wettability of the system is assumed water-wet, and the water velocity profile within the fracture is described by a Poiseuille flow. The size of the NAPL drops is investigated for various water flow velocities and NAPL entrance diameters. A force balancing method was used to determine the instant that the drop detaches from its NAPL source. The drop sizes calculated from the model developed here are shown to be in agreement with available experimental drop size data. It is shown that at low Reynolds numbers the buoyancy force is dominating the force acting on the drop during the formation process and at high Reynolds numbers the viscous forces dominate. A simplified expression relating the geometry of the fractured system to the drop radii is developed, and it is shown to predict drop radii within 5% of the radii calculated by the force balance method.

H21D-0845 0830h POSTER

Acoustically Enhanced Nonaqueous Phase Liquid Dissolution in Water Saturated Porous Media

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The effects of acoustic waves on the dissolution of dense nonaqueous phase liquids (DNAPLs) in water saturated porous media are investigated in this study. Experiments of trichloroethylene (TCE) ganglia dissolution within a water saturated column, packed with glass beads are conducted. Acoustic waves with pressure amplitudes ranging from 0 to 1625 Pa and frequencies ranging from 0 to 285 Hz are employed to the interstitial fluid at the inlet of the packed column. Effluent dissolved TCE concentrations are observed to increase by over 120% in the presence of acoustic pressure waves compared to the case where TCE dissolution without acoustic waves is monitored. Several peaks in effluent concentrations were observed for specific frequencies that may be attributed to resonant frequencies and/or the presence of standing waves. The observed effluent dissolved TCE concentration increase is attributed to increased mass flux at the TCE-water interface, caused by acoustic waves. The acoustic waves employed were found to be highly attenuated with distance from the acoustic source but may be compensated by greater acoustic source pressure.

H21D-0846 0830h POSTER

NAPL Mass Reduction Effects on Contaminant Source Strength: Laboratory Experiments

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The longevity of sites contaminated with chlorinated solvents, and the associated implication for plume management options, has made source zone remediation an attractive option. However, source zone remediation is challenging and recent field scale demonstrations of aggressive source zone remediation have pointed to the technical infeasibility of complete restoration of the source zone. Another approach to evaluating the success of source zone remediation is in a risk-based framework, where the technology is evaluated for its ability to reduce the source strength to a level where the risk to down-gradient receptors is lowered below a certain threshold. Virtually all field and laboratory research of source zone remediation to date has focused on the technology's ability to remove mass from the source zone and has not evaluated the impact of the remediation on source strength. This prevents the analysis of previous work in a risk-based framework. In this work we evaluate relationships between mass reduction and source strength (mass flux of contaminant) in two-dimensional laboratory flow cells with heterogeneous distributions of porous media. The flow cell features a segmented extraction well which allows for segmented measurements of water and contaminant flux. The flow cell is designed to investigate the effects of NAPL morphology and distribution (source-zone architecture) in relation to a heterogeneous flow field on mass reduction/flux reduction relationships. Results indicate a linear relationship between mass reduction and flux reduction with relationships for individual well segments oscillating about a mean trend describing the entire system. Results from a series of experiments, with varying degrees of heterogeneity are presented with an emphasis on contaminant flux plane response to changes in source-zone architecture.

H21D-0847 0830h POSTER

Natural Remobilization of Multicomponent DNAPL Pools: Laboratory Evidence

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Dense non-aqueous phase liquids (DNAPLs) trapped in the subsurface can act as long-term sources of contamination by dissolving into flowing groundwater. Many of these DNAPLs are actually mixtures of different chemical components. In general, the components of higher solubility are removed more quickly, thus altering the composition of the remaining DNAPL, and possibly leading to changes in its physical properties. We theorised that a multicomponent DNAPL pool may become mobile due to the natural dissolution process. The potential for natural remobilization depends on two primary mechanisms: the reduction in pool height as mass is lost by dissolution, and the changes in fluid properties with changing molar ratio of the DNAPL. The difference between the rate of change of each determines whether the potential for remobilization increases or decreases. The purpose of the laboratory experiments presented here was to demonstrate and quantify this process of natural remobilization of a multicomponent DNAPL pool. In the four experiments, a DNAPL pool comprised of tetrachloroethene (PCE) and benzene was created as an open pool overlying glass beads within a water-saturated flow box. Experiments included rectangular and triangular pools. In each of the experiments, remobilization (as breakthrough) was observed more than two weeks after formation of the initial pool. During each experiment, the pool height declined as mass was lost by dissolution, while both aqueous and NAPL sampling indicated a decrease in the molar ratio of benzene, the more soluble component. Small protuberances (displacement) formed along the bottom of the pool as its composition changed with time and the displacement pressure was achieved for various pore throats. Eventually one of the protuberances extended further, forming a finger (breakthrough). In general, the pool emptied as the finger proceeded further into the beads.

H21D-0848 0830h POSTER

Controlled Mobilization and Recovery of Dense Nonaqueous Phase Liquid From a Heterogeneous Porous Media System

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Remediation of a persistent class of contaminants known as dense nonaqueous phase liquids (DNAPLs) from saturated subsurface systems is a complex environmental problem. As DNAPL migrates through porous media, it becomes entrapped in pore spaces due to capillary forces. This entrapped residual has neither a predictable nor a uniform distribution. If a sufficient volume is released, relatively long length-scale features, or pools, can form over a range of length scales. Although pools can be removed through pumping over extended periods of time, such approaches are usually not practical since a large fraction of DNAPL remains in the system as residual. To investigate this problem of remediating DNAPL, three-dimensional laboratory experiments were conducted in a saturated heterogeneous porous medium by using a combination of three remediation technologies: a surfactant, a brine barrier, and vapor extraction. Surfactant was used to mobilize entrapped DNAPL downwards by decreasing interfacial tension. A dense brine barrier was established below the source zone prior to the surfactant flush to control downward mobilization. The buoyancy forces associated with the brine barrier promoted pooling of mobilized DNAPL on top of the barrier. Approximately 72% of the initial trichloroethylene (TCE) mass was removed by extracting the DNAPL pool formed on the dense brine barrier. Dewatering of the system also resulted in further reductions of buoyancy forces. Vapor extraction was performed after dewatering, decreasing the remaining residual to less than 1% of the initial mass. The use of additional surfactant, implementation of a stepped down extraction point system and the use of a force-gradient approach were considered to decrease entrapment of mobilized DNAPL in fine sand regions and to increase recovery during the well extraction portion of the experiments. Well recovery using these techniques ranged from 76–86%.

H21D-0849 0830h POSTER

In Situ Remediation of Contaminated Groundwater via Enhanced Reductive Dehalogenation and Dual-Screened Wells

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Groundwater contaminated by chlorinated solvents, principally cis-dichloroethene (cis-DCE), was cleaned *in situ* by a technology that combines enhanced reductive dechlorination with dual-screened treatment wells. The prolonged historic presence of cis-DCE at the contaminated site suggested that natural attenuation rates were limited by the supply of electron donors. Therefore, propionate was added to the contaminated groundwater to serve as an electron donor and to accelerate the reductive dechlorination process. Propionate was added from the ground surface via a pair of dual-screened wells emplaced in the contaminated portion of the aquifer. The wells were screened at two depths, from 3.0–7.6 m below ground surface (bgs) and from 9.1–12.2 m bgs. These wells functioned to intercept the contaminant plume, augment the contaminated water with propionate, recirculate a portion of the contaminated water, and release treated water for continued downgradient migration. Treatment occurred wholly *in situ*. Within the recirculation zone of the well pair, cis-DCE was effectively removed during a two-month period of operation. In the lower aquifer zone, 800 μg/L cis-DCE was converted stoichiometrically to ethene. In the upper aquifer zone, the concentration of cis-DCE was reduced from over 400 μg/L to less than 40 μg/L. Dechlorination was accompanied by significant sulfate reduction, but not by methanogenesis. The hydraulics of the groundwater flow are described with a relatively simple analytical mathematical model. Measured concentrations of a bromide tracer agree very well with model predictions, suggesting that the model is valid for this contaminated site. At this site, it appears sufficient to model the aquifer as consisting of two homogeneous layers separated by an impermeable aquitard; smaller-scale heterogeneity in the hydraulic conductivity can apparently be ignored.

H21D-0850 0830h POSTER

Hydraulic conductivity dependency of biodegradation of fuel hydrocarbon contaminants in a natural attenuation field site

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Two biodegradation models are developed to represent natural attenuation of fuel-hydrocarbon contaminants as observed in a comprehensive natural-gradient tracer test in a heterogeneous aquifer on the Columbus Air Force Base in Mississippi. The first, a first-order mass loss model, describes the irreversible losses of BTEX and its individual components, i.e., benzene(B), toluene (T), ethyl benzene (E), and xylene(X). The second, a pathway model, describes sequential degradation pathways for BTEX utilizing multiple electron acceptors, including oxygen, nitrate, iron and sulfate, and via methanogenesis. The heterogeneous aquifer is represented by multiple hydraulic conductivity (K) zones delineated on the basis of numerous flowmeter K measurements. A direct propagation artificial neural network (DPN) is used as an inverse modeling tool to estimate the biodegradation rates associated with each of the K zones. In both the mass loss model and the pathway model, the biodegradation rate constants show an increasing trend with the hydraulic conductivity. The finding of correlation between biodegradation kinetics and hydraulic conductivity distribution is of general interest and relevance to characterization and modeling of natural attenuation of hydrocarbons in other petroleum-product contaminated sites.

H21D-0851 0830h POSTER

MTBE Hydrolysis in Dilute Aqueous Solution Using Heterogeneous Strong Acid Catalysts

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The objective of this research has been the development of a potential in situ catalytic process for the hydrolysis of methyl tertiary butyl ether (MTBE) to tertiary butyl alcohol (TBA) and methanol in ground water. Bench-scale batch reactor studies were conducted over a temperature range of 23 deg C to 50 deg C with several heterogeneous strong acid catalysts to obtain rates of hydrolysis of MTBE to TBA and methanol at dilute concentrations in water. Continuous flow experiments were then conducted to obtain kinetic data over a temperature range of 15 deg C to 50 deg C for various flow rates for the most active catalysts. It was found that the batch and continuous flow experiments yielded similar intrinsic kinetic rate constants when sorption of MTBE to the catalyst was accounted for. Additional fixed-bed experiments were conducted with deionized water and 0.005 M CaCl2 feed solutions containing 100 mg/L MTBE, respectively, to assess the deactivation of the catalyst, and deactivation was found to be controlled by ion exchange of H+ in the catalyst with Ca+2 in the feed. Our results indicate that, for low to moderate groundwater velocities and cation concentrations at ambient temperatures, an in situ reactive barrier process using the most active catalysts studied in this research could be a viable process in terms of both suitable conversion of MTBE and catalyst life. Although application to in situ remediation is emphasized, the results of this research are also applicable to ex-situ groundwater treatment.

H21D-0852 0830h POSTER

Characterization of Reactive Solute Transport in Laboratory Column Experiments Using Temporal Moments

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A method is presented for the analysis of contaminant breakthrough curves from laboratory column experiments using temporal moments. The temporal moments are used (1) to determine if an experimental breakthrough curve can be predicted by one of three advection/dispersion/sorption models (linear equilibrium, linear one-site, and linear two-site) and (2) to estimate the corresponding transport and sorption parameters. The technique was developed for both known and unknown Peclet number. It was first tested for ideal breakthrough curves (error-free data with small time increments), and was generally successful in identifying the correct model and providing accurate estimates of transport parameters. The exception was the two-site model for unknown Peclet number, where problems were encountered in solving the system of three non-linear equations required to estimate the transport and sorption parameters. To test the robustness of the technique, it was then applied to breakthrough curves more representative of those that might be obtained experimentally. These curves were produced by introducing random error into the concentration data and increasing the time increment between data points. Although the technique ultimately failed with increasing error and time increment, the envelop of values for which it was successful includes a range that can reasonably be achieved experimentally. For example, it was successfully applied to equilibrium data (retardation factor = 1.5 and Peclet number = 100) with a time increment of 0.3 displaced pore volumes and relative experimental error of 10%.

H21D-0853 0830h POSTER

Laboratory Measurement of Dispersion in a Saturated Two-Dimensional Flow Field.

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Laboratory experiments show the effect of a single large heterogeneity in a two-dimensional flow field. Potassium Chloride (KCl), a conservative tracer, was used to examine the effect of the heterogeneity on miscible dispersion. The porous medium is created using two different distributions of spherical glass beads packed inside a 32 x 32 x 1 cm box. The heterogeneity is a 16 x 16 cm inclusion within the box - forming two distinct regions. The box is initially saturated with 0.02 M KCl and is displaced with 0.2 M KCl during the experiment. The changing chloride concentrations are measured at 256 locations within the box, every 0.75 seconds, with total experimental times up to 9000 seconds (depending on the flow rate). The experimental measurements clearly show the flow paths, tracer travel times, and positional breakthrough curves of the tracer.

H21D-0854 0830h POSTER

Limit Theorems and Their Relation to Solute Transport in Simulated Fractured Media

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Solute particles that travel through fracture networks are subject to wide velocity variations along a restricted set of directions. This may result in super-Fickian dispersion along a few primary scaling directions. The fractional advection-dispersion equation (FADE), a modification of the original advection-dispersion equation in which a fractional derivative replaces the integer-order dispersion term, has the ability to model rapid, non-Gaussian solute transport. The FADE assumes that solute particle motions converge to either α-stable or operator stable densities, which are modeled by spatial fractional derivatives. In multiple dimensions, the multi-fractional dispersion derivative dictates the order and weight of differentiation in all directions, which correspond to the statistics of large particle motions in all directions. This study numerically investigates the presence of super- Fickian solute transport through simulated two-dimensional fracture networks. An ensemble of networks is gen

H21D-0855 0830h POSTER

Modeling Seawater Intrusion in a Coastal Aquifer System for Effective Management

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Baldwin County is situated along the Gulf of Mexico containing pristine beaches that attract many visitors to Alabama each year. Development of the region as a resort destination along with increasing numbers of visitors each year have placed growing demands on the water supply available in the region. As more wells are placed in the coastline vicinity and put into production seawater intrusion becomes more likely. We have developed a variable-density groundwater model for part of Baldwin County to characterize the extent of the seawater intrusion. The model predicts reasonably well the current location of the freshwater/saltwater interface based on 1996 pumping data. The model is used to evaluate the coastal aquifer system and to determine if current pumping strategies could jeopardize future water supply. The study will provide a scientific basis for effective management of groundwater resources in the coastal regions experiencing rapid economic growth.

H21D-0856 0830h POSTER

Seawater Upconing Under a Pumping Horizontal Well in a Confined Coastal Aquifer

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Coastal margins are one of the nation's greatest natural resources and economic assets. Due to increasing concentration of human settlements and economic activities in the coastal margins, it is critical to find better technologies of managing the coastal groundwater resources. Coastal aquifers always have saline water underneath the fresh water. This phenomenon substantially limits the groundwater pumping rates using traditional vertical wells because of the upconing of the fresh/saline water interfaces and the potential of sea water intrusion. With the advancement of horizontal well technology, we propose to use long-screen (kilometers) horizontal wells in coastal aquifers to increase groundwater supply and prevent sea water intrusion into those wells. In this study, we have developed two mathematical models to predict the equilibrium location of upconed sharp interfaces due to pumping horizontal wells based on the linear model of Muskat (1982) and the non-linear model of Dagan and Bear (1968) which described the upcoming due to a partially penetrating vertical pumping well. The horizontal well solution is obtained by integrating the point sink solution along the horizontal well axis. The linear solution based on Muskat's model (1982) is acquired by neglecting the pressure field variation caused by the change of the fresh/saline water interface, while the nonlinear solution includes that variation. The computed interface profiles based on these two models are compared with those of vertical wells. The critical pumping rate is calculated and the sensitivity of the interface profile on aquifer anisotropy, horizontal well depth, and horizontal well length is tested. References: G. Dagan and J. Bear, Solving the problem of local interface upcoming in a coastal aquifer by the method of small perturbations, J. Hydraulic Research, 6, 15-44, 1968. Muskat, M, The flow of homogeneous Fluids Through Porous Media, International Human Resources Development Corporation, Boston, 763 PP, 1982.

H21D-0857 0830h POSTER

A New Approach to Measuring the Direction of Horizontal Groundwater Flow

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A Passive Flux Meter (PFM) has been developed to simultaneously measure the magnitudes of groundwater and contaminant fluxes in porous media. The PFM consists of a permeable sorptive media in the shape of a homogeneous cylinder that is inserted into a borehole and that exactly fits the diameter of the well screen. The PFM, which initially contains a known amount of a resident tracer, thus intercepts groundwater and contaminant flow causing the partial elution of the resident tracer from the PFM and the sorption of contaminants onto the PFM. Quantitative analysis of the PFM for the amount of resident tracer remaining on the PFM media and the amount of contaminant sorbed onto the PFM after exposure to groundwater and contaminant flow allows for the determination of the magnitudes of groundwater and contaminant fluxes. In this work, two modified configurations of the PFM are presented and compared that are capable of measuring the horizontal flow direction simultaneously to the magnitudes of groundwater and contaminant fluxes. The first configuration is characterized by a simple separate analysis of various sub areas within the circular cross section of the PFM. Thus, the flow direction can be measured by identifying the direction of the movement of the resident tracer across the cross section. The second configuration makes use of different directional tracers in three sectors of the circular cross section of the PFM. A single analysis of the whole cross section determines the mass of each directional tracer remaining in the PFM, which allows for an estimation of the flow direction. For both configurations a geometric approach is used to derive the relationships between the measured tracer masses and the flow direction. Tracer and contaminant sorption is assumed linear, instantaneous and reversible, and dispersive transport is neglected. The solutions obtained for both configurations are used to evaluate and compare the two alternatives regarding their theoretical potential to measure flow direction. Some practical aspects concerning the differences between the two modified configurations are discussed and first results of laboratory tests configuration are presented.

H21D-0858 0830h POSTER

Determination Of Pressure Field And Hydraulic Diffusivity Of Sub-Sea Formations By Continuous Measurements Of Pore Pressure

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Potential field and hydraulic properties of sub-sea formation govern the groundwater flow below sea bottom, and hence, control the location and flux of Submarine Groundwater Discharge (SGD). Because SGD is considered to be one of the important pathways of material transport from land to coastal sea, determination of both potential field and hydraulic properties can improve our understanding of land-sea interaction processes. In this study, we developed a new devise to continuously measure pore pressure and seafloor pressure, and applied the theory of poroelasticity to obtain hydraulic properties from measured data. The developed devise has multi-depth pressure ports; one is on the sea floor and the others are set at two different depths in the sub-sea formation, and measures pore pressure data synchronously. The devise was set up for a month at the water depth of 20m, offshore Kurobe alluvial fan, Japan, where fresh ground water discharge has been discovered and studied. The depths of the pressure measurements were at 0.50 meters below sea floor (mbsf) and 0.84 mbsf. Pressure data were acquired every 30 minutes throughout the experiment. To evaluate the effect of water wave loading, we measured pressure data with 2 Hz frequency two times per day. The resolutions of measured data were 0.01 Pa for the lower frequency measurement and 2 Pa for 2 Hz frequency measurement, respectively. At 0.84 mbsf, pore pressure value was about 0.6 to 0.7 kPa higher than hydrostatic pressure. On the other hand, it was nearly hydrostatic pressure to 0.3 kPa higher than hydrostatic pressure at 0.50 mbsf. These data showed the upward hydraulic gradient of at around 0.1 $\sim$ 0.2, which was consistent with the existence of fresh groundwater discharge at the location. The hydraulic diffusivities were estimated using two phenomena; one was pore pressure recovery process due to the disturbance of pore pressure field by installation of the devise, and the other was pore pressure response to the water wave loading. The analysis of pressure recovery at 0.84 mbsf indicated that the hydraulic diffusivity was on the order of 10^{-9} m^2/s. At 0.50 mbsf, pressure recovery was not observed, suggesting the higher hydraulic diffusivity at this depth. The difference of the recovery patterns suggested that the formation was made up of at least two layers. Using the two layer model of the pore pressure response to water wave (Mu et al, 1999), the hydraulic diffusivity of upper layer was estimated to be 0.3 $\sim$ 1.5 m^2/s. According to the direct observation by diving survey, the sub-sea formation at the location was composed of sands overlying the clay layer. Thus, the obtained hydraulic values are consistent with those expected from the observed geology. Reference Mu, Y., A. H-D. Cheng, M. Badiey and R. Bennett, 1999. Water Wave Driven Seepage In Sediment And Parameter Inversion Based On Pore Pressure Data. Int. J. Numer. Anal. Meth. Geomech., 23, 1655-1674.

H21D-0859 0830h POSTER

Determination Of Hydraulic Properties From Pore Pressure Fluctuation Measured At Multiple Depth Intervals

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Fluctuation of water level induced by atmospheric loading has been observed in many wells and has been used to estimate hydraulic properties of the subsurface material. However, the methods of estimating hydraulic properties developed in previous researches have some problems concerned with the attenuation of

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atmospheric pressure in unsaturated zone and the too many unknown parameters relative to data available from the conventional water level measurement in a well. In this study, we introduce the concept of measuring pore pressure at multiple depth intervals in a well, to overcome these problems. This approach increases the number of the data available and enables us to estimate the specific storage and the hydraulic diffusivity separately from the data. Furthermore, we developed the theory based on the poroelasticity to estimate the hydraulic diffusivity in saturated zone unaffected by the attenuation in an unsaturated zone and the method of estimation by the careful arrangement of the instruments. Our method developed in this study has advantages over the previous methods with respect to the accuracy of estimation, because we can expand the data window for dimensionless depth and can avoid the attenuation in the unsaturated zone. We developed a new device for measuring pore pressure at multiple depth intervals in a single borehole to apply this method to an actual field. Using data obtained from this device, we demonstrate that the specific storage and the vertical hydraulic conductivity in Tertiary sedimentary rocks can be estimated both in fully saturated zone and saturated zone underlying an unsaturated layer. The results showed that the specific storage and the vertical hydraulic conductivity can be estimated within an order of magnitude error, which was well within the acceptable range, considering otherwise both are not easy to measure in situ. The method presented here seems to be useful to estimate hydraulic properties in site investigation especially at an early stage, because hydraulic properties can be estimated from only passive monitoring pore pressure, which is becoming popular in site investigation.

H21D-0860 0830h POSTER

Finite Element Modeling of Transient Head Field Associated with Partially Penetrating, Slug Tests in a Heterogeneous Aquifer with Low Permeability, Stratigraphic Zones and Faults

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Preliminary field work shows slug interference tests using an array of multilevel active and monitoring wells have potential of permitting enhanced aquifer characterization. Analysis of these test data, however, ultimately will rely on numerical geophysical inverse models. In order to gain insight as well as to provide synthetic data sets, we use a 3-D finite element analysis (code:FEHM-LANL) to explore the effect of idealized, low permeability, stratigraphical and structural (faults) heterogeneities on the transient head field associated with a slug test in a packer-isolated interval of an open borehole. The borehole and packers are modeled explicitly; wellbore storage is selected to match values of field tests. The homogeneous model exhibits excellent agreement with that of the semi-analytical model of Liu and Butler (1995). Models are axisymmetric with a centrally located slugged interval within a homogenous, isotropic, confined aquifer with embedded, horizontal or vertical zones of lower permeability that represent low permeability strata or faults, respectively. Either one or two horizontal layers are located opposite the borehole packers, which is a common situation at the field site; layer thickness (0.15-0.75 m), permeability contrast (up to 4 orders of magnitude contrast) and lateral continuity of layers are varied between models. The effect of a "hole" in a layer also is assessed. Fault models explore effects of thickness (0.05-0.75 m) and permeability contrast as well as additional effects associated with the offset of low permeability strata. Results of models are represented most clearly by contour maps of time of arrival and normalized amplitude of peak head perturbation, but transient head histories at selected locations provide additional insight. Synthesis of the models is on-going but a few points can be made at present. Spatial patterns are distinctive and allow easy discrimination between stratigraphic and structural impedance features. Time delays and amplitude reduction increase nonlinearly with increasing permeability contrast. The capacity to discriminate the effect of layer thickness decreases as permeability contrast increases.

H21D-0861 0830h POSTER

Multilevel, Multiwell Slug Tests as a Means to Determine Hydraulic Properties of Aquifer Heterogeneities: Preliminary Tests at a Geologically, Well-Constrained Test Site

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Efforts are on-going to develop a high resolution, aquifer characterization procedure based upon cross-well hydraulic tomography using multiwell (interference) slug test data from an array of multilevel wells with pressure measuring ports and flow ports. This poster presents preliminary results of a series of slug tests in a multilevel well network in a faulted, siliciclastic aquifer/aquitard system in central Texas. Emphasis is on presenting the testing methodology and showing how known, low permeability, stratigraphic and structural (faults) heterogeneities are manifest within measured transient pressure histories and their spatial patterns. The aquifer is a sandstone-dominated deposit with a few discontinuous mudstone interbeds that grades upward into interbedded sandstone and mudstone strata representing the confining aquitard. At the test site a 20 m displacement normal fault partially offsets the aquifer/aquitard system and impedes cross-fault flow. Prior work provides a highly constrained geological model of the site. Mulitlevel monitoring systems in eight boreholes provide 94 hydraulically isolated, pressure measurement zones distributed in a region 40 m by 20 m by 70 m encompassing the fault and adjacent aquifer/aquitard strata. In addition, 25 zones have "injection/withdrawal" ports, which can be used to perform the localized, slug tests. Both falling-head and rising-head slug tests are performed, using initial slug magnitudes of 20 to 40 m. Using pressure transducers with 20 Pa (0.003 psi) resolution, a test series for a single slugged interval typically provides usable pressure histories for 30 to 40 zones located from 3 m to 27 m away. Normalized peak amplitudes of head changes range from 0.1 to 0.0003. The effects of low permeability strata and faults are most easily seen in the spatial patterns of the arrival time and amplitude of the maximum head change. Examples are presented to demonstrate these effects. Having multiple zones within and across a flow impedance structure appears critical to inferring properties of the zone. Somewhat unexpectedly, in addition to the later arriving, diffusive pressure wave response, a prominent, early-time, poroelastic response is measured in selected zones of low permeability.

H21D-0862 0830h POSTER

Influence of correlation on the permeability and on well-test interpretation of two-dimensional fractal porous and fractured media

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How does correlation influence the medium hydraulic properties and the choice of the relevant modeling framework? We have investigated this question both in fractured and in porous media displaying fractal correlation pattern. In porous media, we show that fractal correlations let the equivalent permeability decrease with scale. However, their well-test response remains, on average, close to that of homogeneous media. In fractured media, observations of outcrops show that fractures are correlated at all scales of the medium and that there are also fractures of sizes ranging from the micro- to the macro-scale. Recent studies have shown that the correlation pattern is often a fractal and that the fracture-length distribution is a power law. This double-absence of characteristic length scale challenges for two reasons the use of homogenization techniques to model fractured media. We have studied the effect of these long-range heterogeneities on the fracture network connectivity and on the equivalent medium permeability. The correlation and the length distribution have opposite effects on connectivity and permeability. Increasing correlation lets connectivity and permeability decrease and conversely for the variance of the length distribution. In most cases, one of the characteristic (i.e. length or correlation) supersedes the other. There is only a small area where both characteristics have a simultaneous influence on permeability. In this latter area, the influence of the correlation remains low, more precisely a scale increase of at least 5 orders of magnitude is required to produce a permeability increase of one order of magnitude. Although the correlation pattern does not have much influence on the equivalent permeability, its influence on the flow pattern increases from negligible for networks at threshold to important for dense networks.

H21D-0863 0830h POSTER

Mechanical Clogging Processes in Unconsolidated Porous Media Near Pumping Wells

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In the Netherlands water supply companies produce over more than one billion cubic meters of drinking water every year. About 2500 water wells are used to pump up the groundwater from aquifers in the Dutch subsurface. More than 50% of these wells will encounter a number of technical problems during their lifetime. The main problem is the decrease in capacity due to well clogging. Clogging shows up after a number of operation years and results in extra, expensive cleaning operations and in early replacement of the pumping wells. This problem has been acknowledged by other industries, for example the metal, petroleum, beer industry and underground storage projects. Well clogging is the result of a number of interacting mechanisms creating a complex problem in the subsurface. In most clogging cases mechanical mechanisms are involved. A large number of studies have been performed to comprehend these processes. Investigations on mechanical processes are focused on transport of small particles through pores and deposition of particles due to physical or physical-chemical processes. After a period of deposition the particles plug the pores and decrease the permeability of the medium. Particle deposition in porous media is usually modelled using filtration theory. In order to get the dynamics of clogging this theory is not sufficient. The porous media is continuously altered due to deposition and mobilization. Therefore the capture characteristics will also continuously change and deposition rates will change in time. A new formula is derived to describe (re)mobilization of particles and allow changing deposition rates. This approach incorporates detachment and reattachment of deposited particles. This work also includes derivation of the filtration theory in radial coordinates. A comparison between the radial filtration theory and the new formula will be shown.

H21D-0864 0830h POSTER

Scale Effects on the Hydraulic Conductivity: Real or Artifact?

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Field results for the hydraulic conductivity, K, often indicate that K increases with scale. This effect has been justified by appeal to the possibility that, with increasing scale, a) the connectivity of the highly conducting pathways increases, or b) that larger pores/fractures become accessible. The latter equates to a statistical bias in that the definition of the medium (and the porosity) become scale-dependent. For the former case, with one exception, it is not possible to connect sides of a medium at a large scale withoug having connections at a small scale too. If these highly conductive regions are properly weighted, it will be seen that K becomes either constant, or diminishes with scale. A noteworthy exception occurs in anisotropic systems, where more connections can be gained by increasing the system size than are lost. However, this effect is shown here to be more properly a dimensional effect, resulting from a cross-over from 1D conduction at small scales to 3D conduction at large scales. Appropriate upscaling would remove the effect, but field experiments cannot be configured to do so.

H21D-0865 0830h POSTER

The Use of Hydraulic Head and Atmospheric Tritium to Identify Presence of Fractures in Clayey Aquitards: Numerical Analysis

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Surficial clayey aquitards can provide underlying aquifers with strong protection from contamination if vertically connected open fractures are absent. Hence, methods are needed to identify such contaminant pathways. An existing two-dimensional model for steady-state groundwater flow and solute transport (FRACTRAN) was used for cross-sectional simulations to assess the prospects for using field measurements of hydraulic head and atmospheric (i.e. bomb) tritium in surficial aquitards to determine presence and nature of hydraulically connected fractures. Simulations for a 15-m thick horizontal aquitard, with shallow water table and downward groundwater flow, show that field measurements of head and tritium at points appropriately spaced along a horizontal line at the lower part of the aquitard provide unique insight since they offer the highest chance for detecting vertical fractures. Simulations represented sets of predominant vertical and horizontal fractures of uniform aperture (25 m) and variable length. The simulations focused on fracture-network features assigned based on the literature of field investigations. The horizontal profiles show peaks and troughs for head, and always peaks for tritium concentrations at fracture localities. Use of only head or tritium alone may locate fractures, but may not discover whether each fracture is connected to the ground surface or aquifer top, or both. On the other hand, the coupled patterns of head and tritium can be used to identify fractures more accurately. For example, a head trough and a tritium sharp peak represent a fully penetrating fracture, while a head peak and a rounded-tip tritium peak represent a partially penetrating fracture. Moreover, these two are easily differentiated from an embedded fracture that is represented by a relatively small head trough and a short sharp tritium peak. The method of monitoring along a horizontal line was applied to the conceptual 15-m thick aquitard imitating horizontal groundwater head monitoring and formation sampling events at different spacing intervals. The modeling indicates that, monitoring at 3-m spacing along a line at an elevation positioned deep in the aquitard locates and determines connectivity of most vertical fractures. Moreover, it may be possible from measured tritium distributions in aquitards to estimate the depth of hydraulically active partially penetrating fractures. Thus, horizontal monitoring is a valuable complement to vertical monitoring nests in the study of aquitard integrity.

URL: http://www.science.uwaterloo.ca/earth

H21D-0866 0830h POSTER

On the Hydraulics of Flowing Horizontal Wells

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A flowing horizontal well is a special type of horizontal well that does not have pumping/injecting facility. The discharge rate of a flowing horizontal well is controlled by the hydraulic gradient between the aquifer and the well and it generally varies with time if the hydraulic head of the aquifer is transient. This type of well has been used in landslide control, mining dewatering, water table control, underground water transportation through a horizontal tunnel, agricultural water drainage, and other applications. Flowing horizontal wells have quite different hydrodynamic characteristics from horizontal wells with fixed pumping or injecting rates because their discharge rates are functions of the aquifer hydraulic heads (Zhan et al, 2001; Zhan and Zlotnik, 2002). Hydraulics of flowing horizontal wells have rarely been studied although the hydraulics of flowing vertical wells have been extensively investigated before. The purpose of this paper is to obtain analytical solutions of groundwater flow to a flowing horizontal-well in a confined aquifer, in a water table aquifer without precipitation, and in a water table aquifer with precipitation. The functions of the flowing horizontal well discharge rates versus time will be obtained under above mentioned different aquifer conditions. The relationships of the aquifer hydraulic heads versus the discharge rates of the well will be investigated. The rate of water table decline due to the dewatering of the well will also be computed, and this solution is particularly useful for landslide control and mining dewatering. The theoretical solutions will be compared with results of experiments that will be conducted in the hydrological laboratory at Texas A&M University. Reference: Zhan, H., Wang, L.V., and Park, E, On the horizontal well pumping tests in the anisotropic confined aquifers, J. hydrol., 252, 37-50, 2001. Zhan, H., and Zlotnik, V. A., Groundwater flow to a horizontal or slanted well in an unconfined aquifer, Water Resour. Res., 38(7), 10.1029/2001WR000401, 2002.

H21D-0867 0830h POSTER

Hydraulic Travel Time Tomography Appraisal Using Synthetic Data Sets

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Hydraulic tomography is an aquifer characterization method allowing the two and three dimensional spatial identification of hydraulic properties in the subsurface. Such information is essential for rigorous analysis of a variety of engineering, geotechnical and hydrogeological problems within the context of water resources management. We propose a tomographic approach providing the inversion of travel times of multi-well slug tests. The inversion is based on the relation between the travel times of a recorded transient pressure curve and the diffusivity of the geological medium. Usually, just one value of a measured hydraulic signal, mostly the peak time, is used as the data for the inversion in order to reconstruct the diffusivity field of the investigated system. This situation is not satisfying because much information is lost. Therefore, we have developed a transformation factor allowing to apply our approach to several travel times characterizing each signal. Thereby, each travel time is inverted separately. The main focus is to appraise the influence of the various travel times on the inversion results. It can be assumed that early travel times are dominated by preferential flow along fast, high permeability paths, while the inversion results based on late travel times reflect an integration of the received signal over many flow paths. Synthetic data sets were created using the Finite Element Heat and Mass Transfer Code (FEHM) from Los Alamos National Laboratory. The data base of the inversion comprises simulated slug tests, in which the position of the sources (injection ports) and the receivers (observation ports) isolated with packers, are varied between the tests. We also investigate the effects of input parameters such as the number of source-receiver positions used, borehole storage and permeability distribution. The hydraulic tomography appraisal shows a strong dependence of the inversion results on the used travel times and input parameters. Results of the inversion of the synthetic data sets demonstrates the effectiveness of the proposed technique. In particular, the reconstruction of a layered geological medium including a vertical fault is shown.

H21D-0868 0830h POSTER

Inter-aquifer Dynamics in and Near a Confining Unit Window in Shelby County, Tennessee, USA

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An interdisplinary research team is investigating the interaction between the surficial alluvial aquifer and the deeper confined Memphis aquifer in the Memphis area, Shelby County, Tennessee. Previous research has identified a window in the clay-rich, upper Claiborne confining unit that separates the two aquifers near a closed municipal landfill in east-central Shelby County, an area undergoing rapid urbanization. For this investigation, a combination of environmental tracers (tritium/helium-3), major and trace ion geochemistry, hydraulic response testing, measurement of hydraulic gradients, and groundwater flow modeling is being used to quantify recharge of young water from the alluvial aquifer through the window to the Memphis aquifer. The research will provide results to better understand how windows were formed and how they influence recharge and water quality in otherwise confined parts of the Memphis aquifer downdip of its outcrop/subcrop area. Examination of continuous core samples and geophysical logs from wells installed for the study using Rotasonic drilling methods confirmed the existence of a sand-dominated window that may be as much as 1 km in diameter in the upper Claiborne confining unit. The upper Claiborne confining unit is 15 to 20 m thick in most of the study area and is overlain by a 10 to 12 m thick alluvial aquifer. The window is interpreted to have formed as a result of depositional and incisional processes in an Eocene-age deltaic system. Hydraulic gradients of several feet exist vertically between the alluvial and Memphis aquifers within the window, indicating downward flow. Groundwater age-dates from tritium/helium-3 analyses indicate that groundwater in the window at the depth of the base of the surrounding confining unit (approximately 30 m) has an apparent age of 19.8 years, which confirms the occurrence of downward flow. Young groundwater age dates (less than 32 years) also were obtained from wells in the Memphis aquifer at confined sites downgradient of the window, suggesting that a plume of young water is spreading outwards from the window and mixing with the older Memphis aquifer water. Preliminary inverse modeling of the site using a genetic algorithm coupled with a central finite difference flow model indicates a probable steady-state downward flux of about 12,000 m^3/d through the window. Collection and analysis of additional groundwater samples are planned to examine geochemical conditions in the confining unit and in the Memphis aquifer upgradient of the window. These analyses will aid in developing a final conceptual model and in subsequent numerical modeling of mixing of the young recharge water with the older Memphis aquifer water.

H21D-0869 0830h POSTER

The Hydroclimatic Response of the Whitewater River Basin: Influence of Groundwater Time Scales

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A near-surface groundwater model was developed to assess the impact of land use and climate variability on the overall water budget of the Whitewater River Basin. The watershed is located in southeastern Kansas within the ARM-SGP as part of the DOE Water Cycle Pilot Study. The Whitewater River Basin has an area of 1,100 square-kilometers, an elevation range of 380 - 470m (amsl), and an average annual precipitation of 858 millimeters. The approach presented here attempts to examine the importance of groundwater in the water budget and hydroclimatic response at the river basin scale. In order to identify the time scales of groundwater in this system, time series and geospatial analyses were used to identify significant spatial structure and dominant temporal modes in the climate, runoff and groundwater response. In this research, we show that the time scales of groundwater baseflow to the river network are proportional to drainage density and position in the hydrologic landscape. The concept of a hydrologic landscape (Winter, JAWRA, April 2001) defines three zones: recharge (upland), translation (intervening steep slopes), and discharge (lowland), and the hydrologic landscape is useful for standardizing the evaluation of physical properties within any watershed. Singular spectrum analysis was used for a 50-year simulation to determine dominant modes and time scales for the hydrologic landscape units in the Whitewater River Basin. We found that the time scale of groundwater baseflow response increases with increasing drainage density. The sensitivity of this response is important to understand and close the water budget for a river basin through observation network design. The effects of climate forcing, both precipitation and evapotranspiration, can be seen through the hydrologic landscapes and channel networks by changes in the baseflow response time. Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36.

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H21D-0870 0830h POSTER

The Influence of Ground Water on Stream Restoration Following Dam Removal

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With the exception of ground-water seepage beneath dams and the resulting impact on structural failure, there is a void of work directly examining the downstream impacts of dams from the perspective of ground-water/surface-water interaction. This work considers alterations in an alluvial basin caused by: (1) erection of a dam upstream, (2) followed by ground-water pumping in the basin, and (3) dam removal. Theoretical results predict that when dams are removed in developed ground-water basins, downstream baseflows may be greatly reduced relative to natural baseflows, as a result of lower water table elevations in the developed basin relative to the natural setting. Without the dam as a safety valve' providing extra streamflow during low-flow seasons, there is a real potential for ephemeral conditions downstream of the previous location of the dam as the dry season progresses. MODFLOW simulations are used to test these theoretical results, by quantifying the impact of dam removal on downstream surface water and ground water. The simulations incorporate an improved stream-aquifer interaction and streamflow routing package to represent movement of water in the vadose zone between the stream and a lowered water table. An idealized MODFLOW model with the new stream package has been constructed, which extends from the upland bedrock headwaters of a stream to the downstream sediment-filled basin. The model domain is 180 km long, 15 km wide, and 2.2 km deep, including a stream with a potential length of 180 km. In the upper reaches, the stream is divided into a north, south, and main stem with their confluence upstream of a dam situated in the domain above the bedrock/basin contact. Horizontal discretization is 1000 m in the direction parallel to the stream, 200 to 600 m perpendicular to the stream, and vertical discretization is 100 m. This modeling framework affords the opportunity to examine a variety of cases with and without the presence of an upstream dam. Initial MODFLOW results are consistent with the theoretical results regarding the impact of dam removal in developed basins, indicating that dam removal is unlikely to regenerate natural streamflows in developed groundwater basins.

H21D-0871 0830h POSTER

Heterogeneity and Stream-Aquifer Interaction in an Unconsolidated Aquifer

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In north central Kansas the Republican River and its associated alluvial sediments are important regional surface and groundwater supplies. A test site, adjacent to the Republican River, has been established within the porous alluvial sediments to study stream-aquifer interaction and aquifer heterogeneity. This is potentially important research for understanding how to maintain a desired stream flow in the presence of withdrawals from the stream and the aquifer. The site installation consists of seven observation wells located along a line perpendicular to the river channel and centered about a productive irrigation well. In addition to water level data, several geophysical techniques (direct push electrical conductivity, ground penetrating radar, and shallow seismic methods) have been used at this site to characterize the aquifer. The results of the geophysical methods are reported in another paper at this meeting. Water level data collected over a two-week period shows two consecutive irrigation cycles. Each cycle consists of two days of intensive pumping followed by five days of recovery. Several significant elements of stream-aquifer systems can be seen in the data. The water level data demonstrates a regional water level decline in the alluvium that mimics stream gage data located up and down stream from the site, thereby confirming stream-aquifer interaction. Most of the observation wells located symmetrically around the irrigation well show the normal asymmetry expected for a river acting as a specified head boundary. However, heterogeneity causes one pair of symmetric wells to behave differently. Hydraulic data analysis with an automated program (SuprPumpII) demonstrates a degree of heterogeneity within the alluvial sediments not evident from descriptive geologic drilling logs or geophysical logs. A time-drawdown plot of a symmetric pair of observation wells, 310W and 310E, shows an atypical response of the aquifer during early pumping times due to heterogeneous effects; the drawdown plots “cross-over” (transition point) and then behave in a more expected manner during latter pumping times. This “cross-over” phenomenon is an illustration of the interaction between heterogeneity and stream-aquifer influences. At later times the stream influences the observed drawdown to a greater degree than aquifer heterogeneity.

H21D-0872 0830h POSTER

Elution of Nitrate at the NABIR Field Research Center, Oak Ridge Reservation, Oak Ridge, TN

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As part of a bioremediation project for the in situ bioreduction of uranium at the Department of Energy Natural and Accelerated Bioremediation Research (NABIR) Field Research Center (FRC) in Oak Ridge, TN, aquifer and groundwater conditioning is required before conducting the remediation experiment. One step includes flushing of the aquifer with pH-adjusted fresh water in order to remove extremely high concentrations of nitrate, calcium, and aluminum that would interfere with in situ bioreduction. The elution of nitrate from the test zone was used as an inverse tracer to discern contaminant transport pathways and model parameters. Concentration time series data augmented pressure tests, a bromide tracer study, and electromagnetic borehole flowmeter (EBF) measurements. The aquifer at the FRC is a fractured shale with strike of about 1.5 degrees north of west, and dip of about 30 degrees to the southwest, as inferred from area observations and EBF logging. A network of injection and extraction wells are aligned along strike, while a separate network of observation wells with multiple screen intervals (MLS wells) are oriented along dip at the midpoint of the injection/extraction well network. Flow generally occurs along strike in fractures associated with bedding planes, however other lesser fracture networks provide communication between the major fracture sets. Previous data have indicated a high hydraulic conductivity zone, approximately 10-50 cm thick located at a depth of about 12 m along the centerline of the injection/extraction well network. Above the major flow zone, the matrix weathers to saprolite, decreasing hydraulic conductivity. The elution tracer test was conducted by injecting clean, acidified tap water in the farthest upgradient injection well, and extracting at half the injection rate from the farthest downgradient extraction well. This flow ratio was chosen to produce flushing focused on a small cell of the aquifer which will later be used as an in situ bioreactor. Nitrate concentrations were measured frequently over 100 hours. Concentration time series indicate that flushing occurred predominantly in the previously identified high conductivity zone at 12 m depth. The strongest, most rapid nitrate concentration decrease was observed at a similar depth in each MLS well, which is consistent with the depth at which injection and extraction occurred. A decrease in downdip, nitrate concentration extended to 15m depth, whereas at the centerline and updip, little nitrate concentration reduction occurred below 13.75 m depth. This asymmetry is consistent with the competing contributions of bedding plane fractures and weathering depths. In the future, time series crosshole seismic and ground penetrating radar collected by Lawrence Berkeley National Laboratory, and borehole electrical conductivity measurements collected by Oak Ridge National Laboratory will be integrated with the concentration, pressure, and EBF data to obtain a comprehensive interpretation of this test.

H21D-0873 0830h POSTER

Macroscopic Longitudinal Dispersion in Porous Media From Pore-scale Simulation

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The behavior of longitudinal dispersion as a function of rate and the properties of the porous medium is important for the prediction of contaminant dispersal in aquifers, the performance of packed beds and nuclear waste containment. We describe a novel means of simulating dispersion within a network of pores which is completely physically based. The method uses the flow field calculated from an existing network simulator. We use particle tracking to move the contaminant through a semi-analytically defined flow field in each pore adding a random component to simulate molecular diffusion. We use physically consistent rules to transport particles across pore junctions. Periodic boundary conditions have been implemented, allowing us to simulate diffusion on the scale of centimeters with minimal extra computational effort. We benchmark the particle-tracking random-walk model by comparing the longitudinal dispersion with Taylor-Aris analytical solutions in single ducts. Previous workers have (e.g. Sorbie and Clifford, 1991, Damion et al, 2000, Bernabe and Bruderer, 2001) have only been able to provide qualitative insights into the effect of Peclet number and pore-scale heterogeneity on longitudinal dispersion with Peclet number. We use a range of homogeneous and heterogeneous networks, including topologically disordered lattices taken directly from glass bead-packs, sand-packs and consolidated Berea sandstone, to investigate the influence of pore-scale heterogeneity (connectivity, pore-size distribution) on macroscopic dispersion. We show that our technique can predict quantitatively experimental measurements of longitudinal dispersion over a wide range of Peclet numbers ($0<Pe<10^5$).

H21D-0874 0830h POSTER

Estimation of Streambed Seepage using Time-Series Analysis of Heat as a Tracer in Three California Coastal Rivers

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Heat has been used as a natural tracer for decades, generally using forward models to simulate thermal conditions within the stream and streambed. We are developing a new method for analysis of streambed thermal records from multiple depths to estimate seepage rates. This approach differs from those developed previously in that we use models of heat transport through the stream bed to derive “type curves” of time-series behavior, then interpret long- term records to estimate seepage rates throughout the water year. Daily variations in stream temperature of several degrees or more are common in many river systems. These thermal perturbations propagate downward into the streambed with time. Streambed sediments act as a filter on these perturbations, reducing the amplitude of temperature variations with greater depth, and causing the peaks in temperature to be shifted in time. These behaviors are readily predictable, based on the thermal properties of the streambed sediments, the rate and direction of fluid flow, the magnitude of temperature variations, and the spacing between sensors. Time series data (T vs. t) were collected in three settings in California during 2002-03 to test this method: Russian River, Pajaro River, and Corralitos Creek. We analyzed a subset of these data using a forward model to estimate apparent seepage rates during selected intervals, then applied the time series approach to estimate seepage rates during the same time intervals. Processing of field data required filtering to extract the diurnal signal, and a series of programs was developed to aid picking of temperature peaks and troughs so that records of phase shift and amplitude ratio could be derived. We also show results of modeling studies where we vary seepage rates and generate time-series records, then back-calculate variations in seepage rate to assess the accuracy of this approach. Flow rates derived from model temperature records are similar to those estimated from differential discharge measurements during field seasons, equivalent to about 0.6 to 1.5 m/day near the end of the water year.

H21D-0875 0830h POSTER

Temperature Profiles and Hydrologic Implications from the Nevada Test Site Area

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The Nevada Test Site (NTS) is located 65 miles northwest of the city of Las Vegas. The NTS encompasses 1,375 square miles of desert and mountainous terrain. Prior to 1992, 828 underground nuclear tests were conducted at the NTS. Approximately one-third of these underground nuclear tests were conducted deep enough below the ground to impact the water table. Since the late 1980s the U. S. Department of Energy has been working to characterize groundwater flow systems at the NTS. A major portion of this effort is the construction of regional- and Corrective Action Unit-scale numerical groundwater flow and transport models. Given the large aerial extent and geologic complexity of the NTS, combined with the limited number of boreholes from which geologic and hydrologic information can be derived, reduction of model uncertainty is of great concern. Groundwater flow and transport models often utilize hydraulic head or solute concentration as calibration targets. Alternate calibration targets such as tempera

H21D-0876 0830h POSTER

Solution of the One-Dimensional Consolidation Equation for Saturated Clays Using a Spectral Method

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The nonlinear, one-dimensional consolidation equation of fully saturated clays interbedded in an aquifer, derived by Gibson and others in 1967, is solved using a spectral method. This equation considers the variation of soil compressibility and permeability during consolidation and recasts Darcy's law so that the relative velocity of the soil skeleton and the pore fluid are related to the excess pore fluid pressure gradient. The spectral solution presented herein uses the matrix representation with Chebyshev collocation to compute the spatial derivative of functions that depend on void ratio, vertical hydraulic conductivity, and the vertical gradient of effective stress. A fourth-order Runge-Kutta algorithm is used to solve the derivative of the void ratio with respect to time. The spectral method requires neither the linearization of the originally nonlinear equation nor the convergence of iterative processes of traditional numerical methods such as finite differences and finite elements. The solution identifies temporal changes in void ratio within the clay lenses occurring in the aquifer system. The compaction is calculated from void ratio changes accumulated throughout the simulated time periods. Laboratory data were used to obtain the mean value for the soil grain density and depth-dependent profiles for aquifer compressibility, hydraulic conductivity, and initial vertical distribution of void ratio for each clay lens. The vertical gradient of the effective stress, needed in the consolidation equation, was derived and the resulting expression was evaluated by using the depth-dependent void ratio profile and drawdown data from a well hydrograph. Compactions and expansions of the clay lens resulting from temporal variations in drawdown due to groundwater withdrawals and recharge periods were simulated for two observation wells in the Santa Clara Valley, California. The solution of the one-dimensional consolidation equation generated temporal changes in void ratio that closely matched measured compaction in both observation wells, demonstrating that this equation and the numerical solution presented could be used to simulate subsidence.

H21D-0877 0830h POSTER

Hydrogeologic Framework of the Southeastern Funeral Mountains, California-Nevada, and Implications for the Major Water-Supply Springs in Death Valley National Park

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We are using a combination of geologic mapping, geophysical surveys, hydrologic computer modeling, and a drilling-and-testing program to evaluate the hydrologic framework of the southeastern Funeral Mountains. Our work addresses: (1) the hydrologic connection of the Furnace Creek springs on the south side of the Funeral Mountains to the regional aquifer system on the north side, and (2) potential impacts on these springs from human activities, including possible leakage from the proposed radioactive waste repository under Yucca Mountain, 50 km to the northeast, and ongoing agricultural overdrafting of groundwater in the southern Amargosa Desert, 25 km to the northeast. Discharge from the springs at Furnace Creek provides the major water supply for Death Valley National Park and, at 5000 acre-ft/yr, is at least 10 times larger than that attributable to recharge in the adjacent, arid Funeral Mountains. Moreover, hydrochemical data indicate that the spring water is derived mainly from interbasin groundwater flow through the regional carbonate aquifer. This aquifer extends northeastward across much of southeastern Nevada. Our geologic map data indicate that the carbonate aquifer is continuous under the southeastern Funeral Mountains. The base of this aquifer is, however, structurally uplifted under the axis of the range, to an elevation that is much higher than most of the springs at Furnace Creek, but that is locally lower than the water table on the opposite (northeast) side of the range. Rather than forming a barrier that blocks groundwater flow under the Funeral Mountains, as previously interpreted, this uplift evidently forms a spillway. The 700 m drop in the water-table elevation across this range, into Death Valley, thus does not indicate the presence of any feature that would divert or slow groundwater flow. Because of the spillway mechanism, flow from the springs at Furnace Creek may be sensitive to the water-mining activities that have been progressively lowering the hydraulic head on the northeast side of the Funeral Mountains. DOE proposes to emplace nuclear waste in Yucca Mountain, above a volcanic aquifer, which is separated from the underlying regional carbonate aquifer by a leaky volcanic confining unit. An upward hydraulic gradient, from the carbonate aquifer to the overlying volcanic aquifer, has been measured in a single well. This upward gradient is inferred to act as a natural barrier that will keep radionuclides from leaking into the regional carbonate aquifer. There are reasons to question the efficacy and durability of this mechanism. First, with data from only one well penetration into the carbonates, it is unknowable whether the observed upward gradient is a regional feature, or a relatively local one. Second, if recent trends in water mining in this region are projected into the future, it is plausible that the current upward gradient, even if it is regionally effective today, could be reversed. We hope to shed some light on these issues by: (1) testing the chemistry of water in the carbonate aquifer under the Funeral Mountains to see if volcanic-aquifer water from nearby areas such as Yucca Mountain is entering the carbonate aquifer, and (2) developing better computer models of this hydrologic system that could be used to forecast potential long-term impacts of water mining.

H21D-0878 0830h POSTER

Prevention of Pollution or Salinity Expansion in the Aquifers by Stream of Compressed Air Through the Well

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Stream of compressed air through the well between polluted (or sea) water and fresh water creates the "hydraulic wall" that prevents mixing of them. Steady influx of air to saturated soil produces the pressure gradient from the well and replaces the water by air. Interfaces increase between air and water. After stopping the compression process the conductivity of the soil will decline because the pores are blocked by the air. It is very welcome phenomenon in the interfaces area that prevent on one hand the lost of the fresh water to the sea and decreases the sea water movement into the aquifer on the other hand. Upper streaming the air through unsaturated zone declines the water and pollution vertically down-seepage and defends the fresh water against pollution. Approximately obtained shape of air-water interface, for quasi steady-state stream, is an inverted cone. The necessary pressure to initial the air stream in the deep layers of the aquifer is about tens percent higher than static water pressure in the well in these layers. Key words: Prevention of pollution, compressed air

H21D-0879 0830h POSTER

Modeling saltwater-freshwater interface within the river-mouth dyke

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In Korea, many rivers are being or have been dyked at their mouths to obtain freshwaters for agricultural and industrial purposes in coastal areas. Seepage of seawater through the river-mouth dyke, which bisects the seawater and freshwater, may cause a serious salinization problem for the freshwater body formed inside of those dykes. However, the seawater seepage process through the dykes where two water bodies of different densities are in contact has been poorly understood. In this study, we employed a two-dimensional, flow and transport model to see how the two waters having the different densities interact within the river-mouth dykes by fluctuation of sea levels, and to evaluate the effect of density difference on the seepage of seawater into the fresh water body. Since the flow velocity in the dyke is strongly related to the safety of the dyke that was constructed of sandy materials, the changes in flow velocity field by the density differences were also assessed. To simulate the density-dependent flow within the dyke, two governing equations, one for fluid flow and the other for salt transport, were coupled into the model. The results of this study strongly suggest that, in this hydrologic system, both sea level fluctuation and the density differences have to be considered for a good estimation of seawater seepages through the dykes and velocity field of the flows within the dykes. The results show that the saltwater seepage and flow velocity field could be significantly changed under the hydrologic system of this study by the sea-level fluctuation and the density difference between the two waters are considered.

H21D-0880 0830h POSTER

Geochemical and Isotopic Constraints on the Source of Groundwater to Lower Kane Cave, Wyoming

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Most karst features occur due to the dissolution of limestone by carbonic acid charged phreatic or meteoric water. However, an important subset of caves forms when anaerobic groundwater transports hydrogen sulfide into an oxidizing environment, resulting in speleogenesis via sulfuric rather than carbonic acid. The actively forming Lower Kane Cave in the Mississippian Madison Limestone of the Bighorn Basin near Lovell, Wyoming, is an accessible example of this alternative method of cave development. Located along the fold axis of the Little Sheep Mountain anticline of the Bighorn Basin, this system hosts a diverse range of microbial organisms, including acid-producing and sulfide and sulfate utilizing species, whose role in speleogenesis is currently under investigation. Water samples were collected from cave springs, nearby springs, freshwater wells and produced water from oil wells in the local area. Samples were analyzed for major and trace elements, stable isotopes and Sr isotopes by multicollector ICP-MS, as well as dissolved gas and organic acid analyses. These data were used to examine the regional flow of groundwater to the cave and potential oil-field sources of hydrogen sulfide. The Madison Aquifer in this area is characterized by relatively fresh water, and in the cave vicinity is the source of municipal water supplies for the towns of Cowley and Greybull. The Madison water samples collected in the area are Ca-HCO3 to Mg-SO4 type, with relatively little Na and Cl. Overall the cave water chemistries are characterized as Ca-Mg-HCO3-SO4 waters; Ca = 70 ppm, Mg = 25 ppm, HCO3 = 205 ppm and SO4 = 110 ppm. However, when compared to other Madison water samples, the waters of Lower Kane Cave are slightly higher in TDS (around 400 ppm), significantly warmer (22 C versus between 6-12 C), and contain much higher dissolved sulfide (up to 2ppm). Additionally, Sr isotope signatures for the cave waters are significantly more radiogenic than that of other Madison water samples collected in the region. The 87Sr/86Sr of cave water samples ranged from 0.710009 to 0.710124. Madison water samples from other sampling sites ranged from 0.708907 to 0.709253, while water samples from the overlying Amsden and Phosphoria were consistently less radiongenic than the Madison waters, with 87Sr/86 values ranging from 0.707889 to 0.708561. Previous investigators suggested that the sulfate and high TDS of the cave waters derived from mixing between the low TDS Madison formation waters and those of the more saline overlying Phosphoria-Tensleep aquifer. Preliminary results of this investigation suggest that a simple Phosphoria-Madison mixing model, while able to account for the major element chemistry and raised TDS, is insufficient to explain the higher temperatures and radiogenic Sr characteristics observed. Alternative sources of the observed water chemistries include upward leakage of water from underlying units, including the leaky aquitards of the Devonian Jefferson and Cambrian Gros Ventre Formations, or the Cambrian

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Flathead sandstone aquifer. The cave waters may also demonstrate heterogeneity within the Madison aquifer and tap into a particular siliclastic and sulfidic zone, the presence of which is masked at other sampling sites that derive a greater percentage of water from the main body of the aquifer. While the exact origin of the water to Lower Kane Cave remains unclear, it is evident that the flow regime at this location is more complicated than originally believed.

H21D-0881 0830h POSTER

Transport by Eigendecomposition

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The Fourier transform of the transport equation is a Fredholm integral equation of the second kind. When expressed as a linear sum, this integral equation becomes a homogeneous system of linear equations whose eigendecomposition determines the eigenvalue frequencies at which eigenvector concentration densities satisfy the transport equation. Corresponding spacetime concentration densities are computed by inverse transforming the linear combination of said eigenvectors that honor some initial condition. This paper finds that the key to a successful inverse transform is to choose length and time scales that prevent phase wrapping at mid transform. A numerical demonstration, treating the problem of predicting the fate of radionuclides invading the groundwaters of Nevada's fractured welded tuffs, is provided. Using the same random fractal flow parameters as was used for the author's previous travel times [WRR 37(12) 2915-2918, 2001], this paper shows that concentration densities derived by eigendecomposition satisfy the transport equation with an average relative error of 3.7 percent. And, in excellent agreement with [WRR 37(12) 2915-2918, 2001] this direct solution also predicts that an impulse radionuclide source entering the groundwaters of Nevada's fractured welded tuffs will on average spread to a 5 km monitoring point in a few centuries.

H21D-0882 0830h POSTER

Wavelet Analysis of Permeability Anisotropy

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Since the permeability of porous media is anisotropic, an accurate representation of anisotropy is needed in order to reliably predict the movement of fluids and contaminants in the subsurface. We use wavelet analysis to identify principal axes of anisotropy in a porous medium and to identify the boundaries between regions with different principal axes. Wavelet analysis uses an integral transform that extracts local information at multiple scales and orientations. We have tested the technique on hypothetical two-dimensional permeability fields, and we have conducted a preliminary evaluation of the technique using laboratory-measured permeability data from a block of Massillon sandstone. We demonstrate the wavelet analysis technique for identifying principal axes of anisotropy, and we evaluate the effects of sparse data on the results.

H21D-0883 0830h POSTER

Benzene and MTBE Sorption in Fine Grain Sediments

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The practice of adding methyl tert-butyl ether (MTBE) to gasoline started in the late 1970s and increased dramatically in the 1990s. MTBE first was added as a substitute for tetra-ethyl lead then later as a fuel oxygenate. Although the use of MTBE has resulted in significant reduction in air pollution, it has become a significant groundwater contaminant due to its high solubility in water, high environmental mobility, and low potential for biodegradation. A recent report (1999-2001) by the Metropolitan Water District of Southern California in collaboration with United State Geological Survey and the Oregon Health and Science University found that MTBE was the second most frequent detected volatile organic compound in groundwater. In Illinois, MTBE has been found in 26 of the 1,800 public water supplies. MTBE has also been blended in Mexico into two types of gasoline sold in the country by the state oil company (PEMEX) but is not monitored in groundwater at this time. Early research on MTBE considered it unable to adsorb to soils and sediments, however, by increasing the organic matter and decreasing the size of the grains (silts or clays) this may increase sorption. The objective of this study is to determine if fine grained materials have the potential for sorption of MTBE due to its high specific surface area (10-700 m ^{2}/g) and potentially high organic matter (0.5-3.8%). The experiment consisted of sorption isotherms to glacial tills from DeKalb, Illinois and lacustrine clays from Chalco, Mexico. Experiments were performed with various concentrations of MTBE and benzene (10, 50, 100, 500 and 1000 ug/L) at 10°C and 25°C. Results showed a range of values for the distribution coefficient (Kd, linear model). At 10°C the Kd value for MTBE was 0.187 mL/g for lacustrine clay while the glacial loess had a value of 0.009 mL/g. The highest Kd values with MTBE were 0.2859 mL/g for organic rich lacustrine clays and 0.014 mL/g for glacial loess at 25°C. The highest values with benzene were 0.323 mL/g for organic rich lacustrine clays and 0.119 mL/g for glacial loess at 10°C. At 25°C the organic rich lacustrine clays the Kd value was 0.332 mL/g, while Kd value for glacial loess was 0.114 mL/g. Sands with no organic matter (Ottawa sand) had a value of $<$ 0.001 mL/g for both temperatures 25°C and 10°C and both organic compounds. The retardation factor (R) for MTBE was 1.559 at 10°C and 1.855 at 25°C for lacustrine clays; while the glacial tills R was 1.058 at 10°C and 1.095 at 25°C. The retardation factor for benzene was 1.967 at 10°C and 1.996 at 25°C for lacustrine clays; while the glacial tills R was 1.039 at 10°C and 1.037 at 25°C. These results indicate higher retardation values than previously determined for a clayey sand; therefore show that sorption can occur in fine grain materials especially with high organic matter. This study contributes to the understanding of the sorption of MTBE and improves the knowledge to implement the optimal remediation method for sites contaminated by MTBE.

H21D-0884 0830h POSTER

An Operator Splitting Algorithm for Numerical Simulation of Transport of Reactive Compounds in Porous Media

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Chemical and/or biological processes are of great importance in modeling transport of pollutants in many hydrogeological settings. When considering these phenomena, a system of partial differential equations (PDE's) nonlinear and coupled in the reaction terms is obtained. Besides these numerical difficulties and the non-physical oscillations in advection-dominated flows, stiffness may be introduced into the system since the range of characteristic reaction time is huge. In this work an operator splitting method is applied to simulate transport of species undergoing biodegradation in porous media. It is the Θ scheme which is second order. The mathematical model takes into account the mass balance of all the chemical species involved in the successive transformations. A Monod type kinetics is assumed for biodegradation. The advection-diffusion operator is solved implicitly in the first and third subintervals and the biochemical terms are solved implicitly in the intermediate one. In this way, stiff matrices are avoided. By a special treatment of the source terms, the system of PDE's is totally decoupled. Numerical results are obtained in one spatial dimension.

H21D-0885 0830h POSTER

Capture Zone of a Horizontal Well

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Horizontal wells are regarded as effective means of removing contaminated groundwater from aquifers. However, delineation of capture zone of a horizontal well has not been carefully studied in a systematic way. In this paper, we have presented analytical solutions for the capture zones of horizontal wells in a homogeneous, confined aquifer with uniform flow, considering three possible well locations at the middle, the boundary, and an arbitrary position. We find that the capture width enlarges and the bisector line of the capture zone moves toward the centerline of the aquifer when moving away from the well in the upstream direction for an arbitrary well location. The capture width and bisector line approach their ultimate width and position, respectively after an ultimate distance of about 1.5 times of the aquifer thickness. The ultimate capture width depends on the well discharge but not on the well location. We have provided type curves of the ultimate bisector line position versus discharge for different well locations. Compared to the vertical well capture zone, the ultimate capture width of a horizontal well is smaller than that of a vertical well given the same discharge rate per unit length because of the constraining effect of the upper and lower aquifer boundaries. Furthermore, the relationship between the ultimate capture width and the well discharge rate is nonlinear due to the influence from the aquifer boundaries, in contrast to the linear behavior often observed in the vertical well capture zone.

H21D-0886 0830h POSTER

Study on the Groundwater Flow along the Seawater / Freshwater Interface

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The shape of Seawater / Freshwater Interface is effected by the groundwater flow at the coastal area, and decide the position of submarine groundwater discharge that should be existed everywhere in the world. The hydraulic gradient is too small to estimate the groundwater flow in the area, usually. On the other hand, the groundwater that discharges to the marine have to runs along this interface. And the water discharged to the marine is from the deep zone. That's why the water discharges to the marine (runs on the interface) might have many information of the deep zone of groundwater. The Hasunuma Beach Park located on the Kujyukuri Long Beach close to the New Tokyo Int'l Airport is selected of the study for the groundwater flow along the Seawater / Freshwater Interface. The layered aquifer in the deposited rocks lies in the area, until over than 1000 m depth. The shape of the interface was observed by some kinds of physical sounding from the surface (e.g. specific electricity, AMT method), the logging data in the observation well (EC, T, Flow meter logging, Electric logging etc.) and water quality analysis (incl. Isotopes). And the Flow Meter measurement in the well was done, so that the actual groundwater flow was measured in the aquifer (in the crack of the aquifer, exactly). The observed groundwater flow is thought on the interface and the important element of the shape (angle and depth) of the interface, simultaneously. Two interfaces are found at the well point (200 m onshore). The shape of the interface was also confirmed from a diving work that found the submarine discharge of fresh groundwater at 320 m offshore. The distribution of pressure (hydraulic gradient) in the aquifer and the shape of the interface are made cleared by these tests. The progress expression of the Glover's solution was suggested by the study.

H21D-0887 0830h POSTER

Pharmaceuticals as Groundwater Tracers - Applications and Limitations

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Pharmaceutically active substances and metabolites are found at concentrations up to the microgram/L-level in groundwater samples from the Berlin (Germany) area and from several other places world wide. Among the compounds detected in groundwater are clofibric acid, propyphenazone, diclofenac, ibuprofen, and carbamazepine. Clofibric acid, the active metabolite of clofibrate and etofibrate (blood lipid regulators) is detected in groundwater at maximum concentrations of 7300 ng/L. Among the most important input paths of drugs are excretion and disposal into the sewage system. Groundwater contamination is likely to be due to leaky sewage systems, influent streams, bank filtration, and irrigation with effluent water from sewage treatment plants. There are no known natural sources of the above mentioned pharmaceuticals. The use of pharmaceuticals as tracers may include: (a) Quantification of infiltration from underground septic tanks (b) Detection of leaky sewage systems / leaky sewage pipes (c) Estimation of the effectiveness of sewage treatment plants (d) Identification of transport pathways of other

organic compounds (e) Quantification of surface water / groundwater interaction (f) Characterization of the biodegradation potential. The use of pharmaceuticals as tracers is limited by variations in input. These variations depend on the amount of drugs prescribed and used in the study area, the social structure of the community, the amount of hospital discharge, and temporal concentration variations. Furthermore, the analysis of trace amounts of pharmaceuticals is sophisticated and expensive and may therefore limit the applicability of pharmaceuticals as tracers. Finally, the transport and degradation behavior of pharmaceuticals is not fully understood. Preliminary experiments in the laboratory were conducted using sediment material and groundwater from the Berlin area to evaluate the transport and sorption behavior of selected drugs. Results of the column experiments show that clofibric acid exhibits no degradation and almost no retardation (Rf = 1.1) whereas ibuprofen is biodegraded (> 90 %) under aerobic conditions. Carbamazepine shows no degradation in the soil column experiments but significant retardation under the prevailing conditions. We conclude that clofibric acid will show the transport behavior of a conservative tracer, whereas ibuprofen may be used to characterize the biodegradation potential in the aerobic zone.

H21D-0888 0830h POSTER

On transient capture zone analysis: The importance of dispersion

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Transient analyses of capture zones of water supply wells are in many practical cases superior to commonly apply steady-state analyses. Recently there was increased number of case studies on this topic but most of them took into account the advection only (similarly to the most steady-state studies). In the transient case, however, taking into account only the advection without dispersion can produce substantial bias in the capture zone estimates. The advection flowpaths could be not representative for the potential contaminant flowpaths; the advection flowpath and arrival-time estimates could not be representative for the location and/or time of the potential plume arrival. We present synthetic studies and case study of water-supply wells in Espanola basin to demonstrate our conclusions. Obtained transient capture zone estimates are very sensitive to heterogeneity and properties of the medium; especially the porosity and dispersion parameters.

H21D-0889 0830h POSTER

Local and Regional Scale Simulation of River Aquifer Interactions.

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Overdraft of groundwater in Sacramento County, California has severely depressed regional groundwater levels and depleted base flows along the Cosumnes River. These developments continue to negatively impact riparian vegetation and threaten the fall migration of endangered Chinook salmon. In this study river aquifer interactions are investigated along a 200m reach of the Cosumnes River using continuous field measurements of riverbed temperature, water content and matric potential to a depth of 10m below the riverbed. These data demonstrate complex seepage patterns including fracture flow and the formation of perched aquifers due to geologic heterogeneity. Riverbed sediment heterogeneity was characterized using geostatistical indicator simulations based on continuous core data. A 3-dimensional reach-scale model was developed using the TOUGH2 simulator. Modeling results suggest that the success of riparian vegetation may depend on the presence of perched aquifers. The reach-scale model will also provide better estimates of riverbed hydraulic properties for use in a larger regional-scale groundwater flow model. The regional model was developed based on detailed geostatistical simulations of the Cosumnes alluvial fan hydrostratigraphy using a version of MODFLOW that includes the ability to simulate unsaturated flow between the river and the aquifer. The regional model is used to assess management scenarios that are developed to improve fall flows and to enhance overall river ecology.

H21D-0890 0830h POSTER

Stable Isotopes in Snow: Implications for the Design of Precipitation Collectors and Studies of Groundwater Recharge

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The stable isotopes 18-O and 2-H are widely used as tracers in the hydrologic system. Numerous studies have collected precipitation in order to determine its stable isotopic signature at locations around the world. This signature varies seasonally, theoretically allowing determination of the relative importance of snow and rain to groundwater recharge. Data for the isotopic signature of precipitation collected over large regions are often contoured, and used to make inferences about weather patterns and processes such as evaporation during rainfall. An issue that, until recently, has generally been ignored in hydrologic studies is that the isotopic composition of snow can change significantly prior to, and during melting. Many studies have compared the isotopic signatures of fresh snow and rain to that of groundwater in order to determine the proportion of each responsible for recharge. However, alteration causes the isotopic signature of snow to become heavier, appearing more rain-like as alteration increases. As a result, many mixing models based on fresh snow and fresh rain end members may provide flawed estimates of the proportion of groundwater recharge derived from snowmelt. We have installed precipitation collectors of various designs, similar to those commonly used in other studies. As two to three different designs of collectors are in place at each of several sites, the impact of the samplers on the isotopic composition of snow can be determined. Our data show that one commonly-used type of collector yields values that are significantly enriched compared to values for fresh snow. At one site in New Mexico, the bulk winter-season isotope values for this collector were -13.5 per mill for delta 18-O and -98 per mill for delta D, compared to the values -16.6 and -118 per mill yielded by a collector designed to prevent isotopic alteration of snow. Our results suggest that the duration of snowpack alteration affects the magnitude of isotopic shift. Where melt takes place quickly due to higher temperatures and/or lower amounts of fall, the isotopic shift is smaller than at sites where large amounts of snowfall and low temperatures allow long periods of alteration. Although collectors that allow the isotopic alteration of snow are inappropriate if values for fresh precipitation are desired, they can be useful for determining the relative importance of snow and rain in groundwater recharge. Mixing calculations from one of our field sites show that using a fresh snow signature in a mixing model would predict groundwater recharge was 40 % snow-derived and 60 % rain-derived. Using the isotopic signature of altered snowmelt from one of our collectors, the proportions were reversed, with snow making up 60 % of the recharge.

H21E MCC: Level 2 Tuesday 0830h

Dealing With Hydrogeologic Uncertainty in Practice: Data Collection, Models, Predictions, and Regulatory Guidelines II Posters

Presiding: **T Harter,** University of California, Davis**; M C Hill,** U.S. Geological Survey

H21E-0891 0830h POSTER

Sensitivity of Seawater Intrusion in Coastal Aquifers to a Hydraulic Barrier

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One of the challenging issues of water resources management is the vulnerability of coastal aquifers to seawater intrusion. Mitigating the impacts of seawater intrusion in coastal aquifers is a formidable task that often requires minimizing extraction of freshwater and finding viable means to protect the freshwater aquifer either by reclaiming the already saline aquifer and/or limiting the advance of the interface farther inland. One of the methods that can be employed to mitigate the impacts of seawater intrusion involves creating a hydraulic barrier where injected freshwater alters the flow of intruding seawater by creating a localized zone of higher pressure in the aquifer. A hydraulic block can be created to contain the advance of seawater by a number of techniques that include injecting freshwater into the seawater intruded area and increasing the surface recharge through recharge ponds and canals. This research reports the results of a numerical modeling experiment where a hydraulic block is created by injecting freshwater into an already saline aquifer using injection wells. The comparison of concentration values at selected monitoring wells indicates that there is a significant improvement in the ambient water quality as a result of the injection of freshwater. The improvement in concentration is also noticed to vary from layer to layer. Information obtained from such numerical modeling experiments could be used to determine the locations of injection wells for efficient performance of the mitigation system.

H21E-0892 0830h POSTER

Ground-Water Capture Zone Delineation of Hypothetical Systems: Methodology Comparison and Real-World Applications

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A capture zone is the aquifer volume through which ground-water flows to a pumping well over a given time of travel. Determining a well's capture zone aids in water-supply management by creating an awareness of the water source. This helps ensure sustainable pumping operations and outlines areas where protection from contamination is critical. We are delineating the capture zones of hypothetical conceptual models that resemble the Fairbanks, Alaska floodplain both in aquifer parameters and boundary conditions. We begin with a very simple hydrogeologic system and gradually add complexity such as heterogeneity, anisotropy, multiple wells, and zones of permafrost. Commonly-used delineation methods are applied to each case. These include calculated fixed-radius, analytical and numerical models. The calculated fixed-radius method uses a mathematical equation with several simplifying assumptions. Analytical techniques employ a series of equations that likewise assume simple conditions, although to a lesser degree than the fixed-radius method. Our chosen numerical model is MODFLOW-2000, which offers a particle-tracking package (MODPATH) for delineating recharge areas. The delineations are overlayed for each conceptual model in order to compare the capture zones produced by the different methods. Contrasts between capture zones increase with the complexity of the hydrogeology. Simpler methods are restricted by their underlying assumptions. When methods can no longer account for complexities in the conceptual model, the resulting delineations remain similar to those of simpler models. Meanwhile, the zones generated by more sophisticated methods are able to change with changes to the conceptual model. Hence, the simpler methods now lack accuracy and credibility. We have found that these simpler techniques tend to overestimate the capture zone. Water-supply managers must consider such inaccuracies when evaluating the costs of each method. In addition to comparing delineation methods, we are using the series of hypothetical MODFLOW cases to aid in modeling a site within the Fairbanks floodplain. We learn how the site-specific complexities may affect the capture zone by examining the effect of each modification to the hypothetical models. The area is located on Fort Wainwright, AK and consists of multiple water-supply wells. They are screened through a formation known as the Chena Alluvium, which is composed of braided-stream deposits. The wells supply water to a power plant for cooling and to a water treatment plant for drinking water use. The power plant discharges heated water into a cooling pond while the water treatment plant releases back-wash water into a small discharge pond. The Chena River is also nearby, approximately 0.4 km from the wells. Data available from the pumping-well facilities, observation wells, and geologic logs are used to determine input parameters for the model.