We present the mathematical and numerical development of a new hillslope hydrology model as well as validation and sample applications. The new model is a distributed, physically and mechanistically based hillslope hydrology model. The model couples the fully two-dimensional hydrodynamic equations for overland flow, Richards equation for infiltration, and a set of sediment detachment and transport equations. This model, based on the fundamental physics of the governing processes of hillslope hydrology is used to test our ability to fully explain the fine scale processes and mechanisms leading to the development of erosion drainage networks . Three sample applications are presented to show how the model is capable of capturing the interaction between overland flow, erosion and infiltration at very small scales and of modeling the evolution of hillslope caused by spatially variable erosion caused by small scale variability of the hydraulic and soil properties. We also present analyses with respect to energy expenditure during hillslope evolution.

H42D-1112 1330h POSTER

Modeling the influence of subsurface topography on spatial and temporal variability of subsurface stormflow

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Recent investigations of spatial patterns of soil depth, water table and subsurface flow response at the hillslope scale suggest that the variability in depth to bedrock (or to any other low permeable layer) may be a primary control on the space-time variability of subsurface stormflow. However, simulating or even predicting subsurface flow variability is still a challenge. Even more problematic is the fact that spatially explicit soil depth information is generally lacking at hillslope and catchment scales. We investigate how soil depth variability affects the spatial and temporal response of subsurface stormflow and propose a new way forward to defining these controls on sites without soil depth data. We used long-term data of spatially explicit subsurface flow measurements from a trenched hillslope at the Panola Mountain Research Watershed, as well as soil depth and soil property information, to calibrate and verify the HillVi hillslope model. Then we generated numerous realizations of the subsurface topography using geo-statistical information of the observed soil depth in the watershed. Subsurface flow variability was simulated based on these subsurface topography realizations. The spatial-temporal properties of the modeled flow were compared with the spatial and temporal variability of the observed flow. HillVi is a quasi 3D spatially explicit saturated and unsaturated water balance model and is well suited for this approach as it captures all major subsurface runoff generation processes (matrix and macropore flow and infiltration, lateral subsurface flow and pipe flow). We discuss the potentials and drawbacks of this approach to simulate spatially variable outflow from hillslopes and the general role of subsurface topography on the spatial and temporal patterns of subsurface flow.

H42D-1113 1330h POSTER

Controls on the Spatial-Temporal Cl- Pattern in the Coastal Plain Aquifer of Israel

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The Coastal Plain Aquifer of Israel, a Pleistocene granular formation consisting largely of sands, sandstone, and calcareous sandstones, is an important regional source of high quality drinking water. The land surface overlying the aquifer has witnessed massive increases in human population and changes in land use and land cover over the past half-century. There is widespread concern in the region about pollutant threats to the aquifer, primary among them dissolved solids originating from 1) repeated irrigation cycles using both conventional freshwater and reclaimed municipal sewage, 2) seawater intrusion, and 3) naturally occurring salt deposits in neighboring geologic strata. The median Cl- concentration of the aquifer has increased at a rate of approximately 1.1 mg/L/annum since 1949, albeit with considerable spatial heterogeneity. This research seeks to explain the spatio-temporal salinity distribution using a variety of explanatory variables derived from agricultural, lithological, hydrological, and land use/land cover datasets. Preliminary estimates indicate that direct salinity inputs from conventional and wastewater irrigation are not the major driver of the salinity change.

H42D-1114 1330h POSTER

Variation of the Surface Roughness of a Stream Channel Based on a Simple Cellular Automata Model Given an Initial Particle Distribution, Channel Width and Slope

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The roughness of a stream channel boundary is an important control on the movement of sediment particles. The likelihood of a particle being entrained and transported from a surface composed of coarse-grained particles will depend in part on the local roughness geometry defined by the surface particles, i.e., particle motion will depend on a particle's size and elevation relative to the size and height of the surrounding particles. Over time, movement of particles can modify the shape of the channel boundary, and size-selective particle motion can change the distribution of surface particle sizes. These changes then modify the roughness of the boundary. We have constructed a cellular automata that models a simple version of this dependency of particle motion on the roughness of the surrounding surface. Cellular automata (CA) are models defined on a grid of cells, and changes in the state of a given cell depend solely on the current state of nearby cells. This CA evaluates the mobility of a given particle or group of particles based on whether or not the particles rise above or are sheltered by the surrounding particles. The CA results indicate the modeled sheltering mechanism can result in preferential transport of some particle sizes, a shift in particle size distributions over time, spatial sorting of particles to form convoluted patches of similarly-sized particles, and other effects. Previous CA models for simulating particulate surfaces, although not in the context of stream channels, have investigated roughening of particulate surfaces over time. Such studies identified scaling laws that describe the roughening of the evolved surfaces, and surface roughening in this model will be compared to the previously identified scaling. Roughening of surfaces with varying slope will also be evaluated. We plan further model variants using an evaluation of the forces on particles for different configurations of surrounding particle sizes to further characterize such effects of particle motion, surface roughening and evolution of channel form.

H42D-1115 1330h POSTER

Stream order and fractal as scaling factors for watershed water quality

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Scaling of water quality in watersheds would facilitate effective monitoring and modeling of nutrients and pollutants in stream networks. Stream baseflow nitrate concentration and loading were studied based on stream order and related landscape factors in two agricultural watersheds. The watersheds were delineated into numerous sub-basins based on stream orders. With increasing stream order, nitrate-nitrogen loading increased in a power function, while nitrate and total nitrogen concentration showed a decreasing trend. Landscape characteristics as a function of stream order were also analyzed based on land use, surface geology, topography, and soil properties. Our preliminary results show that stream order and fractal nature of river basin could be used to aid in scaling nitrate concentration and loading during baseflow periods. Landscape variables explain the observed variations within the same stream orders.

H42D-1116 1330h POSTER

Analysis of Spatial Soil Hydraulic Properties to Investigate Soil-Water Movement and Scaling in an Agricultural Field

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The coupled processes of overland flow, infiltration, and multidimensional soil-water flow and storage affect the space-time scaling behavior of measured soil-water content. Previous work on this farm field in eastern Colorado revealed simple scaling behavior in near-surface (0-30 cm) water content, despite generally poor correlation with landscape topographic attributes. In this study, we have analyzed soil hydraulic properties along a transect to help investigate coupled overland-subsurface flow processes and how the scaling behavior of measured and simulated soil-water content may be linked to such processes. Soil cores have been collected and analyzed for textural and hydraulic properties. Detailed analyses include three-step outflow experiments followed by numerical inverse simulations to estimate hydraulic conductivity and storage parameters. Spatial patterns of selected parameters and their correlations with topography will be illustrated. Hourly soil-water data has also been collected with capacitance probes at eight landscape positions and four depths along the undulating transect. The soil-water data suggests that significant lateral flow of soil water occurs at seasonal time scales, despite a lack of obvious impeding layers or perched groundwater. Overland flow also occurs during high-intensity rainfall events. Numerical simulation results of the coupled hydrologic processes may provide further insights into causative links with soil-water scaling.

H42E MCC: Level 2 Thursday 1330h

Watershed Processes and Linkages to Regional and Watershed Patterns in Stream Channel Morphology III Posters

Presiding: **P R Kaufmann,** U.S. Environmental Protection Agency**; B P Bledsoe,** Colorado State University

H42E-1117 1330h POSTER

Analytical Prediction Of Meandering Channel Evolution

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The evolution of meandering channels, as a complex phenomenon, has been the research subject challenging river engineers for decades. The evolution of meandering channels is a complex morph-dynamic process resulted from the interaction among flow, sediment, and bank material. The rate of bank erosion was conventionally assumed to be proportional to the magnitude of near-bank excessive velocity or shear stress. A number of laboratory experiments on mild curved channels of flat beds indicated that the high velocity zone crosses the channel centerline at the neighborhood of the downstream inflection point instead of immediately downstream of the apex. If bank erosion only occurs at the places of high shear stress, the erosion of convex banks should be observed in these laboratory flumes, and the

bends tend to subside. However, numerous experiments proved that a moderately or highly sinuous channel was initiated from a straight or mildly curved channel of no transverse slope by eroding the concave banks. Obviously

H42E-1118 1330h POSTER

Sedimentation Investigation of the Granite/Rhoads Creek Subwatershed, Delta-Clearwater River, Delta Junction, Alaska Using the Hydraulic Modeling Tool FLO-2D

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Concern in central Alaska over the impact of erosion and sedimentation in the Delta-Clearwater River watershed has prompted the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) to evaluate sources and sinks of sediment within the watershed. In the spring of 2003, NRCS completed a sensitivity analysis on the Granite/Rhoads Creek subwatershed by evaluating existing data with FLO-2D, a two-dimensional flood routing model with a sediment transport component. A grid network covering an area of approximately 5,350 acres and containing 23,310 grid elements was overlain on a portion of the Granite/Rhoads Creek subwatershed in the area of interest. Four model scenarios were evaluated to represent a range of best and worst case watershed conditions. Two-dimensional plots of "net change in elevation" and "maximum velocity" by grid element were developed from each of the simulations and provide information on the geographic distribution of erosion and sedimentation within the modeled area. Processing of the model output has provided information on the relative severity of erosion in terms of sediment yield and rates of erosion.

H42E-1119 1330h POSTER

Channel response to dam removal, Clear Creek, California

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Clear Creek drains 720 km2, joining the Sacramento River south of Redding, California. The 4.6-m high Saeltzer Dam blocked upstream migration of chinook salmon (Oncorhynchus tshawytscha) since it was built in 1912 to divert water for irrigation. Saeltzer Dam was removed in 2000 to restore anadromous fish access to upstream reaches. Before the dam was taken down, 19,000 m3 of sediment stored behind the dam was mechanically removed, but substantial deposits remained. A 2001 survey (Stillwater Sciences and University of California Davis 2001) detected little channel change in the former reservoir area over the 2001 flow season (peak flow 35 m3s-1). We resurveyed the channel in 2003 (peak flow 130 m3s-1). Our survey documented post 2001 incision of more than 1 m, over about 320 m upstream of the former dam site to an active headcut, and lateral erosion of 15-18 m, for total erosion of over 3000 m3 from the former reservoir deposit. Dam removal has led to desiccation of riparian trees (mostly Alnus spp.), with over 50 trees visibly dead or dying, and lateral bank erosion has removed more trees.

H42E-1120 1330h POSTER

Effects of Harvest and Roads on In-stream Woody Material in Blue River Basin, Cascade Range, Oregon

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Despite many studies of large wood in streams, few landscape-scale studies have been conducted, and yet the history of forest harvest and road building might be expected to have left a signal on wood patterns in streams. This study examined this question at large (>50 km^2) spatial and long (>25 year) temporal scales, based on longitudinal surveys of 25.2 km of stream length in five sub-basins of the Blue River Basin, Cascade Range, Oregon. Six sites, ranging from 1.6 km to 14.1 km in length, were surveyed along 2nd to 5th-order channels on public forest land. Wood volumes, numbers of pieces of large wood, numbers of accumulations and timing of emplacement were determined in the surveys. Survey data were matched with spatial data on harvest and road building practices using GIS. Study streams have undergone distributed patch clearcutting and road construction concentrated during the 1950s and 1960s. The proportions of surveyed stream lengths with harvest and road activities within 40 m was 66% (Cook Creek), 55% (Mack Creek), 53% (Lower Lookout), 37% (McRae Creek and Upper Lookout), and 7% (Quentin Creek). For all study locations combined, 50-m channel segments when there is no harvest or road influence had an average of 356 m^3/ha, whereas harvested and roaded areas had from 80 to 157 m^3/ha (Bonferroni adjusted $p<0.03$). Approximately 80

H42E-1121 1330h POSTER

Assessing the Role of Floods, Land Conversion and Bank Materials in Determining Channel Change Along the Willamette River, 1850-1996

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Floods and land development often trigger dramatic changes in planform and alter the evolution of floodplains. In this study, we combine historical analysis with a 2D flood model and a meander migration model along a 200 km section of the Willamette River in western Oregon to examine the relative importance of floods, bankful flows and land use patterns in determining channel change. Digitized historical datasets from 1850, 1895, 1932, 1972 and 1995 are used to calculate rates of channel change and to measure trends in channel width and sinuosity. Historical maps also provide information on riparian vegetation, bank materials and revetments. To estimate erosion resulting from the 1996 flood, we use power estimates derived from the 2D flood model of Denlinger et al., (2002). Using this model, the distribution of observed high water marks allows us to estimate average bed roughness during the flood. The product of velocity and bed shear stress estimated from bed roughness gives us a pattern of stream power that we can compare with observed channel changes. We compare these results with near-bank velocities (a proxy for bank shear stress) generated by bankful flows using a linear meander migration model in which velocity is the result of channel curvature. By comparing estimated shear-stress distributions from both models with observed erosion patterns, we can observe differences in the magnitude and style of erosion arising from each mechanism. Preliminary results show that avulsions, channel widening and decreases in sinuosity are associated with historic flooding. Periods of lower magnitude flows allow lateral migration to become dominant, thereby increasing sinuosity and migration rate. Floodplain variables such as bank materials, riparian vegetation and revetment placement will be analyzed to determine their influence on migration rates under different flow regimes. Further analysis will allow us to compile information on planform, erosion rate, bank materials and landuse conditions over the 5 time periods. By linking this information to model results, we hope to identify combinations of floodplain variables and flow conditions that support unique styles or rates of channel change.

H42E-1122 1330h POSTER

Debris Flow Initiation and Fan Reworking in the Green River Canyons of the Eastern Uinta Mountains: The Limited Role of Wildfire and the Significance of Low-Magnitude Floods

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The primary determinant on channel organization of the Green River in the canyons of the eastern Uinta Mountains is the occurrence and frequency of debris flows in tributary watersheds. The frequency of these debris flows appears to be related to climatic factors, not factors related to wildfire. Debris flows in the eastern Uinta Mountains occur by a process known as the firehose effect, wherein overland flow generated on bedrock slopes cascades down steep cliffs and saturates and impacts colluvium stored in bedrock hollows. The colluvium fails, initiating debris flows that travel downslope to the Green River. The dry climate and high-strength bedrock cause hillslopes to be weathering-limited, prohibiting the formation of extensive regolith and vegetative cover. This reduces the degree vegetation regulates geomorphic processes and, in turn, causes wildfire to have little influence on debris flow initiation; slight increases in watershed runoff do not appear to alter the likelihood of this process occurring. A secondary determinant on channel organization in debris fan-dominated canyons are the magnitude of mainstem discharges and the degree to which they rework debris flow deposits; in this case flows are regulated by Flaming Gorge Dam. Substantial reworking of debris flow deposits can be accomplished by mainstem floods with discharges greater than 75% of the pre-dam two year flood, whereas floods with magnitudes less than 40% of the pre-dam 2-year flood do little reworking.

H42E-1123 1330h POSTER

Assessing Suspended-Sediment Transport Rates at the Regional Scale: Lake Tahoe Basin

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In recent years, suspended-sediment transport has received increased attention due to a greater emphasis being placed on water quality issues. Secchi-disk data has shown a trend of decreasing water clarity in Lake Tahoe over the past 35 years that can be partly attributed to delivery of fine sediment from channel and upland sources. In an effort to quantify the magnitude and sources of suspended sediment into Lake Tahoe, the USDA-ARS National Sedimentation Laboratory with support from the U.S. Army Corps of Engineers initiated a study to examine these issues. Historical flow and sediment-transport data from more than 30 gages were used to determine bulk suspended-sediment loads and yields for sites around the lake. Eighteen index stations were used to make comparisons between sediment production and delivery from individual watersheds and between different sides of the lake. Fine-grained sediment transport was determined for 20 sites based on relations derived from particle-size distributions across the range of measured flows. Suspended-sediment loads and yields vary over orders of magnitude from year to year, from west to east and north to south across the basin. Median annual suspended-sediment loads for index stations range from about 2200 tonnes/yr (T/y) from the Upper Truckee River to 3 T/y from Logan House Creek. Based on the historical data, the largest annual contributors of sediment are in decreasing order, Upper Truckee River (2200 T/y), Blackwood Creek (1930 T/y), Second Creek (1410 T/y), Trout Creek (1190 T/y), Third Creek (880 T/y) and Ward Creek (855 T/y). Data from

Second and Third Creeks may be somewhat misleading though because of a short period of data collection in the case of the former, and the fact that data collection occurred during major construction activities and following storm-induced debris flows in these basins. Analysis of suspended-sediment transport ratings with longer periods of record show that sediment loads from northeastern streams have significantly decreased across the entire range of flows. Suspended-sediment yields were used to compare suspended-sediment contributions from different watersheds of varying size and location. Western and northern streams produce the highest yields. Sediment yields from northern streams have been decreasing since the early 1970's while those from the Upper Truckee River have also decreased albeit at a slower rate than in Third and Incline Creeks. In other parts of the basin, temporal trends of decreasing loads per unit area and unit water were subtler. No statistically significant trend of increasing suspended-sediment loads or yields was identified as reported recently by other workers. Fine-grained loads show a similar pattern as total loads with the greatest contributors being the Upper Truckee River (1010 T/y), Blackwood Creek (844 T/y), Trout Creek (462 T/y) and Ward Creek (412 T/y). In terms of fine-grained loadings per unit area, a slightly different picture emerges. Blackwood, Third, and Ward Creeks, all disturbed streams have the greatest fine-grained suspended-sediment yields at 21.5, 20.2, and 16.4 T/y/km2. In comparison, the Upper Truckee River produces 7.1 T/y/km2; General Creek, 2.8 T/y/km2; and Logan House Creek, 0.4 T/y/km2. Overall, the contribution of channel materials to sediment loads varies widely throughout the Lake Tahoe basin. Watersheds disturbed by human intervention produced orders of magnitude more sediment than stable, undisturbed watersheds. Undisturbed channels tend to have greater amounts of their sediment load emanating from upland areas.

H42E-1124 1330h POSTER

Channel Responses to Fluctuations in Water and Sediment Supply on the Lower Duchesne River, Utah

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Channel responses to flow depletions in the lower Duchesne River over the past 100 years have been highly complex, and variable in both space and time. The gravel bed reaches aggraded only when gravel was supplied to the channel through local bank erosion, and degraded only during extreme flood events. In general, sand-bed reaches adjusted to all perturbations with bed-level changes, whereas the gravel-bed reaches adjusted primarily through width changes. No tributaries enter the Duchesne River within the study area, so all reaches have experienced identical changes in stream flow and upstream sediment supply. A 50% reduction in stream flow and an increase in fine sediment supply due to local gully erosion produced distinctly different responses in the gravel-bed and sand-bed portions of the study area. Gravel-bed reaches responded primarily with channel narrowing, whereas bed aggradation and four large-scale avulsions occurred in the sand-bed reaches. These avulsions almost completely replaced a section of sinuous channel about 14 km long with a straighter section about 7 km long. The most upstream avulsion, located near a break in valley slope and the transition from a gravel bed upstream and a sand bed downstream, transformed a sinuous sand-bed reach into a braided gravel-bed reach, and eventually into a meandering gravel-bed reach over a 30-year period. Later, a slight increase in flood magnitudes and durations caused widening and secondary bed aggradation in the gravel-bed reaches, whereas the sand-bed reaches incised and narrowed.

H42E-1125 1330h POSTER

Regional, Basin, and Local Factors Influencing the use of Synoptic Survey Data to Assess Anthropogenic Changes in Streambed Stability and Fine Sediment

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To evaluate anthropogenic changes in stream bed stability or texture from synoptic stream surveys, we calculated relative bed stability RBS* as the ratio of the geometric mean bed surface substrate diameter to the estimated bankfull critical diameter. RBS* decreased with increasing watershed and riparian disturbance in a previous survey of Oregon and Washington coastal streams, but showed a greater apparent response in streams draining basins underlain by weak sedimentary rock than in those underlain by more resistant volcanic rocks. Systematic natural variation in RBS* (e.g., downstream trends, local variation due to channel morphology, regional differences due to geology or climate) might affect its utility as a routine assessment tool by leading to differences in the relationship between RBS* and land disturbance. To explore these issues, we sampled streams over a wide range of disturbance intensity and geologic erodibility in the northern Oregon Coast Range, eastern Oregon, and mid-Atlantic USA. In each of 17 watersheds we sampled 3 closely-spaced main stem reaches (25-50 km^2 drainages in the Oregon Coast Range and mid-Atlantic USA, 250-400 km^2 in eastern Oregon) and 3 reaches each in 1 to 3 smaller tributaries to assess local variability and within-basin longitudinal trends in RBS* relative to variation between watersheds with different land use intensity. Preliminary results show significant regional differences in RBS*. The northern Oregon coastal streams exhibited a wider range of RBS* values than the other two regions, with higher average RBS* but also the lowest values. These coastal streams also showed the strongest (inverse) relationship between RBS* and anthropogenic disturbance. Contrary to expectations, RBS* generally increased with watershed area in this part of Coast Range, although the downstream pattern of RBS* values within individual watersheds was quite variable.

H42E-1126 1330h POSTER

Multi-scale factors influencing stream substrate size within and among watersheds

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Variables representing processes at multiple spatial scales that influence stream bed substrate at the outlet of a basin (a sample location) are developed to augment existing models that include only stream bed gradient and upstream drainage area. These multi-scale models can explain up to 95 percent of the variation in stream bed substrate size and consistently explain an additional 32 to 52 percent of the variation in substrate size when compared to models that use only channel gradient and drainage area. Results demonstrate that variables reflecting valley topographic configuration in the vicinity of a sample location explain significant additional variation in substrate size. When the geographic extent being considered exhibits significant variability in hydroclimatic processes and basin lithology, accounting for variability in these controlling factors can significantly increase the explanatory power of these models. In contrast, when considering an area of relatively homogeneous hydroclimatic processes and basin lithology, including variables that reflect the distribution of flow energy and/or relief in the upstream channel network significantly improves models to predict substrate size. The ability to produce reliable predictive models of substrate size using only variables generated from geospatial data is also addressed. Values of channel gradient obtained through field survey are substituted with values of channel gradient sampled from digital elevation models and model development repeated. Models developed in this fashion explain up to 91 percent of the variation in stream bed substrate size and can, in general, explain as much or more variation in substrate size as models that use only field surveyed channel gradient and drainage area. Furthermore, when appreciable variability in hydroclimatic processes and basin lithology exists, models using only variables derived from geospatial data can explain more variation in substrate size than similar models that use field surveyed channel gradient. Important applications for several fields that could benefit through these analyses are discussed.

H42E-1127 1330h POSTER

Mapping Stream Hydrogeomorphic and Disturbance Regimes Throughout Drainage Networks

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Hydrologic regimes and geomorphic characteristics interact to create and alter the spatial and temporal distribution of aquatic habitats in drainage networks. We present an approach for mapping stream hydrogeomorphic types and disturbance regimes at the drainage network scale using geospatial data. We selected stream gauges of relatively high quality and long-term record to develop models for predicting membership of ungauged sites into ecological disturbance classes. Cluster analysis is used to group streams with similar disturbance regimes using significant, non-redundant streamflow characteristics. Different suites of metrics are used to represent disturbance and derive multiple sets of disturbance classes. Average frequencies and durations of hydrologic disturbance for each class are then computed to facilitate interpretation. Discriminant analysis is used to characterize the disturbance regime of ungauged sites using geologic, topographic, climatic and other watershed attributes. All of the watershed metrics used are computed from remotely sensed data using a GIS. Geomorphic characterization of each stream link is performed using previously developed models based, in part, on 10m digital elevation models to compute metrics including slope, stream power ($SA^{0.4}$) and substrate size. The models of disturbance regime and geomorphic context are then combined to map the hydrogeomorphic disturbance type of each stream link within an entire watershed. Two watersheds on the west slope of the Cascades in Washington are used to illustrate and test the approach. Predictions for stream links with USGS gauging stations are compared to disturbance metrics calculated directly from streamflow gauge data. The ability to identify stream hydrogeomorphic types and disturbance characteristics from readily available digital geospatial data can improve methods for stratifying aquatic habitats within ecoregions to more effectively explain patterns of biological variation and facilitate understanding of linkages between biotic and hydrogeomorphic diversity.

H

H42E-1128 1330h POSTER

Geomorphometry of Drainage Basin for Natural Resources Management Using High Resolution Satellite Data an Indian Example

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Application of Remote Sensing and Geographic Information System for the development of land and water resources action plan at micro level for appropriate management of land/water resources of a watershed in rain fed region of Prakasam District in Andhra Pradesh, India forms the focal theme of this paper. The quantitative description of drainage basin geometry can be effectively determined using Remote Sensing and GIS techniques. Each of the sixty-two sub-watersheds of the study area have been studied in terms of the Morphometric parameters - Stream length, Bifurcation ratio, Length ratio, Drainage density, Stream frequency, Texture ratio, Form factor, Area Perimeters, Circularity ratio and Elongation ratio and prioritized all the sub-watersheds under study. The prioritization of sub sheds based on morphometry is compared with sediment yield prioritization and found nearly same for the study area. The information obtained from the thematic maps are integrated and action plans are suggested for land and water resources development on a sustainable basis. Landuse/Landcover, Hydrogeomorphology and Soil thematic maps were generated. In addition slope and Drainage maps were prepared from Survey of India toposheets. Based on the computerized database created using ARC/INFO software, information derived in terms of natural resources and their spa-

tial distribution was then integrated with the socio economic data to formulate an action plan, which includes suggestion of alternative Landuse/Landcover practices. Such a plan is useful for natural resources management and for improving the socio-economic status of rural population on a sustainable basis. Keywords: Natural Resources, Remote Sensing, Morphometry sustainable development.

H42E-1129 1330h POSTER

Pecos River Water Management Project

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Sandia National Laboratories is providing technical assistance to farmer members of the Carlsbad Irrigation District (CID) to better plan the storage, delivery, and application of water to the Carlsbad Project. The surface waters along the Pecos River are allocated by the State of New Mexico to three major entities: 1) The State of Texas - each year a percentage of water from the natural river flow must be delivered to Texas as governed by the Interstate Streams Commission; 2) CID farmer members - a fixed portion of water must be delivered to the farming members of the CID; and 3) wildlife - an amount of water must be allocated to support the wildlife habitat in the Pecos River, most notably, the endangered Pecos Bluntnose Shiner Minnow. The Pecos Bluntnose Shiner Minnow habitat preference is under investigation by other state and national agencies and preliminary work has established that water depth, water velocity, and sediment activity (dunes, ripples, etc.) are the key parameters influencing minnow habitat preference. The amount of water (river flow rate) necessary to maintain a preferable habitat to support this species has yet to be determined. With a limited amount of water in the Pecos River and its reservoirs, it is critical to allocate water efficiently such that habitat is maintained, the farmers of the CID are supported, and New Mexico meets its commitments to the State of Texas. This study investigates the relationship between flow rate in the river and water depth, water velocity, and sediment activity. The goal is to establish a predictive tool that supports informed decisions about water management practices along the Pecos River that will maximize water available for agriculture and the State of Texas while maintaining the aquatic habitat.

H42F MCC: Level 2 Thursday 1330h

Interactions Between Fluids and Fractures I Posters *(joint with T, V, NG, MR)*

Presiding: **L C Murdoch,** Clemson University**; L Germanovich,** Georgia Institute of Technology

H42F-1130 1330h POSTER

Effect Of Interaction On Apertures Of Multisegmented Natural Veins

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Echelons of multisegmented fluid-driven natural fractures (such as dikes, veins, and sometimes joints) with consecutive overlapping are one of the most common types of structures in the Earth's crust. The mechanical behavior of these fractures is quite different from that of single fractures, because of the interaction between the segments. In this work we compute the apertures of a highly segmented calcite vein, with 71 segments, in siltstone (Culpeper Quarry, Virginia) described by Vermilye and Scholz [1995]. The effect of elastic interaction between the segments is considered at three different special scales and accurately evaluated by solving the corresponding system of singular integral equations. For comparison, the case of ignored interaction is also considered. Our results unambiguously suggest that the effect of interaction highly affects the vein apertures. By using two net pressures in the vein as fitting parameters, it is possible to obtain an excellent match of the computed and measured apertures (based on 3,000 data points). This indicates two episodes in the history of vein evolution. Based on the performed simulation, a concept of effective fracture (vein) has been suggested. This is a single fracture of the same overall size (length) as the real vein. It is also pressurized by two net pressures that are determined by fitting the field data. As a result, practically the same net pressures are obtained as by accounting for the full interaction between the vein segments. The concept of effective fracture allows the sufficiently accurate computation of the vein (fracture) apertures, but without considering the interaction between the multiple segments.

URL: http://www.ce.gatech.edu/~leonid/rockmechgroup/research.html

H42F-1131 1330h POSTER

Experiments on Hydraulic Fracturing in Weakly Cemented Sediments

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Hydraulic fracturing in weakly cemented sediments was studied in the laboratory. Viscous liquids were injected into dry sediments at a constant flow rate while the injection pressure was monitored. The injected liquid solidified after the experiment, and was extracted from the particulate sample. The liquid flow appears to be localized in thin conduits. Often, these channels resemble cracks; by analogy we call them hydraulic fractures. Also, non-fracture phenomena (e.g. cavity expansion, leak off) occur under certain conditions. Different transition stages (i.e., from bulb to thin fracture) can exist. The appearance of the fractures depends on (i) the density, (ii) the particle size distribution and (iii) the stress state (both stress ratio and magnitude) of the particulate materials, and (iv) the viscosity and (v) the flow rate of the injection fluid. The properties of the particulate media (i to iii) and the injection liquid (iv to v) affect the shape and thickness of the fractures. In contrast, the initial stress ratio in the sediment (iii) controls the orientation of the fractures. The injection pressure is affected by all five parameters. Since all the tested materials exhibit strain-softening behaviour, the obtained results suggest that the mechanism of fracture propagation may be due to localized shear bands originating from the fracture tip. The slip of the shear band sides is inclined with respect to the main fracture plane. This results in the normal (mode I) fracture opening, which creates space for continued fluid flow at the fracture tip during its propagation.

URL: http://www.ce.gatech.edu/~leonid/rockmechgroup/research.html

H42F-1132 1330h POSTER

Forms and Analysis of Hydraulic Fractures at Shallow Depth

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The form of a hydraulic fracture plays a key role in the performance of the fracture during environmental remediation projects. Fractures that are relatively thick and flat lying are suited to improve the performance of remediation wells, whereas fractures that are steeply dipping may be suited to the creation of reactive barriers. To sharpen the resolution of the details of fracture form at shallow depth in Piedmont soil, the vicinity of four hydraulic fractures initiated at 1.5 m depth was excavated and mapped on trench exposures. The data from these maps were used to characterize fracture form, including geometry, sand thickness, distribution of sand within the fracture, and ground surface deformation during fracturing. The fractures were roughly elliptical in plain view, and the centers of the fractures were offset from the injection casing. In general, they were shaped like gentle bowls whose sides dip from 12 to 16 degrees. A peculiar aspect of the fracture form occurred in the vicinity of the injection casings, where three of the fractures curved downward and then back up to produce gentle trough-like structures around the casings. The finite element code FRANC2D was modified to simulate fluid flow in a propagating fracture. The modified code predicts curved fracture traces that are gentle bowl-like forms, where the enveloping medium is uniform and characterized by material properties similar to field conditions, and ambient stresses result from body forces. Another model was created using two layers, where the elastic modulus of the upper layer was greater than that of the lower layer. Fractures simulated using this model curve downward toward the softer layer, and then curve upward as they become longer to produce a trough-like form similar to the field. The fractures were created in a layer of relatively stiff clayey silt that was underlain by softer saprolite, and this layering may be able to explain the downward propagation observed in the field. Additional simulations have been conducted to evaluate the effects of fracture toughness and in situ state of stress on fracture form, and preliminary results suggest that these parameters can explain field observations from a variety of sites.

H42F-1133 1330h POSTER

Discriminating Between Different Fracture Network Geometries Using Well Test Analysis

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Realistic 3D geometrical models of different styles of fracture networks have been investigated based on well-exposed examples of fault and joint networks from exposures in southwest England. From these, generic models of various types of strike-slip and normal faults have been built. These form the basis of a series of well test simulations designed to analyse and quantify the influence of different fracture elements on hydraulic behaviour. In this methodology, each fault and fracture segment is discretised individually as a plane using a triangular mesh; realistic transmissivity and storativity values are then assigned to the different parts of the mesh. A commercial finite element code is used to solve the pressure diffusion equation for a transient case in these meshes. The simulations have been tested against other numerical codes. Experiments were conducted with constant and varying fault transmissivities and varying well positions relative to the fault network. Monitoring pressure drawdown in observation wells around the fault network simulated interference tests. The results demonstrate that a single geometrical structure may display significantly different pressure responses at a single well; as a function of distance to the well and of the transmissivity distribution within the fracture network and matrix. Where the fracture network is well connected, it is the ratio of the fracture to matrix transmissivity that dominates the behaviour of the pressure diffusion. Preliminary conclusions are that fracture properties have a higher order effect on pressure diffusion than fracture density.

H42F-1134 1330h POSTER

Evolution of Fracture Permeability

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Pore fluid flow and fluid composition within fractured rocks is a subject of primary importance to fields including hazardous waste isolation and remediation, oil and gas production, geothermal energy extraction, and formation of vein fillings and ore deposits. For these reasons, considerable effort has been placed on characterization and modeling of flow in fractures and fracture systems. We are investigating the complex active chemical interaction between pore fluid and fractures that causes the fluid composition and topography of these systems to change over time. Our experimental model consists of $CaSO_4$ samples pressed with a constant force against an inert textured fracture surface. Pore fluids ranging from unsaturated to supersaturated which are at a variety of flow rates are introduced to one end of the sample in order to actively alter the