several tens of square kilometers. In recognition of the uncertainties inherent in analyses based upon relatively sparse point data available for Fortymile Wash, the Center for Nuclear Waste Regulatory Analyses and the Nuclear Regulatory Commission have developed a surface geophysics program that targets the inter-well regions utilizing gravity, magnetic, electrical resistivity, and electromagnetic measurements to support confirmatory analyses and performance assessment calculations. This presentation describes various aspects of these surveys and their results. In particular, the presentation presents new models for the structure of the Fortymile Wash (including an improved mapping of the tuff valley-fill interface) based on the integrated geophysical approach and provides an independent basis for the watertable configuration over the region. By combining the watertable data with the improved structural model the watertable transition point from the tuff to the valley is better constrained. In addition, the presentation describes the application of the data to the continued development of a hydrologic framework model that incorporates characteristics of the wash and is used to support hydrogeologic modeling.

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## H41D MC: Hall D Thursday 0830h

## Watershed-Scale Sediment Routing Through River Networks I *(joint with T)*

***Presiding:*** **J Pizzuto,** University of Delaware**; T Lisle,** USDA Forest Service, Pacific Southwest Research Station

### H41D-0304 0830h POSTER

### Spatial and Temporal Analysis of Lower Mississippi River Bathymetry, 1921-1992

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The analysis of historical bathymetric data can aid in the understanding of the evolution of controlled rivers. Such data are often not readily available, and when they are, it may be discovered that older datasets are not held to the same geodetic and cartographic standards as more recent ones. Surveys conducted around the years 1921, 1937, 1948, 1964, 1975, 1983, and 1992 have recently been digitized and released by the Army Corps of Engineers (ACE)-New Orleans District. Prior to and during the eighty years spanned by these surveys, the river has been extensively modified for flood control, while the river valley has been developed. These bathymetric surveys of the lower Mississippi River can be used to examine the rivers response to these modifications of the drainage basin, river channel, and levee system.

For this analysis, the ACE bathymetry datasets were assembled from various formats, geo-referenced, adjusted to account for differences in vertical datums and stage, corrected for errors, interpolated, and differenced at the one-river-mile level. The differenced bathymetric data and bankline data depict riverbed aggradation, erosion, and channel migration over the interval between each independent survey.

According to this analysis, the lower Mississippi River has been aggrading from the New Orleans metropolitan area up to Baton Rouge (miles 110-200), and deepening from New Orleans down to Head of Passes (miles 110-0), at a rate of about one foot per 10 river miles, with most of this bathymetric change occurring in the 1921-1948 time period. The data also show that, from 1921-1992, channel changes from New Orleans to Baton Rouge varied to a slightly greater degree than has occurred in the lower 100 miles, which concurs with the bathymetric observations. River channel changes in the X, Y, and Z directions may be used to characterize the rivers responses to increasing development and flood control.

### H41D-0305 0830h POSTER

### Rates of Erosion Determined From $^{10}$Be Analysis of Alluvial Sediments, Great Smoky Mountains, Tennessee and North Carolina

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We measured $^{10}$Be in quartz extracted from sediment samples (n=22) collected from a network of 22 rivers and streams draining the Great Smoky Mountains and calculated model erosion rates that average 31$\pm$5 m My$^{-1}$. Network analysis and mass balance calculations verify two main assumptions on which model erosion rate calculations depend: no significant storage within the sampled basin (also indicated by field observations) and good mixing of sediments from different sources within the sampled basins.

Mass removal rates from each sampled basin were calculated from $^{10}$Be model erosion rates and basin size. For the two basins that we studied in detail (i.e. most of the main tributaries and the main stem were sampled; Oconaluftee River and Raven Fork), total area and mass removal rates of the tributaries were compared with area and calculated mass removal rates of the main stem. Tributaries supplied a fraction of the total mass removed from the basin equal to the area they cover within the drainage system. This correspondence suggests that erosion rates are spatially uniform throughout the mountain range.

We analyzed different sand and gravel fractions (250-850 um, 850-2000 um, and >2000 um) to test whether different grain sizes of sediment have different cosmogenic nuclide activities. Grain size tests of two samples in the Oconauftee River (GSCO-1, GSCO-7) yielded similar nuclide activities for the three different fractions, suggesting that different grain sizes have similar cosmic-ray dosing histories. However, the >2000 um fraction in one of the samples (GSCO-1) had a nuclide activity 40% lower than the <2000 um fractions, implying less cosmic ray dosing for the larger than for the smaller grains. The low $^{10}$Be activity of this sample might result from a single mass wasting event that rapidly delivered large grain size, previously shielded sediment to the channel (c.f., Brown et al., 1995, EPSL, 129: 193-202).

Rates of erosion do not correlate with drainage basin area and variance diminishes as drainage basin area increases; the 3 largest basins have $^{10}$Be model erosion rates (30.2$\pm$2.2 m My$^{-1}$) similar to the mean erosion rate (27.5$\pm$4.6 m My$^{-1}$) of the 11 smaller headwater basins. We found a very weak correlation between rates of erosion and maximum drainage basin relief ($R^2$= 0.13) and are currently testing the relationship between nuclide activity and other basin parameters including drainage density and slope.

### H41D-0306 0830h POSTER

### Downstream Changes in Channel Morphology Through a Network of Gravel-Bed Streams

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Increased development of water resources and alteration of natural stream flow regimes in mountain watersheds necessitate an assessment of these changes on sediment transport. A possible approach to better understand the long-term sediment balance of a stream network utilizes the time-integrated nature of channel morphology and the principle of mass conservation. The present study will test a physically-based model of channel form which states that gravel-bed channels adjust to maintain a bed shear stress slightly above the threshold for motion. One implication of this model is that the downstream dimensionless shear stress should remain constant in an idealized watershed. This may further imply that bed load transport per unit width, commonly expressed in terms of excess shear stress, should also remain constant downstream. Field data were collected from 27 alluvial reaches in Halfmoon Creek in the Sawatch Mountains of central Colorado. Reach slopes range from 0.006 to 0.046 and median grain size of the bed material ranges from 32 mm to 87 mm. Surveys of at least three cross-sections along each reach were made to characterize the average bankfull depth. Velocity measurements were made in selected reaches to evaluate energy losses due to form drag from large particles. Surface and subsurface sediment samples were also collected at or near each reach. These data will then be used to characterize the downstream changes in bankfull dimensionless shear stress and sediment transport capacity through the stream network. This data set will yield an important field test on a physically-based model of sediment transport that could prove to be a useful tool for restoration and predictive purposes.

### H41D-0307 0830h POSTER

### Physical Modeling of Sediment Transport in Steep Boulder-Bed Channels

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Sediment mobilized in mountainous regions must transit through steep boulder-bed channels before reaching streams that are large enough to bear fish. Although steep channels are important components in basin-wide sediment routing, their hydraulic complexity precludes the use of traditional resistance and sediment transport equations. Steep boulder-bed channels are characterized by shallow flows relative to grain dimensions and by spatially variable shear stresses. In these channels, drag caused by large relatively immobile boulders reduces the stress available for transport of finer, more mobile material. Episodic supply of a wide range of grain sizes, mobilized during different flow regimes, further complicates sediment routing.

We hypothesize that the total shear stress in steep boulder-bed channels can be partitioned between large immobile grains and a finer, more mobile fraction. The stress borne by the immobile grains will increase with boulder concentration, size and protrusion above the bed. One should be able to estimate the flux of the finer, more mobile sediment from simple field measurements, using conventional transport theories modified to account for the stress borne by the boulders. We hypothesize that streambed coverage by mobile sediment is directly related to the immobile grain concentration and the sediment supply.

We tested these hypotheses using a small steep flume (15 cm wide, 10 percent gradient). We used a constant discharge of 750 cm$^3$/s and a sediment supply rate that varied from 3 to 43 g/s. Supplied sediment was 3.7 mm gravel that encountered fields of immobile spheres (3 cm in diameter). We found that even at low supply rates, the flow resistance due to immobile grains led to widespread areas of gravel deposition. With increasing transport rates, finer patches thickened more than they expanded laterally, limiting the protrusion and drag of the spheres. Thus, boulder protrusion may be a better indicator of sediment supply than mobile grain coverage. These results should depend on the supplied grain size distribution and therefore additional experiments with a range of particle sizes and immobile grain distributions are underway.

### H41D-0308 0830h POSTER

### Use of Morphology-based Gravel Budgets to Anticipate the Locations of Channel Instability on the Lower Duchesne River, Utah

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Channel instabilities, such as meander bend cutoffs and accelerated bank erosion, on the lower Duchesne River have historically occurred where local accumulations of gravel in the channel decrease channel capacity and force flow over point bars. The spatial distribution

of lateral channel instabilities can be anticipated by the use of morphology-based gravel budgets developed from geographic information system (GIS) analysis of aerial photography. The gravel budgets are based on field measurements of gravel deposit thicknesses and areas of gravel erosion and deposition occurring over decade-scale time intervals between 1936 and 1997. The magnitudes of gravel erosion, gravel deposition, and net changes in gravel storage were evaluated for individual subreaches along a 19-km stretch of river. Net transfers of gravel to the active channel are associated with subsequent downstream channel instabilities. Net gravel storage changes were determined to be better predictors of channel instability on the lower Duchesne River than are gross quantities of gravel erosion and deposition.

Historical reconstruction of channel activity derived from this work were applied to development of habitat-maintenance flow recommendations for the lower Duchesne River. This river is inhabited by endangered native fish species whose habitat needs depend on the continuation of dynamic channel processes.

### H41D-0309 0830h POSTER

## Predicting Change in Sediment Transport Rates in the Wake of the Cerro Grande Fire: Limitations and Potential of a Physically-based Approach

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One of the benefits of physically based hydrologic models is that since they are based on physics, they can potentially be used to describe hydrologic response to change. On the Pajarito Plateau in New Mexico the introduction of cattle in the late 1800s, and then establishment of the Los Alamos National Laboratory in the 1940s has had a profound effect on the cover on the watersheds surrounding Los Alamos, with a proliferation of a more dense under story, on the hillsides, and more impermeable areas at the town site. Since the establishment of the Laboratory, there have been several large forest fires, most recently, the Cerro Grande Fire in May 2000. Hydrologic models suggest an eight-fold increase in the 100yr-6hr-flood peak in Los Alamos Canyon, and a corresponding three to four fold increase in sediment transport in the Canyon under post-burn conditions. However, the magnitude of the predicted scour depends strongly on what processes are allowed to occur in the model. The predicted scour is much greater if the model incorporates an observed inset channel, where modeled velocities are much greater than in the full wetted area. Furthermore, the model suggests that armoring has the potential to cut off the supply of sediment in the bed, so that scour and sediment transport are limited by the capability of the flow to transport larger particles that might otherwise armor the bed. Therefore, the magnitude of the predicted increase in sediment transport depends strongly on the ability of channels to armor as well as an a-priori understanding of how scour and deposition will occur in the canyon in response to flows much greater than the historical record. As such, reliance on model estimates of sediment transport based on the physics of flow is inadequate for assessing the effects of change and, at-best, provides only a range in the possible response to an extreme event. In this poster we examine available data on post-fire armoring rates, and observations about historical changes in channel morphology to bound the range of possible sediment transport rates for a large flow in Los Alamos Canyon.

### H41D-0310 0830h POSTER

## Changes in Mirror Lake as a Result of the Diversion of Water From the Nooksack River

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Mirror Lake, a small lake in northwest Washington, has been used as a settling pond for water diverted from the Middle Fork of the Nooksack River since 1962. The purpose of this project was to document the changes in sedimentation that have resulted from this diversion. The previous study was in 1991.

Mirror Lake was surveyed in the summer of 2000 using a theodolite and sonar depth gauge. A contour map was generated from the results of this survey. The map from the survey of 2000 was compared to that from the survey from 1991, but inconsistency between the two surveys prevented comparison of the bathymetry except in an area near the delta. The first survey of the lake, which was in 1946, was not detailed enough to allow comparison.

The next step of the project was to remove four cores from the lake and collect grab samples. The goal of this was to determine the thickness, grain size and organic content of the deposits since 1962 and compare this sediment to pre-diversion sediments. The sediments from the diverted water have a thickness of about 1.3 meters at the middle of the lake, and medium to coarse silt predominates at this location. The pre-diversion sediment is primarily gyttja that has a size equivalent to very fine sand.

Based on this study, about 15,000 cubic meters of sediment have been deposited between 1991 and 2000; this is about 1700 cubic meters per year. Future studies could involve imaging of the sediments, could use more accurate surveying, or could involve a more detailed study of the pre-diversion sediments.

### H41D-0311 0830h POSTER

## Sediment source analysis through in-stream monitoring of sediment loads at many sites

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In the past year, we have measured suspended sediment concentration and load at 50 sites in California's Central Coast region. Each site was manually sampled multiple times during the major storm events of the 2000-2001 winter. How then do we convert this valuable data set into an analysis of sediment source locations? Storm event size varied throughout the region, so statistical techniques are explored to account for stochastic climatically induced spatial variation in sediment sources. By working with regionalization of flood frequency curves, and construction of hysteric concentration-discharge curves for each site, we are able to predict the sediment load for each site at a unifying, short recurrence interval. This then leads to a map estimating the major sediment source areas of an 11000 $km^2$ study area under non-extreme conditions after a single season of monitoring.

### H41D-0312 0830h POSTER

## The value of manual, event-based sediment sampling in local-scale sediment budget studies

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Many contemporary sediment-budget studies lack two things: a first-hand understanding of the behavior of the system, and high-frequency data during storm events. In a study designed to understand sediment source areas, we have approach these deficiencies through manual sampling, almost exclusively during storm events. Manual sampling leads to better understanding. Frequently, the researcher finds oneself standing in streams observing phenomenon that contradict their a priori, desktop, or textbook-based perception of system behaviour. The case study we present reflects this in its observations of very high percolation rates, differing levels of land-stream connectivity under different sized events, and landowner intervention in water and sediment flux. In drier regions with episodic rainfall, event sampling is essential. During one season, we sampled 13 sites in a 316 $km^2$ watershed about 50 times each. The sampling times were targeted to observe the start of the rising stage, many points immediately around the hydrograph peak, once or twice during the falling stage, and once after the return to pre-event conditions. The same number of samples spread over the year at regular intervals would lead to a grossly inaccurate representation of the system by the data. For example, event sampling permitted a reasonably accurate characterization of total annual load at each site. A simple, static model was then used to apportion total loads to different land use sources, and in-channel sources.

### H41D-0313 0830h POSTER

## Magnitude and Frequency of Sediment Transport During Earthquake and Typhoon Events in Taiwan

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Processes of sediment mobilization and transport on hillslopes and in rivers in many humid, tropical mountain belts are dominated by typhoons and earthquakes. These events are believed to be especially effective geomorphic agents when they occur closely in time. We examine this assertion using a twenty-five year record of stream discharge, seismicity and suspended sediment for several drainage basins in the Eastern Central Range, Taiwan. The data are analysed in terms of discrete events of sediment discharge correlated with indices of storminess and seismicity calculated for locales in mountainous sub-basins and further downstream alike. The seismicity index represents a newly defined empirical relation between earthquake magnitude and associated ground acceleration as well as distance from focus. The role of sediment storage on hillslopes and in channels, which itself depends on the history of a system, is shown to be critical in determining the drainage basin's response to any particular event. We also present a joint probability distribution of seismicity and storminess which illustrates the relative importance of geomorphic work done by these extreme event types individually and when they occur together in time. The results of our analysis contribute to the understanding of the magnitude and frequency of geomorphic processes in humid tropical mountain belts and can ultimately be used to provide stochastic inputs to surface process models.

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# H41E MC: Hall D Thursday 0830h

## Recent Advancements and Future Prospects in Hydrologic Remote Sensing I *(joint with A)*

***Presiding:*** **P Houser,** NASA-GSFC**; M F Jasinski,** NASA Headquarters

### H41E-0314 0830h POSTER

## Measurement of Soil Moisture on 50 m Postings Using InSAR

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We are developing a new method for measuring soil moisture at 50 m spatial resolution using differential SAR interferometry (DInSAR). Analogous to using stereoscopic imaging techniques, two ERS-2 satellite acquisitions are used to determine relative changes in microwave echo path length on a scale of millimeters. These methods are widely employed in determining ground displacement due to earthquakes, subsidence, and ice motion. Because the ground surface in our study area is stationary, we interpret the changes in path length we observe as changes in penetration depth or phase delay of the microwave radiation into the soil. Penetration depth is related to the soil dielectric which is in turn closely related to soil moisture.

Our results show strong spatial consistency between DInSAR phase signals and watershed boundaries, vegetation types, and soil types. These changes are on the order of 1 cm in the SAR look direction and are not consistent with topographic or atmospheric artifacts. Factors that help make this type of measurement possible are the relatively flat and sparsely vegetated rangeland of this southern Colorado study area and a very high resolution digital elevation model (50 cm vertical accuracy). Our investigations are hampered by long measurement intervals (35 days) and short wavelengths (C band). Future missions could be designed with L band instruments with a 1 day measurement interval with all-weather guaranteed acquisitions that could turn this technique into a reliable production tool.