ES04: Morphodynamics of River Systems

Conveners: Jeremy Venditti[1,3], and Brett Eaton[2,4]

Co-chairs: Lucy MacKenzie[2,5], Dan Haught[1,6], and Ryan Bradley[1,7]

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Session Description

The interaction of fluid flow, sediment movement and topographic change in river systems give rise to a wide range of channel morphologies and patterns. It is widely thought that the morphology of rivers is invariant with scale, but there is emerging evidence that many of the world's largest river systems exhibit behaviors and morphologies that differ from smaller scale channels. While the physics of fluid flow and sediment transport must be scale invariant, the dominant processes appear to vary across rivers of different sizes. This has important implications for predicting the behavior of river systems as well as understanding sediment deposits and the rock record. The goal of this session is to draw together geomorphologists, sedimentologists, and river engineers to explore the dynamics of rivers across all scales. Topics may include alluvial river channel dynamics, morphodynamics of fans and deltas, bedform dynamics, scale effects on flow and sediment transport processes, external forcing (geological or climate) on river dynamics and controls on the architecture of river channel and floodplain deposits. We welcome studies that use field, experimental, theoretical and numerical approaches to understand the morphodynamics of rivers.

Primary Affiliation: CGU Earth Surface Processes

NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION ES04a

Chairs: L. MacKenzie, R. Bradley, D. Haught **Room: GEOG 229**

Monday, May 29th

TIME	AUTHORS	TITLE
9:00 9:15	Jeffrey A. Nittrouer, and Hongbo Ma	On the Exceptional Sediment Load of the Huanghe (Yellow River), and its Capacity to Produce Subaerial Deltaic Landscape
9:30	Ray Kostaschuk and Jeremy G. Venditti	The scale of river dunes
9:45	Ryan W. Bradley*, Jeremy G. Venditti	What Controls Dune Dimensions in Rivers?
10:00	Matilde Welber, Peter Ashmore, Bruce MacVicar	Sediment dynamics in semi-alluvial urban streams
10:15	Ashley Dudill*, Michael Church, and Jeremy Venditti	Formal testing of reproducibility in fluvial geomorphology

ORAL SESSION ES04b

Chairs: R. Bradley, D. Haught, L. MacKenzie **Room: GEOG 229**

Monday, May 29th

TIME	AUTHORS	TITLE
14:00	Sarah Peirce*, Pauline Leduc, and Peter Ashmore	Active width and bedload transport relationships in gravel-bed braided rivers
14:15	Hamed Dashtpeyma*, and Bruce MacVicar	Surface, Corner and Ramp Rollers: Numerical Analysis of Flow Patterns in Isolated Pool-Riffle Units
14:30	Emma Buckrell*, and Marwan Hassan	Formation and adjustment of pool-riffle sequences
14:45	Matteo Saletti*, Peter Molnar, and Marwan A. Hassan	Step formation and stability in steep streams: insight from a reduced-complexity model
15:00	Laura Hempel*, Brett Eaton, Marwan Hassan, and Gordon Grant	Hydrograph Shape Controls Channel Morphology and Organization in a Sand-Gravel Flume
15:15	Sarah Davidson and Brett Eaton	A stochastic model of channel width adjustment: how does the hydrologic regime influence the effective discharge?

ORAL SESSION ES04c

Chairs: D. Haught, R. Bradley, L. MacKenzie **Room: GEOG 229**

Monday, May 29th

TIME	AUTHORS	TITLE
16:00	Claire Beveridge*, Erkan Istanbulluoglu, Christina Bandaragoda and Christopher Curran	Reconstructing Sediment Supply and Transport Behind the Elwha River Dams Using a Watershed Modeling Approach
16:15	Colin Brennan*, Colin D Rennie, and Ousmane Seidou	Effects of Climate Change on Stream Erosion in a Small Watershed: Long-term simulation
16:30	Jim Miller*, Tony Curtis, David Chanasyk, and Walter Willms	Influence of Riparian Grazing Management on Channel Morphology and Riparian Health of the Lower Little Bow River
16:45	Kat Woodrow, Paul Villard, and Heather Gammie	Historical Meander Adjustment and Projections of Future Channel Planform
17:00	Elli Papangelakis*, Vernon Bevan, Kimisha Ghunowa, Bruce MacVicar	60 years of channel evolution in a suburban semi-alluvial creek: Wilket Creek, Toronto
17:15	Carie-Ann Lau*, Brent Ward, Matthias Jakob, and Carl Schwarz	Morphologic influence and recognition of channel scour hazards on fans in British Columbia

POSTER SESSION ES04

Chairs: J. Venditti, R. Bradley, D. Haught, L. MacKenzie **Room: ESB Atrium**

Monday, May 29th

Poster No.	AUTHORS	TITLE
P01-ES04	Simon Gauthier-Fauteux*, Brett Eaton	Linking fluvial dynamics to white sturgeon habitat in the Nechako River, BC
P02-ES04	Kai Tsuruta*, Marwan A. Hassan, Simon D. Donner, and Younes Alila	Development and application of a large-scale, mechanistic, distributed suspended sediment transport model on the Fraser River Basin, British Columbia, Canada
P03-ES04	Dan Haught*, Jeremy Venditti, and Michael Church	Acoustically derived annual and instantaneous sediment flux on the Fraser River, BC, Canada
P04-ES04	Lucy MacKenzie*, and Brett Eaton	Large grains and channel stability
P05-ES04	Maria Elgueta*, Marwan Hassan, and Garry Clarke	Experiment on the effects of episodic sediment supply on bedload transport variability and grain size dependence

P06-ES04	Lara Middleton, Peter Ashmore[1], and Pauline Leduc	Braiding planform dynamics in a proglacial river

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SUBMITTED ABSTRACTS

ES04-01 The scale of river dunes

Ray Kostaschuk[1] and Jeremy G. Venditti[1]

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Abstract
Modern research on river dunes began with the pioneering work of G.K. Gilbert in the early 20th century in a shallow laboratory flume, an approach that remains productive today. Technological developments in hydroacoustics at the turn of the century, particularly multibeam echosounders and acoustic Doppler profilers, have led to a proliferation of studies of large dunes in deep rivers. Here we compare dunes in deep and shallow flows by focusing on the downstream-facing slipface, a key diagnostic parameter that controls dune morphodynamics. We show that dunes fall into two distinct groups. High-angle dunes in shallow (<2.5m) flume and river flows and some deep flows have steep downstream-facing slipfaces >28º with separation zones and upslope counter-currents. In contrast, most bedforms in large, deep (>2.5m) rivers are low-angle dunes with gently sloping slipfaces (<20º, often <10º), no flow separation and pronounced downslope currents. We examine several hypotheses for slipface gradient and conclude that the principal control is the dynamics of subaqueous granular avalanches. Of particular importance is excess pore water pressure generated during the initiation of the avalanche at the top of the slipface. Thin avalanches on small high-angle dunes are characterized by rapid dissipation of pore pressure and are steepened by counter-currents. On large low-angle dunes with thicker avalanches, excess pore pressure dissipates slowly, allowing the avalanche to travel on lower slopes. Downslope currents accelerate avalanche motion and independently transport sediment downslope on low-angle dunes. High-angle dunes in deep flows may result from local sediment starvation and sediment dilation. Reliance on high-angle dunes as the standard dune model can lead to overestimation of flow resistance in rivers and misinterpretation of sedimentary rocks. [271 words]

Presentation type: Oral Presentation

ES04-02 Active width and bedload transport relationships in gravel-bed braided rivers

Sarah Peirce[1*], Pauline Leduc[1], and Peter Ashmore[1]

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Abstract
Braided rivers, defined by their multiple channels and ephemeral bars, are well known for their dynamic and complex morphology and bedload transport. While fundamentally linked, the relationship between morphology and transport in these rivers is not completely understood. The complexity of these systems makes them ideal for use of the morphological method, which utilizes changes in elevation to inform us about sediment processes. The overall goal of this research was to investigate the relationship between morphology and bedload transport with specific focus on the morphological active width over a range of morphologies. The morphological active width refers to the relatively narrow area of the channel that transports bedload over time. To generate a variety of braided morphologies experiments were completed on a Froude-scaled physical model (D_{50}=1.3mm) with adjustable discharge (0.7-2.1l/s) and slope (1.5-2%). High-resolution DEMs (±2mm) were generated using Agisoft Photoscan from the dry model bed every 15 minutes using digital cameras situated 3m above the model surface. Additional processing was done to create DEMs of difference, highlighting and quantifying areas and volumes of erosion and deposition, which were used to estimate a reach-averaged active width and a morphological sediment budget for each experimental run. Bedload transport was independently determined from sediment baskets located at the downstream end of the model. Results indicate that active width and bedload transport increase with discharge above a threshold and vary linearly with unit stream power over time. The active width is also strongly correlated with bulk change (deposition- erosion volumes) providing a reliable index of total volume of bed sediment mobilized. These results highlight the connection between morphology and bedload transport in complex systems and confirms that variation in bedload transport relates to variation in the morphological active width.

Presentation type: Oral Presentation

ES04-03 Influence of Riparian Grazing Management on Channel Morphology and Riparian Health of the Lower Little Bow River

Jim Miller[1*], Tony Curtis[1], David Chanasyk[2], and Walter Willms[1]

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Abstract
Unmanaged grazing of riparian areas by cattle may negatively impact rivers. The objective was to determine the influence of riparian grazing management on selected channel morphology properties and riparian health. The three study reaches were a fenced reach with cattle exclusion (2001-2012) followed by two years (2013-2014) of periodic grazing of the riparian pasture, an unfenced reach with low cattle impact, and an unfenced reach with high cattle impact. Selected channel morphology properties were measured for three years (2013-2015), and streambank erosion was measured over six years (2009-2014). The riparian health of the fenced reach was also assessed before and after 4, 8, and 11 yr of cattle exclusion, and then after 2 yr of periodic grazing. The findings generally supported the hypothesis that reduced or no grazing would significantly ($P \leq 0.10$) increase bank undercut, water depth, and bankfull depth; and lower flow width, wetted width:depth ratio, bankfull width, and ratio of bankfull width:depth. The particle size distribution of riverbed sediment supported the hypothesis that no grazing significantly increased the mean-weight diameter compared to grazed reaches, and shifted the particle size distribution from finer to coarser. In contrast, reduced or no grazing did not influence bank angle, bank erosion, and yearly changes in riverbed elevation (stability). The overall riparian health score of the fenced reach was increased from 65% (healthy but with problems) prior to fencing to 85% (healthy) after 11 yr of cattle exclusion, but then decreased to 78% (healthy but with problems) after two years of periodic grazing. Improvements in certain morphological properties of the cattle-excluded reach may have been due to greater vegetative cover of streambanks, increased streambank root mass protection, and decreased bare ground. Overall, most channel morphology variables had a positive response to reduced or no grazing, but some showed no response. [297 words]

Presentation type: Oral Presentation

ES04-04 Sediment dynamics in semi-alluvial urban streams

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Abstract

Urban rivers are often characterized by a flashy flow regime and irregular sediment supply that may cause widespread erosion and incision. In Southern Ontario, the response of riverine systems to urbanization is modulated by the glacial legacy. In many urban streams in the Greater Toronto Area, local incision has led to the removal of alluvium and the exposure of the underlying glacial till. Little is known about bedload transport in these semi-alluvial channels and a thorough understanding of sediment dynamics is needed for flood risk assessment and for the design of river restoration projects.

We used a large physical model to simulate alluvial cover evolution in a till-bed stream and to explore the influence of sediment supply, channel morphology and roughness on cover stability and sediment flux. The concrete channel comprised a straight section and a sinuous section and was fed with graded sediment. We tested a set of different initial configurations including fully uncovered and fully covered beds and beds with large roughness elements representing boulders. Bedload flux was sampled at regular intervals and cover evolution was reconstructed from high-resolution images. Model runs show that the system tends to a steady state characterised by sediment input/output balance and a stable proportion of covered bed area. Equilibrium cover area increases with sediment supply and is only slightly sensitive to the presence of an initial alluvial cover. In the straight channel, a complete cover is attained at very high feed rate. In the sinuous channel sediment forms a series of point bars at low feed rate, while at high feed rate the bars coalesce into a continuous strip, but patches of exposed bed are always present along the outer bank of channel bends. Roughness elements promote sediment retention, increasing the proportion of covered bed and bar thickness.

Presentation type: Oral Presentation

ES04-05 Linking fluvial dynamics to white sturgeon habitat in the Nechako River, BC

Simon Gauthier-Fauteux[1*], Brett Eaton[2]

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Abstract
Considerable effort has been dedicated to restoring white sturgeon habitat in dammed river systems. However, sedimentation often causes long-term failure because survival through early life-stages depends on refuge habitat provided by interstitial voids. Based on the premise that a better understanding of geomorphic processes will improve restoration design, this study sought to characterize flow and sediment transport dynamics within a critical spawning reach of the Nechako River. To do so, an extensive dataset on sediment transport was collected throughout the 2015 flood hydrograph. Results indicate that sediment transport into the reach was positively correlated with discharge. This relation progressively weakened with downstream distance until no correlation was observed at the downstream end of the reach, where transport rates remained low and constant relative to upstream. Preferential pathways of sediment transport were observed at both the reach and cross-sectional scales, where bedload was primarily transported through secondary channels conveying disproportionate amounts of sediment compared to flow. Within the single-thread channel, locations conveying the greatest amount of sediment remained spatially consistent over time. Hydrodynamic modelling used to supplement the analysis suggests that a bridge crossing located at the downstream end of the spawning reach causes the flow to backwater upstream during moderate to high flows. Backwatering consequently causes velocity, shear stress and transport capacity to decrease within the downstream portion of the reach as discharge increases. The fluvial dynamics described by this study identify challenges and opportunities for habitat restoration within the spawning reach. The backwater is problematic because it promotes mid-reach sediment deposition during peak flow and limits shear stress magnitude over the downstream spawning substrate. Meanwhile, the presence of sediment transport pathways within the mainstem and through secondary channels can be used to site restoration projects in areas apt to maintain suitable habitat. [293 words]

Presentation type: Poster

ES04-06: 60 years of channel evolution in a suburban semi-alluvial creek: Wilket Creek, Toronto

Elli Papangelakis[1*], Vernon Bevan[1], Kimisha Ghunowa[1], Bruce MacVicar[1]

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Abstract
As cities expand in Canada and around the world, the importance of effective management of urban waterways is increasingly made clear. Widespread erosion and channel instabilities in urban waterways can put infrastructure at risk and reduce the value of ecosystem services provided by the streams. Channel enlargement is a typical response to watershed urbanization, though it may be expressed differently in different streams due to the variability introduced by factors such as watershed geology, the amount and history of urban development, and sediment supply characteristics. Channel evolution models (CEMs) can be used to model trajectories of channel adjustments to in all situations. In this study we a) assess channel enlargement at multi-decade, decadal, and annual time scales in an urban creek and b) propose a region-specific CEM to describe the response to urbanization. The field site is Wilket Creek in Toronto, a semialluvial channel characterized by a convex longitudinal profile, a mixture of bed material from alluvial and other sources, and a shallow active layer. Channel enlargement was measured through analysis of historical and contemporary surveys. Bank erosion tends to dominate at the annual time scale, while incision occurs intermittently and was only captured on the decadal scale. In one example, it appears the steepened slope in an avulsion created the conditions to move coarse glacial lag and anthropogenic boulders, initiating a local incision of almost 1 m. Over 60 years the channel has significantly enlarged but has not reached a new stable equilibrium. Understanding channel enlargement and choosing the appropriate model of channel evolution in response to urbanization is imperative for successful river management. [278 words]

Presentation type: Oral Presentation /Poster

ES04-07 Formal testing of reproducibility in fluvial geomorphology

Ashley Dudill[1,2*], Michael Church[1], and Jeremy Venditti[3]

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Abstract
Reproducibility is how closely the results of independent tests agree when undertaken with the same material and under the same conditions of measurement. Despite implicit evidence in classifications, formal testing of reproducibility is rare in geomorphology. Testing of reproducibility is unpopular as the current scientific culture encourages rapid publication of new, previously unreported findings. Yet reproducibility is central to scientific method as it serves to verify results, encourages reporting of properly described methods and questions possible cases of selective reporting. As a formal test of reproducibility, two sets of experiments were undertaken with the same experimental procedure, at the same scale, but in different laboratories. Using narrow, steep flumes and spherical glass beads, grain size sorting was examined by introducing fine sediment of varying size and quantity into a mobile coarse bed. The general setup of the flumes was identical, including the width and slope; however, there were some variations in the materials and construction. Comparison of the results, both qualitatively and quantitatively, includes examination of the infiltration profiles, sediment mobility and transport characteristics. The phenomena were reproduced but not quantitatively replicated. This comparison raises the following questions: (1) Would one expect there to be a difference in the results of a reproducibility test? (2) If so, how large would one expect the difference to be? (3) Are differences due to variations in the flow structure or sediment behaviour, or a change in the dominant processes? Answers to these questions are important as they determine whether one can assume that phenomena observed in a laboratory are the same as in another. Additionally, if it is not possible to reproduce results in two laboratories with the same conditions, how can we expect to use experiments to quantitatively model real rivers. [289 words]

Presentation type: Oral Presentation

ES04-08 What Controls Dune Dimensions in Rivers?

Ryan W. Bradley[1*], Jeremy G. Venditti[1]

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Abstract
The dimensions of dunes in sand-bedded rivers have been long argued to be controlled by flow depth (h) with height (H) scaling as $1/6h$ and length (L) as $5h$. These depth-scaling relations are used in predictions of dune related sediment transport and flow resistance as well as in the reconstruction of past fluvial environments. A recent compilation of dune dimension data shows order of magnitude scatter about the relations, suggesting depth is not the fundamental control. Furthermore, steep asymmetric dunes in shallow flows ($h < 2.5$m) grow relatively larger than $1/6h$ while low-angle rounded dunes in deeper flows are relatively smaller than $1/6h$. Here, we use a series of flume experiments to systematically explore what controls dune growth. A mobile bed of 550 micron sand was flattened before each run and the bed morphology was mapped as the bed evolved to equilibrium features. A series of three experiments were undertaken at flow depths of 15, 20 and 25 cm. Each series included experimental runs with flow strengths that ranged from the threshold of motion to upper stage plane bed conditions. The results show that under constant h different equilibrium H and L emerge for different flow strengths. Dune height increases with flow strength until a point where the increasing flow strength leads to smaller H. Length continues to increase with flow strength until dunes wash out to a flat bed. At higher transport stages, where suspended sediment dominates over bedload, dunes are flatter due to increased erosion at the crest. The results show that dunes do not fundamentally scale with h, but rather transport stage, which is a function of slope, grain size and h. Relying on simple depth scaling relations will poorly predict dune dimensions.

Presentation type: Oral Presentation

ES04-09 Effects of Climate Change on Stream Erosion in a Small Watershed: Long-term simulation

Colin Brennan[1*], Colin D Rennie[2], and Ousmane Seidou[2]

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Abstract
The purpose of this project is to look at the effects of climate change on stream erosion in the Watt's Creek basin, located in Ottawa, Ontario considering multi-year simulations. The subwatershed has a drainage area of 21 km^2 with land use split between urban development (60%), forest (15%) and agricultural lands (25%). A lumped hydrologic model (using the SWMHYMO platform) was developed to generate continuous flow hydrographs in response to rainfall forcing for the Watts Creek subwatershed. The model was calibrated to field measured conditions based on data collected between May and August 2015 and May and October 2016. Statistical downscaling of the CRCM4.2 regional climate model outputs was conducted using the MacDonald Cartier International Airport as the reference station. Downscaled mode output for scenario RCP8.5 for the 2041-2080 period was used to represent anticipated local future climatic conditions for the watershed. The projected rainfall time series was used as input to the hydrologic model. The hydrologic model was used to calculate reach-averaged shear stress in reach M3 of Watts Creek in response to historic rainfall (1967 – 2007) and eventually for the projected future rainfall (2041-2080). The shear stress calculated in Reach M3 of Watts Creek is used to calculate the cumulative work index for existing and future conditions. The cumulative work index will be calculated for a range of bed material strength values (critical shear stress, τ_c), encompassing the range of τ_c values (clay bed, $1 < \tau_c < 5$ Pa) that are appropriate for Watts Creek. The work index results from the existing and future rainfall simulations will be compared to one another to assess expected changes in erosion potential due to the future conditions climate statistics from the Canadian Regional Climate Model 4.2, scenario RCP8.5 downscaled for the Watt's Creek subwatershed.

Presentation type: Oral Presentation

ES04-10 Reconstructing Sediment Supply and Transport Behind the Elwha River Dams Using a Watershed Modeling Approach

Claire Beveridge[1*], Erkan Istanbulluoglu[1], Christina Bandaragoda[1] and Christopher Curran[2]

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Abstract
The Elwha River watershed in Olympic National Park of Washington State, USA is predominantly a steep, mountainous landscape where dominant geomorphic processes include landslides, debris flows and gullying. The river is characterized by substantial variability of channel morphology and fluvial processes, and alternates between narrow bedrock canyons and wider alluvial reaches for much of its length. Literature suggests that the Elwha watershed is topographically and tectonically in steady state. The removal of the two massive hydropower dams along the river in 2013 marked the largest dam removal in history. Over the century long lifespan of the dams, approximately 21 million cubic meters of sediment was impounded behind them. We aim to reconstruct sediment supply and transport behind the Glines Canyon Dam (furthest upstream dam) over its lifespan using a watershed modeling approach. Long term erosion rates documented in this region and reservoir sedimentation data give unprecedented opportunities to test watershed sediment yield models and examine dominant processes that control sediment yield over human time scales. In this study, we developed alternative models of varying complexity for sediment production and transport at the network scale driven by hydrologic forcing. We simulate erosion and sediment transport in tributaries upstream of the dam and compare their relative transport supply and capacity. The modeled hillslope erosion and sediment transport dynamics are based on calibrated formulae (e.g., bedload transport is simulated using Wilcock-Crowe 2003 with modification based on observed bedload transport in the Elwha River). Observational data that aid in our approach include DEM, channel morphology, meteorology, and streamflow and sediment (bedload and suspended load) discharge. We aim to demonstrate how the observed sediment yield behind the dams was influenced by upstream transport supply and capacity limitations, thereby demonstrating the scale effects of flow and sediment transport processes in the Elwha River watershed. [298 words]

Presentation type: Oral Presentation (but willing to do a poster if convener prefers)

ES04-11 A stochastic model of channel width adjustment: how does the hydrologic regime influence the effective discharge?

Sarah Davidson[1] and Brett Eaton[2]

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Abstract
Predictive models of channel behavior, including traditional regime models, emerged in response to the need to quantify channel response to imposed flows in a range of settings. Most existing models rely on the assumption that average channel dimensions can be predicted from a single formative discharge (i.e. the flow that dictates channel geometry) that is approximately equal to the effective discharge, or the flow that transports the most sediment over time. These models yield limited insight into intermediate-term variability in channel form, and neglect the importance of relatively rare, large floods. We developed a biogeomorphic model – the STochastic Channel Adjustment SIMulator (STOCHASIM) – to explore the role of hydrologic regime in determining channel form. The model simulates the interplay between erosion, resulting from a random sequence of flood events, and the colonization of exposed bars by vegetation. We used a Monte Carlo approach to investigate the influence of flow variability, defined in terms of the Flood Magnitude Index (FMI), on average channel size and erosion rate, as well as the relative magnitude of the effective discharge and formative flow. Rivers in arid regions and small headwater streams are typically characterized by high FMI values, while the most often-studied rivers in humid regions are characterized by low FMI values. Our results show that the annual bank erosion rate and the long-term average channel width increase with flow variability. The magnitude of the effective discharge and formative discharge also diverge as flow variability increases, suggesting that rivers with variable hydrology are shaped by two populations of flows: moderate effective flows that dictate the bed texture, and larger floods that determine the channel capacity. STOCHASIM provides an avenue for modeling systems that are poorly described by traditional regime models, and is particularly well suited to gravel bed streams with moderate to high flow variability. [300 words]

Presentation type: Oral Presentation

ES04-12 Hydrograph Shape Controls Channel Morphology and Organization in a Sand-Gravel Flume

Laura Hempel[1*], Brett Eaton[2], Marwan Hassan[2], and Gordon Grant[3]

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Abstract
For over half a decade, scientists have studied how flow shapes river channels. The prevailing view has been that channel dimensions adjust to an "effective discharge", which is often approximated as the bankfull flow. But using a single flow to reference the geomorphic effectiveness of an entire flow regime discounts many observations showing that different flows control different channel processes. So, to explore the relation between channel morphology and a *range* of flows, we conducted a series of flume experiments to examine how hydrographs with different shapes, durations, and magnitudes result in different channel capacities, but also different degrees of channel organization, which we define in terms of the regularity, spacing and architecture of self-formed channel features, including pools, bars, and riffles. Our experiments were run in a 12m long adjustable-width, adjustable-bed flume that developed a self-formed meandering channel. We used spatial autocorrelation analysis to quantify channel organization; a highly organized channel, for example, is one that has well-developed and evenly space bars and a high autocorrelation value. We found that hydrograph shape does control channel organization and in particular, channels formed by hydrographs with slower rates of rise and fall were more organized than those formed by flashier hydrographs. We explain this pattern by comparing the duration of steps in the hydrograph to the time required for the channel to develop a regular meander pattern under simplified constant flow conditions; hydrographs with step durations equal to or longer than the time to organization will be organized, whereas hydrographs with step durations shorter than the time to organization will be poorly organized. This work points to the importance of the hydrograph as a fundamental control on channel morphology, and offers the prospect of better understanding how changing hydrologic regimes, either through climate, land use, or dams, translates into morphodynamic changes. [300 words]

Presentation type: Oral Presentation or Poster

ES04-13 On the Exceptional Sediment Load of the Huanghe (Yellow River), and its Capacity to Produce Subaerial Deltaic Landscape

Jeffrey A. Nittrouer[1], and Hongbo Ma[1]

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Abstract
The Huanghe (Yellow River) of China, possessing a sediment concentration approximately thirty times greater than any other large, lowland river system, is the most efficient terrestrial river system in the world in terms of sediment delivery to its receiving basin. Transporting between 500-1000 million tons of sediment to the coastline annually, the deltaic topset grows at a rate of 25-50 km^2 yr^{-1}. Herein, we analyze: the physical conditions that produce such significant sediment transport for this fine-grain, yet sand-bed system (D_{50} ~ 90 μm). A physically-based sediment transport formula is proposed to predict measured sediment flux, and show that the lower Huanghe tends toward upper-regime plane bed, whereby dunes possess large aspect ratios (wavelength-to-height). This prediction is validated by high-resolution multibeam field observations collected during a flood discharge. We use a semi-theoretical approach to show that the large bedform aspect ratio in the lower Huanghe produces minimal form drag, so greatly enhancing the efficiency of shear stress utilized for sediment transport. The validated theory, for the first time, reveals the physics behind the anomalously high sediment transport rates for a non-hyperconcentrated flow over a fine-grain bed. Furthermore, combined with sediment transport database from the sandy bed environments, we determine an abrupt phase transition whereby sediment grain size changing over a narrow range of 130 μm to 190 μm produces an order of magnitude change in flux. The universal sediment transport relation describing this phase transition is therefore presented. [238 words]

Presentation type: Oral Presentation

ES04-14 Development and application of a large-scale, mechanistic, distributed suspended sediment transport model on the Fraser River Basin, British Columbia, Canada

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Abstract
Simulating sediment transport through large basins presents a challenging problem to modelers; the relationship between water flux and sediment load is complex and non-linear, and significant sediment generation can occur over small spatial and time scales. To date, most studies have employed lumped empirical models that predict annual load at the outlet of a study basin, but do not consider variability across the basin or sub-annually. In this study, we develop a physically-based, distributed suspended sediment transport model that operates at an hourly time scale and a 1/16◦ latitude × 1/16◦ longitude spatial scale. The sediment model is integrated into the Terrestrial Hydrology Model with Biochemistry (THMB) to make use of THMB's dynamic water routing. The coupled model is applied to the 230,000 km2 Fraser River Basin (FRB) in British Columbia, Canada using climate, surface runoff, and subsurface drainage inputs provided by a historical run of the Variable Infiltration Capacity (VIC) land-surface hydrology model. Simulation results are compared with historical monthly observations at five stations using the coefficient of determination (R2), Nash-Sutcliffe coefficient of efficiency (NSE), and percent bias (PBIAS) metrics. Overall, simulated load values match well with observed values, with the simulation near the outlet scoring R2 = 0.78, NSE = 0.77, and PBIAS = -18%. A model capable of matching historical observations to this degree is a unique tool for the study of large basin landscape evolution on a sub-basin scale. [233 words]

Presentation type: Poster

ES04-15 Acoustically derived annual and instantaneous sediment flux on the Fraser River, BC, Canada

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Abstract
Suspended sediment concentrations and grain size in rivers are of great interest due to their influence on riverine and coastal morphology, socio-economic viability of infrastructure development and ecological health. Prediction of suspended sediment transport from hydraulics remains a difficult problem, particularly for the washload component, which is controlled by sediment supply from the drainage basin. This has led to a number of methods for continuously monitoring suspended sediment concentration and mean particle size, the most cost and time efficient being hydroacoustic methods. Here, we explore time-dependent, grain-size specific sediment fluxes to the Fraser River Delta using three side-looking acoustic Doppler current profilers (ADCP) installed in a collocated array at Mission, BC. The ADCPs have frequencies of 300, 600, and 1200 kHz and ensonify a range of 25 to 60 m across the 550 m wide channel. A bottle sampling program was undertaken from between 2012 and 2014 where we collected a series of point-integrated sediment samples in the ensonified range for acoustic calibration purposes. We also collected a series of vertical profiles of point-integrated samples to correlate the grain-size specific sediment flux in the river to the acoustic observations. All samples were analyzed for both mass concentration and sediment size distribution. Each ADCP records data continuously at six minute intervals, through the full range of flows, allowing for an estimate of the annual grain-size specific sediment flux. Acoustic calibrations relate signal characteristics to silt/clay, sand, and total concentration. Good calibrations and correlations were obtained for all three frequencies, with 1200 and 600 preforming better than 300 kHz. Time-series show that total, sand, and silt/clay flux lead increases in discharge, causing clockwise hysteresis. Acoustic records also reveal a ‘first flush’ of fine sediment through the system as the freshet begins. Acoustically derived annual flux are somewhat smaller for a given discharge when compared to sediment flux measured by the Water Survey of Canada between 1965 and 1992.

Presentation type: Oral Presentation

ES04-16 Formation and adjustment of pool-riffle sequences

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Abstract
Pool-riffle sequences are a common bedform observed in gravel bed rivers in many environments. Much research has been done in the field relating to their development, but little detailed research is available surrounding their adjustment in response to changing discharge and sediment supply. In order to overcome the difficulty involved in collecting detailed particle size, velocity, and sediment transport data in the field, flume experiments were conducted on a scale model of a pool-riffle sequence identified in East Creek, British Columbia for which 14 years of channel adjustment field data is available. Flume experiments were conducted at four ascending discharges and sediment feed rates, scaled to model 1.00, 1.19, 1.67, and 2.14 times the bankfull discharge. Sediment transport rates were measured over the pool and riffle and at the flume outlet. Gravel tracers were used to measure virtual velocities and to study patterns of particle entrainment and deposition over the pool and riffle. Measurements of particle size, bed topography, and nearbed velocities were also taken. A combination of aggradation and degradation developed the pool-riffle morphology. Conditioning the bed from a flat initial surface to equilibrium morphology was a relatively slow process, but subsequent responses to increased flow and sediment supply were much faster. Particle mobility increased with flow rate, but became constant at high flows. Contrastingly, particle virtual velocities were similar for all but the highest flow rate, where a large increase in virtual velocity of pool particles was observed. Results on textural adjustments and spatial and temporal near-bed velocity patterns will also be presented. [255 words]

Presentation type: Oral Presentation

ES04-17 Surface, Corner and Ramp Rollers: Numerical Analysis of Flow Patterns in Isolated Pool-Riffle Units

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Abstract
Pools and riffles are common morphologic units in rivers and restoration projects. The deeper parts of undulations in the bed are called pools, whereas the shallower parts are riffles. They can be shaped naturally or artificially to control the stream energy, improve fish habitats, or control the sediment transport rate. Previous studies in the field, experimental flumes, and numerical studies have highlighted the complex interaction between the morphology, turbulent flow and sediment transport, but the characteristics and significance of turbulent structures generated over the riffle and into the pool remain poorly understood. In this research, we use large eddy simulations (LES) of turbulent flow in an isolated pool-riffle with different riffle heights to illustrate how vortices are created and dissipated. Three different types of vortices were found and named as surface rollers, corner rollers, and ramp rollers. Surface rollers are shaped on the flow surface due to the flow critical condition, while corner rollers are shaped close to the corners near the walls at the pool head. Ramp rollers are shaped at the ramp at the pool head. The simulations showed that all three types of vortices interact with each other, combine, amplify or cancel out each other as they travel downstream. The strength of vortices and how they interact result into different types of flow patterns. Where flow is close to critical in riffles, the surface rollers combine with corner rollers to make a jet like plunging flow near the pool bed. In other cases with lower riffle heights, ramp rollers tend to cancel out the corner rollers, which leads to higher turbulence near the bed and higher velocity near the flow surface (skimming flow). These findings provide new clarifications to long-standing questions related to the hydraulics of pools and riffles. [290 words]

Presentation type: Oral Presentation

ES04-18 Large grains and channel stability

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Abstract
While the stabilizing function of large grains in step-pool streams has long been recognized, the role they play in gravel-bed streams is less clear. Most researchers have ignored the role of large grains in gravel bed streams, and have assumed that the median bed surface size controls the erodibility of alluvial boundaries, however the results of experiments presented here challenge this convention. Mobile bed and bank experiments run using two different bed material distributions demonstrate the effect that a slight change to the coarse tail of that distribution can have on channel morphodynamics. While the two distributions had the same range of particle sizes and nearly identical bulk d_{50} values (1.6 mm), the d_{90} of GSD 1 was slightly finer (3.7 mm) than that for GSD 2 (3.9 mm). Despite only the small differences between the distributions, the experiments conducted with GSD 1 had significantly greater transport rates than GSD 2 and developed a meandering channel pattern with well-developed riffles, pools and bars at a discharge of 0.7 L/s. In contrast, for the same discharge, channel form in GSD 2 did not deviate greatly from that the initial rectangular channel and developed only a series of poorly defined, low amplitude alternate bars. While there were small differences in the bed surface texture for the two experiments, the estimated dimensionless shear stress for GSD 1 was significantly lower than that for GSD 2, which is contrary to expectations based on existing theories about channel stability. The failure of our existing models to explain the observed differences in the channel morphodynamics implies that we need to refine our ideas about what controls channel stability. [272 words]

Presentation type: Poster

ES04-19 Experiment on the effects of episodic sediment supply on bedload transport variability and grain size dependence

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Abstract
A flume experiment was conducted to study channel adjustment to episodic sediment supply in mountain streams. The bulk sediment used for the bed and feed included grain sizes 0.5–64 mm with geometric mean D_{gbulk} of 5.7 mm. Water discharge was held constant at 65 L/s and 300 kg of sediment was supplied every 40 h through a range of scenarios, which included constant feed as well as episodic supply regimes. Bed slope, sediment storage, sediment transport, and bed surface texture responded to sediment supply. Bed slope increased with the sediment feed as the bed aggraded mainly due to preferential storage of grains >8 mm. Sediment transport rate and bed-surface particle size were significantly affected by magnitude-frequency of sediment feed. Under constant feed, transport rate increased gradually and $D_{gsurface}$ varied within a range. Instead, sediment pulses caused a pronounced increase in sediment transport rate and evident surface fining, trends that were inverted as sediment evacuated and bed mobility was counteracted by bed armoring. The increase in transport rate and surface fining were proportional to pulse size. There was evidence of size selective transport in fractional sediment transport rates. The intensity of movement decreased with grain size and the limit between partial and full mobility was around 8 mm most of the time. To better characterize the response of specific grain size fractions to sediment feed, the memory structure of bedload rate time series was analyzed for different grain sizes and time scales. In general, fine gravel (2-8 mm) transport resembled more closely the patterns observed for the aggregated bedload rate. Occasional bursts in the sediment transport rate were observed overall the experiment and their composition was inspected. Many cases involved the movement of coarse material, which proportion apparently increased during periods of relatively low sediment transport.

Presentation type: Poster

ES04-20 Step formation and stability in steep streams: insight from a reduced-complexity model

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Abstract
Steep streams in mountain regions dominate the cumulative length of river networks but they have been historically much less studied than their lowland fluvial counterparts. This work focuses on one of the most commonly encountered steep channel type: the step-pool morphology. In these streams, large boulders and woody debris create high channel-spanning structures (steps) followed downstream by pools due to the tumbling water flow. Step-pool sequences are destroyed and reformed by floods with a return period of usually more than 50 years but their formation and stability are topics still under debate. Many theories have been proposed and tested against experimental and field data in the last decades, but a modeling effort to simulate the conditions leading to step formation and survival is missing. We present here a new reduced-complexity particle-based model to simulate the step-pool morphology: CAST (Cellular Automaton Sediment Transport). The model contains phenomenological rules for sediment supply, particle entrainment and deposition, and basic granular interactions for uniform and bimodal sediment, that can be treated in a deterministic or stochastic manner. In unsteady simulations, by changing entrainment and sediment supply conditions, and by considering the granular effect of particle blocking and jamming, CAST shows the temporal dynamics of the formation and stability of steps, in agreement with the jammed-state hypothesis proposed by Church and Zimmermann. Model results are consistent with field observations collected in different step-pool streams and they highlight the importance of granular phenomena that need to be considered together with hydraulics and sediment supply conditions in order to properly assess steep stream dynamics, where the grain-size distribution includes large, mostly immobile, boulders. Moreover, the reduced-complexity framework used here can be used to study interactions between sediment transport and channel morphology in other fluvial systems where self-organization processes generate a wide spectrum of bedforms and bed structures. [300 words]

Presentation type: Oral Presentation preferred

ES04-21 Morphologic influence and recognition of channel scour hazards on fans in British Columbia

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Abstract
Alluvial and colluvial fans are common landscape features at the base of steep mountain slopes. Fans are subject to a variety of hydrogeomorphic hazards including debris flows, debris floods and clearwater floods. Surface and subsurface infrastructure crossing fans, including highways, pipelines, fibre-optic cables and transmission lines must be protected from these hazards. A hydrogeomorphic hazard assessment, including scour potential, is required prior to developing mitigation measures. However, little guidance exists to estimate the potential scour depth for steep creeks on alluvial fans. In this study, we examined the morphometric controls on channel scour depth on 116 temperate fans in British Columbia, Canada. Scour was measured from lidar digital elevation models as the relative elevation difference between the stream channel and adjacent fan surface. It is unknown if this scour occurred in a single event or progressively. Hybrid debris flow/debris flood fans displayed the deepest average scour depths. Debris flow fans had the largest range in observed scour depths. From these measurements, we developed a multivariate statistical model to predict scour depth from morphometrics using multimodel inference. Watershed area, fan gradient, and fan relief were determined to be statistically important variables contributing to channel scour. Watershed area is related to flow generation in the upstream catchment and thus determines peak channel discharge. Fan gradient is controlled by grain size and hydrogeomorphic processes and in turn influences channel morphology and stability. Finally, fan relief is a function of watershed sediment output and local base level changes. The analysis demonstrated fan scour prediction is a complex multivariate problem and that single variables fail to satisfactorily explain observed variability. The results of this work provide future direction for laboratory flume experiments in which the three variables identified could be varied individually to improve the predictive power of the model presented herein.
[297 words]

Presentation type: Oral Presentation

ES04-22 Historical Meander Adjustment and Projections of Future Channel Planform

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Abstract
Channel planform is a product of the adjustments of individual geomorphic units over time. In the case of sinuous single-thread channels, planform projections can be simplified by quantifying changes in a series of adjacent meanders. Several models have been developed for tracking characteristics of individual meanders and forecasting future channel planform. Projections based on past channel adjustments assume that hydrologic conditions are temporally steady and that surficial geology is spatially homogenous. These are acceptable assumptions for many large river systems over short time periods. These are not realistic assumptions in smaller watersheds – particularly in Southern Ontario with its complex surficial geology. This study assesses the effectiveness of a simple linear model for tracking individual meanders and projecting future planform for smaller channels with variable surficial geology. Understanding the potential limits of meander migration or future planform is important when assessing risk to existing and proposed infrastructure. [146 words]

Presentation type: Oral Presentation

ES04-23 Braiding planform dynamics in a proglacial river

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Abstract
Morphological and planform changes in gravel braided rivers occur rapidly during high flow periods and are linked to thresholds and increased rates of bedload transport. Occurrence and rates of planform change (bar-scale erosion-deposition, channel migration, channel switching etc.) are expected to correlate with bed material transport and therefore with discharge but there is very limited quantitative data on this relationship. Daily planform change in relation to daily discharge variation was analyzed during summer melt-water periods from June to October in 2012 and 2013 from the Sunwapta River, a proglacial gravel-bed braided river located in Alberta, Canada. Oblique time lapse images taken from a cliff overlooking the river which covered an area of approximately 100 meters square across the entire width of the river, at an interval of 30 minutes for 4 months each year covering the full range of discharge in the river. The oblique images were rectified to vertical view for measurement. Daily hydrographs and planform change were analysed for a total of 219 days. Planform change was measured as the proportion of a fixed area of the river bed which underwent detectable planform change during the daily meltwater hydrograph on successive days. A critical discharge was found below which no planform change occurred. Above the critical discharge of 11 m^3s^{-1} (unit stream power of approximately 50-60 W m^{-2}) daily planform change increased with higher discharges but with considerable variation related to the contingencies of flow sequences and intrinsic variability in braiding processes. The next step in this research is to tie rates and styles of planform change to known rates of bedload transport and bed erosion/deposition using a Froude-scale physical model of Sunwapta River.

Presentation Type: Poster