GRAVEL BED RIVERS 9

Villarrica, Chile - 2023

Gravel Bed Rivers: Processes, resilience and management in a changing environment

CONFERENCE PROGRAM

10 – 13 January 2023

INTRODUCTION

Welcome to Villarrica

The organizing committee welcomes you to Villarrica, Chile for the 9th International Gravel-Bed Rivers workshop (GBR9). The theme of this edition is "Gravel bed rivers processes, resilience, and management in a changing environment". The event takes place in the little town of Villarrica, located in southern Chile, facing a lake and an active volcano. The workshop was originally scheduled for January 2022 but had to be postponed due the pandemic. As for previous events, this workshop focuses on fundamental forms and processes of gravel bed rivers. Along with traditional sessions focusing on sediment transport processes, recent advances in numerical and physical modeling, and new tools and technologies, this edition incorporates sessions on topics that have been progressively added to previous editions as our understanding of gravel bed rivers evolved and matured over time. There are thus sessions focusing on the role of vegetation, large wood and animals in gravel bed rivers and also focusing on contaminants and microplastics. We included sessions on restoration and integrated assessment of gravel bed rivers, and also one session that looks at the costal areas where sediments are eventually delivered. One session looks at extreme events that are particularly common in Chile, such as volcanic eruptions and glacier lake outburst floods. We also included a session that explores the cultural values of gravel bed rivers. There are 13 sessions, each of which is comprised of 2 keynote presentations. On each session, the keynotes will be followed by a discussion open to all attendees. Most attendees will present a poster and the poster sessions will favor further informal discussions

We prepared a pre-, mid- and post-conference field trips near Santiago and Villarrica, to discuss gravel bed river processes in the beautiful landscapes of Chile.

We hope that you will enjoy the event, and also the local landscape, people and culture.

The organizing committee of the GBR9

Acknowledgements

We thank the International and the National Advisory Committees for their inputs in the preparation of the workshop.

We also thank the following colleagues and friends for their help in organizing and preparing the Gravel Bed Rivers 9 workshop:

Mario Darrigrandi, Minga del Sur, for helping out with the logistics in Villarrica;

Isabel Rojas, Pontificia Universidad Católica de Chile, for leading on the organization of the discussion panels;
Barbara Aravena, Victoria García and Pablo Rojas, Universidad Diego Portales, for supporting us throughout the process;

Felipe Flores, Sernageomin, for organizing the post-conference tour in the Villarrica volcano;

Juan Pedro Martin, Universidad Politécnica de Cataluña, for organizing and delivering the mid-conference tour;

Mauricio Montecinos, Pontificia Universidad Católica de Chile, for supporting the organization of the discussion panels.

The Committees

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Hernan Alcayaga. Universidad Diego Portales, Chile
Cristian Escauriaza. Pontificia Universidad Católica de Chile, Chile
Luca Mao, University of Lincoln, UK

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The Program at-a-glance

Monday 9th January 2023: Pre-Conference Tours, Option 1 (Middle Maipo valley) and Option 2 (Upper Maipo valley) from the UDP University in Santiago.

Tuesday 10th to Friday 13th January 2023: Workshop at the campus Villarrica UC in Villarrica (Bernardo O'Higgins 501). Includes a mid-conference tour at the Allipen-Tolten confluence.

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Saturday 14th January 2023: Post-conference tour at the lahars of the Villarrica

PROGRAM OF THE EVENT

Monday 9th January 2023

Pre-Conference Tour Option 1: Middle Maipo valley

Lead by Cristian Escauriaza (Catholic University of Chile)

8:30: Accreditation and Welcome at Universidad Diego Portales (UDP

9:20: Departure from UPD

11:00: Pirque Reserva Río Clarillo/Canalistas del Maipo. Visit to the hydraulics structures

13:00: Aguas de Ramon. Debris Flow monitoring and modeling

14:30: Return to UDP University

Pre-Conference Tour Option 2: Upper Maipo valley

Lead by Luca Mao (University of Lincoln, UK) and Alejandro Dussaillant (Aysén University, Chile)

8:30: Accreditation and Welcome at Universidad Diego Portales (UDP

9:20: Departure from UPD

11:45 – 12:45: Estero Morales. Monitor sediment transport in a glacierized Andean basin

13:45 – 14:45: Estero San José. LSPIV monitoring station

17:15: Return to UDP University

Tuesday 10th January 2023

8:00: Registration at the venue in Villarrica

8:30: Welcome speech by Escauriaza C, Alcayaga H., Mao L.

Session 1: *Gravel-bed rivers at the scale of grains (session moderated by Chapuis M.)*

9:00: Recking A.: **The contribution of grain sorting to the dynamics of the bedload active layer**

9:25: Yager E.: **Automated measurement of bed structure: the role of sediment sorting on particle mobility**

9:50: **Discussion**

10:15: *Coffee break*

Session 2: *Sediment transport processes (session moderated by Curran J.)*

10:35: Link O.: **Physical Scale Modelling of Sediment Transport Processes in Gravel Bed Rivers**

11:00: Liébault F.: **Bedload tracing with RFID tags in gravel-bed rivers: review and meta-analysis after 20 years of field and laboratory experiments**

11:25: **Discussion**

11:50: *Coffee break*

Session 3: *Advances in numerical modelling (session moderated by Escauriaza C.)*

12:10: Siviglia N.: **Chaotic interactions between riverbed evolution and vegetation dynamics prevent long-term predictions of fluvial morphology**

12:35: Flora K.: **Uncertainty quantification of bank vegetation impacts on the flood flow field in the American River, California: Insights gained via large-eddy simulation**

13:00: **Discussion**

13:25: *Lunch*

Session 4: *Gravel-bed rivers and global environmental changes (session moderated by Bertoldi W.)*

14:55: Tucker G: **Exploring the implications of equilibrium channel geometry for long-term landscape evolution**

15:20: Macklin M.: **Metal mining impacts on river systems**

15:45: **Discussion**

16:00: *Coffee break*

Session 5: *Gravel-bed rivers affected by extreme disturbances (session moderated by Bathurst J.)*

16:30: Russell A.: **Gravel bed river response to volcanic sediment loading**

16:55: Loriaux T.: **Geomorphic signatures of glacier lake outburst floods in Patagonia**

17:20: Discussion

17:45: Close

Poster Session

18:00: Poster session

19:00: Dinner (independent)

Wednesday 11th January 2023

Session 6: *Vegetation and large wood in gravel-bed rivers (session moderated by Wilcox A.)*

9:00: Johnson J.: **Feedbacks among vegetation, channel morphology, and bankfull discharge recurrence intervals**

9:25: Ruiz-Villanueva V.: **Is it all just about sediment in gravel-bed rivers? Current progress in research on instream large wood**

9:50: **Discussion**

10:15: *Coffee break*

Session 7: *Not only gravel in gravel-bed rivers (session moderated by Caamaño D.)*

10:35: Ockelford A.: **Source or Sink? Exploring the role gravel bed rivers play in modulating the flux of microplastics in the environment**

11:00: Johnson M.: **The Power of Biology in River Environments**

11:25: **Discussion**

11:50: *Coffee break*

Session 8: *Integrated assessment of gravel-bed rivers (session moderated by Iroumé A.)*

12:10: Belletti B.: **Integrated assessment of riverscapes from local to global scale: applications of hyper-temporal remote sensing data**

12:35: Scorpio V.: **Historical changes on long-impacted European rivers**

13:00: **Discussion**

13:25: *Lunch*

Session 9: *River management and restoration (session moderated by Tranmer A.)*

14:55: MacVicar B.: **The management of small gravel-bed rivers in urban environments: Insights from 10 years of research**

15:20: Polvi L.: **River restoration in glacial-legacy landscapes: unique characteristics & challenges**

15:45: **Discussion**

16:00: *Coffee break*

Session 10: *People and gravel-bed rivers (session moderated by Dussaillant A.)*

16:30: Tunnicliffe J.: **Catchment-scale monitoring of river change to support a gravel management plan, Waiapu River, Aotearoa New Zealand.**

16:55: Aigo J. & Bañales C.: **Biocultural approaches to revalue waterscapes: (dis) encounters in Wallmapu-Patagonia**

17:20: Discussion

17:45: Close

Poster Session

18:00: Poster session

19:00: Dinner (independent)

Thursday 12th January 2023

Mid-Conference Tour: Allipen-Tolten confluence

Lead by Juan Pedro Martín-Vide (Universitat Politècnica de Catalunya)

9:30: Meet at the UC Villarrica campus hall

10:00: Confluence Ríos Allipen and Toltén

13:00: Return to UC Villarrica campus

13:30: Lunch

Discussion session: Challenges of river management in Chile

Lead by Rojas I. (Catholic University of Chile)

In this session, local stakeholders will provide insights into the current challenges of river management in Chile, and then small panels will discuss examples from abroad, potential ways forward, and will recommend good practices around three main topics:

- Sustainable River management
- Sustainable sediment management
- Sociocultural management of rivers

14:30: General introduction to the activity (Rojas I.)

14:40: Introduction to Chilean rivers (Mao L.)

14:55: Presentation of the stakeholders attending the event

15:30: Group discusión (coffee available)

16:30: Plenary discusión

17:00: Closure

19:00: Social Dinner

Friday 13th January 2023

Session 11: *Gravel-bed rivers beyond their watersheds (session moderated by Mao L.)*

9:00: Williams M.: **Bar-built estuarine dynamics and watershed-coastal interactions**

9:25: Ferrer Boix C.: **Decline of sediment supply and delta regression in the Mediterranean due to human interventions. Effects of river engineering works**

9:50: **Discussion**

10:15: *Coffee break*

Session 12: *New tools for advanced studies of gravel-bed rivers (session moderated by Camenen B.)*

10:35: Pizarro A.: **The use of innovative technology for fluvial monitoring**

11:00: Hodge R.: **The potential of new methods for improving predictions of critical shear stress in gravel bed rivers**

11:25: **Discussion**

11:50: *Coffee break*

Session 13: *Advances in monitoring of gravel-bed rivers (session moderated by Rickenmann D.)*

12:10: Bolster D.: **Transport of solutes and more complex substances in streams and rivers**

12:35: Coviello V.: **Monitoring bedload transport in glacier-fed streams by seismic techniques**

13:00: **Discussion**

13:25: *Lunch*

15:00: Closing comments and GBR10

Saturday 14th January 2023

Post-Conference Tour. Lahars in the Villarrica Volcano

Lead by Franco Vera and Felipe Flores (SERNAGEOMIN, Chile)

9:30: Meet at the UC Villarrica campus hall. Introduction by the trip leader Franco Vera and Felipe Flores,

9:40: Bus trip to Villarrica Volcano. The trip includes a short walk (30-40 min) and presentation in the field. A packed lunch will be provided in the field, but attendees should carry water for themselves.

14:00. Arrival at the UC Villarrica campus hall.

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ABSTRACTS OF THE KEYNOTES

There are 13 sessions, each of which is comprised of 2 keynote presentations of 25 minutes. On each session, the keynotes will be followed by a discussion (25 minutes) open to all attendees.

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The contribution of grain sorting to the dynamics of the bedload active layer

Recking A.[1], Vazquez D.[2] & Piton G.[3]

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[2]Geological Hazards Division, Geological Survey of Spain (IGME, CSIC), Madrid, Spain

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During the last 20 years, flume and field experiments have shown that grain sorting contributes to bed level fluctuations and bedload pulses. In this work, we propose a new analysis of these experimental data. From the flume data, we derive a model for gravel bed rivers where both local (bedform scale) slope and bedload are known to fluctuate through space and time, in the so-called 'bedload active layer'. The model uses standard concepts and empirical tools with reach averaged data for the hydraulics and sediment transport. It considers a maximum slope for local armoring equal to the mean bed slope (reach scale) affected by a coefficient which expresses the difference of mobility of the coarse fraction considered alone or in a mixture. The minimum local slope for bed erosion is the mean bed slope corrected by a coefficient that depends on the armor ratio Ar (ratio of the surface to the sub-surface grains diameter) and the reach-averaged transport rate. The model is compared with a compilation of scour-fill depths measured in the field. Results suggests that the slope fluctuations in 1D flume experiments are consistent with in-channel bed-level fluctuations associated to scour-fill processes in the active layer. The model also suggests that although the length scale of the maximum scour depth δ is on the order of the bed surface D_{90}, it is well explained by the product between the mean bed slope S and the active channel width W, with $\delta \approx 1.4SW$. For the pulse intensity, we provide a justification to the simplified squared slope equation for solid concentration $C = Q_s/Q \propto S^2$ (with Qs the solid discharge, Q the water discharge and S the slope), which has often been used in place of standard bedload equations for modelling highly concentrated bedload transport events in mountain streams.

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What is in a cluster? The influence of random grain arrangement, hydraulics, and particle interactions in bed structure formation

Yager E.M.[1] & J Shim[1]

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River bed structure, such as the development of clusters in armored beds, can impact a variety of channel processes including sediment transport, flow roughness, and physical components of aquatic habitat. Clusters in particular, are commonly observed in gravel-bedded rivers and laboratory flume experiments and have been hypothesized to form through a combination of local flow hydraulics and particle interactions. The identification of clusters can involve some subjectivity and therefore recent studies have developed quantitative and objective methods to distinguish clusters or structures from the surrounding bed material. Despite these advances, uncertainties remain in cluster identification and formation mechanisms. In particular, few studies have investigated if some clusters are simply from random arrangements of grains or if all clusters are caused by interactions between flow hydraulics and particles.

We investigate this topic through a combination of Discrete Element Method (DEM) modeling and laboratory flume experiments. In the DEM modeling, we randomly place a distribution of grain sizes on a simulated river bed and allow the grains to settle through gravitational forces and particle interactions without any fluid flow. Between DEM simulations, we vary either the locations of random grain placement or the sorting of the grain size distribution. Using previously published cluster identification criteria, we assess whether objectively identified clusters occur in these simulations, which could imply that some clusters are inherently random rather than flow driven. In addition, we evaluate if the likelihood of cluster identification varies with the sorting of the grain size distribution for these randomly arranged beds. We also conducted five laboratory flume experiments, ranging from narrow to wide gravel grain size distributions. In each experiment, we water worked the bed for 16 hours using a sequence of flows capable of moving the bed D_{84} and D_{50}. We photographed the bed at the same location before water working and at the end of each experiment and used these photographs in Structure from Motion software to construct the bed topography. We again use cluster identification criteria for these experiments to determine if clusters: 1) occurred before water working and were caused by random grain arrangements, 2) increased in density after water working, and 3) had greater frequency with wider grain size distributions both before and after water working.

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Physical Scale Modelling of Sediment Transport Processes in Gravel Bed Rivers

Link O.[1] & Ettemer B.[2]

[1] Departamento de Ingeniería Civil, Universidad de Concepción, Chile

[2] Hochschule Magdeburg-Stendal Universität, Deutschland

The fundamental laws for achievement of similitude in physical scale models of prototype gravel bed rivers are revised. Similitude for different sediment transport processes such as incipient motion, formation, evolution and migration of bedforms, armoring, bed load transport, entrainment into suspension, fractional transport, local scouring around obstacles and sedimentation is analyzed. Critical issues for simulation of gravel bed rivers at the laboratory scale, such as simulation of unsteady flows, the use of lightweight materials as model sediments, the effects of temperature of laboratory water on the sediment transport processes, and the repeatability of experiments are discussed through examples gained over recent years.

Bedload tracing with RFID tags in gravel-bed rivers: review and meta-analysis after 20 years of field and laboratory experiments

Liébault, F

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The use of tracers in gravel-bed rivers for the field observation of bedload transport is a long-standing approach gradually evolving when a new tagging solution appears. Such a gradual step occurred 20 years ago, when passive RFID tags have been deployed for the first time in a river channel for investigating gravel mobility. We can estimate from the literature that during the last 20 years, more than 30 000 RFID tracers have been injected in rivers all around the world. The decisive advantage of remote identification of individual particles (as compared to magnetic tags), combined with the high recovery rates reported by early field experiments, have made that RFID progressively became the reference technology for bedload tracing in fluvial environments. The most recent methodological developments based on the use of active UHF RFID tags show that it is now possible to conduct efficient bedload tracing experiments not only in small streams, but also in large gravel-bed rivers. We can also monitor real time particle mobility and time-integrated bedload transport, providing key-data for predictive approaches. What are the main achieved methodological improvements? What did we learn about bedload transport in gravel-bed rivers? What are the remaining key challenges with RFID tags? This paper proposes to address these questions by reviewing field and laboratory experiments of the last 20 years and providing new results from a meta-analysis.

Chaotic interactions between riverbed evolution and vegetation dynamics prevent long-term predictions of fluvial morphology

Nunzio Siviglia

Department of Civil, Environmental and Mechanical Engineering, Università degli Studi di Trento, Italy

River managers are challenged by the need to ensure flood protection, water resources availability, and ecosystem health in a changing environment. Predicting the interaction between riparian vegetation and river morphology is crucial to assess river trajectories under a changing climate, for flow regulation, and for river restoration scenarios. The development of numerical models, which quantify the interaction of the relevant physical processes is crucial for predicting the morphodynamics of these areas and for planning sustainable restoration and flood mitigation measures. Here, we develop a simple one-dimensional numerical model which couples hydromorphodynamics with vegetation growth and mortality by uprooting. Then, we study the evolution of the riverbed of a straight gravel channel with a vegetated patch, subject to periodic growth periods and flood events (growth-disturbance periods). We show that, owing to the interaction between vegetation growth and riverbed evolution during flood events, fluvial morphology and vegetation biomass distributions display a sensitive dependence on initial conditions under a wide range of realistic conditions. Our results also suggest that the Lyapunov time is small and the predictability horizon is limited to a maximum of three growth-disturbance periods. Such chaotic behaviour limits the long-term predictions of fluvial trajectories and similarly to what is done for numerical weather prediction, calls for the adoption of ensemble methods producing forecast uncertainty estimates.

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Uncertainty quantification of bank vegetation impacts on the flood flow field in the American River, California: Insights gained via large-eddy simulation

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Bank vegetation play a key role in both hydrodynamics and morphodynamics of natural rivers, however, they are often unaccounted for in the computational flow dynamics of NATURAL waterways. Recent studies using the large-eddy simulation (LES), however, have attempted to gain insights into the impacts of bank vegetation on the mean flow field of the natural rivers using vegetation models, which use a sink term in the momentum equations of motion to account for the effects of the vegetation and provide a practical approach to account for the complex patches of bank vegetation in large-scale rivers. To incorporate the effect of natural trees on the flow field, vegetation models utilize a drag coefficient, which can be a significant source of uncertainty, and the choice of the drag coefficient in the vegetation model can alter the computed flow field. In this study, we use LES to investigate the bank vegetation effect on the riverine hydrodynamics by incorporating trees into the flow domain using two different approaches: (1) resolving numerous individual trees as discrete objects and (2) treating the vegetation as a momentum sink along the banks. The computed hydrodynamics results of the cases were compared to a base-line case, which did not include any trees. We used the polynomial chaos expansion and Monte Carlo sampling to determine the uncertainties associate with the drag coefficient in the vegetation model. Overall, both the tree-resolving and vegetation model approach compared well with one another with respect to redistributing the flow field, thereby, demonstrating the crucial impact of bank vegetation on river flow dynamics.

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Exploring the implications of equilibrium channel geometry for long-term landscape evolution

Tucker G.E., Gabel V., & Campforts B.

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Rivers shape terrain and carry sediment to the ocean, and so theory for fluvial erosion and sediment transport forms a key part of mathematical and numerical models of landscape evolution. But most models treat rivers in a highly simplified way. For example, landscape evolution models usually rely on an empirical treatment of hydraulic geometry, effectively ignoring the tendency of channels to adjust their width, depth, and roughness to the prevailing water and sediment supply. Here, we build on recent advances in understanding gravel-bed and bedrock-influenced rivers to formulate a revised model for long-term fluvial sediment transport and incision into bedrock. The theory combines four elements that are commonly observed in mountain channels: (1) the existence of a coarse alluvial cover over bedrock, (2) channel incision into bedrock, (3) progressive downstream loss of gravel-sized sediment to attrition, and (4) the tendency of width to adjust such that bankfull stress is slightly higher than the gravel mobility threshold (the “near-threshold" principle). The last of these is based on the observation that mountain channels often have one or both banks formed from coarse sediment, and exhibit hydraulic geometry scaling consistent with gravel alluvial channels. The new formulation represents a a gravel alluvial layer overlying bedrock. Alluvial thickness varies as a function of bed-load input/output, addition of gravel liberated from rock by plucking, and loss of gravel to abrasion. The bedrock exposure fraction is calculated as a decaying exponential function of sediment thickness. The rates of both sediment transport and bedrock incision are modulated by the fractional bedrock exposure. The rock surface lowers over time through a combination of plucking and abrasion. We explore the consequences of this model both in 1D (channel longitudinal profiles) and 2D (an evolving network of channels embedded in a landscape evolution model). We find that the model can reproduce several observed aspects of natural channels, including concave-upward long profiles, a positive correlation between relief and erosion rate, and hydraulic geometry scaling. The model can also account for the observation that bedrock-incising channels tend to be steeper when fed with a supply of coarse, resistant gravel from upstream. One interesting implication of this theory is that downstream gravel attrition – a process almost never included in landscape evolution models - can have a major influence on topography and landscape evolution.

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Metal mining impacts on river systems

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This paper is a first-ever quantitative analysis of the global dimensions and environmental impacts of past and present metal mining activity on river systems that emerge as a major worldwide problem. A novel geo-referenced global data set is presented detailing all known metal mining sites, tailing storage facilities and their failures. This is evaluated using process-based and empirically tested modelling to produce a global assessment of the impact of mining on river systems and floodplains, as well as on human populations and livestock. Our results reveal the serious nature of long-term metal contamination of river environments and the significant under-reporting of mining activities and incidents. Worldwide, metal mines impact 479,200 km of river channels and 164,000 km2 of floodplains We show that the number of people likely to be exposed to contamination by long term discharge of mining waste into rivers is almost 50 times greater than the number directly impacted by tailings dam failures.

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Gravel bed river response to volcanic sediment loading

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Rapid addition of coarse-grained sediment to river systems by catastrophic mass movements, volcanic eruptions and glacier outburst floods is known to result in major hydrogeomorphological response. Knowledge of such events is based largely on studies of their immediate impacts with less attention focussed on their long term geomorphological and sedimentary signatures. Consideration of the long-term response of sediment loading to gravel bed river systems is important for river management and risk mitigation in the wake of a sudden 'convulsive' event. Fluvial systems within active volcanic landscapes may receive copious volumes of sediment both during and after episodes of volcanic activity, generating considerable hydrogeomorphological response over a range of timescales. This paper examines the hydromorphological response and sedimentary signatures of fluvial systems in Iceland (Eyjafjallajökull) and Chile (Calbuco) to syn- and post-volcanic eruption sediment loading.

During the 2010 eruption of Eyjafjallajökull glaciated volcano the Gígjökull proglacial catchment received two glacier outburst floods (jökulhlaup) on 14 and 15 April which recoupled the proximal and distal components of the fluvial system by infilling a proglacial lake with sediment and glacier ice. Elevated water and volcanic sediment discharge over a period of several weeks resulted in continued aggradation, channel widening and overprinting of the initial jökulhlaup deposits. Volcanic sediment and meltwater were delivered to the glacier margin sub-, en- and supraglacially. Post eruption reduction in sediment and water flux over a decade have resulted in proximal fluvial system erosion influenced by the melt of buried glacier ice.

Volcán Calbuco in the Los Lagos region of Chile experienced large eruptions on 22, 23 & 30 April, 2015. The initial eruption generated Pyroclastic Density Currents (PDCs) which interacted with snow and glacier ice to form lahars which descended into river catchments radiating from the volcano for distances of up to 14 km. PDCs overprinted proximal lahar deposits in the Rio Blanco Este and Rio Blanco Sur on the northern and southern flanks of Calbuco respectively. Satellite imagery acquired following the first two eruptions demonstrate that there was no fluvial system adjustment at this time in the Rio Blanco Este. Comparison of pre- and post-eruption DSMs indicate net aggradation of up to 100 m in the headwaters of the Rio Blanco Este. Between July 2015 and April 2016 the Rio Blanco Este experienced major proximal erosion of PDC deposits consequently generating medial and distal aggradation. In the proximal Rio Blanco Este study reach erosion of PDC deposits generated a suite of erosional terraces, each capped by <2m thick high energy fluvial deposits. The aggrading medial and distal reaches of the Rio Blanco Este were characterised by channel avulsion and widening. Since April 2016, major rainfall events have repeatedly mobilised volcanic sediment in the headwaters of the Rio Blanco Este generating hyperconcentrated flows which have widened and aggraded the proximal reach. Each rainfall-triggered event was characterised by aggradation followed by rapid, terrace-forming, incision imposing further pulses of sediment on the medial and distal reaches.

These case studies demonstrate contrasting primary and secondary volcanic sediment delivery process. Eruption style and the presence of a glacier are major controls on the primary volume and aerial distribution of volcanic sediment. During the Calbuco eruption there was initially no primary fluvial response contrasting with Eyjafjallajökull, where volcanic sediment delivery to the fluvial system via the glacier plumbing system was instantaneous allowing the recoupling of proximal and distal fluvial systems. At Gígjökull, post eruption proximal fluvial system response has been mainly erosional in response to reduced sediment availability and lower river discharge. At Calbuco, fluvial system response has occurred following the main eruption period by ‘threshold’ rainfall driven floods capable of entraining highly erodible PDC deposits. Given the large volume of PDC deposits at high elevations on Calbuco, rainfall events will continue to generate sediment rich flows delivering sediment waves to the Rio Blanc Este, representing an ongoing management issue for decades. Increased sediment load within both systems was accompanied by river channel widening by lateral erosion and the generation of distinctive landform and sedimentary assemblages.

Geomorphic signatures of glacier lake outburst floods in Patagonia

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One of the major implications of glacier retreat on the Patagonia landscapes is the increasing occurrence and expansion of glacial lakes. These lakes may affect the downhill geomorphology as they are subject to Glacial Lake Outburst Floods (GLOFs). Associated sediment deposits have not been much investigated in the region so far. Here, we present some results from UAV surveys, field mapping and remote sensing, carried out by the Geoinfomatic Laboratory of the Universidad Austral de Chile (UACh) over the past few years. Are also included data from fieldworks in the Exploradores valley, where recent GLOFs cut one of the main touristic roads of the region.

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Feedbacks among vegetation, channel morphology, and bankfull discharge recurrence intervals

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The pervasiveness of vegetation in terrestrial riparian zones makes it difficult to separate effects of vegetation from hydrological and sedimentological controls on gravel-bed river morphodynamics. I will discuss two examples of vegetation influence in relation to discharge variability. First, in dryland channels near the Henry Mountains of southern Utah, USA, bed and bank vegetation varies dramatically near short spring-fed channel reaches. This unique variability provides an opportunity to isolate effects of vegetation from flood discharges and long-term sediment supply. Airborne LiDAR is used to quantify vegetation density, and ANUGA flood modeling is used to estimate wetted channel geometry at different discharges. Denser bank vegetation correlates with narrower channel reaches, as is commonly observed. However, reaches with more vegetation on channel beds (made possible from a lack of baseflow in these channels) are wider and shallower, demonstrating that vegetation can drive morphological change in opposite directions.

Second, I present a conceptual model describing how vegetation could influence flood frequencies through morphodynamic feedbacks. Bankfull flow and the “effective discharge” that transports the most sediment, on average, often have similar recurrence intervals of ≈1.5-3 years. However, this correlation is not mechanistically well understood, and is not universally agreed upon for gravel-bed rivers. A 1.5-3 year timescale is comparable to that required for riparian vegetation growth to withstand floods, and therefore to stabilize of bars and banks, as inferred for a variety of vegetation types and settings. Previous work argues that overlapping response timescales mean that processes likely interact and influence one another. While “near-threshold” channel theory can explain why gravel-bed channels can be stable at bankfull discharge, it generally only assumes a single discharge, not accounting for a discharge distribution or explaining why channel morphology may naturally adjust to a particular discharge recurrence interval. Timescales for riparian vegetation stabilization may provide a simple, mechanistic, and undoubtedly incomplete explanation for correlations between bankfull and effective discharge recurrence intervals.

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Is it all just about sediment in gravel-bed rivers? Current progress in research on instream large wood

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Instream large wood drives both form and function of forested gravel-bed rivers. The beneficial effects of wood in rivers, largely overlooked, are now widely recognized, as well as that together with the flow and sediment regimes, the wood regime controls both the physical and ecological integrity of rivers. Yet, large quantities of wood transported during floods can pose additional hazards, potentially damaging infrastructures like bridges or dams and exacerbating flooding. However, unlike the water and sediment regimes intensively studied over the past decades, the instream wood regime or budgeting has been only recently defined, and thus is still rarely quantified. The instream wood budget describes the different cascading processes from supply or recruitment, entrainment and transport, deposition and storage to decay. These processes show a highly spatial and temporal variability, but they can be characterized in terms of magnitude, frequency, timing, duration and mode. Instream wood budgeting is challenging, mostly because of the lack of data, monitoring stations and standardized protocols. This contribution reviews the most important recent advances made to quantify the different instream wood budget components, notably the wood recruitment and flux. Case studies showing applications of videography, artificial intelligence, numerical modelling, tracking or biogeochemistry illustrate the current progress. Still, important challenges remain, we identify and describe some of them, and discuss how wood in riverine sciences may develop in the near future.

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Source or Sink? Exploring the role gravel bed rivers play in modulating the flux of microplastics in the environment

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Microplastic burden in aquatic environments is increasingly recognized as being a threat to human and environmental health. To date, the focus has been on marine environments however, up to 80% of the plastics in the oceans are believed to have been transferred from river networks. Whist recent work indicates microplastic contamination of river sediments is pervasive at the global scale there remains a paucity of research on the pathways and mechanisms of microplastic transfer, particularly between gravel bed rivers and the oceans.

As well as acting as a source, data from the sedimentological literature points towards river beds as being resilient sinks for contaminants including heavy metals, organic contaminants and microorganisms such as viral pathogens. Limited research has shown this to also be the case for microplastics, where they can accumulate in sediments at an order of magnitude higher than in the overlying water column. In gravel bed rivers, active layer dynamics will likely drive the vertical exchange of microplastics and will therefore control whether the river bed acts as a source or sink of microplastics. This suggests that gravel bed rivers have the potential to be key global drivers in microplastic dynamics yet remain relatively overlooked.

This paper will report the findings from flume experiments and field surveys which serve to (i) elucidate upon the mechanisms responsible for controlling microplastic flux in gravel bed rivers; (ii) identify the spatio-temporal variations in microplastic contamination in response to changes in flow regime and; (iii) identify the role microplastics play as vectors of microorganisms such as viral pathogens which are important for human health

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The Power of Biology in River Environments

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Animals have been shown to be able to move sediments in rivers, with important implications for sediment structure and mobility; however, the significance of biogeomorphic processes relative to physical processes remains poorly understood. Therefore, this study aimed to quantify the biological power available to fluvial invertebrate fauna to move sediment and compare this to the stream power. Two methods were employed to quantify the energy expenditure of invertebrates. The first consisted of measuring invertebrate abundance at 11 sites in England in spring and autumn and calculating the total energy (calories) associated with each community. This represents a theoretical maximum energy associated with the community. The second method placed a single Signal Crayfish (*Pacifastacus leniusculus*) in a sealed tank and estimated energy expenditure as a function of respiration rate. As a validation, videography of grain movements was used to estimate energy expenditure associated with sediment reworking by multiplying the energy required to move a single grain by the estimated distance the grain was moved. The unit power (Watts/m^2) of invertebrates at the 11 sampling sites was broadly similar between spring and autumn and were an order of magnitude higher than the power associated with Q10 flows. Only a proportion of that energy would be used for sediment alterations; however, the same is also true of the stream power. Oxygen measurements indicated that crayfish expended approximately 6 Joules per hour (i.e. 0.0017 Watts m^{-2}), confirmed by videography that found crayfish moved 300 grains an average of 6 grain diameters, indicating a power of 0.0015 W m^{-2}. Extrapolating to crayfish populations recorded in the River Nene, UK, crayfish would expend 0.08 W m-2 per night, much lower than the recorded stream power associated with the Q10 (37 W m^{-2}). However, crayfish were found to move sediments up to 40 mm in diameter, which according to standard size-power relationships would require 30 W m^{-2} to mobilise. Therefore, crayfish are likely to use their power more efficiently when moving sediment than the flow, complicating direct comparisons between biological and physical processes. However, it is clear that the biological power associated with invertebrate animals in rivers is substantial with the potential to do significant work, and that using metrics of energy expenditure and power may offer a useful framework for better integrating biogeomorphological processes into river science.

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Integrated assessment of riverscapes from local to global scale: applications of hyper-temporal remote sensing data

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All rivers adjust and change, some just more or less than others. The observed gradients reflect the wide spectrum of existing riverscape diversity where intrinsic forms and functions (the mix of water, sediment and vegetation) are influenced or impacted on by external forces such as geological, climatic and anthropogenic. Assessing changes and adjustments in space and time is key to appreciate the hydromorphological diversity of riverscapes and to understand how they behave, how they respond to external forces and how to monitor their health condition in an integrated way. Having tools and procedures in place that can adequately assess, monitor and evaluate river condition will better support process- and nature-based management solutions in the global environmental change era.

The use of remote sensing in fluvial geomorphology as tool for integrated river assessment has grown in recent decades. In particular, a huge amount of satellite remote sensing data are nowadays available to assess riverscape functioning, changes and health at unprecedented spatial extent and temporal resolution. These data can be processed using new machine learning techniques and cloud-computing platforms and then be used to monitor riverscapes through “participative” observatories. However, a number of methodological questions still need to be addressed, as for example: what can be assessed with these “new” data? Which indicators can be extracted? Which step(s) of the river assessment can be performed?

To illustrate the purposes, this work presents a methodological framework and a set of examples of worldwide applications of satellite remote sensing for integrated assessment of riverscapes. The examples include gravel-bed and sand-bed rivers that have been more or less impacted by human pressures and in many cases are still adjusting to these new conditions. The work is based on the recent developments made by a community of researchers which are exploring how to upscale riverscape science at global scale using hyper-temporal remote sensing data.

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River restoration in glacial-legacy landscapes: unique characteristics & challenges

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Approximately 15% of the Earth's ice-free land mass was glaciated during the Pleistocence, which has created landscapes with a glacial legacy, included unsorted till and mainstem lakes. These landscape characteristics in turn form unique river characteristics with stepped longitudinal profiles and semi-alluvial channels with coarse boulders or cohesive clays that are not adjusted to current sediment and flow regimes that we define as paraglacial semi-alluvial channels. The objective of this article is to (1) highlight unique characteristics of rivers with glacial legacy sediment in both continental- and alpine-glaciated landscapes, (2) describe common or predicted responses to various anthropogenic impacts and restoration case studies, and (3) discuss unique challenges and future directions for restoring rivers in these landscapes. We show the results of a literature review of channels with glacial legacy sediment, case studies of restoration on glaciated channels in Scandinavia, and recommendations for research aims to improve river restoration in glaciated landscapes. There is a vast literature on restoring dynamic alluvial rivers, and in this study we aim to bridge this gap in understanding and provide future directions for research in restoring commonly less dynamic paraglacial semi-alluvial channels.

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The management of small gravel-bed rivers in urban environments: Insights from 10 years of research

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Alternatives such as stormwater management (SWM) and channel restoration have been developed to counteract the negative impacts of watershed urbanization such as river degradation. Degradation is a known function of both water and sediment fluxes, but management alternatives are rarely evaluated with respect to their impact on the sediment regime. In the current paper we offer insights from a 10-year research project in Toronto, Canada, where the objectives are to: 1) assess the impact of an instream restoration project on bedload transport processes; 2) model the benefit of intentional (SWM) and unintentional (beavers) hydrologic modification on sediment dynamics; and 3) outline a framework for sediment augmentation as an alternative to instream restoration of urban rivers. We use a combination of field monitoring, numerical modelling, and physical experiments to explore these strategies for smaller gravel-bed rivers where most of the watershed has been developed. Both successes and ongoing challenges are discussed, and we place these strategies within a conceptual model that seeks to address the root cause of urban river degradation by rebalancing the sediment supply and capacity of these channels.

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Historical changes on long-impacted European rivers:

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River morphology is dynamic in nature, in that it is dictated by unsteady driving variables (water, sediment, and wood fluxes). These driving variables are subject to naturally and anthropically induced variations that may occur both at the basin and the channel scales. Channel adjustments have been widely reconstructed on European river systems and a variety of studies have demonstrated that human pressures have greatly affected the vast majority of rivers. In this light, a literature review of channel adjustments across European rivers over the last centuries and their main controlling factors is presented in this study.

Analysis showed that human interventions such as extensive channel rectifications, floodplain drainage and basin-scale deforestation took place from the late Middle Ages to the 19th century. During this period, several European rivers widened and aggraded, as well as during the concurrent "flood-rich" LIA period. However, the evolutionary trajectory soon reversed, since the end of the 19th century with a fairly significant acceleration after the middle of the 20th century. Hillslope afforestation, erosion control works, and hydropower dam construction led to a general reduced sediment supply to the downstream river reaches, causing channel narrowing and bed degradation. Nonetheless, in-channel gravel mining—very pronounced from the 1960s to the 1990s—was the most important cause of stream degradation in several rivers whereas in others narrowing was also significant due to embankments or vegetation encroachment following peak flow lowering downstream dams. Since the end of the 20th century, many rivers started experiencing a channel recovery mainly in relation with the end of the intense mining period. Moreover, also to comply with the goals of the European Union (EU) Water Framework Directive, several channel restoration actions have started to be implemented. Finally, ongoing global warming, increasing in severity since the late 20th century, could determine channel variations in those (few) rivers that are still free to adjust, and the most-relevant changes are expected at the higher elevations and latitudes, where glacial and periglacial processes still exert strong controls on river dynamics through sediment delivery.

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Catchment-scale monitoring of river change to support a gravel management plan, Waiapu River, Aotearoa New Zealand.

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River aggregate is an increasingly sought-after resource in Aotearoa New Zealand. For East Cape rivers (North Island, Gisborne Region, Te Tairāwhiti), despite having some of the highest rates of sediment yield per unit area in the world, the considerations required to manage industrial-scale gravel removal are complex. The Waiapu River is central to the cultural identity of Ngati Porou, the largest iwi (Māori kinship group) in the region. From a Maori perspective the river is a living entity, an ancestor, and a focal point of the community. Since 2015, Te Runanganui o Ngati Porou and Gisborne District Council have become joint managers of freshwater and land resources within the Waiapu Catchment. As gravel mining has transitioned from marginal workings to consent requests in the order of 450,000 $m^3 \cdot y^{-1}$, there are numerous and interwoven issues to address. This reflects multiple overlying values, whether they are constructive, in tension, or potentially both: (1) community/cultural values (2) river character and morphology (3) environmental and ecosystem function (4) river protective works and (5) cumulative effects.

In this paper we review the available evidence to help assess the sustainability of gravel extraction in this unique system. A simple routing model is applied to a 2-year difference map from two LiDAR surveys, covering over 200 km of the river and its tributaries. The river shows marked contrast in sediment supply conditions in different parts of the catchment, reflecting the episodic nature of mass wasting and geologic controls on sediment availability. Maps of sediment storage and transfer provide an important information layer that, in combination with other layers of ecological, cultural and hazard-mitigation information (among others), can provide critical guidance for decision-makers. With this multi-layered approach, Te Runanganui o Ngati Porou and Gisborne District Council are taking important steps toward developing a sustainable whole-of-catchment plan for one of the last wild braided river systems on the North Island of Aotearoa New Zealand.

Biocultural approaches to revalue waterscapes: (dis) encounters in Wallmapu-Patagonia

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Our research work together with Mapuche communities that live in different river basins in Wallmapu (indigenous territory) seeks to understand the relationship between societies and bodies of water from a transdisciplinary perspective. By using a biocultural approach, we recognize river basins as complex socio-ecological systems, where the relations of interdependence between people and water prevail. These relationships are strongly based on people's perception of water and nature and the relationship they have sustained through generations as biocultural memory. We have applied mixed qualitative and quantitative methodologies, including participatory mapping and monitoring tools, seeking to highlight the practices and perceptions of the Mapuche communities in their relationship with water bodies. Our experiences include careful trust-building, complex scenarios of meetings, dialogues and coexistence of multiple ways of learning-doing. They also reveal disagreements between multiple realities and normalized ways of conducting traditional scientific research and/or management-conservation plans in waterscapes where indigenous voices are ignored or deemed hierarchically less important or valid. Much of this research and management has been guided by an extractive imprint and conception of nature as an object and provider of natural resources. Through our applied experiences in Wallmapu, we have identified common ground to reinforce the importance of biocultural approaches to study and relate with waterscapes. We propose to shift the attention towards a genuine evaluation of the possibilities and limitations that emerge within academic and state institutions, when it comes to wanting to go beyond the dialogue of knowledge systems.

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Toward an integrated watershed-oceanic understanding of coastal basins in Mediterranean and semi-arid climates

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The integrated effects of coastal watershed hydrology and hydrodynamics are felt in wetlands, estuaries, deltas, and exposed coasts. Natural processes (precipitation, snow melt, groundwater recharge) and strongly anthropogenic activities (e.g., dam construction, agricultural water use) are changing with increased temperatures, drought, and changing atmospheric patterns associated with climate change. From the ocean-side, rivers are also affected by coastal forcings, as channels reaches of up to tens of kilometers can be significantly affected by tides, storm surges and waves, while coastal atmospheric processes control weather in coastal watersheds. Watersheds of central Chile, California, Australia, South Africa, and Spain exist in Mediterranean or semi-Arid climates where precipitation is seasonal and rivers and streams discharge into coastal environments with moderate tides and strong wave forcing. These systems exist across gradients of anthropogenic and climate pressures. In this presentation we highlight the dominant forcings that drive hydrodynamic and morphodynamic changes in these watersheds. Analyzing the fundamental co-dependent watershed and oceanic factors that interact in a wide range of spatial and temporal scales, we aim to present an integrated perspective of current science with the aim to better inform climate and hazard planning. Two case-studies from central Chile will show some implications of watershed and oceanic forcing on sediment transport and morphology at the ocean edge of these watersheds.

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Decline of sediment supply and delta regression in the Mediterranean due to human interventions. Effects of river engineering works

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Human induced impacts occurred since mid 19th century both at catchment and at river scales have largely affected Western European river landscapes. Llobregat River, a Mediterranean gravel-bed river in Northeastern Iberian peninsula is an example. River engineering works, floodplain encroachments, construction of dams and weirs and changes in land use have strongly modified Llobregat River morphology and have ultimately led its delta to retreat by 800 m since late 19th century. This paper focuses on estimating how sediment transport capacity in the lower 30 km-long reach have evolved since mid-20th century in response to river engineering works. These estimates have been compared with scarce and indirect field data. Our analyses suggest that river training works carried out in the lower reach since mid-20th century have reduced coarse sediment supply. However, despite of the magnitude and extent of these works, reduction in sediment supply and thus delta retreat is mostly attributed to the construction of approximately 90 weirs (4.2 m-height, on average) in the mid Llobregat River between 1850 and 1920 and to change in the frequency of large floods which started in early 20th century.

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The use of innovative technology for fluvial monitoring

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Image velocimetry has enormous potential to be used as an alternative to standard gauging stations. Fixed cameras, smartphones and/or unmanned aerial systems (UASs) can be used to acquire RGB (and thermal or multispectral) data to estimate water surface velocities and river discharge. However, image-velocimetry frameworks currently have some limitations at operational levels, mainly because of the need for standardised procedures and unquantified uncertainty in results. Possible reasons can be attributed to the lack of uniformly and sufficiently distributed seeding density; changes in illumination; noise generated by moving aquatic or edge vegetation; winds that affect surface flow velocities; and, video stability. This work aims to tackle the quantification of UAS image-velocimetry and discharge errors by analysing the sources mentioned above. In particular, seeding distribution and stabilisation issues are taken into consideration. Errors were quantified in terms of velocity (with respect to field measurements) and river discharge. This methodology allowed an error reduction of around 20-30% with respect to the entire video configuration. This novel idea appears suitable for performing image velocimetry in natural settings where environmental and hydraulic conditions are extremely challenging and particularly useful for real-time observations from fixed river-gauged stations where an extended number of frames are usually recorded and analysed.

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The potential of new methods for improving predictions of critical shear stress in gravel bed rivers

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Gravel comprising river beds starts to move when the applied shear stress (τ) is greater than the critical shear stress (τ_c) of the sediment. Predicting when sediment will move is essential for a wide range of management applications. Our aim here is to demonstrate how recent methodological advances provide new opportunities to better understand the grain-scale controls on τ_c. We focus on advances in two areas: 1) methods to identify the onset of bedload transport; and 2) methods to quantify grain-scale gravel bed structure. The first area is important because identifying the conditions under which sediment starts to move in different channels will show how much τ_c varies spatially and temporally. The second area is important because, although τ_c depends on grain-scale sediment structure, the difficulty of measuring sediment structures means that we have very limited information on how they change spatially and temporally. We illustrate advances in this second area with new data comparing three different methods for measuring sediment structure in the field: direct measurements, terrestrial laser scanning (TLS) data and CT scanning data. We conclude by considering how findings from these two areas could be combined to identify which aspects of sediment structure most closely control values of τ_c, and hence which properties of gravel beds should be measured to improve τ_c predications.

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Transport of solutes and more complex substances in streams and rivers

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Rivers and streams transport the products of erosion and weathering, as well as anthropogenic materials collected from industrial, agricultural, and urban environments. While waterways are efficient transport networks, they are also important biogeochemical hotspots. Microbial biofilms colonizing organic and inorganic substrates at the sediment-water interface drive important biogeochemical reactions. The hyporheos is so efficient at cleaning up systems this that it is often referred to as a river's liver, but the water flow there is orders of magnitude slower than in the main water channel while reaction rates are orders of magnitude greater. In brief, streams are complex heterogeneous systems characterized by a broad distribution of spatial and temporal transport scales influenced by water column and adjacent subsurface properties. This broad separation of scales leads to systems that are difficult to model mathematically, particularly over relevant scales of practical interest. Conventional modeling approaches simply fail and transport in streams and rivers is commonly observed to be "anomalous". Here we present the results from a series of field experiments of flow and conservative tracer transport that explore the characteristics of stream and hyporheic flow that control anomalous behaviors. We present a stochastic model with which we can model the observations and with which we can parse out individual mechanisms controlling large scale transport more clearly, enabling us to move towards building predictive mechanistic large scale models. We conclude with preliminary results and a discussion on what the implications for transport of more complex substances of interest might be, including nutrients and other biological matter, such as DNA.

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Monitoring bedload transport in glacier-fed streams by seismic techniques

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In mountainous areas, the ongoing climate change is increasing the sediment delivery from glacierized areas to the channel network. However, quantitative estimations of sediment transport in such harsh environments are particularly challenging due to frequent geomorphic changes, snow cover/melt dynamics and glacier retreat. A growing number of studies investigate the use of seismic techniques to indirect monitor fluvial processes. Seismic methods are attractive, as they provide continuous recordings of processes occurring in large areas from a safe distance. Hydraulic structures equipped with geophone plates are established methods to monitor bedload in mountain rivers, but they have the drawback of being expensive to install and to maintain. Recently, seismic sensors installed nearby a stream channel have been used to characterize the main seismic sources associated to fluvial processes, i.e., bedload transport and flow turbulence.

Here, I present the analysis of a multi-annual seismic dataset collected in a glacierized area of the Italian Alps, the Sulden/Solda basin (South Tyrol, Eastern Alps). In the Sulden River, bedload transport is monitored with geophone plates since 2014. Direct measurements were used to derive the calibration equations adopted to quantify the transported bedload mass. In 2019 and 2020, the upper sector of the Sulden basin was equipped with an additional seismic network. During the summer seasons, three single-component geophones (4.5 Hz) have been installed along the proglacial stream draining the Western Sulden glacier, immediately downstream of a glacier snout.

Results indicate how large variations of bedload rates cannot be explained in terms of differences in water discharge alone. Climatic factors (i.e., temperature and snow cover) have a strong impact on bedload fluxes, as the highest bedload rates are produced by summer rainstorm events occurring during snow- and glacier melt periods. In the headwaters, the geophone signal mirrors well the daily melt flow cycles and the bedload pulses propagating downstream. At the basin outlet, the sustained bedload transport measured during melt flows – corresponding to the effective bedload discharge range – benefits from the activation of glacial and proglacial sediment sources. These observations show how seismic techniques can provide precious insights into the sediment dynamics at the catchment scale.

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LIST OF ABSTRACTS / POSTERS

Posters will be on display during the event and discussion will take place in an informal manner at breaks and lunch times. Presenters will be asked to be standing next to their poster on the two poster sessions on Tuesday and Wednesday afternoon.

1. Barlow V. & Ashmore P.: River confinement and braiding loss within the Canterbury Plains, New Zealand
2. Barahona J.T., Alcayaga H., Caamaño D., Mao L. & Pizarro A.: *Detecting river morphological changes due to multiple disturbances: Laja river as case of study in Chile.*
3. Bray E., Pettyjohn S. & Litwin-Miller K.: *How Tough is Tuff? Quantifying how river rocks round and fine due to abrasion during bedload transport of different grain size distributions.*
4. Caamaño D., Tranmer A.W. & Alcayaga H.: *Variation in Effective Discharge Over the Chilean Longitudinal Gradient.*
5. Camenen B., Masquelier F., Bonnefoy A., Kieffer L. & Dramais G.: *Origin of sand suspension measured in the River Rhône at Lyon-Perrache during a flood.*
6. Carrillo R. & Mao L.: *Morphological effects of a large flood in a step-pool Andean stream.*
7. Chapuis M. & Adnès C.: *Pluri-annual bedload monitoring in a Mediterranean mountain stream prior and after a ~200-year flood.*
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23. Rindler R. Schwarz S., Shire-Peterlechner D., Kreisler A., Liedermann M., & Habersack, H.: *Characteristics of bedload transport in Austria.*
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27. Villablanca, L., Batalla, R.J., Piqué, G., Iroumé, A.: *Climate-Contrasting Rivers React Differently to Dams: Geomorphological Evidence from Chile.*
28. Wilcox, A.C., DeLuca, Z., Persico, L., & Dixon, J.L.: *Spatial variation in geomorphic effects of 2022 floods in Yellowstone National Park*
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30. Wolstenholme J.M., Skinner C.J., Milan D., Thomas R.E. & Parsons D.R.: *Monitoring and modelling riverine geomorphic evolution in response to leaky wooden dam installations.*
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32. Zingaretti, V., Sánchez K., Iroumé A. & Pacheco, P.: *Gravel bed Nilahue river after eruption: an emerging scenario for vegetation development. Eleven years after the Cordon Caulle eruption*.
33. Liedermann M, Carling PA, Gmeiner P., Pessenlehner S., Hauer C., Habersack H.: Characterization of gravel dunes in the free-flowing danube river east of vienna based on in situ observation

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River confinement and braiding loss within the Canterbury Plains, New Zealand

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In relation to the wider concern that rivers in New Zealand are increasingly confined, nine braided rivers from the Canterbury Plains, were studied using aerial imagery to compare river width and pattern (including braiding intensity) between a period prior to significant development (mid-1900s) and the present. Channel narrowing was recorded along >90% length (~490km) of the rivers studied (375km historically braided). The main causes appear to be agricultural encroachment and vegetation change. In total, the rivers narrowed by an average of 43% (48% for braided reaches). Coinciding with narrowing, braided reaches lost 1.3 channels, on average. Overall, 20% (over 100km) length of the rivers recorded a change from braided to more simple pattern types including wandering (~18%) and single channel (~1%). The relationship of channel width and pattern change demonstrates the predictability of braiding change based on channel narrowing. As channels narrow, the likelihood of pattern simplification increases, although the amount of narrowing required to induce change depends on the initial width and pattern. Based on these results, a predictor of channel pattern change, based only on channel width and width change, can be applied to aid with room for river management plans for conserving or restoring braided river morphologies.

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Detecting river morphological changes due to multiple disturbances: Laja river as case of study in Chile.

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This work develops a hydromorphological analysis to evaluate changes in water and sediment flows due to multiple disturbances. The study considers the morphological changes for a river reach of 19 km of the Laja River in the center-south zone of Chile.

The disturbances sources correspond to hydroelectric plants, water withdrawals for irrigation and the sustained decrease trend in rainfall in the basin. The changes in the plan-view shape of the river reach were quantified using remote sensing techniques, through a supervised classification of Landsat 5 TM and 8 OLI satellite images, identified Water (W), Islands and riverine vegetation (IRV) and bars and banks without vegetation (BBWV), with a Kappa index>0,83. for a period of 15 years (2006-2021).

Compared to historical records, the period of analysis shows a decrease in annual rainfall by 17.5%. In addition, water withdrawals for irrigation have contributed to a 64% decrease in monthly stream discharge during the dry season. As a consequence of the decrease in annual rainfall and water withdrawals for irrigation, the sediment transport capacity has also decreased by 10.5%.

The changes in morphological driving variables (stream flows and sediment transport regimes) have manifested themselves in morphological changes, where it was possible to establish that a change in the channel form occurred in the last 15 years, going from a river with a single channel to a braided one. An important vegetation establishment has accompanied this morphological change on both riverbanks and the central bars. The colonizing vegetation corresponds to fast-growing non-native species (*Salix* spp., *Populus* spp. and *Alnus* spp). According to what has been observed, a stabilization of the channel form is expected, consolidating itself as a braided section with alternating vegetated bars.

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How Tough is Tuff? Quantifying how river rocks round and fine due to abrasion during bedload transport of different grain size distributions

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Along rivers, bedload transport causes collision and wear of sediment particles, and riverbed sediments exhibit two downstream trends: rounding in which rocks tend to get rounder, and fining where particle size decreases with distance downstream. Sediments supplied by hillslopes to rivers are initially angular upstream, and smooth into rounded gravels downstream as a result of abrasion. The transition from angular to round particles in fluvial environments indicates that a significant fraction of particle mass has been lost due to abrasion, but very little is known about what controls the ubiquitous pattern of rounded river rocks in real rivers. Previous studies have shown abrasion to occur in two phases: the first phase being dominated by rounding, and the second phase resulting in size reduction. However, few studies have investigated what is the role of grain size distribution on wear rates, and questions remain on the role of abrasion in downstream fining. Further, abrasion rates measured in laboratory experiments have been limited to a relatively few types of lithologies. To quantify the response of felsic volcanic rocks to abrasion in the fluvial environment, we performed tumbling experiments on Bishop Tuff which erupted from the Long Valley Caldera in eastern California at 760 ka during one of the world's largest Quaternary volcanic eruptions. Our samples were collected from the densely welded portion of Bishop Tuff exposed within the middle Owens River Gorge. We used laboratory tumbling mill experiments to quantify abrasion rate as a result of collisions of varying grain size distributions to (1) simulate high-energy collisions of rocks of different grain sizes, and (2) examine downstream evolution of shape and size of thousands of pebbles. Using a combination of laboratory experiments and image-based shape parameters, we show that (1) Bishop tuff exhibits the highest wear rates during the first phase of abrasion, (2) densely welded tuff tends to retain angularity despite significant mass loss, (3) fragmentation and chipping are the dominant mechanisms for the observed mass lost, and (4) the wear product of abrasion consists predominantly of fine silt.

Results show that narrow grain size distributions wear slowly, whereas wider grain size distributions yield higher wear rates and higher rates of fragmentation but display limited rounding relative to other lithologies. Overall, fragmentation is the dominant mechanism of abrasion in the downstream reduction of particle mass in the lithology studied, with important implications for sediment mobility and generation of fine sediments.

Miller, K.L., Szabó, T., Jerolmack, D.J. and Domokos, G. (2014) Quantifying the significance of abrasion and selective transport for downstream fluvial grain size evolution. Journal of Geophysical Research: Earth Surface, 119(11), pp.2412-2429.

Arabnia O. and Sklar, L.S. (2016) Experimental study of particle size reduction in geophysical granular flows. International Journal of Erosion Control Engineering, 9(3), pp.122-129.

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Variation in Effective Discharge Over the Chilean Longitudinal Gradient

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Effective discharge is the flow that theoretically performs the most geomorphic work by transporting the greatest amount of sediment over time. To explore the range and variability in the effective discharge over a broad latitudinal range in South America, daily records of discharge and suspended sediment concentrations were selected from 43 government-administrated gaging stations distributed throughout the climatic gradient in Chile. From 2000 to 2018 these gaging stations collected concurrent information, which was used to empirically estimate effective discharge at each station over different time periods. The greatest concentration of stations was located in the central part of the country, whereas a fewer number of stations were available to define effective discharge in the northern and southern portions of Chile. Changes in the magnitude in the effective discharge were evaluated using three approaches, 1) for the entire 18-year period, 2) applying a yearly increment, and 3) employing a sliding 10-yearmobile window.

Results were sparse for the northern and southern regions, but spatially classifying the gages shows a correlation with climate and geology when considering the totality of the period. The magnitude of effective discharge changed depending upon the time period and climatic region that we examined. However, for the entire 18 years period the values ranged from 0.5 to 1500m^3/s. Additionally the return periods for those rivers varied between 1.5 and 16.6 years. Effective discharge was found to increase, decrease or remain constant in time, but many changes can be explained by natural and anthropogenic forcings. Results help understand the spatial distribution of this channel forming discharge across different climatic conditions and can help better estimate effective discharge in data-sparse regions that lack sediment records.

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Origin of sand suspension measured in the River Rhône at Lyon-Perrache during a flood

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The estimation of sand transport in gravel bed rivers is a complex task since bedload or suspended load may prevail depending on hydrodynamic conditions and because sediment transport capacity may be affected by an insufficient sediment supply. A challenge is first to sample suspended load due to strong vertical and lateral gradients and such direct sampling, though necessary, has a prohibitive cost and cannot provide high frequency estimates. A sediment rating curve may be applicable if the system is not supply limited. Dramais (2020) measured suspended load in the River Rhône at Lyon-Perrache during the January 2018 flood. He proposed a sediment rating curve model based on Bayesian inferring to evaluate continuously the suspended load. Eventually, he obtained a total sand flux of 175 000 tons. The object of this study is to understand where the stocks of fine sediment were to supply this system. For this purpose, the method proposed by Deng et al. (2023) was applied on river bars located upstream. About 70 patches were sampled showing a significant amount of fine sand within the gravel bed matrix. Using a 1D model, one found that vertical erosion of gravel bars remained however limited. Fine sands should originate from the River Ain, which presented large avulsion during the event, as well as the upstream River Rhône.

Dramais, G. (2020). Observation et modélisation des flux de sable dans les grands cours d'eau [Observation and modelling of sand fluxes in large rivers]. PhD thesis, Claude Bernard University, Lyon 1, 313p. (in French)

Deng, J., Camenen, B., Legout, C. & Nord, G. (2023). Estimation of fine sediment stocks in alpine rivers including the sand fraction. In revision for Sedimentology.

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Morphological effects of a large flood in a step-pool Andean stream

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Step-pool sequences are quite stable geomorphic units, but high magnitude floods (i.e. RI>50 years) can destroy and reform these features and lead to significant channel changes. However, our current knowledge of channel changes due to floods of different magnitude is still limited to few field sites, and limited evidence are available for high-gradient streams. The study was conducted on the Estero Morales, a 27 km^2 glacierized Andean catchment located in central Chile. The study site is a 150-m long, step-pool/cascade reach (mean slope 0.11 m m^{-1}). A high-magnitude flood occurred between April 13 to 19, 2016, and was generated by an ENSO event (El Niño South Oscillation) coupled by an unusually high zero isotherms. The flood destroyed a bridge and removed turbidity meters and pipe hydrophones installed since 2013. Detailed topographical surveys of the reach were taken before and after the flood (March 17th and April 28th 2016). Multiple photos were taken with a Phantom 3 Professional UAS. Approximately 300 and 570 photos were taken before and after the flood event. Several ground control points were surveyed with a dGPS. Digital Elevation Models (DEM) with 1 cm resolution were derived using the SFM method. Geomorphological changes due to the flood event were assessed by comparing the pre- and post-flood DEMs. The flood event, which is estimated to have recurrence interval higher than 30 years, was able to move boulders up to 2 m, and caused remarkable changes in the study sites. The channel avulsed in several points, and the morphology changed considerably. The number of steps along the study sited were 25 and 17 before and after the flood event, respectively. However, only 4 of the original 25 steps remained stable in the channel. The number of pools remained constant before and after the flood, but only 9 of the 26 pools remained in their place. A preliminary version of the DoD revealed that the study reach experienced vertical changes up to 1m, especially due to bank erosion. Overall, the volume eroded and deposited within the study reach was about 1140 and 1820 m^3, respectively, for a net volumetric change of 680 m^3. A high-magnitude flood in occurred in a glacierized mountain basin due to a late rainfall event caused considerable channel changes in a high-gradient, step-pool stream. The reach experienced avulsions, and most steps were destroyed, even if the channel soon developed new step-pool sequences. More detailed analysis of changes in step-pool geometry and cross-sections are ongoing, along with modelling efforts.

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Pluri-annual bedload monitoring in a Mediterranean mountain stream prior and after a ~200-year flood

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The Roya is a 60 km-long semi-alluvial riverbed, with alpine/mountain influence upstream and Mediterranean influence downstream. It is characterized by steep and narrow gorges (mean slope: 3.2%) on long reaches, and a local wandering pattern when the narrow valley floodplain allows it (mean active width: 40 m). Sediment load on the catchment (area: 660 km2) comes from steep hillslopes mainly constituted of limestones, marls and flyschs, very sensitive to erosion. As in Mediterranean streams, hydrology is characterized by an acute contrast between low flows (mean daily flow: 12 m^3/s; Q2 = 100 m^3/s) and floods (max. known in 2019: 1130 m^3/s). Because of its narrow floodplain and steep hillslopes, the Roya riverbed is mostly embanked. Despite several hydropower infrastructures, it is renowned because of its endemic trout population.

We began a bedload monitoring in 2016, in order to assess 1) sediment fluxes in a mountain Mediterranean stream and 2) the link between hydrology and morphosedimentary evolutions of trout spawning areas, that displayed intriguing interannual spatial stability.

An exceptional rainfall occurred on Oct. 2nd, 2020 on the Mediterranean Riviera region (max. 663 mm in 24h, return period ≥ 1000 years; CEREMA, 2021). With a maximum flow assessed between 1100 and 1800 m^3/s (return period: between 100 and > 500-years; DDTM 06, ONF-RTM 06 & Inrae, 2022), the Roya experienced exceptional active width widening (W × 2.4, Melun et al., 2022) that generated human fatalities and huge infrastructure damage (approx. 1 billion euros worth).

Based on bedload fluxes monitoring (RFID tracking and geophone) before, during and after the Oct. 2020 flood, this study contributes 1) to define travel distances in a Mediterranean mountain stream, including a ~200-year flood, 2) to understand the spatial and temporal dynamics of trout spawning areas and 3) to develop a prospective conceptual model of sediment connectivity in the Roya catchment and stress few essential guidelines for the reconstruction of the valley.

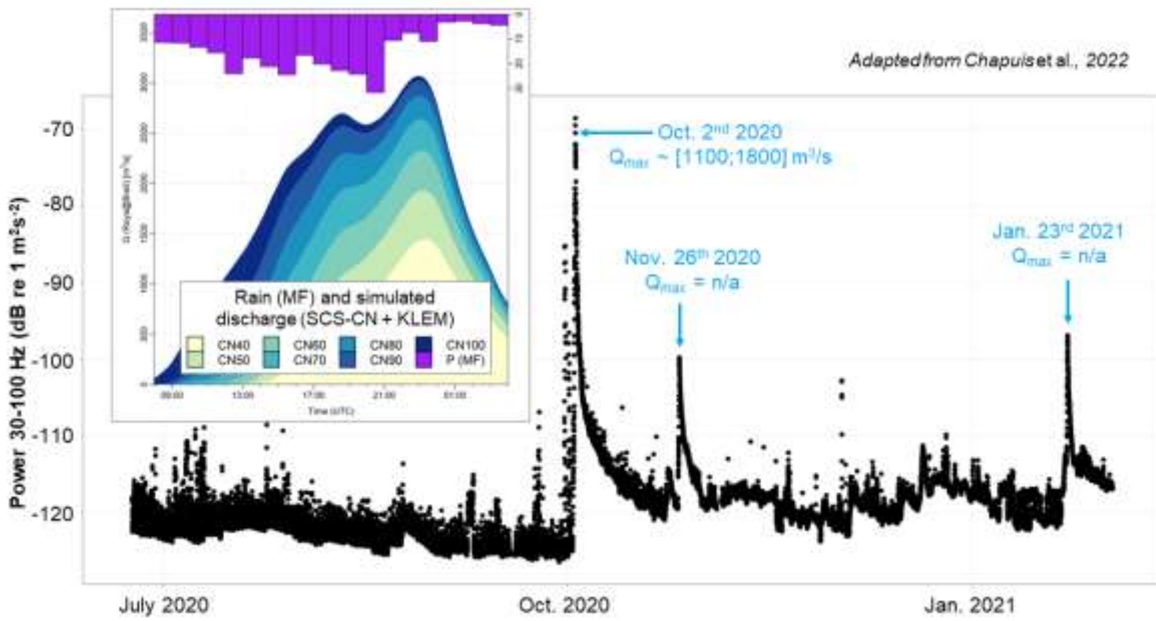

Fig.1. Roya Oct. 2020 flood kinetics from seismic analysis and rain/discharge simulation.

CEREMA (2021). RETEX technique ALEX - Inondations des 2 et 3 octobre 2020 - Expertise hydrologique – Rapport d'étape. Technical report (in French, hydrological expertise).

DDTM 06, ONF-RTM 06, Inrae (2022). Retour d'expérience technique de la crue du 2 octobre 2020 dans la vallée de la Roya - Volet torrentiel. Technical report (in French, torrential expertise). https://drive.google.com/drive/folders/1nzwplHXasGfr4FF5W8hFpQkrPEMmCK1E?usp=sharing

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Chaos in rivers: should we give up with the prediction of river trajectories?

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In rivers the interactions among the flow field, sediment transport and vegetation, show a strong non-linearity and complex behaviour. As a result, simulations of gravel bed river trajectories may display a strong dependence on initial conditions and aperiodicity, limiting or making impossible long-term predictions.

The goal of this work is to study the complexity of such interactions and quantify the time scale of river trajectories predictability.

We study the evolution of the riverbed of a straight gravel channel with a vegetated patch, performing numerical simulations with a one-dimensional deterministic mathematical model. The model couples the key ecomorphodynamic feedbacks among the flow field, sediment transport and vegetation. Vegetation grows during low flow periods, and it may be uprooted during flood events (disturbance).

By changing the ratio between the vegetation growth time scale and the flood frequency we demonstrated that the deterministic governing model shows a chaotic behaviour. That is, shows strong dependence on initial conditions, positivity of the maximum Lyapunov exponent and thus, chaotic behaviour.

Then, we developed a zero-dimensional model containing all the ecomorphodynamic feedbacks with the aim of characterizing the chaotic behaviour of the ecomorphodynamic interactions. Results obtained with this simplified model confirm that chaos is generated by positive feedbacks between vegetation dynamics and morphodynamic disturbance and that the route to chaos is of period doubling type. Calculation of the maximum Lyapunov exponent demonstrates that chaos limits the predictability of the river trajectories to few flood events. We conclude that for river trajectory predictions the adoption of statistical approaches for the estimates of the uncertainties is necessary.

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Deciphering the impacts of glacial melt, lahars, debris flows, flood regulation, levees, and downstream channel avulsion on sediment transport in the White River, Mt Rainier, Washington State

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A critical first step in managing a gravel and sand river through a populated area is measuring sediment transport rates to identify areas of persistent erosion or aggradation and trends in bed grain size distribution; to understand the relative influence of large and small flows over sediment mobility and bed exchange and long-term channel adjustment to external perturbations. In rivers transporting sediment sizes from silt to boulders, data collection necessarily includes multiple approaches, both direct and indirect. Sediment measurement efforts, and how collected data are used to understand and manage the river, are described for a river in the Cascade Mountains in Washington State.

The White River originates at Emmons Glacier on Mount Rainier and flows approximately 105 km downstream to a confluence with the Puyallup River and then another 16 km to Puget Sound. It is a wandering channel in that it has an irregularly sinuous planform with both meandering and braided reaches. Sediment eroded from Mt Rainier transports by debris flows, lahars, and atmospheric river driven floods. Flow and sediment transport rates are altered by operations at Mud Mountain Dam at RKm 42 and a fish trap and barrier at RKm 34. Bed surface and subsurface sediment samples have repeated throughout the river but transport data are less frequent. Suspended sediment was measured in the 1970s. Direct bedload sampling was undertaken in 1974 with a Helley Smith at RKm 34 and again in 2010 with an Elwha Sampler at RKm 14. Recent analyses have focused on indirect estimates of transport though bed volume change. Repeat LiDAR, aerial imagery, and Structure-from-Motion have been applied to develop hypotheses of on-going channel bed adjustment to a 1906 avulsion that lowered the channel between RKm 11-8. A recent levee setback at RKm 8 is being monitored for its impact on bed elevations and side channel deposition rates. Current efforts are focused on the reach at the barrier where sediment transport occurs only when river flow exceeds 113 m3/s and the barrier gates are lowered. Reach bathymetry is measured after each transport event and sequential data sets differenced to estimate the minimum sediment transport volume past RKm 34 with each high flow and over each water year. Hydrophones have been installed 300 meters downstream of the barrier to monitor gravel transport. The hydrophone signal will be correlated to the measured bathymetric change over the barrier reach.

Improving our Understanding & Management of Gravel-Bed Rivers in Chilean Patagonia: Studies in Río Simpson, Aysén

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There have been few studies on Chilean Patagonia rivers altogether, even less so on gravel-bed rivers and their processes. On the other hand, pressures are mounting from human activities such as gravel mining, water abstractions, flood structures, cattle trampling, invasive species, land use change including accelerated floodplain urbanisation. While accelerating climate change might impact the magnitude and frequency of high and low flows and therefore flow regimes and associated ecosystem processes. High intensity atmospheric rivers and deglaciating catchment hydrology have particularly impacted some areas. Here we report on hydrological, geomorphological and ecological studies performed at the Río Simpson (2019-2022), a highly valued GBR for fly-fishing, whitewater and other recreation activities, as well as water and gravel extraction. In particular, FIC40033100/FSEQ210010 projects focused on methods to estimate sediment transport and develop tools for more sustainable management of river gravel mining, as well as river-aquifer interactions relative to resources for drinking water. We developed techniques to estimate streamflow (using image velocimetry techniques and lidar altimetry with R-Pi in-situ processing and data telemetering) and sediment discharge (with bedload samplers, traps and morphological methods), low-cost turbidity sensors and photo-sieving for bed sediment characterisation, together with monitoring wells and water tanks. We will report results on Río Simpson hydrology, geomorphology, gravel extraction, sediment transport, aquatic biota and propose alternatives towards reducing negative impacts of gravel mining and water abstractions.

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LW dynamics after the Chaitén volcanic eruption along the Blanco River (Chilean Patagonia). Eight years has passed, dynamics remains

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The Chaitén volcanic eruption in 2008-2009 severely affected the fluvial pattern, hydraulics, and morphology of the gravel bed Blanco River (Chilean Patagonia), obliterating large areas of riparian forests (Swanson et al., 2013, Iroumé et al., 2020).

We examined the large wood (LW) dynamics between December 2017 and January 2022 (5 surveys), i.e., from 8 to 13 years after the eruption. LW and wood jam (WJ; accumulation of two or more LW pieces in contact with one another) locations and volumes were calculated using the structure from motion (SfM) technique for campaigns performed using a drone once a year in seven 80 m-long reaches located within a 2.9 km-long segment of the river. The RGB images were processed to generate georeferenced orthomosaics, and digital elevation models were created from each point cloud. Single LW and WJs were, thus, identified and measured.

Results show that wood volume greatly vary between 61 and 1342 m3/ha among reaches and surveys. Volumes (m3/ha) both as individual LW or WJ have remained higher in the upper reach, and tend to reduce toward downstream, but with important fluctuations of volume between the subsequent surveys. In average, during the study period, the aggregation type was 20% and 80% for individual LW pieces and WJs, respectively. In the study, 70% of WJs with a volume ≤100 m3 identified in one campaign were not found in the successive campaign. Moreover, 75% of WJs with volumes >100 m3 were relatively stable and remained in place for more than one subsequent campaign. The same percentage of WJs found in a subsequent survey fluctuated up and down more than 50% in volume. Finally, 62% of WJs remaining more than 2 consecutive campaigns reduced less than 50% in volume, while the remaining 38% increased by less than 50% in volume.

We did not find significant relationships between WJ stability and the distance to the main flowing channel.

Bank erosions and the exhumation of buried wood in volcanoclastic deposits are the main LW sources. The high LW dynamics is indicative of a still unlimited availability of wood logs along the entire fluvial corridor. The river is still adjusting its geometry and wood balance, which is expected to continue for decades after such type of infrequent disturbance.

This research is developed withing the framework of Project FONDECYT 1200079.

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A new photo-sieving approach: quick and effective semi-automated method for gran size counting for gravel beds, and application to a Chilean Patagonia river

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Many rivers in Chilean Patagonia are difficult to access, experience high flow variability and frequent sudden floods, which make traditional grain size distribution sampling and analysis extremely challenging. There are several diverse methods and software that attempt to determine grain size using analysis of photographs. Manual methods, although of high precision, are extremely labour and time intensive as they process particle by particle by hand. On the other hand, automated methods although fast, still produce low precision in particle identification and size determination. This motivated us to develop a field and desktop method that is fast, precise and requires light equipment. It includes good natural light management with a light and inexpensive kit, considering a good representative selection of the study site. Preliminary to the automated method, the photographic sample is calibrated regarding tones, colors and brightness, with the aim of generating high contrast between clasts and therefore an easier recognition by the software ImageJ. We tested the method with 50 photographs analyzed with manual and other (semi)automated methods, characterizing the surface deposits of río Simpson between the towns of El Blanco and Coyhaique, in Chilean Patagonia. We identified and mapped sediment patches using an UAV. Results show that our method has a lower error and processing time. Ongoing challenges include the underestimation in size and number of some clasts, and overestimation of sand, with respect to the manual method, but it still outperforms other (semi)automatic methods.

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Field observations and modeling of the formation of repeating bedforms (flats-bars) in ephemeral channels

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Gravel bed channels of single-thread ephemeral streams in arid and semiarid environments are typified by alternations of steep, coarse-grained 'bars' and less steep, fine-grained 'flats'. The origin of both macroforms has been discussed but has yet to be fully explained.

The ephemeral Yatir channel in Israel has a well-developed sequence of bars (average D_{50} = 16 mm; S = 1.41%), and flats (average D_{50} = 4 mm; S = 0.26%). To study the generation of this macroform sequence, the channel bed was mixed with a back-hoe digger, forming an almost plane, undifferentiated bed surface. Flash flood stage was monitored and repeat ground surveys were undertaken during two years. After each flood event, the channel bed was photographed by repeat low-altitude drone flights. Orthorectified 3D images of the bed and ground control points were uploaded to AGISOFT Metashape. Macroform borders were manually identified on Arcmap GIS Digital Elevation Models. The bed topography was detrended to obtain individual macroform surfaces, for which distributions of bed heights were determined. Bedload characterisations of the orthophotos/DEMs and the roughness statistics indicate that the bar flat sequence began to re-establish itself from the first post- treatment flood event and continued to develop gradually over subsequent events. The total length of the flats had more-or-less re-established itself by the end of the two-year monitoring period, demonstrating that bedload transport accommodates the stable generation and continued presence of these macroforms.

A suggested explanation for the origin of bar-flat patterns is sought via the application of linear stability analysis of the one-dimensional model of flow over an erodible bed composed of a bimodal mixture of sediments. The analysis leads to an integral-differential linear eigenvalue problem, the solution of which shows that bar-flat patterns may arise as an inherent free instability mechanism that is mainly driven by the different mobility of sediment fractions. The resulting linear perturbations of bed slope and composition are such that the coarse-grained fraction tends to accumulate where the local slope is steepened. Formative conditions for bar flat patterns occur when the standard deviation of sediment mixture is relatively large, as in the case of Yatir channel, and the flow is near to critical conditions for bedload transport. Application of linear theory suggests that bar-flat patterns were likely to form in the Yatir channel during the recessions of the monitored flash flood stage.

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Whose pool-riffle is it anyway?

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Pool-riffle bedforms in gravel-bed rivers have been investigated over many years using a range of field campaigns, laboratory experiments and numeric simulations. The observations from the studies have revealed many patterns of interest but there has been relatively little investigation on how the observations and the conclusions drawn by different researchers might be influenced by the variability of pool-riffle morphologies.

To explore the diversity of pool-riffles we analyze a database of quantitative and qualitative measurements from sites where pool-riffle morphologies have been studied and apply two morphologic classification systems. We further use a flume experiment to examine riffle formation for an endmember case.

The first system follows from the classic Wolman and Leopold (1957) approach of comparing the discharge and slope of different sites. The analysis shows that sites in the literature vary widely. The threshold line between single and braided pattern channels does help to constrain the possible discharge-slope combinations, but only if we consider the particle size, because many sites with coarse beds (median grain size larger than 16 mm) would otherwise plot in a region of braided channels.

The second classification system follows from the Kleinhans and van den Berg (2011) approach of comparing specific stream power and the size of the bed material. In our approach we used a the 84th percentile for the representative bed particle size because of the importance of the coarse fraction of the sediment for the formation of riffles and the resistance of the bed to degradation. This approach shows that studied pool-riffles occur at different distances relative to mobility and morphologic transitions, which means that they have different flow and sediment regimes. The appreciation of the morphologic diversity that is likely to occur due to these different regimes may help to clarify the importance of different flow and sediment transport phenomenon that underlie pool-riffle mechanics.

As a final contribution we present a flume experiment to track the movement of coarse sediment during floods in a scaled model of an endmember case, where sediment mobility is high relative to typical pool-riffles and it sits close to a morphologic transition due to high stream power as a by-product of urbanization.

Kleinhans, M. G. and J. H. van den Berg (2011). River channel and bar patterns explained and predicted by an empirical and a physics-based method. Earth Surface Processes and Landforms 36(6): 721-738.

Leopold, L. B. and M. G. Wolman (1957). River channel patterns: braided, meandering, and straight. Geological Survey Professional Paper 282-B: 85 p.

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Coupling Sediment Transport Dynamics with Sediment and Discharge Sources in a Glacial Andean Basin

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Suspended and bedload transport dynamics on rivers draining glacierized basins depend on complex processes of runoff generation together with the degree of sediment connectivity and coupling at the basin scale. This paper presents a recent dataset of sediment transport in the Estero Morales, a 27 km^2 glacier-fed basin in Chile where suspended sediment concentration (SSC) and bedload (BL) fluxes have been continuously monitored during two ablation seasons (2014–2015 and 2015–1016). The relationship between discharge and SSC depends on the origin of runoff, which is higher during glacier melting, although the hysteresis index reveals that sediment sources are closer to the outlet during snowmelt. As for suspended sediment transport, bedload availability and yield depend on the origin of runoff. Bedload yield and bedload transport efficiency are higher during the glacier melting period in the first ablations season due to a high coupling to the proglacial area after the snowmelt period. Instead, on the second ablation seasons the peak of bedload yield and bedload transport efficiency occur in the snowmelt period, due to a better coupling of the lower part of the basin caused by a longer permanency of snow. Differences in volumes of transported sediments between the two seasons reveal contrasting mechanisms in the coupling dynamic of the sediment cascade, due to progressive changes of type and location of the main sources of runoff and sediments in this glacierized basin. Here we highlight the importance of studying these trends, as with retreating glaciers basins are likely producing less sediments after the “peak flow”, with long-term consequences on the ecology and geomorphology of rivers downstream.

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Riverbed sediment size and morphological changes from Sentinel-1-2 satellite data

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Satellite data from the Sentinel missions have opened new perspectives in fluvial geomorphology by delivering freely available data at global scales and at temporal and spatial resolutions that are meaningful to many medium-large rivers (e.g., active channel width > 30-50 m) of the world. The understanding of the potentials and limits of detectable processes and river-derived indicators based on these satellite data is still to be explored.

In this work the potential of Sentinel-2 multispectral data and Sentinel-1 radar data was investigated to infer information about bed sediment size of exposed river bar and proxies of river morphological changes, respectively. UAV derived products collected in 3 major Italian rivers, were used as ground-truth datasets to calibrate and correlate satellite information. The main outcomes of this work show that:

i) Orbital grain size mapping of sand- vs. gravel-dominated bars from Sentinel-2 data is possible because of an inverse correlation between reflectance intensity and the D50 fractions of the surface sediment grain size. Results show statistically significant predictive models (MAE of ±8.34 mm and R^2 = 0.92). The trained model, applied on 300 km of the Po River in Italy, reproduced the expected downstream fining trend and identified the gravel–sand transition occurring along this river length. This finding opens new perspectives in the monitoring of riverbed sediment size at the river network scale (>100 km) with the possibility to derive information on the gravel and sand dominated bars, and gravel-sand transition position and its evolution through time.

ii) In contrast to the initial assumptions, Sentinel-1 radar data show scarce effectiveness to discriminate erosion/deposition and stable areas in a highly dynamic fluvial environment. River morphological changes (in the range of ± 0.5-2 m) measured in a wandering river reach were not detectable from Sentinel-1 radar data. Future research should further investigate the correlation among morphological changes and radar data, by increasing the spatial and spectral resolution of the sensor and/or by increasing the dimensions of the target and the magnitude of the changes registered.

Marchetti G., Bizzi S., Belletti B., Lastoria B., Comiti F., Carbonneau P. (2022) Riverbed sediment size from Sentinel-2 satellite data. Earth Surface Processes and Landforms. 47: 2544-2559. https://doi.org/10.1002/esp.5394

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Assessing large wood abrasion using terrestrial LiDAR, RFID tracking and cylinder modelling

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Wood forms an important component of fluvial ecosystems, creating ecological niches for a variety of species, influencing fluvial dynamics, and presenting significant carbon stores. Wood also causes management issues, for example blocking bridges and inducing local flooding, often resulting in its removal by river managers. Removing wood has deleterious effects to ecosystems and river processes, so understanding whether wood can be left alone within a river system to degrade naturally is of use. Understanding the nature and rate of large wood abrasion may improve flooding risk management, whilst also minimising habitat damage or carbon removal. We used terrestrial LiDAR to monitor wood abrasion of 9 trees transported along the Allier river, France, between November 2020 and June 2022. We were able to scan the same trees on ~3 occasions, and RFID tagging of the trees allowed us to identify the same tree as they changed over time, even after some trees had been transported considerable distances downstream. We created cylinder models of trees from the point clouds, that allowed us to derive several useful metrics of tree complexity (branch order, reverse branch order), cylinder radius, total length and volume changes. Visual comparisons show point clouds to fit the cylinder models very well and points were usually within 0.02m of the cylinder surface. However, as trees were scanned on their sides on bar surfaces, lack of data from underneath the tree led to some occlusion issues with missing points often found towards the base of the tree. Although some tree radius populations showed a shift to larger cylinders over the duration of the study, indicating loss of small branches, the pattern was not consistent. For some trees oversized cylinders were fitted to parts of the point cloud, causing a skewing of the tree radius population. Wood abrasion is initially rapid with a 66% reduction (median) in volume (between November 2020 and June 2021), and a further 60% reduction between June 2021 and June 2022. Growth length reduced by 55% in the seven months between November 2020 and June 2021, then by a further 19%, when considering June 2021 to June 2022. Good relationships were also found between field-derived and LiDAR-derived complexity metrics. Although we highlight some issues with the approach, we conclude that terrestrial LiDAR point clouds in conjunction with cylinder modelling does appear to provide a promising approach to monitor large wood abrasion.

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On the role of survey frequency and confinement on morphological changes detection

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The application of indirect methods in large and morphologically heterogeneous gravel bed rivers is often the only way to obtain a reliable estimation of sediment flux. In this work, we investigate the effect of survey frequency in the detection of morphological changes and we explore the role of flow confinement in setting the spatial and temporal scales of scour and fill patterns, taking advantage of controlled laboratory experiments. We reproduced three different morphological configurations, from braiding to wandering with alternate bars, increasing the discharge from 0.7 to 1 and 2 l/s, in a flume 0.6 m wide and 25 m long, filled with a 1 mm homogeneous grainsize sand. For each discharge we conducted a set of 9 consecutive runs interposed by a topographic survey, performed by a laser scanner on a 5 x 50 mm grid. Two cameras fixed directly above the flume recorded the morphological evolution and were used to get spatially and temporally detailed information on the occurrence of sediment transport. In addition, load cells at the flume outlet directly measured the bedload flux. The three sets of DEMs were used to produce Dem-of-Difference (DoDs) with different time steps between surveys. The DoDs provided time sequences of morphological activity, from which we computed volumes, active width and thickness of changes.

Results show that morphological change is significantly underestimated, for increasing timesteps between surveys. This is caused by compensation processes where sequences of scour and deposition occur in the same location. This is confirmed by the analysis of the temporal sequences for each pixel of the DoDs, which highlights that scour and deposition processes last in most cases for only one timestep, followed by a period of inactivity or by a compensation process. This is valid for all of the three configurations, but with significant differences, caused by the increasing lateral confinement and therefore by the larger values of active width. Similarly, the timelapse of bedload activity have been used to explore the time evolution of the active width and show how this change with the lateral confinement. These results highlight the importance of the survey frequency in the application of indirect methods and suggest when and where these methods can be used to accurately estimate the sediment transport flux.

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From sediment source areas to gravel-bed rivers in an eruptive environment: Insights from the Chaitén River (Chile)

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Rivers transport water, sediment, and large wood (or LW), and these transport dynamics depend on the interaction of multiple factors acting at different temporal and spatial scales. Thus, river morphology is constantly adjusting due to changes in the balance between water and sediment. River processes can be altered by anthropogenic disturbances (e.g., gravel extraction, dams) and by natural disturbances (e.g., climate change, tectonic control, volcanic activity, extreme floods, slope processes, and landslides). Among these disturbances, volcanic eruptions are characterized by generating major changes in the landscape, affecting hydrological and sedimentary dynamics and the processes of storage and transport of woody material in nearby river systems, producing a wide range of natural hazards that can persist for years and decades after the disturbance. Tephra accumulation and vegetation mortality gradually increase slope instability due to loss of root resistance from decomposition, which can lead over time to increased sediment flow from the slopes into the active channel. In this study, we focus on gravel-bed river sediment source responses affected by a watershed-scale disturbance. The main objective of this work is to identify landslides that can generate potential sediment and wood supplies toward the active channel in a basin affected by a volcanic eruption. The study area comprises the Rio Blanco watershed (72°39′7″W, 42°50′1″S). We identified 415 landslides, which were used as input for training a susceptibility model with the Random Forest algorithm, twelve conditioning factors (altitude, slope, orientation, plane, and line curvature, topographic moisture index, topographic deposition index, total precipitation, lithology, the time after the eruption, NDVI and tephra series) were applied in the model and ROC and AUC curves were calculated to assess the model performance. The degree of landslide connectivity was identified using the connectivity index.

The results indicate that the areas most affected by the volcanic eruption present higher degrees of landslides connected to the active channel, while the existence of large floodplains in the lower part of the basin, generates a barrier to the entry of sediment and wood using large landslides. The results of this work allow a better understanding of the morphological evolution and cascading processes generated by a volcanic eruption in a gravel-bed river. Allowing the identification of potential threats to infrastructure and human life by modeling future sources of sediment and LW input to the active channel of the Blanco River.

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What happens when a pebble hits a geophone plate?

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Seismic geophones plates have been frequently used to indirectly estimate bedload flux in gravel bed rivers. This indirect methodology, when appropriately calibrated, proved effective to provide relevant information on spatial and temporal scales otherwise impossible to explore. Notwithstanding, a detailed description of how these plates vibrate when impacted is still lacking, limiting the possibility to accurately interpret the signal. We performed two sets of experiments where we explored the geoplate response and computed the frequency and amplitude of different vibrational modes.

A first set of experiments was designed to investigate the variability of the signal as a function of the impact location on the plate, in dry conditions. A second set reproduced standard flow conditions, with single pebbles impacting the plate when transported by the flow. Results highlighted the occurrence of two main vibration modes, with a first rapid phase (lasting only about 5 ms) characterized by higher frequencies (larger than 1 kHz, and a second longer (up to 50 ms) and more stable phase of vibration with a frequency in the range of 300–400 Hz. We showed that a detailed analysis of the signal can be used to distinguish between pebbles impacting different locations on the plate and that impacts close to the center produced the best correlation with pebble mass. Results also highlighted that signal amplitude is not strongly affected by flow conditions, opposite to the number of impacts per pebble. The evaluation of the grain size is a challenge given the variability of the signal generated by similar impacts. We propose a filtering strategy to improve grain size estimation. Our analysis shows that a more detailed understanding of the vibrational modes helps identifying best practices for an improved signal acquisition and elaboration.

More details in Portogallo, M., Simoni, S., Vignoli, G., & Bertoldi, W. (2022). Analysis of the vibration modes of impact geoplates and implications for bedload flux and grain size measurements. Water Resources Research, 58, e2022WR032116. https://doi.org/10.1029/2022WR032116

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Modeling variable critical shear stress in sediment transport using FastMECH

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The critical Shields stress (τ_c*), a dimensionless threshold at which sediment transport is initiated, is often assumed to be a constant, although recent work suggests that variability in critical Shields stress may be caused by slope, stress history, and other factors. At river reach scales or larger, spatial variations in this threshold distribute normally around a mean and permit "reach-average" calculations using that mean. However, at the dekameter scale, at which local erosion and deposition occur, “reach average” assumptions are often invalid, creating inaccurate predictions of morphodynamics. The movement of surface water around vegetation in the floodplain at high flow creates strong velocity and depth gradients when compared to the reach as a whole, requiring a different approach to τ_c* to predict topographic and landform changes at dekameter scales over time.

To evaluate sediment transport and topographic change at dekameter scales we will use a river flow solver, FastMECH from iRIC, to generate velocity and depth fields around simulated topography similar to what occurs in natural gravel bed rivers. While FastMECH includes optional sediment transport calculations, it does not allow the flexibility to modify τ_c* over time, so we will perform sediment transport and topography changes in an external python script using the water depth, velocity, and shear stress field outputs from FastMECH. External modification of topography based on erosion and deposition sites at the dekameter scale overcomes limitations within FastMECH and permits more accurate understanding of development of characteristic fluvial landforms over time. By combining research on spatial variability of shear stresses due to flow disruption around topographic features with temporal variability in τ_c* due to changes in grain-scale bed organization, we can develop better predictions of erosion or deposition at the dekameter scale over the range of flows experienced in snowmelt-driven gravel bed rivers.

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Bedload transport in five Swiss mountain streams: continuous one-minute surrogate measurements and predictive equations

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The Swiss Federal Research Institute WSL has used impact plates with piezoelectric and geophone sensors to determine bedload transport intensities for more than 25 years at the Erlenbach stream. In the last decade, direct bedload samples were also obtained at four other field sites in Switzerland, along with surrogate bedload transport measurements with the Swiss Plate Geophone (SPG) system, namely at the Riedbach torrent, the Albula river, the Navisence stream, and the Avancon de Nant stream. These measurements resulted in relatively robust and simple calibration relations for the SPG system between so-called impulse counts and bedload transport rates (linear or power-law relations). In addition, recently a refined method was presented to determine bedload transport by grain size classes for all the four field sites (based on the raw signal of the SPG measurements).

For this study we determined the measured bedload transport rates Qb (kg/s), for the entire stream width, vs. discharge Q for the five Swiss field sites, and we compared the SPG measurements with a few bedload transport equations, expressing the predicted transport as a function of shear stress. The calculated transport rates represent the following equations: (i) Two approaches described in Schneider et al. (2015), which are modified equations of Wilcock & Crowe, adjusted for field measurements with mostly the Bunte trap in mountain streams. (ii) An equation proposed by Recking (2013), which was developed and tested with a large number of field measurements worldwide, many of which were made with the Helley-Smith bedload sampler. Since the indirectly measured bedload transport rates were recorded with a temporal resolution of one minute, it is not surprising that for a given discharge level they typically show large fluctuations, covering up to three orders of magnitudes. Therefore, we determined binned means, including up to 1000 minute-observations, to facilitate the comparison between observed and predicted values. For some field sites, the agreement between observations and calculations can be considered to be rather promising, whereas for others and particularly for small flow intensities, there is partly more disagreement between observed and predicted values. In Figure 1, examples are given for the for the measurements in and calculations for two Swiss mountain streams.

Schneider JM, Rickenmann D, Turowski JM, Bunte K, and Kirchner JW (2015) Applicability of bed load transport models for mixed-size sediments in steep streams considering macro-roughness. *Water Resources Research*, 51, 5260–5283, https://doi:10.1002/2014WR016417

Recking A (2013) Simple method for calculating reach-averaged bed-load transport. *Journal of Hydraulic Engineering*, 139, 70–75. http://dx.doi.org/10.1061/(ASCE)HY.1943-7900.0000653

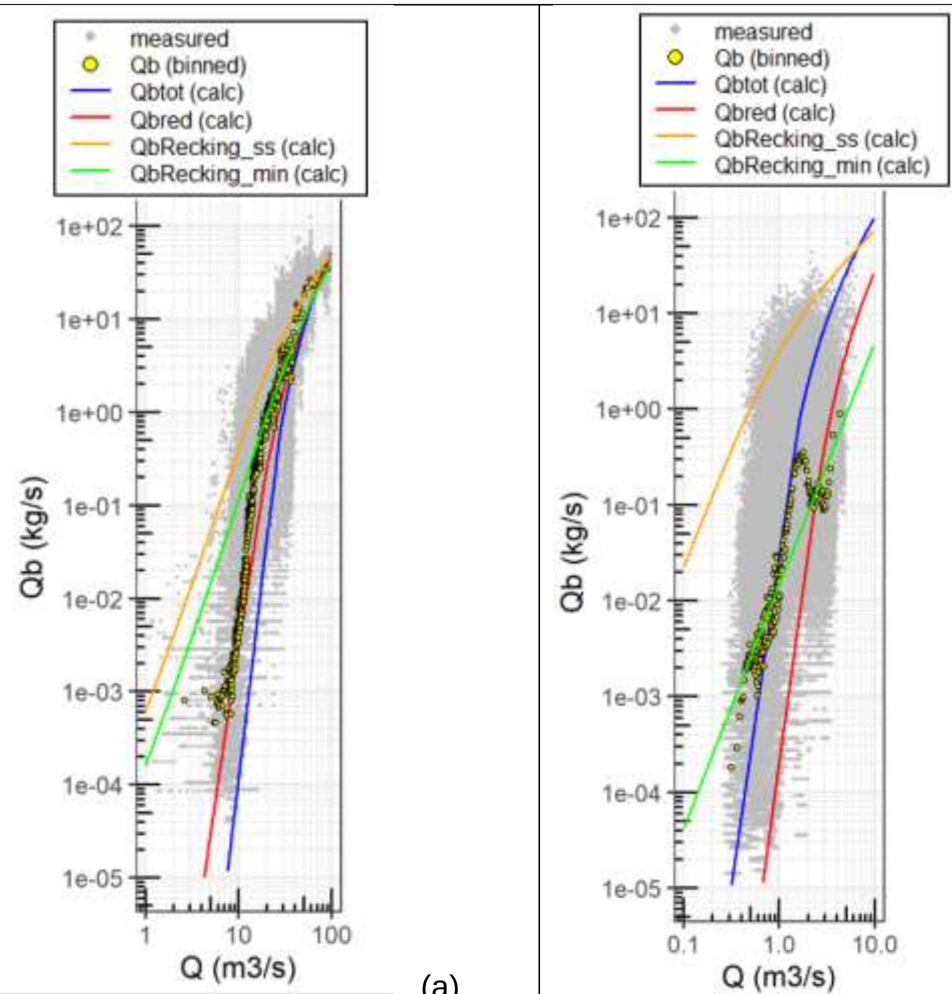

Figure 1. Measured bedload transport rate Qb vs. discharge Q for (a) summer 2016 at the Albula River, and (b) summer 2019 at the Avancon de Nant stream. The measured minute-values are gray points, the binned means are yellow points, the red and blue lines represent the predictions with equations of Schneider et al (2015), and the orange and green lines represent the predictions with equations of Recking (2013).

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Characteristics of bedload transport in Austria

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Bedload transport monitoring and its processes are challenging tasks in river research that have captured the worldwide attention of researchers since decades. In Austria, bedload transport has been recorded an integrative way (direct and indirect bedload measurements) at seven sites, from high alpine regions down to the Danube, for over ten years now. Catchment areas range in scale from 52 km^2 on the Johnsbach to 104,177 km^2 on the Danube. For the direct measurements, different basket samplers adapted to the river type and slot samplers are used. Maximum bedload transport rates of 29.5 kg/s were measured with basket samplers in Vent and 21.9 kg/s with slot samplers on the Johnsbach. Indirect and continuous bedload transport is recorded with geophones at all stations except the Danube. The bedload transport as well as the bedload yield itself can be determined on a station-by-station base using the Integrated Bedload Discharge Calculation Approach (Integrated Approach) and/or the Bedload Evaluation Curve Approach (Habersack et al., 2017). The measurement methods used made it possible to record all relevant extreme events during the study period. For example, maximum bedload transport rates of 131 kg/s were recorded in Dellach/Drau on 31 October 2018 during a 30-year flood, or a maximum of 312 kg/s on 6 June 2013 on the Danube at Hainburg during a flood that topped the 100-year discharge. The mean annual bedload transport yield at the surveyed monitoring sites ranges from approx. 4800 t at the Drau/Falkensteinsteg site to approx. 380,000 t at the Danube in Hainburg, whereby the annual loads are partly subject to strong fluctuations depending on the hydrology and the size of the catchment area. To give an example: the annual load at the Falkensteinsteg monitoring site was six times higher than the average annual load as a result of an intensive flood event in October 2018, triggered by a pronounced snow melt. Due to long-term monitoring, it is possible to make reliable statements about bedload yield and bedload transport characteristics (Rindler et al., 2023). Our analyses showed that the dependence of bedload transport on discharge decreases with reducing catchment size and with fluctuating sediment supply.

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Understanding the use of rivers and riparian biodiversity in farmlands to plan climate-smart agriculture in southern Chile

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Restoration and protection of riparian ecosystems in farms has been identified as a key tool to improve habitat available for species, while mitigating agricultures' contributions to climate change. But these conservation actions frequently conflict with human's uses of the land, limiting where and how much land can be saved for conservation. To develop landscape conservation plans that are socially and environmentally acceptable, then, understanding social values of the land and associated biodiversity is critical. We explored land owner's values toward riparian ecosystems in Chile, where ongoing large-scale restoration efforts are underway. We applied a questionnaire addressing how farmers use their riparian zone to 105 farmers in the Toltén River watershed. We found that 69 % (45) of 65 farmers that raise cattle in their farm rely on the riparian zone to provide water (n=39), food (n=30) or refuge (n=17) for their cattle. On the other hand, farmers that produced crops said to not rely on the riparian zone in their productive system. However, when we compared the width of the riparian buffer between farms dedicated to livestock and crops, we found that farmers dedicated primarily to produce crops had on average the narrowest riparian buffers ($p < 0,03$). Our results have implications to plan large-scale restoration and biodiversity protection in farmlands. Since, livestock farmers value and tend to maintain wider forested riparian buffers, they may be more willing to protect existing or restore degraded riparian buffers. This could facilitate the implementation of conservation action. In contrast, crop producers may have a high trade-off when deciding between restoring riparian forest or cropping the land. Further development of this research includes integrating farmer's values, the ecological condition of riparian ecosystems and exposure to climate change on a land use prioritization model to identify where restoration of riparian ecosystems in the watershed is most needed.

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Flash Floods and Debris Flows Monitoring using Low-Cost System with In-Situ Image Velocimetry Processing

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We will present a low cost system that acquires laser altimetry and camera image data that is processed in-situ to obtain velocity (and flow) that are telemetered via cellular network and/or iridium satellite. The low cost of the system allows the monitoring of many hazardous sites covering a larger area, and in locations with unreliable networks. The image velocimetry method includes a brightness filter and normalized cross correlation. To eliminate outliers a flow direction filter is used. We will present both laboratory and field test results under a variety of conditions.

The system is based on a Raspberry Pi plate, with which, by means of particle image velocimetry obtain in-situ data on surface speed, using photogrammetry by means of local ground control points, obtain images to work in a geometric optics system, the velocity calculated on Raspberry is near to real time, useful and no invasive system. On the other hand, the speed measurement system is supported by a measurement system of altimetry changes, this through the use of a Lidar sensor, with these two parameters it is possible to obtain information on flash floods, precursors of events greater as alluvial risks.

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Characterizing the geomorphic consequences of instream infrastructure in a highly-modified gravel-bed river

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Physical heterogeneity within gravel-bed rivers provides a mosaic of interacting hydraulic and morphologic habitats over the range of annual flow conditions that supports recruitment processes, biodiversity, and ecological function in aquatic and riparian communities. However, gravel-bed rivers in both urban and rural landscapes have been modified by instream infrastructure to support anthropogenic activities, which has resulted in alluvial channels with diminished morphologic complexity and topographic variation (Tranmer et al., 2022). To assess the impacts of instream infrastructure on the physical heterogeneity of the channel, the topographic coefficient of variation (CV) was computed in a series of 200 m-long reaches over the entire 100 km of a gravel-bed river using high-resolution bathymetric LiDAR data. Here we use CV as a dimensionless metric for the physical variation of both the streambed (CV_{bed}) and the total hydraulically-connected channel ($CV_{channel}$) in each reach. In the highly-modified Boise River, USA, both the CV_{bed} and $CV_{channel}$ increased linearly with dimensionless levee width (W^* = levee width/average channel width). The $CV_{channel}$ increased 12% as W* increased from 0.5 to greater than 3.5. However, CV_{bed} rose more steeply with W^*, increasing 37% over the same range of W^*, indicating the streambed is more sensitive to levee width than the total channel. An exception to this trend occurred where islands and vegetated medial bars were located in narrow, levee constrained reaches. Individual or clusters of islands within reaches with low values of W^* increased the CV_{bed} up to 50% greater than the average CV_{bed} in the river. In addition to levee width, channel-spanning infrastructure like agricultural diversion structures, engineered kayak waves, and major bridge abutments locally impact the topographic variation. On average, CV_{bed} is ~30% greater downstream than upstream of these structures ($p < 0.0001$) owing to deposition and scour processes. Removing the influence of levee width by comparing CV_{bed} in reaches of similar W^* with and without infrastructure, average CV_{bed} upstream of infrastructure is reduced by 11% whereas CV_{bed} downstream of infrastructure is increased by 16%. Therefore, both instream and channel adjacent infrastructure impact the physical complexity of alluvial channels.

Tranmer A.W., Caamaño D. and Arteaga A.E. (2022) Urban stream syndrome: Quantifying topographic variation along an urban-rural gradient. *Journal of Environmental Management* **317**: 115413. https://doi.org/10.1016/j.jenvman.2022.115413.

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Climate-Contrasting Rivers React Differently to Dams: Geomorphological Evidence from Chile

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The construction and operation of dams modifies the water regime and interrupts the transfer of sediments, affecting the main instream geomorphic processes (e.g., erosion, transport, and sedimentation) and forms (e.g., hydraulic geometry, dimension and location of the morphological units, changes in the drainage pattern). In the latitudinal gradient of Chile more than twenty large reservoirs (> 20 hm^3) are located, and so far, only few investigations have been carried out on the geomorphological effects of reservoirs on Chilean rivers. In this research we examined morphological changes within the active channel downstream of dams in two gravel-bed rivers: the Elqui in the North (29°S), and the Biobío in the South (37°S). The Elqui River is regulated by the Puclaro reservoir since 1999 for irrigation, while the Biobío River is regulated by three reservoirs: Pangue (1996), Ralco (2004), and Angostura (2014), all for hydroelectric generation. The morphological changes were evaluated using satellite images, in a 16 km segment on the Elqui River and an 88 km segment on the Biobío River. The analysis were carried out to quantify the changes in the morphological units (bars, islands), channel patterns, and flow magnitude and frequency alterations (bankfull discharge, flow duration curves, Q_2).
Results showed a reduction in the magnitude of flows with a 2-year return period (Q_2) of 15% in the Elqui River, and 64% in the Biobío River (Villablanca et al., 2022). The active channel area was reduced by 58% in the Elqui River (1994-2011) and by 26% in the Biobío River (1994-2018). In both rivers, the active sedimentary areas (central bars) practically disappeared (-99% in the Elqui River and -96% in the Biobío River), which led to a simplification of the channel pattern. The main difference regarding geomorphological changes was observed in the areas covered with vegetation; while there was a decrease of 87% in the Elqui River, a 20% increase was observed in the Biobío the reduction in

vegetated areas in the Elqui may be related to the lower number of high flow pulses, which are necessary for the recruitment of young seedlings in semiarid ecosystems (Philipsen and Rood, 2022).

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Philipsen, Laurens J., Rood, Stewart B. (2022). Riparian recruitment persists after damming: Environmental flows and coupled colonization of cottonwoods and willows following floods along a dryland river. *River Research and Applications* ***38*** (9) https://doi.org/10.1002/rra.4030

Villablanca, L., Batalla, R. J., Piqué, G., & Iroumé, A. (2022). Hydrological effects of large dams in Chilean rivers. *Journal of Hydrology: Regional Studies*, ***41***, 101060. https://doi.org/10.1016/j.ejrh.2022.101060

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Spatial variation in geomorphic effects of 2022 floods in Yellowstone National Park

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In June 2022 an atmospheric river delivered 50–150 mm of rain to high-elevation snowpack in and around northern Yellowstone National Park, resulting in peak discharges on the Yellowstone River and its tributaries that at many gaging stations exceeded the flood of record, and at two exceeded the 0.2% (1 in 500) flood. These floods caused extensive channel change and infrastructure damage, closing large portions of the park and disrupting local economies. Extreme rain-on-snow floods, which have created large and persistent channel changes in Yellowstone in the past, are likely to be more common in the greater Yellowstone ecosystem and in other mountain landscapes as a result of climate change. Our research examines how the June 2022 event compares to historic floods in northern Yellowstone; the effect of the flooding on channel and floodplain morphology; physical controls on geomorphic response; and sediment connectivity, from hillslopes to channels and longitudinally in the channel network. To document the geomorphic changes caused by the floods, reconstruct flood hydraulics, and estimate sediment supply and transport dynamics, we completed field surveys, analysis of gaging station and lidar data, and hydraulic modeling, focusing on several gravel-bed tributaries to the Yellowstone River. Our observations suggest that, on the one hand, the greatest amounts of runoff were generated from high-elevation areas in the Beartooth Mountains, but on the other hand, substantial sediment supply derived from valley-fill erosion in lower-elevation regions of Yellowstone National Park with paraglacial, highly erodible hillslope sediments. As in many mountain rivers, alternation between erosional, confined reaches and depositional, less-confined reaches exerts strong control on sediment routing. Documentation of sediment connectivity and downstream variation in shear stresses can help inform decisions about infrastructure, such as where to reconstruct roads and bridges damaged by flooding, and about how to strengthen resilience to future impacts of extreme events.

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Geomorphic response of two gravel-bed rivers to the November 2021 atmospheric river and flood event in British Columbia, Canada: the role of sediment supply

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Spatial patterns of sediment availability may influence the morphological changes experienced by gravel-bed rivers during extreme flood events. An atmospheric river (AR) in November 2021 brought two days of intense rainfall to southwestern British Columbia (BC), Canada, leading to extreme flooding and landsliding across numerous watersheds in the region. Many channels experienced significant planform changes, including the Coquihalla River and Coldwater River along BC's Coquihalla Highway. The lateral channel instability of these two rivers resulted in severe damage to transportation infrastructure, with bridges and other sections of road left destroyed or inoperable, aiding the near complete isolation of Vancouver, BC by road and rail. Lidar data were collected one week after the flood event in support of engineering design efforts to rebuild the highway and mitigate other nearby infrastructure. We compared the post-flood event lidar to 190 km 2 of available pre-flood event lidar, capturing channel changes in 47 km of the Coquihalla River and 28 km of the Coldwater River, to determine locations of lateral instability within the captured reaches. The locations of large sediment inputs into these two rivers that were triggered by the AR event were mapped and analyzed in conjunction with the lidar comparison to identify relationships between local sediment sources and lateral channel instability. A key finding of this analysis was that the morphological changes that resulted in the most significant damage to linear infrastructure were associated with localized sediment input. Reaches without external sediment supplied were more likely to be laterally stable. Potential morphological impacts from nearby sediment sources should be considered when designing transportation and linear infrastructure in riparian environments, as the sediment supplied from these sources may cause lateral channel instability that impacts structural integrity.

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Monitoring and modelling riverine geomorphic evolution in response to leaky wooden dam installations

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Leaky wooden dams are an increasingly popular method of natural flood management (NFM). These are often installed as semi-permanent features through live felling and anchoring of tree branches and trunks in-situ within river channels. Currently, most modelling of NFM interventions is hydrological and focuses on flood risk without accounting for how sediment transport fluxes are altered and the geomorphic system evolves in response to these 'fixed' features. We argue that the assessment of the long-term effectiveness of NFM interventions requires an understanding of sediment transport processes and associated morphological feedbacks. Leaky dams that are designed to attenuate the hydrograph and 'slow-the-flow' may induce deposition and/or scour, potentially affecting the effectiveness of a leaky dam to reduce flood risk over time.

Here, we assess the influence of different storm scenarios on two leaky wooden dams in North Yorkshire, UK, through combining a new 'Working with Natural Processes' (WwNP) toolbox developed for the CAESAR-Lisflood model, along with repeat high-resolution surveys. The WwNP toolbox uses three parameters: gap size, height and roughness to simulate leaky wooden dams. The impact of these parameters on flood water storage and sediment transport is assessed by exposing the model reach to increasing storm durations and return periods.

Key findings include gap size as primary control for increased water storage, as well as controlling the ability of the structure to increase floodplain connectivity. Additionally, CAESAR-Lisflood can simulate the generation of underflow and plunge pools, as seen in field observations. Most importantly, results indicate that deposition and scour do play a crucial role in reducing or increasing water storage; simulated leaky wooden dams store up to twice as much water when sediment transport was modelled than when considering hydraulics alone.

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21st Century Channel Response of the Lower Rhine River to Climate Change and Human Intervention

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The lower Rhine River (300 km, Germany – the Netherlands) flows through the most densely populated region in Europe and is the backbone of inland navigation in the continent, with over 300 million tons of goods being transported every year (Jonkeren et al., 2014). As such, the river is intensely managed and monitored.

Domain-wide river training works were carried out in the lower Rhine during the 19th and 20th centuries with the aim to protect the land against floods and to improve navigation. These consisted of generalized channel narrowing (width reduction of 30-40%) and bend cutting (net shortening of about 10%). As a result, the channel bed has incised over the length of the river, thereby increasing profile concavity. This has led to up to 5 m of incision over the past century (Ylla Arbós et al., 2021). In addition, the bed surface grain size has become coarser over the whole domain, and the Rhine River's gravel-sand transition has migrated downstream and flattened, gradually fading.

While the lower Rhine continues to adjust to past human intervention, climate change increasingly alters the river controls through changes in precipitation, ice-, and snow-melt, and sea level rise, which in turn alter the hydrograph and sediment flux. Here we investigate the influence of climate forcing on channel response over the 21st Century. To do so, we set up a highly schematized one-dimensional numerical model of the lower Rhine River, representative of the current (period 1990-2020), non-graded state of the river, and subject it to scenarios of water discharge, sea level rise, and sediment flux, following climate scenarios.

Our results show that channel response in 2100 continues to be dominated by past human intervention, leading to over 1.5 m of river bed incision. Climate change adds up to this response, resulting in additional incision of up to 1 m. This is mostly due to hydrograph changes consisting of larger moderate-to-high discharges, which lead to a smaller equilibrium channel slope, achieved through river bed incision. The effects of other controls (sea level, sediment flux) appear to be minor, compared to the effects of a changing hydrograph. Interestingly, while channel response to human intervention slows down as the river approaches a new equilibrium state, channel response to climate change accelerates as the rate of change of river controls increases. As a result, the relative influence of climate forcing on channel response will likely increase with time.

Jonkeren, O., Rietveld, P., van Ommeren, J., & te Linde, A. (2014). Climate change and economic consequences for inland waterway transport in Europe. Regional Environmental Change, 14(3), 953–965. https://doi.org/10.1007/S10113-013-0441-7/TABLES/6

Ylla Arbós, C., Blom, A., Viparelli, E., Reneerkens, M., Frings, R. M., & Schielen, R. M. J. (2021). River Response to Anthropogenic Modification: Channel Steepening and Gravel Front Fading in an Incising River. Geophysical Research Letters, 48(4), e2020GL091338. https://doi.org/10.1029/2020GL091338

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Gravel bed Nilahue river after eruption: an emerging scenario for vegetation development. Eleven years after the Cordon Caulle eruption.

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Volcanic eruptions affect the dynamics of river corridors. They alter the drainage pattern and fluvial geomorphology by changing the sediment-wood supply regime, its deposition and transport, as well as the removal of vegetation cover (Pierson & Major, 2014; Swanson et al., 2013). The 2011 eruption of Cordón Caulle altered the biogeomorphological dynamics of the gravel bed of the Nilahue River in the south of Chile.

We processed RGB images from drone flights (between April 2021 and November 2022) to generate georeferenced orthomosaics (SfM) from create digital elevation models, to calculate DoDs and surface roughness of the confluence of the Nilahue River and Contrafuerte (1 km length). In addition, vegetation cover was sampled in 5 wood piles, along 3 transects from the centre outwards at 25 and 50 m, where diversity and abundance were measured in each 1 m² sampling plot in order to characterise vegetation regeneration in relation to wood jam and distance from the water table.

The results show that from October 2021 to April 2022 there is an increase in erosion of approximately 2 m associated with areas where the water sheet flows, from April to November 2022 there is an increase in deposition in areas abandoned by the flow. Roughness values are low throughout the study period with the exception of November 2022 with an increase in roughness at the margins of the sheet of water that is consistent with the increase in deposition. Regarding vegetation regeneration in November 2022 there is an abundance of herbaceous species in the areas adjacent (25 m) to the wood jam, decreasing towards the outer areas (50 m), while the distribution of shrub species shows an inverse pattern (greater at 50 m and decreasing in the 25 m zone). Tree species are abundant in the centre of the wood jam and minimal in the surrounding areas of 25 and 50 m. The biogeomorphological dynamics eleven years after the eruption of the gravel

bed of the Nilahue River tends towards a dynamic equilibrium, where the processes of erosion and deposition are concentrated at the margins of the sheet of water expressed in an increase in roughness, allowing us to observe a process of arboreal regeneration that dominates in the centre of the wood jam, herbaceous regeneration dominates in the adjacent area from the WJ (25 m and a dominance of shrubs in the area far from the accumulation (50 m).

This research is supported by the FONDECYT 1200079 project.

Pierson TC, Major JJ. (2014). Hydrogeomorphic Effects of Explosive Volcanic Eruptions on Drainage Basins. Annual Review of Earth and Planetary Sciences, 42(1), 469–507. doi:10.1146/annurev-earth-060313-054913

Frederick J. Swanson, Julia A. Jones, Charles M. Crisafulli, Antonio Lara (2013). Effects of volcanic and hydrologic processes on forest vegetation: Chaitén Volcano, Chile. Andean Geology 40 (2): 359-391. doi: 10.5027/andgeoV40n2-a10

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Characterization of gravel dunes in the free-flowing danube river east of vienna based on in situ observation

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At one of the last free flowing sections of the Austrian Danube River, a comprehensive monitoring within the scope of a restoration project was conducted over 15 years. Recurring bathymetric measurements using multi-beam echo sounders (MBES), however, revealed the occurrence of bedforms, which strongly influence bedload transport. Due to their grains-size composition and configuration these bedforms were characterised as gravel dunes. As dunes in gravel rarely are detected and described, the dune properties and propagation were investigated by surveys conducted every ten minutes over two hour intervals. The results show that the medium distance between the observed gravel dune crests lies at 10 m, the medium dune height is strongly dependent on discharge varying between 5 cm for low water levels and more than 30 cm with rising discharge. With the high temporal resolution measurements it was possible to delimit and track individual dunes. Dune velocities were recorded as up to 9 mh^{-1} with an average value of 5.26 mh^{-1}. A comparison with bedload measurements in the dune field showed, that, at least for medium discharges, almost the entire bedload transport takes place in form of dunes. The fact that dunes form and migrate under the given hydraulic boundary conditions can be explained by existing literature, but their occurrence even at low flow conditions is unusual. The findings presented have implications for process understanding, river management measures as well as for future restoration projects.