# International Symposium for Bedload Management

## Take-home messages from the workshops.

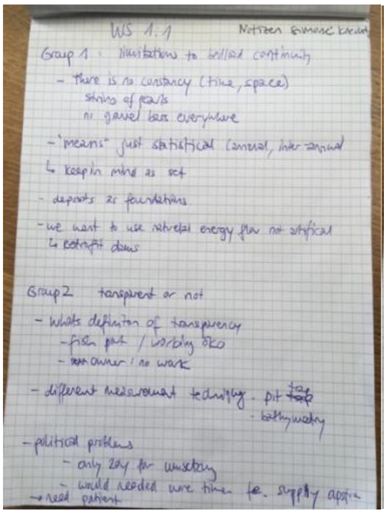
## 1.1 Workshop 1.1 «What are measures for sediment continuity at dams and weirs and proof of concept?»

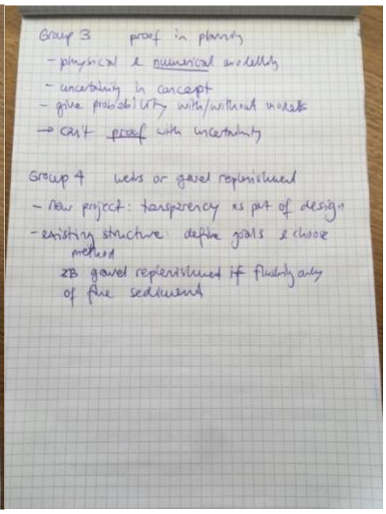
**Organization:**

- Moderation: Robert Boes (VAW)
- Input presentation: Melanie Bachmann (AXPO)

**Take-home messages:**

- Continuity
  - Continuity should not be confused with constancy.
  - It is important to differentiate continuity between the space and time domain.
    - *Variations over space*. In the downstream direction, river corridors can alternate between narrow confined transport reaches with wider response. In narrow reaches, sediment is flushed through. Gravel replenishment won't result in gravel bar deposition in narrow reaches but may accumulate in wider reaches downstream. <u>Don't expect excellent habitat uniformly along channel</u>.
    - *Variations over time*. Interannual variability: pronounced in Swiss rivers, and much greater in Mediterranean climate rivers. In this context, mean annual flow and sediment load are statistical artifacts.
  - Need to understand and quantify the "natural range of variability".
  - Ecological implications on restoring sediment continuity:
- Ecological implications
  - Case study data suggests (Trinity River), that on river stretches with a lack of bedload transport, habitat complexity increases following gravel additions until a peak is reached. Further additions of gravel can result in channel aggradation, for example filling pools, and resulting in a temporary homogenization of the channel.
  - When seeking to optimize the habitat in a richer stretch by adding gravel or ensuring the continuity of bedload transport, it is important to define the target species and respective live stages. It is moist likely not realistic to optimize habitats for all living organisms.
- Important context: Virtually all rivers are now regulated. Frequent floods have been cut off, although morphogenic flows may restore some of this lost dynamism.



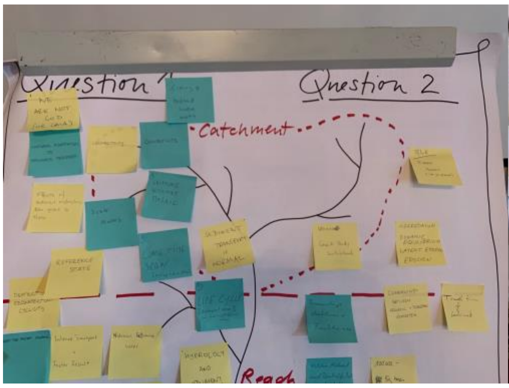
## 1.2 Workshop 1.2 «What is the role of bedload transport intensity for morphodynamics and ecology?»

**Organization:**

- Input presentation and moderation: Christine Weber (Eawag)

**Take-home messages:**

- Increasing our understanding in ecomorphological processes is important and urgent.
- Key questions to tackle:
  - Restorations target state is primordial: What do we want/can achieve?
  - Should the natural state be the target state after restoration? If so, how is it possible to describe the natural state of a dynamic system?
  - How to optimize data collection in view of the target condition? Time dimension and timing of the survey will be related to the lifecyle of the organisms and the hydrological flows. Physical and biological parameters may correlate positively or negatively.
  - Are the habitats that the engineers envision the habitats that appeal to the fish?
  - When a fish is the target species of the restoration, how to quantify if the fish is satisfied with the restored habitat?


## 1.3 Workshop 1.3 «What are new tools for predicting and monitoring bed load transport and depositions?»

**Organization:**

- Moderation: Martin Detert (Meiser Vermessungen)
- Input presentation: Fanny Ville (Universita Catalunia)

**Take-home messages:**

- Monitoring technologies
  - Direct methods
    - Retention basin (classic, point measurement)
    - Slot sampler, etc.. (classic, can provide continuous information)
    - Moving particles (classic, point measurement)
    - River widening (point measurement, being tested in several places to allow some sediment continuity)
    - Tracer Particles (classic)
      - Naturally magnetic (rarely applicable, can provide continuous information)
      - Passive tagging (CHF 10 per bedload particle, can provide continuous information)
      - Active tagging (CHF 100 per bedload particle – battery live problem, can provide continuous information)
  - Indirect methods
    - Active Sensors
      - ADCP (kind of new, provides continuous information)
      - Radar (classic, can provide continuous information)
      - Sonar (classic, can provide continuous information)
      - Camera (time-discrete measurement, although significant progress is being made)
        - Advances in technology allows extraction of information like difference in volume (erosion or deposition), DEM of the riverbed, or even the quantification of the change in GSD before and after an event.
    - Passive Sensors
      - Hydrophones (kind of new, mostly used in France, suitable for large rivers, provides continuous information)
      - Geophones and Accelerometers (classic, but significant progress is being made in the interpretation of the recorded signal, suitable for rivers with coarse GSD, can provide continuous information on transported GSD, intrusive)
      - Seismometers (new, significant progress is being made, great potential for rivers with coarse GSD, not intrusive)
- Prediction
  - Prediction, which is usually done with numerical models, requires accurate observations (monitoring) to calibrate the models.

## 1.4 Workshop 1.4 «How to approach risks and uncertainties of bedload restoration measures?»

**Organization:**

- Moderation: Christian Marti (Kt. LU)
- Input presentation: Roni Hunziker (HZP) und Urs Zehnder (Kt. LU)

**Take-home messages:**

- River engineering is not an exact science → based on assumptions, different results are obtained.
  - Yearly transported bedload volumes, grain sizes, flood events, external factors.
  - Calibration often difficult due to lack of geometry and only a few acquired data points.
- Important to consider in the planning of restoration measures: Monitoring, intervention options and flexibility.
- Boldness is needed to plan and implement bedload budget restoration measures
  - Learning through experience and adaptation of measures (adaptive management)
  - Considering a project as not finished after implementation. Point out adaptation possibilities already during planning.
- Transparency
  - Risks are better tackled with transparency.
  - Clear objectives before weighing interests.
  - Uncertainties, e.g. in models and calculations, must be well-founded and assumptions plausibly justified.
  - Providing a comprehensible explanation of the method used.
- Communication
  - Risk minimization can be achieved through communication strategies.
  - Cooperation at the specialist level.
  - Identify uncertainties by cooperating with other experts.
- Open questions
  - Is a deposition state preferable because of intervention and correction/adaptation possibilities?
  - After the implementation project, a maintenance is needed → problem of financing.

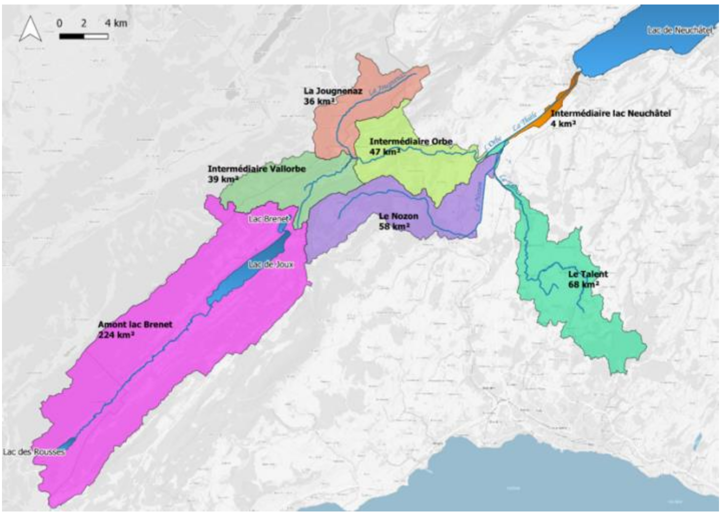
## 1.5 Workshop 2.1 «How to restore bedload transport at a cascade of installations?»

**Organization:**

- Moderation: Estelle Lecomte & Nicolas Michon (SIG)
- Input presentation: Marina Launay (Stucky)

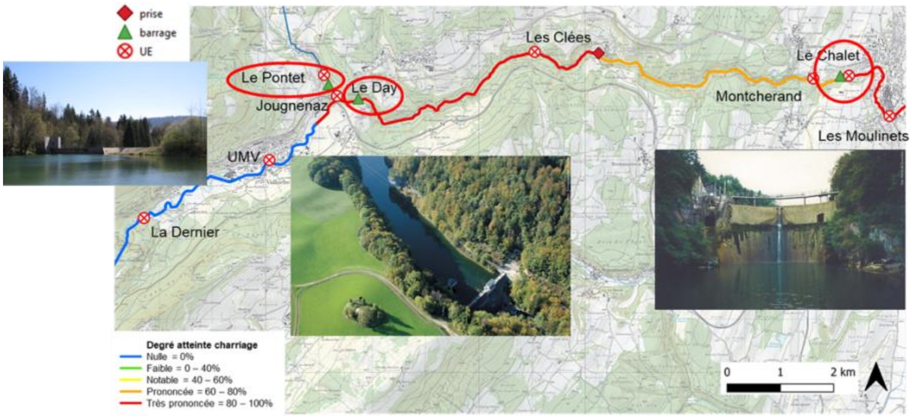
**Take-home messages:**

- Input presentation (case study).
  - The Orbe is a river in the Jura region, which originates in France in the Rousses area. The topographic catchment area of the Orbe is approximately 224 km² at Lake Brenet and 346 km² at Orbe. At its mouth in Lake Neuchâtel in Switzerland, the Orbe, which has been called Thièle since its confluence with the Talent, has a catchment area of some 475 km².




*Topographic catchment area of the Orbe (sources: FOEN, OpenStreetMap).*

  - The Orbe catchment area is marked by the presence of natural lakes, karstic areas, and caves, including the Vallorbe Cave. In its downstream part, the Orbe flows in its plain with a very low slope and a corrected morphology.
  - The Orbe River is used for hydroelectric power generation with five plants and a mini power station. Its tributary, the Jougnenaz, has two hydroelectric plants in Switzerland. The three most upstream Orbe facilities are operated by Romande Energie (la Dernier, les Clées and Montcherand). The Usines Métallurgiques de Vallorbe (UMV), the two most downstream facilities on the Orbe (Chalet and Moulinet) and the Pontet, the most downstream facility on the Jougnenaz, are managed by VOénergies.
  - In 2009, the Swiss Federal Assembly adopted several amendments to the Water Protection Act with the aim of promoting water renaturation. The amendments to the law are aimed in particular at improving the bedload regime of rivers. In a first phase of strategic planning completed in 2014, rivers with a particularly altered bedload regime and facilities that alter this regime were identified.
  - In the case of the Orbe catchment area, three facilities were selected as priorities for remediation measures: the Day and Chalet dams on the Orbe, and the Pontet dam on the Jougnenaz.




*Location of the three reservoirs concerned by the study of the remediation of the Orbe's bed load regime.*

  - The notion of deficit mentioned in the FOEN strategic planning is the difference between the amount of sediment transported in the initial state before the construction of dams and the amount of sediment transported in the current state. This deficit therefore depends heavily on the estimated natural input of sediment from tributaries and rivers. However, in the case of the Orbe, this remains very uncertain, particularly downstream of the Day. For example, the lateral contributions of the non-permanent watercourses on the sides of the gorges were not considered in the planning phase, which results in an underestimation of the initial transport.
  - Moreover, the application of the methodology of the remediation of the bed load to the Orbe is of particular interest, because it implies taking into account cascading effects at the level of different hydroelectric developments of different nature and scale, taking into account safety aspects once the restored bed load has reached the downstream part of the catchment area and the plain, and the search for synergies with the other components of the remediation (hydropeaking, fish migration and renaturation).
  - In the case of a cascade of installations, all the sediments are successively stopped in the reservoirs and the intermediate sections, this presents a significant deficit. The effectiveness of measures to remidiate sediment transport is therefore very limited unless a global action on the scale of the catchment is undertaken.
    If there are towns downstream of the developments, the postponement of sediment transport poses safety problems (flood management). This is particularly the case for the Orbe valley, located at the break in the slope of the Orbe before it enters the Orbe plain, which is very flat and has almost no transport capacity.

## 1.6 Workshop 2.2 «How to deal with fine sediments in the context of bed load restorations?»

**Organization:**

- Moderation: Chrystelle Gabbud (ALPIQ)
- Input presentation: Romain Dubuis (EPFL)

**Take-home messages:**

- Fine sediment is generally defined as particles < 2mm
- Target state is central.
- Monitoring and modelling
  - Challenge to differentiate between purely suspended clay, silt, and sand.
  - Input data is often hard to find for fine sediment
  - Multigrain sediment model → uncertainty considerable, partly due to the high number of parameters.
  - Target model identification is difficult. Guidelines would be helpful.
  - Modelling should be performed by experienced modelers.
  - Different scales for the model (local to catchment scale) depends on the question your addressing
- Ecological challenges regarding transport/deposition of fine sediment:
  - At the time being, a lot of unanswered questions. Ecological effects around fine sediments are complex.
  - Clogging can prevent ground water from being polluted with contaminated sediments, but
    - Clogging prevents water and oxygen exchange in the interstitial zone.
    - Negative effects on habitats are complex and poorly understood.
    - Lack of reliable tools (devices, guidelines) for decision makers

## 1.7 Workshop 2.3 «Down-to-earth sediment management in small catchments?»

**Organization:**

- Moderation: Simone Messner (Kt. ZH)
- Input presentation: Christian Tognacca (Laboratorium3D)

**Take-home messages:**

- Case study
  - Floods 29.08.2020 with large bedload inputs in 7 side streams on the Ticino River (30-100 annuality)
  - In contrast to bedload removal and disposal, the costs were lower, fewer transport kilometres and lower $CO_2$ emissions.
  - Bedload discharge into the Ticino via emergency law until authorisation was obtained after completion of the fills.
  - Floods in 2021 with bedload discharge in 10 side streams → bedload could be partially discharged at the same locations in Ticino.
  - Based on the procedure for remediation of the bedload budget in the Zurich municipalities, the workshop question was answered.
- Kt. Zurich published a procedure addressed to the municipalities for remediation of bedload budget.
- The following ideas emerged from the workshop:
  - Competition: which municipality can remove how much material, where, and at which cost?
  - Show community residents, workers and authorities how water bodies function (raising awareness on the topic)
  - Financial reward → create incentives!
- Important factors
  - Communication
    - Demonstrate goals
    - Bringing ecology closer
    - Imparting knowledge
    - Listening to and understanding the concerns of those affected, those in positions of responsibility
  - Best practice
    - Training/exercise → Remove bedload for "training purposes" and not during floods in an emergency → Demonstrate the effects of bedload and bedload removal
    - Monitoring of the facilities to reduce the fear when adjusting the management
    - Documentation of the work in order to make improvements in the future and to increase the wealth of experience.

## 1.8 Workshop 2.4 «How to plan and predict bed load additions?»

**Organization:**

- Moderation: Giovanni De Cesare (EPFL)
- Input presentation: Christian Mörtl (EPFL)

**Take-home messages:**

- Input presentation
  - It is important to identify the goals of the project.
  - Introduces different criteria
  - emissions ($CO_2$ and noise) from gravel transport is a problem
  - We do not plan enough bedload fill in the catchment area, but only take individual processes in individual sections into account.
  - The design of gravel fill is often determined by opportunities.
- The following ideas emerged from the workshop:
  - What are the objectives of bedload discharge or how are they defined?
    - by law
    - Habitats, diversity, morphology
    - Reference condition
    - Proportionality, values of society
    - Continuity (bedload)
    - Ecological functionality
    - Infrastructure protection
    - Ecosystem services
    - spatial and temporal dimensions
  - What are restrictions for bedload inputs?
    - Existing morphology
    - Infrastructure
    - Energy production (flexibility, quantity, price)
    - Space, access
    - Financing
    - Availability of materials
    - Sufficient flow conditions for transport
    - HPPP design
    - Limited to the available space
    - Design criteria for bedload input
    - How much, when, where (bedload and water)
    - Gravel size distribution
    - Gravel type, origin
    - Geometry, shape, size
    - Actual state of morphology
    - Integrated approach
    - Dealing with uncertainty
    - Robustness and flexibility of the measure
    - Monitoring during events
  - Assessment of success on the section
    - Has been mobilised

– Grain size distribution? Substrate composition?
– Morphological structures
– Ecological condition
– Time course of the condition
– Costs
– Social acceptance

– Longer discussion on $CO_2$ from trucks:

– Look at life cycle assessment globally: $CO_2$ from trucks is negligible compared to other $CO_2$ sources (transport, industry).
– However, the ecological benefit is great and cannot be achieved in any other way

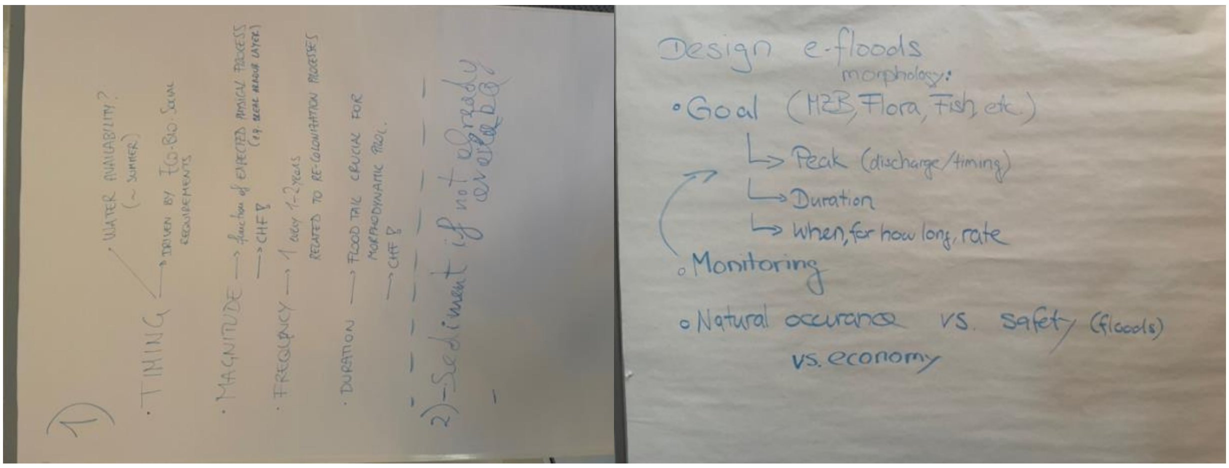
## 1.9 Workshop 3.1 «How to design and plan an environmental flow?»

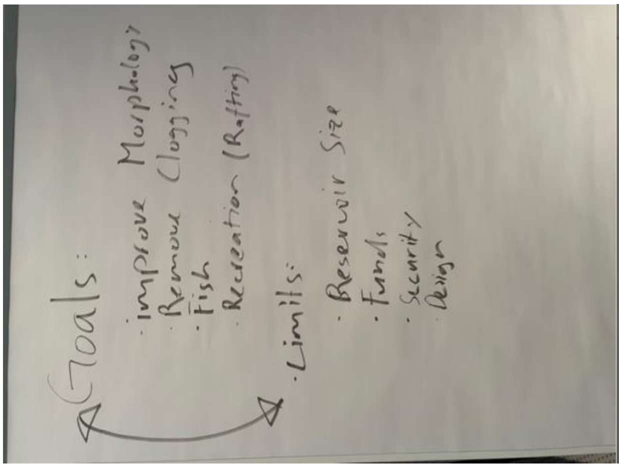
**Organization:**

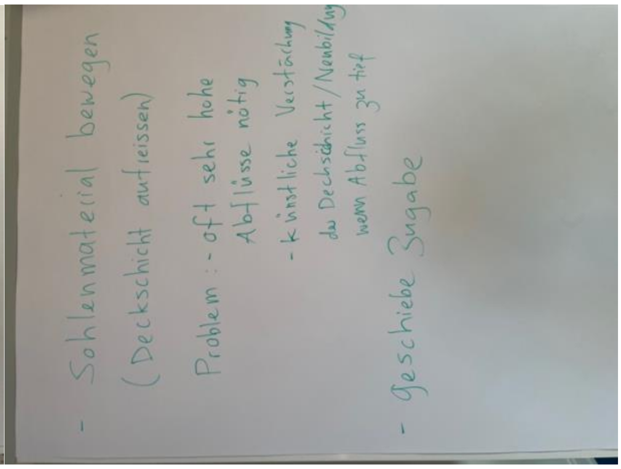
– Moderation: Michael Döring und Diego Tonolla (ZHAW)
– Input presentation: Michael Döring und Diego Tonolla (ZHAW)

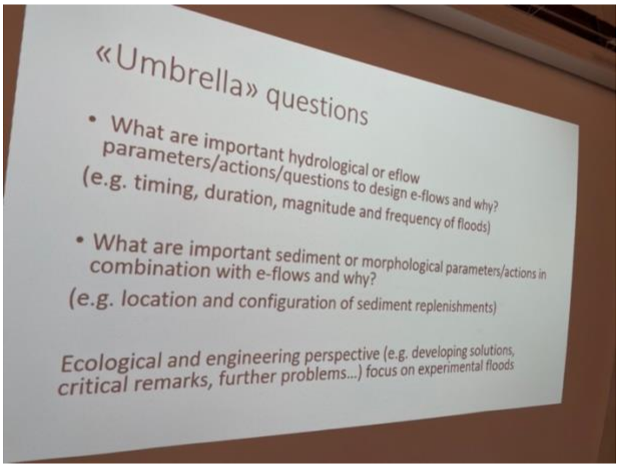
**Take-home messages:**

– Limitations: water availability, reservoir size, stretch length
– Dynamic processes for the design of e-flows -> with specific recommendations for every specific river
– First define goals -> measures are functions of goals
– 250m$^3$ flood and stand-up paddlers -> socialized aspect; Spöl: river to look as natural as possible
– Envolve more social scientists in e-flow planning?
– Because of social aspects, acceptance of projects
– How design e-flow to move sediments, riverbed
– Risk of building an additional armour layer on top, with gravel replenishment (?)
– Timing: once/year, 4-5/year
– Inn River: limited volume to play with
– Necessary magnitude to move riverbed: 20-50 HQ at Inn -> not possible, 15-30 HQ at Sihl -> too dangerous
– Habitat degradation
– Specific reiver region to be considered, so many different anthropogenic modifications
– US: add coarse sediment not required; evt. alle 2 Jahre en 1- und ein 2-jährlicher «e-flow», aber Abflussserhöhung, damit Lachse laichen, zu wenig Q um etwas rauszuspülen -> anderes Verständnis von «e-flow»










## 1.10 Workshop 3.2 «How can we prove the ecological success of bed load restoration?»

- Moderation: Cristina Rachelly (VAW)
- Input presentation: Michael Martin Kuhn (Axpo)

**Take-home messages:**

- Input presentation
  - Usual components of a monitoring campaign by Axpo AG for bedload remediation measures:
    - Bed survey: Cross-section profile or flat
    - Capture of morphological structures
    - Grain size distribution
    - Internal colmation
    - Brood density of gravel-spawning fish (e.g. grayling)
    - Juvenile density of gravel spawning fishes
    - Macrozoobenthos (rare)
    - Dragonflies (rare)
  - Bedload deposits: Location / shape / size / periodicity
  - Monitoring: total duration / time of start of monitoring after implementation / number of study years / frequency
    - Can the total duration / frequency of monitoring of bedload remediation measures be reduced at some point based on experience gained in other projects?

    - How long does the water body need to react to the remediation measure?
  - Difficulties in interpreting the monitoring results:
    - How should fluctuations in grayling larval density, for example, be interpreted?
- Discussion
  - Monitoring strategy: what difficulties arise? Choice of indicators? How are the temporal and spatial resolution / extent of monitoring chosen?
    - Clear definition of objectives and success parameters is important; goal-oriented design of the monitoring strategy.
    - Temporal / spatial resolution and extent:
      - Dependent on relevant processes (e.g. bedload vs. suspended sediment).
      - Dependent on boundary conditions (e.g. residual water stretch).
      - Under certain circumstances, it can take a very long time until the effects of bedload remediation are visible/detectable → flexible duration of monitoring.
      - Bedload remediation can affect long stretches of water! ("propagating effects") → should be considered in monitoring strategy.
        - Combination of local and regional indicators would be necessary.
      - Repeated measurements are essential to record the effects of a restoration measure and to adapt it if necessary ("adaptive management").
      - Where can costs be saved by reducing the temporal and spatial resolution without reducing the informative value?
    - Synergies with other measures and monitoring campaigns in the watercourse should be exploited.
    - Is sufficient attention paid to processes below the river bed in monitoring? (Especially based on biotic indicators)
  - Expected and unexpected experiences in monitoring bedload remediation measures:
    - Monitoring costs: difficult to estimate; long monitoring period requires complex contracts.
    - Winter floods have led to the washing out of spawning pits very soon after the implementation of a restoration measure → is the measure therefore not effective? Or should the monitoring period be extended in response?
    - Morphological and biotic effects of bedload remediation measures can have different spatial and temporal scales.
  - Varia
    - What happens specifically if monitoring cannot demonstrate the success of a restoration measure?
    - Difficulties in interpreting the monitoring results:
    - Statements can only be made relative to a reference condition
      → how is this defined? (discussion not only related to Switzerland)
    - Ecological functions of bedload are not easy to prove

## 1.11 Workshop 3.3 «What are important research gaps for successful projects?»

- Moderation: Robert Boes (VAW)
- Input presentation: Helmut Habersack (BOKU)

**Take-home messages:**

- Research gaps out of Input presentation.
  - Missing sediment data and sediment balance (v.a. high resolution and quality).
  - Model scale.
  - Interaction of flow with the nature and people.
  - Effects of climate + landuse change and socioeconomics.
  - Intergeneration equity and sustainability.
- Question 1: What are the important research gaps from your scientific and practical experience?
  - Missing data (field measurements, monitoring).
  - Defining bedload budget objectives (protection-use, time factor, bedload fine sediment).
  - Diverging interests.
  - Costs (monetary and ecological).
  - Eco-system services.
  - Improvement of models and modelling techniques.
  - New solutions (continuous dams).
- Question 2: How could these research gaps be closed and how could future research contribute?
  - Measure bedload transport.
  - Establish a measurement network.
  - Map and understand field work and processes in physical models.
  - Provide baseline data to improve calibration of models.
- Question 3: Which scientific approaches are needed to fill the research gaps?
  - Harmonise methods, e.g., in publication (manual).
  - Evaluate data on a supra-regional basis (Big Data) in cooperation with analysts and staff working on artificial intelligence.
  - Value the prize of ecological services.
- Question 4: How can the needed research be implemented, funded, and made available for practical application?
  - Applied research (promoting cooperation between research and practice) .
  - Knowledge transfer.
  - Better training.

## 1.12 Workshop 3.4 «How to improve bed load field measurements?»

- Input presentation and moderation: Dieter Rickenmann (WSL)

**Take-home messages:**

- What requirements would be ideally met for bedload measurements (in terms of spatial and temporal resolution, measurement accuracy, etc)?
  - High spatial and temporal resolution.
  - Measurement accuracy adapted to study goal(s).

  - Costs for measurements must be reasonable relative to study goal(s).
- How much will the requirements differ depending on the use/ application of the measurements for a specific purpose or project?
  - Measurement of bedload flux at a cross-section.
  - Partial information on sediment budget via repeated cross-section surveys (bed level changes).
  - Information on transport distances by repeated particle tracking.
- Why are there so few regular bedload measurements by river management authorities?
  - Possibly insufficient knowledge about indirect measuring methods.
- What is needed for a transfer/implementation of bedload measurements into a regular monitoring network (similar do discharge or suspended sediment measuring stations)?
  - Reasonably cheap measuring method; knowledge/awareness of stakeholders.
- How much calibration is required to transform surrogate signal to bedload transport?
  - Accuracy/uncertainty of calibration equation/procedure depends on number and mass of calibration samples.
- Is there a reasonably cheap system with a reasonable accuracy for more widespread application?
  - The most promising surrogate measuring methods are the Swiss plate geophone (SPG) system and the Japanese pipe microphone (JPM) system.
- What is the uncertainty of a given surrogate measuring system in terms of load or transport rates?
  - If there are sufficient calibration measurements available for the SPG system, the uncertainty is of the order of a factor of two.