Influence of fine sediments on the morphodynamics of an alternate gravel bar system in a harnessed mountain river

Influence des sédiments fins sur la dynamique des systèmes de bancs de galets alternés d'une rivière de montagne aménagée

Host laboratory :
RiverLy Research Unit, « River hydraulics » team
Irstea centre de Lyon-Villeurbanne,
5 rue de la Doua - CS 20244, 69625 Villeurbanne Cedex, France

PhD director :
Benoît Camenen, Irstea

Doctoral school :
MEGA, fluid mechanics, University of Lyon

Abstract:
The objective of this PhD work is to better understand the effects of fine sediments on the morphodynamics of gravel bars in engineered alpine rivers. Even if the morphology of these rivers is mainly controlled by bed load transport (and so coarse sediments), fine sediments do affect the dynamics though their interaction with bed load and vegetation through possible deposits on gravel bars. This study will be conducted on the Arc-Isère river system, which is characterized by alternate gravel bar system more or less vegetated and large concentrations of suspended sediment matter (SSM). Following the work of G. Antoine (2013), an important part of the work will be on the SSM dynamics, with a special focus on exchanges between the flow and gravel bars. Another objective is to extend local studies on gravel bars (PhDs of M. Jodeau, 2007, M. Jaballah, 2013, and C. Jourdain, 2016) to the whole river system. The study will be both experimental (field measurements, lidar and aerial picture analysis) and numerical (1D models). An important part of the scientific objectives will be to compare effects of flushing events carried out by the dam managers and natural floods on the morphodynamics of the river. This PhD work will be partly supported by EDF and the Arc-Isère collaborative study site of the ZABR (Zone Atelier Bassin Rhône), a regional multidisciplinary observatory for the Rhône river basin.

Résumé:
Ce travail de thèse concerne la morphodynamique des bancs de galets alternés sur les rivières alpines aménagées. Un objectif important de ce travail sera de mieux appréhender l'impact des sédiments fins sur la dynamique de tels systèmes, en particulier sur le possible atterrissement des bancs de galets, le développement de la végétation et éventuellement la forte réduction de leur dynamique. Cette étude sera réalisée sur le système Arc-Isère qui a en effet la particularité de transporter de grandes quantités de matériaux fins qui peuvent, par les dépôts et leur lien avec la végétation pionnière, fortement influencer les écoulements, le transport solide par charriage, et la morphodynamique des bancs. Dans la suite des travaux de G. Antoine (2013), un effort sera réalisé quant à la dynamique des matériaux en suspension (MES) et les échanges avec le lit moyen. Il s'agira aussi de replacer les études locales de bancs de galets (thèses de M. Jodeau, 2007, M. Jaballah, 2013, et C. Jourdain, 2016) dans leur contexte et de mieux appréhender leur représentativité au sein du système Arc-Isère. Cette étude sera expérimentale (mesures de terrain et traitement de lidar et photos aériennes) et numérique (modélisation 1D). Parmi les objectifs scientifiques, la comparaison entre les effets d'une chasse de barrages par rapport à une crue naturelle sera fondamentale pour les gestionnaires de la rivière. Cette thèse se fera en effet en collaboration avec EdF (CIH Chambery) dans le cadre du site atelier Arc-Isère de la ZABR.

1. Objectives

1.1 General PhD objective

The aim of the thesis is to better understand the interaction between fine sediments and the morphodynamics of a system of alternate gravel bars in an engineered alpine river. In particular, a special focus will be made on exchanges with the bed (erosion and deposit). This work will be done through in situ experimentation and one-dimensional modelling of fine sediment dynamics in the Arc-Isère system.

1.2 Profile of the candidate

Candidates must at least have basic knowledge in the following disciplines:

- River hydraulics, sedimentary transport, geomorphology
- Numerical modeling, programming (Fortran, Matlab)
- GIS, remote sensing, image processing
- French, scientific English

1.3 Supervision and collaboration

This PhD project will be co-funded by Irstea and EDF-CIH through some expertises on the Arc and Isère river system during flushing events.
B. Camenen (HDR, Irstea RiverLY) will supervise this PhD project with an inscription at the university of Lyon at the doctoral school MEGA (speciality: fluid mechanics).
A scientific committee will be created to follow and advise the student. It should include Lionel Pénard (Irstea Lyon), Magali Jodeau (EDF-LNHE), Guido Zolezzi (University of Trento, Italy), Alain Recking (Irstea Grenoble), Cédric Legout (IGE, Grenoble), Eric Valette (EDF-CIH), and Christophe Dal'Osto (SISARC).
Scientific and technical exchanges will be made with different teams such as Hydrimz (IGE), EDF (CIH, DTG et LNHE) or Irstea Grenoble thanks to a ANR (2018 call). The PhD student is expected to participate to field measurements in collaboration to partners. It will also be useful to meet local river managers (SISARC) to discuss on actual river restoration in the Combe de Savoie.

2. State of the art and context

2.1 Engineered rivers

Most European alpine rivers are fully modified with the construction of dikes and hydro-electric infrastructures (Gregory, 2006, Piégay, 2005, Martin-Vide, 2001). Mountain and alpine rivers have been reshaped in a single channel to prevent from flood risk in a context of constrained systems. It led to several morphologic disequilibrium such as a limitation of the maximum flow competence, with a possible fixation of large bedforms, and a poor water quality. Some of these rivers evolved to a system of alternate bars due to the reduction of lateral mobility and a still important sediment input (Jaeggi, 1984, Lisle et al., 1991). Such system will develop naturally as free bars or forced bars due to a bend or the presence of a bridge pier (Crosato & Mosselman, 2009, Zolezzi & Seminara, 2001, Jaballah et al., 2015). Impacts of hydro-electric infrastructures are twofold: (i) limitation of the sediment continuity, sediments being trapped by dam reservoirs, and (ii) perturbation of the natural system due to compensation water, water derivation, and/or dam flushing. Such system often evolved an erosive river downstream. Kondolf (1997) described such river flow dynamics as "hungry water".

If the system also presents a reduction of the energy available to transport sediments (due to dam presence), mobile gravel bars are eventually fixed with a development of vegetation as it has been observed on the Isère River (Allain-Jegou C., 2002; Moulin, 2005; Jourdain, 2017). On the other hand, large amounts of sediment have been dredge until the 90s and significantly impact the morphology of the river together with the modified water regime because of hydropower infrastructures. Such system evolves toward a system of gravel bars with a reduced mobility and shorter periods underwater. Jourdain (2017) observed that the system becomes quickly irreversible when the vegetation develops since large deposits may accelerate the disconnection between main channel and gravel bars (Rodrigues et al., 2005 ; Camenen et al., 2016). Pioneer vegetation develops and eventually high vegetation spreads irreversibly such as large flood could not wash out the gravel bar anymore. On the opposite, the flow concentrates to the main channel (Jang & Shimizu, 2007), which limits its potential of erosion and signifiant deposits of fine sediment may be observed and worsen the situation. This development of vegetation is closely related with the duration of exposition underwater as well and the depth of the water table. Some technical solutions exists to limit the development of vegetation (clearing and levelling of gravel bars) but they are expensive and not necessarily sustainable (Allain Jegou, 2002; Jourdain, 2017).

There exists only few studies on the potential impact of fine sediment on the gravel bar dynamics and they mainly deal with pioneer vegetation (Gilvear et al., 2005 ; Gilvear & Willby, 2006). Gravels bars form an important part of the fine sediment stock (Salant et al., 2008; Marttila & Klove, 2014). Physical and chemical characteristics of fine sediments control erodability (Grabowski et al., 2011, Droppo et al., 2015) and my influence coarse particle dynamics (Perret et al., 2015, Perret, 2017)

2.2 Local context of the study

An increase of the flood risk due to vegetation development is typically observed at the Combe de Savoie reach on the Isère River where the river slope is relatively small (0,1%) compared to the Arc River. Also, several restoration strategies has been attempted by river managers to limit the vegetation such as clearing and levelling of gravel bars. Another issue is about the possible spread of the vegetation upstream on the Arc River as it was observed 30 years ago. The Arc-Isère river although specific remains typical among alpine engineered rivers. Its study could be easily transposable to other French rivers such as the Arves River or the Durance River, but also to other European rivers (Lech, Gremany ; Drau, Austria ; Swiss Rhône ; Adige, Italy ; etc.)

The Arc-Isère river system is one of the study sites of the ZABR (Zone Atelier du Bassin du Rhône; inter-disciplinary working group on the Rhône catchment) since 2008, which enhance collaboration between different laboratories of the region. In collaboration with EdF, le SPC Alpes du Nord, l'IGE et la DREAL Rhône-Alpes, a network of hydro-sedimentary stations (water discharge, fine sediment concentrations) has been build within the Arc-Isère catchment. The River hydraulic team works specifically on the Arc River the end of the 90s, first as experts to evaluate the impact of the motorway construction on the river morphodynamics, then trough the study of some specific reach (PhDs of Magali Jodeau, 2007, and Mohamed Jaballah, 2013). Flushing events are studied since 2005 with specific effort on the fine sediment dynamics using both experimental measurement and 1D modelling (PhD of Germain Antoine, 2013). Some effort have been done recently on the estimation of fine sediment dynamics over gravel bars (Camenen et al, 2013, 2016). In particular, camera have been fixed to provide daily shots of gravel bars in order to evaluate time evolution of the fine sediment surface deposits. Indeed, erosion and deposition of fine sediment over gravel bars remains complex to model in both small and large scale. This is the key issue of the proposed PhD work.

3. Work program

3.1 Scientific objectives

Scientific objectives of this PhD projects are three-fold :

- identify and quantify the gravel bar dynamics along the Arc-Isère river system together with their sedimentation and vegetation rate. Such work will be achieved thanks to an analysis of recent Lidar data sets and corresponding aerial pictures. Such study should also allow to evaluate the quantity of fine sediments available in the system;
- propose some fields experiments on one or several pilot site in order to better understand fine sediment (i.e. deposits) dynamics and to relate it to hydrology. Such sites could be those already instrumented with time-laps camera;
- develop a 1D model based on the software AdisTS developed at Irstea and more specifically improve the source term (erosion ans deposition) representation in order to reproduce fine sediment dynamics along the Arc-Isère river system for typical events (flush or flood).

3.2 Calendar

- Spring 2018 : selection of the candidates
- Autumn 2018 : start of the PhD
- 2018-2019 (1st year):
  - *Bibliography* ;
  - *Remote sensing* : Creation of a data base listing characteristics (surface, volume, vegetation cover, etc.) of gravel bars along the Arc-Isère system for different dates, analysis;
  - *Field experiments* : First experimentations and tests on the fine sediment dynamics over gravel bars ; first analysis of the photograph taken daily on different gravel bars ;
  - *Numerical modelling*: get familiar with 1D models of the Arc and Isère rivers (RubarBE, AdisTS) ;
  - *Writing* : Conference, paper in an international journal (lidar and aerial picture analysis), annual report.
- 2019-2020 (2nd year):
  - *Field experiments* : Study of deposit dynamics on several test cases (drone picture, daily picture from the bank, topographic and grain size distribution measurements etc.)
  - *Numérique* : Application of AdisTS on typical events in the Arc and Isère river. Development et validation of erosion/deposition terms on instrumented test cases ;
  - *Writing* : Conference, paper in an international journal (analysis of deposit dynamics over gravel bars), annual report.
- 2020-2021 (3rd year):
  - *Fiel experiments* : Study of some specific events to complete the data set if necessary.
  - *Numérique* : Development and calibration of a vegetation module in AdisTS to be able to model long-term evolution of the river system, prospective simulations
  - *Rédaction* : paper in an international journal (numerical modelling), PhD report
- Autumn 2021: PhD defense

4. References

4.1 References from the team

Antoine G. (2013). Dynamique des matériaux en suspension le long de rivières aménagées de montagne. Exemple de l'Arc en Maurienne et de l'Isère. PhD thesis, Université de Grenoble, France, 282 p.

Antoine G., Jodeau M., Camenen B., Esteves M., Nemery J. & Lauters F. (2013).Estimation des flux de matières en suspension lors des chasses hydrauliques de l'Arc de 2006 à 2011. La Houille Blanche, 4:43-49.

Balayn, P., Paquier, A. & Lapuszek, M. (2003). 1-D sediment transport model: representation of mixtures and calibration, in proceedings of the XXXth IAHR congress, Thessalonique, GRC, 24-29 August 2003, pp. 557-564.

Caillaud R. (2013). Modélisation hydrosédimentaire de la dynamique des matières en suspension dans l'Arc et l'Isère. Stage fin étude ingénieur, Centrale Lyon.

Camenen B., (2007). A simple formula for the settling velocity of particles, J. of Hydraulic Eng., 133(2), 229-233,

Camenen B. (2012). Discussion of "Understanding the influence of slope on the threshold of coarse grain motion: Revisiting critical stream power" by C. Parker, N.J. Clifford, & C.R. Thorne. Geomorphology 139-140: 34-38.

Camenen B., Bayram A. & Larson M. (2006). Equivalent roughness height for plane bed under steady flow, J. of Hydraulic Eng., 132(11), 1146-1158,

Camenen B., Jodeau M. & Jaballah M. (2013). Estimate of fine sediment deposit dynamics over a gravel bar using photography analysis. Int. J. of Sediment Res. 28(2): 220-233.

Camenen B., Jodeau M. & Le Coz J. (2008). Modélisation du flux sédimentaire pendant une chasse hydraulique (Arc en Maurienne), La Houille Blanche (4) 83-89.

Camenen B. & Larson M. (2005) A bed-load transport formula for the nearshore, Estuarine Coastal and Shelf Science, (63) 249-260.

Camenen, B., Perret, E., Herrero, A., Berni, C., Thollet, F., Buffet, A., Dramais, G., Le Bescond C., & Lagouy M. (2016). Estimation of the volume of a fine sediment deposit over a gravel bar during a flushing event. Proc. River Flow conference, St Louis, Missouri, USA, July 2016, CDRom, pp. 533-540.

Cordier, F., Tassi, P., Jodeau, M., & Camenen B. (2016). Large-scale morphodynamics structures in the Arc en Maurienne River (France). Proc. River Flow conference, St Louis, Missouri, USA, July 2016, CDRom.

Dugué V. (2009). Modélisation morphodynamique d'une rivière de montagne : l'Arc en Maurienne. Stage fin étude ingénieur / Master 2, ENSEEIHT, Université Paul Sabatier, Toulouse.

Eldin C. (2012). Les bancs de graviers de l'Arc en Maurienne : Constitution d'une base de données et analyse de l'évolution des bancs de graviers à partir d'un levé Lidar et de données image. Master 2, Université Paris 1 Panthéon Sorbonne.

El kadi Abderrezzak, K., (2006). Evolution d'un lit de rivière en fonction des apports. Thèse de Mécanique à l'Université Claude Bernard Lyon 1.

El kadi Abderrezzak, K., Paquier, A. & Gay, A., 2008. One-dimensional numerical modelling of dam-break waves over movable beds: application to experimental and field cases. Environmental Fluid Mechanics, vol. 8, p. 169-198.

Guertault, L., Camenen B., Peteuil, C., Paquier, A. (2014). Long term evolution of a dam reservoir subjected to regular flushing events. Advances in Geosciences 39: 89-94.

Guertault, L., Camenen B., Peteuil, C., Paquier, A. (2016). One-dimensional modelling of suspended sediment dynamics in dam reservoirs. J. Hydraulic Eng. 04016033:1-9.

Jaballah M. (2013). Alternate bar morphodynamics in an engineered mountainous river [Morphodynamique des bancs alternés d'une rivière de montagne aménagée], PhD thesis, Université C. Bernard, Lyon, France, 196 p. (en anglais).

Jaballah, M., Camenen, B. & Paquier, A. (2015). Alternate bar development in an alpine river following engineering works. Advance in Water Res. 81:103-113.

Jodeau, M. (2007). Morphodynamique d'un banc de galets en rivière aménagée lors de crues. Thèse de Mécanique à l'Université Claude Bernard Lyon 1.

Jodeau M., Hauet A., Paquier A., Le Coz J. & Dramais G. (2008). Application and evaluation of LS-PIV technique for the monitoring of river surface velocities in high flow conditions. Flow Measurement and Instrumentation, 19(2): 117-127.

Launay, M., Le Coz, J., Angot, H., Dramais, G., Andriès, E., Camenen, B., & Coquery M. (2015). Numerical and physical simulation of soluble contaminant transport through complex large river systems. J. Hydro-engineeing Res. 9:120-132.

Lauters, F., Laperrousaz, E., Camenen, B., Le Coz, J., Thollet, F., Némery, J., & de Linares, M. (2012). Vers une gestion sédimentaire durable de l'aménagement hydro-électrique Arc-Isère, La Houille Blanche, 1:19-25.

Paquier, A. (2003). Aperçu sur le transport de sédiments en rivière. Application à l'Arc. Académie d'Agriculture de France, 89(3): 10.

Paquier, A. & Khodashenas, S.R. (2002). River bed deformation calculated from boundary shear stress. Journal of Hydraulic Research, 40(5): 603-609.

Pénard, L. & Morel, M. (2012). Automatic detection of gravel bars in a river channel from airborne LiDAR-derived DTM. HIC - 10th International Conference on Hydroinformatics, Juil. 2012, Hambourg, Allemagne. 8 p.

Perret, E., Herrero, A., Berni, C., El kadi Abderrezzak, K. & Camenen, B. (2015), Incipient motion of a bimodal mixture of gravel and silt: a laboratory experimental study. Proc. 36th IAHR Congress, 8p.

Perret, E. (2017). Transport of moderately sorted gravels at low bed shear stresses : impact of bed arrangement and fine sediment inltration. Université Claude Bernard, Lyon 1, 373p.
Ramez, P. (2005). Formation de bancs dans un lit endigué. Partie 1 : théorie. Houille Blanche, vol. 6, p. 20 - 28
Ramez, P. (2005). Formation de bancs dans un lit rectiligne. Partie 2 : calage et application . Houille Blanche, vol. 6, p. 29 - 37
Ramez, P. & Paquier, A. (2004). Morphologie des rivières à gravier pavées avec berges érodables. Partie 1 : valorisation d`expériences de laboratoire. Houille Blanche (5): 101-106.
Ramez, P. & Paquier, A. (2004). Morphologie des rivières à gravier pavées avec berges végétalisées. Partie 2 : validation sur des mesures in situ. Houille Blanche (5): 107-114.

4.2 Other references

Allain-Jegou C. (2002). Relations végétation-écoulement-transport solide dans le lit des rivières - Etude de l'Isère dans le Grésivaudan. PhD Thesis, Institut National Polytechnique de Grenoble, Grenoble, France.
Artelia Eau et Environnement (2013). Evolution du lit de l'Isère: Synthèse diagnostique, contribution á l'élaboration d'un plan de gestion et accompagnement des acteurs locaux; Volet 1: Etude globale pour la gestion du tranport solide Dreal Rhône - Agence de l'Eau RMC
Bartholdy, J. & Billi, P. (2002). Morphodynamics of a gravel bar reach. Geomorphology, 42: 293-310.
Brandt, S. (1999). Sedimentological and geomorphological effects of reservoir flushing : The Cachi reservoir, Costa Rica, 1996. Geografiska Annaler A, 81:391-407.
Brandt, S. (2000). Classification of geomorphological effects downstream of dams. Catena, 40: 375-401.
Brandt, S. (2005). Conceptualization of hydraulic and sedimentary processes in downstream reaches during flushing of reservoirs. In proceedings of the XXXI IAHR Congress, Seoul, Korea, 2577-2588.
Crosato A. & Mosselman E. (2009). Simple physics-based predictor for the number of river bars and the transition between meandering and braiding. Water Resour. Res 45(W03424):1-14.
Diplas, P. & Parker, G. (1992). Deposition and removal of fines in gravel-bed streams. In Billi, P., Hey, R.,Thorne, C. et Tacconi, P., éditeurs : Dynamics of gravel bed rivers, 313-329. Wyley & Sons. 11
Droppo, I. G., D'Andrea, L., Krishnappan, B. G., Jaskot, C., Trapp, B., Basuvara, M. & Liss, S. N. (2015). Fine-sediment dynamics: towards an improved understanding of sediment erosion and transport J. Soils & Sediments, 15: 467-479.
Dufour, S., Barsoum, N., Muller, E. & Piégay, H. (2007). Effects of channel confinement on pioneer woody vegetation structure, composition and diversity along the River Drôme (SE France). Earth Surface Processes and Landforms, 32 (8): 1244-1256
EdF (2002). Note de synthèse « chasses et curages de l'Arc », perspectives EdF. Rapport EdF.
Edwards, P., Kollmann, J., Gurnell, A., Petts, G., Tockner, K. & Ward, J. (1999). A conceptual model of vegetation dynamics on gravel bars of a large alpine river. Wetlands Ecology and Management, 7:141-153.
Fasolato, G., Ronco, P., & Tregnaghi, M. (2006). Morphodynamics of mountain rivers following repeated sediment release from reservoirs. In River Flow 2006, 1329-1336.
Gilvear, D., Francis, R., Willby, N. et Gurnell, A. (2005). Gravel bars : a key habitat of gravel bed rivers for vegetation. In Gravel bed rivers 6. 12 p.
Gilvear, D. & Willby, N. (2006). Channel dynamics and geomorphic variability as controls on gravel bar vegetation, River Tummel, Scotland River Res. and Applications, 22:457–474.
Grabowski, R. C., Droppo, I. G. & Wharton, G. Erodibility of cohesive sediment: The importance of sediment properties Earth-Science Reviews, 2011, 105, 101-120.
Gregory, K. (2006). The human role in changing river channels. Geomorphology, 79:172-191.
Hydratec & Irstea. (1999). Etude hydraulique de l'Arc de Maurienne (de Modane à l'Isère), Morphologie du lit de l'Arc. Rapport.
Jaeggi, M. (1984). Formation and effects of alternate bars. Journal of Hydraulic Engineering, 110:142-156.
Jang, C. J.& Shimizu, Y. (2007). Vegetation effects on the morphological behavior of alluvial channels. Journal of Hydraulic Research, 45 (6): 763-772.
Jourdain C. (2017). Les interactions entre le transport sédimentaire, l'hydrologie et la végétation dans la capacité d'auto-entretien d'un lit de rivière. Université de Grenoble, France
Kondolf, G. (1997). Hungry water : Effects of dams and gravel mining on river channels. Environmental Management, 21:533-551.
Krone, R. (1962). "Flume studies of the transport of sediment in estuarial shoaling processes." Final Rep., Univ. of Califormia, Berkeley, CA.

Langlade, L.-R. & Décamp, O. ,(1995). Accumulation de limon et colonisation végétale d'un banc de galets. Comptes rendus de l'Académie des Sciences Paris, Science de la vie, 318:1073-1082.
Lisle, T., Ikeda, H., & Iseya, F. (1991). Formation of stationary alternate bars in a steep channel with mixed-size sediment: a flume experiment. Earth Surface Processes and Landforms, 16:463-469.
Marnezy A. (1999). L'Arc et sa vallée ; anthropisation et géodynamique d'une rivière alpine dans son bassin versant. Thèse de doctorat à l'université Joseph Fourier Grenoble I.
Martin-Vide, J. , (2001). Restoration of an urban river in Barcelona, Spain. Environnemental Engineering Policy,2:113-119.
Marttila, H. & Klove, B. (2014). Storage, properties and seasonal variations in fine-grained bed sediment within the main channel and headwaters of the River Sanginjoki, Finland Hydrological Processes, 28: 4756-4765
Moulin, B. (2005). Variabilité spatiale et temporelle du bois mort dans le réseau hydrographique de l'Isère à l'amont de Grenoble. Thèse de doctorat, Université Jean Monnet, St Etienne, France.
Mürle, U., Ortlepp, J., & Zahner, M., 2003. Effects of experimental flooding on riverine morphology, structure and riparian vegetation: the River Spöl, Swiss National Park. Aquatic Science, 65:191-198.
Partheniades, E. (1962). – A study of erosion and deposition of cohesive soils in salt water. Ph.D thesis, University of California, Berkeley, 182 p.
Piégay, H. (2005). Editorial : sediment management in river systems : a need to assess changing processes in the long term and at a large scale. River Research and Applications, 21:689-691.
Poirel, A. (2001). la gestion des sédiments par chasse (1) : retour d'expérience sur quelques aménagement hydrauliques alpins. La Houille Blanche, 6-7:55-61.
Rathburn, S. & Wohl, E. (2003). Predicting fine sediment dynamics along a pool riffle mountain channel. Geomorphology, 55:111-124.
Rodrigues, S., Bréhéret, J. G., Moatar, F. & Macaire, J.-J. (2005) Impact des crues sur des bilans sédimentaires de chenaux secondaires de la Loire moyenne. Géomatériaux (Sédimentologie), 337 : 487-495
Salant, N. L., Hassan, M. A. & Alonso, C. V. (2008). Suspended sediment dynamics at high and low storm flows in two small watersheds Hydrological Processes, 22: 1573-1587.
Surian, N. (1999). Channel changes due to river regulation : the case of the Piave River, Italy. Earth Surface Processes and Landforms, 24:1135-1151.
van Oorschot, M., Kleinhans, M. G., Geerling, G. W., Egger, G., Leuven, R. S. E. W. & Middelkoop, H. (2017). Modeling invasive alien plant species in river systems: interaction with native ecosystem engineers and effects on hydro-morphodynamic processes .Water Resources Research (in press).
Ziegler, C. & Nisbet, B. (1994). Fine-grained sediment transport in Pawtuxet river, Rhode Island. Journal of Hydraulic Engineering, 120:561-575.
Zolezzi G, Luchi R, Tubino M. (2009). Morphodynamic regime of gravel bed, single thread meandering rivers. J Geophys Res. 114(F01005):1-14.
Zolezzi G, Seminara G. (2001). Downstream and upstream influence in river meandering. Part 1. General theory and application to overdeepening. J.Fluid Mech. 438:183-211.