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1 Executive summary

This deliverable summarises the work related to WP2 in NAIAD through the production and submission of a series of papers. The deliverable provides abstracts and links for papers that describe the work done across the demos in biophysical characterisation of NBS effectiveness.

A total of 23 abstracts and links to already prepared, submitted or published papers as part of the NAIAD project are provided in part A while a further 16 links to abstracts and working documents are provided in part B. These are papers that are being prepared as part of WP2 in NAIAD and will be published immediately post NAIAD.

NAIAD consortium will follow Open Access practises to provide free online access to the scientific information that will be published as a result of the project development and implementation. With this, NAIAD Project pretends to contribute to Europe 2020 strategy to improve access to scientific information and to boost the benefits of public investment in research funded under Horizon 2020.



2 Introduction

Aim of deliverable

This deliverable **summarises the work related to WP2 in NAIAD through the production and submission of a series of papers.** The papers are submitted for separate publication so are not copied here but this deliverable brings extended abstracts for these papers together as a group, within the context of previous deliverables. The deliverable provides abstracts and links for papers that describe the work done across the demos in biophysical characterisation of NBS effectiveness. Most of these papers are joint efforts between NAIAD researchers from different demos.

This deliverable consists of two parts. Part A, provides abstracts and links to papers that have already been published or are under review. All these papers were fully or partially developed under the NAIAD project. Part B provides links to documents with extended abstracts for papers that are being prepared as part of WP2 in NAIAD and will be published immediately post NAIAD.



3 Part A: Abstracts of already prepared, submitted or published NAIAD papers

S. Dupire, Thomas Curt, Sylvain Bigot. Spatio-temporal trends in fire weather in the French Alps. Science of the Total Environment, Elsevier, 2017, 595, pp.801 - 817. [10.1016/j.scitotenv.2017.04.027](https://doi.org/10.1016/j.scitotenv.2017.04.027), Open access: [hal-01510628](https://hal.archives-ouvertes.fr/hal-01510628)

The Alpine area is particularly sensitive to climatic and environmental changes that might impact socio-ecosystems and modify the regime of natural hazards. Among them, wildfire is of major importance as it threatens both ecosystems and human lives and infrastructures. Wildfires result from complex interactions between available vegetation fuels, climate and weather, and humans who decide of the land use and are the main source of fire ignitions. The changes in fire weather during the past decades are rather unknown in the French Alps especially due to their complex topography. Moreover, local institutions and managers wonder if the ongoing climate changes might increase fire risk and affect the environmental quality and the different ecosystem services provided by the mountain forests. In this context, we used the national forest fires database together with daily meteorological observations from 1959 to 2015 to investigate the changes in wildfire danger in the French Alps. We analysed the spatial and temporal variations in terms of intensity, frequency, seasonality and window of opportunity of two fire weather indices: the fine fuel moisture code (FFMC) and the fire weather index (FWI) that measure the daily water content of vegetation and the potential intensity of fires, respectively. Our results showed a major contrast between Southern Alps with a high fire weather danger on average and a significant increase in the past decades, and Northern Alps with low to moderate danger on average that increased only at low elevations. This study contributes to the understanding of the consequences of ongoing climate changes on wildfires in the French Alps. It produced high resolution results that account for the topographic and climatic variability of the area. Finally, the maps of the different fire weather components have practical implications for fire management and modelling and for preventing indirect effects of fires on ecosystems and human assets.



S. Dupire, Thomas Curt, Sylvain Bigot, Thibaut Fréjaville. Vulnerability of forest ecosystems to fire in the French Alps. European Journal of Forest Research, Springer Verlag, In press, [10.1007/s10342-019-01206-1](https://doi.org/10.1007/s10342-019-01206-1). Open access: [hal-02163692](https://hal.archives-ouvertes.fr/hal-02163692)

Forest fires are expected to be more frequent and more intense with climate change, including in temperate and mountain forest ecosystems. In the Alps, forest vulnerability to fire resulting from interactions between climate, fuel types, vegetation structure and tree resistance to fire is little understood. This paper aims at identifying trends in the vulnerability of Alpine forest ecosystems to fire at different scales (tree species, stand level and biogeographic level) and according to three different climatic conditions (cold season, average summer and extremely dry summer). To explore Alpine forest vulnerability to fire, we used surface fuel measurements, forest inventory and fire weather data to simulate fire behaviour and ultimately post-fire tree mortality across 4438 forest plots in the French Alps. The results showed that cold season fires (about 50% of the fires in the French Alps) have a limited impact except on low-elevation forests of the Southern Alps (mainly Oak, Scots pine). In average summer conditions, mixed and broadleaved forests of low elevations suffer the highest mortality rates (up to 75% in coppices). Finally, summer fires occurring in extremely dry conditions promote high mortality across all forest communities. Lowest mortality rates were observed in high forest stands composed of tree species presenting adaptation to surface fires (e.g. thick bark, high canopy) such as Larch forests of the internal Alps. This study provides insights on the vulnerability of the main tree species and forest ecosystems of the French Alps useful for the adaptation of forest management practices to climate changes.

Piton, G.; Recking, A.; Le Coz, J.; Bellot, H.; Hauet, A. & Jodeau, M. 2018, Reconstructing depth-averaged open-channel flows using image velocimetry and photogrammetry. Water Resources Research, American Geophysical Union, 54 (6), pp.4164-4179. [10.1029/2017wr021314](https://doi.org/10.1029/2017wr021314). Open access: [hal-01855840](https://hal.archives-ouvertes.fr/hal-01855840)

Steep streams with massive sediment supply are among the most complex systems to study, even in the laboratory. Their shallow sediment-laden flows create self-adjusting bed geometries that evolve rapidly. Often, morphological changes and flow processes cannot be dissociated. Because these very shallow and unstable flows cannot be equipped with measurement sensors, image analysis techniques, such as photogrammetry (e.g., structure-from-motion, SfM) and large-scale particle image velocimetry (LSPIV), are interesting options for capturing the characteristics of these systems. The present work describes a complete procedure using both techniques to measure spatially distributed surface velocity and bed properties (deposit



patterns, channel slope, local roughness). The velocity data are used to assess the local flow directions along which the channel slope and roughness are extracted from the SfM digital elevation models. Ferguson's "variable power equation" friction law, having been previously validated by comparison with approximately 100 local flow depth measurements, was used in a second step with the collected data to reconstruct a complete mapping of the depth-averaged flows, thereby enabling a comprehensive analysis of the hydro-geomorphic system where shallow water equations apply. The assumptions, details, use of the friction law with roughness standard deviation rather than diameter as parameter and limitations of the procedure as well as possible sources of errors are discussed here, along with possibilities for improvements. This affordable and simple-to-implement procedure can provide a large amount of data, allowing for a more comprehensive analysis of complex hydraulic systems.

Piton, G.; Recking, A. & Tacnet JM.. An attempt to classify malfunctions of steep channel flows justifying building of open check dams or other torrent control works. 5th IAHR Europe Congress, Jun 2018, Trento, Italy. DOI:10.3850/978-981-11-2731-1_230-cd. Open access: [\(hal-01982588\)](#)

Open check dams are widely used in mountainous regions as structures for flood hazard mitigation. They can have diverse shapes enabling to serve various purposes. If ill-design or not perfectly tailored to the catchment flow processes and hazard sources, they sometimes result in excessive downstream sediment starving, too high dredging costs or functional failures. The adjustment of the protection system to the catchment is thus a key step in any natural hazard mitigation study. This extended abstract is a first attempt to propose a classification of the typical malfunctions occurring in steep stream channels. These malfunctions are briefly described and contexts where an open check dams may be a solution are highlighted as well as other protection options.

Tacnet, JM. ; Piton, G., Philippe, F., Gourhand, A., & Vassas, C. 2018 "Décider dans le contexte de la GEMAPI: exemple de méthodologie d'une approche intégrée d'aide à la décision et application aux projets d'aménagements", Revue Science Eaux & Territoires, GEMAPI : vers une gestion plus intégrée de l'eau et des territoires, numéro 26, p. 48-53, DOI:[10.14758/SET-REVUE.2018.26.09](#) (in french)

Decision making in water course management is increasingly complicated notably due to integrated policies. New decision aid tools are consequently required. Based on a case study of the GEMAPI law application (French law on integrated river management making mandatory to



account in all project for both flood mitigation and river restoration), this paper presents a pluridisciplinary and full protocol encapsulating typical concepts of risk analysis (cost-benefit analysis, hazard modelling), environmental assessment and decision aid. Beyond local result, it mostly focus on the procedure and tools proposed or re-used to aid decision making or trace formally the decision procedure.

Piton, G.; Fontaine, F.; Bellot, H.; Liébault, F.; Bel, C.; Recking, A. & Hugerot, T. 2018, Direct field observations of massive bedload and debris flow depositions in open check dams, E3S Web of Conferences, EDP Sciences, 2018 , 40 , 1-8, DOI:[10.1051/e3sconf/20184003003](https://doi.org/10.1051/e3sconf/20184003003)

Sediment detention basins, also called SABO dams, are key facilities in flood protection systems of mountain catchments, specifically in torrents prone to massive bedload transport or debris flows. A better understanding of the processes generating sediment trapping is required to optimize their functioning. Two monitoring stations have been implemented in the French Alps on two torrents: the Manival (Saint-Nazaire-Les-Eymes) and the Claret (Saint-Julien-Mont-Denis). Time-lapse photos show an event depositing 10,000 m³ of debris flow in a basin in less than six minutes and several events partially filling the other basin with gravel, impairing its capacity to store debris flows later. After a presentation of the catchments, this paper qualitatively analyses the dynamics of the depositions. It highlights and stresses the consistency and differences between bedload and debris-flow deposition. Overall, despite clear differences of geomorphic activity, deposits tend to fill the trap basins just enough to enable the sediment transport continuity reestablishment through the basin. The open check dams thus play a role only provided that this continuity precondition is completed. These observations enhance our comprehension of massive sediment trapping in torrents and our capacity to better adjust trap maintenance and design to the objective sought in each site.

Piton, G.; Carlados, S.; Marco, O.; Richard, D.; Liébault, F.; Recking, A.; Quefféléan, Y. & Tacnet, J. 2019, "Usage des ouvrages de correction torrentielle et plages de dépôt : origine, état des lieux, perspectives", La Houille Blanche, 1:57-67, DOI:[10.1051/lhb/2019008](https://doi.org/10.1051/lhb/2019008), Open access: hal-02129862

Large operations of torrent control works in the most active catchments have been launched in France by the 1882's mountain areas restoration policy, based on older pioneer works. It first implemented headwater soil and erosion control structures and plantations, although



protection structures closer from assets were built on alluvial fans to trap sediment and channelize flows. Soil erosion control and the related torrential hazard mitigation continue to be financed by public grants to maintain existing systems and, if necessary, build new ones. The environmental, socio-economic and technical contexts of risk management have changed. The current use of check dams and open check dams in protection strategies may consequently need an update. This paper firstly reviews the historical emergence of check dams and open check dams. It secondly lists their function, i.e., the qualitative effect we can expect they have on hazards in the light of 150 years of tests and trials. The last section gives some perspectives on the use of these structures: why, although complicated and expensive, is it worth maintaining some headwater structures? When is it justified to abandon or even dismantled some structures? And finally what seems to be the future way of designing and planning these structures, especially the open check dams?

Poudyala, S.; Choi C.E.; Song D.; Zhou G.G.D.; Yune C.Y.; Cui Y.; Leonardi A.; Busslinger M.; Wendeler C.; Piton G.; Moase, E. & Strouth, A. "Review of the mechanisms of debris-flow impact against barriers", Proceedings, Proc. 7th Int. Conf. on Debris-Flow Hazards Mitigation, 2019 , 1027-1033, Open access: <https://hdl.handle.net/11124/173112>

Our limited understanding of the mechanisms pertaining to the force exerted by debris flows on barriers makes it difficult to ascertain whether a design is inadequate, adequate, or over-designed. The main scientific challenge is because flow-type landslides impacting a rigid barrier is rarely captured in the field, and no systematic, physical experimental data is available to reveal the impact mechanisms. An important consideration in flow-structure interaction is that the impact dynamics can differ radically depending on the composition of the flow. Currently, no framework exists that can characterize the impact behaviour for a wide range of flow compositions. This review paper examines recent works on debris-flow structure interactions and the limitations of commonly used approaches to estimate the impact load for the design of barriers. Key challenges faced in this area and outlook for further research are discussed.



Camiré, F.; Piton, G. & Schwindt, S. "Hydrogeomorphology and steep creek hazard mitigation lexicon: French, English and German", Proc. 7th Int. Conf. on Debris-Flow Hazards Mitigation, 2019, 589-596, Open access: <https://hdl.handle.net/11124/173167>

Geoscientists, researchers and engineers study and work on similar projects all over the world. The exchange of information between colleagues of different countries who work on homologous projects or in similar fields requires a common technical vocabulary. Differences in the usage of technical terms and their varying definitions in different regions of the world may constrain the transfer of knowledge, for example in guidelines. Translations of technical papers and of presentations are particularly complicated and troublesome. Moreover, writers waste valuable time when they try to find proper technical terms in a different language. This is currently the case in the fields of fluvial geomorphology and steep creek hazard mitigation since several countries are active in these domains. Papers, guidelines, and policies are published in several languages, such as Japanese, Italian, French, German, English, Korean, Chinese and Spanish. International delegates are also submitting papers to journals, presenting and participating at conferences that are predominantly in English. Finally, working groups with multinational participants have been formed to advance research and transfer of knowledge in fluvial geomorphology and steep mountain creek hazard mitigation. Therefore, standardization and better definitions of technical terms are required. We propose in this paper a lexicon of French, English and German technical terms, and their definitions, related to the fields of fluvial geomorphology and steep mountain creek hazard mitigation. This paper focuses on the most important terms. In the future, other languages and supplemental terms could be added to this document with the help of other contributors.

Piton, G.; Mano, V.; Richard, D.; Evin, G.; Laigle, D.; Tacnet, J. & Rielland, P. "Design of a debris retention basin enabling sediment continuity for small events: the Combe de Lancey case study (France)" Proc. 7th Int. Conf. on Debris-Flow Hazards Mitigation, 2019, 1019-1026: Open access: <https://hdl.handle.net/11124/173113>

The Combe de Lancey stream is a relatively calm tributary of the Isère River flowing through the city of Villard-Bonnot near Grenoble (France). In 2005, a long-lasting extreme rainfall event triggered dramatic erosion processes in this 18 km² granitic catchment. A volume of 20,000 m³ of sediment and logs deposited in the paper factory located near the fan apex. This paper focuses on the definition of a new protection system, namely a debris retention structure made of an excavated basin and an open check dam. The design is based on expert knowledge and tested by physical small scale modelling. The particularity of this case study relies on two points:



(i) its design scenarios and (ii) the structure capacity to transfer small events. Attention was paid to define several 100-year return period events used as “design events” for which the structure must have its best effectiveness. Extreme events with higher return periods called “safety check events”, for which the structure must still withstand the event without failure but with acceptable marginal damages, were also modelled. The definition of the scenarios is described in the paper. Secondly, the debris retention basin should have the capacity to transfer small debris floods without trapping sediment in order to prevent downstream incision and heavy maintenance costs. It must however trap nearly totally the sediment and large woods that are erratically supplied by the catchment during extreme events. Classical debris retention basins are usually not able to achieve such a dual objective. Here, two concepts developed in past works, namely a guiding channel and a hybrid open check dam with mechanical – hydraulic control were successfully tested. The paper presents the design and testing procedure of this case study exemplifying the next generation of debris retention structures.

Bokhove O.; Kelmanson M.A.; Kent T.; Piton G. & Tacnet JM. (in press) Communicating (nature-based) solutions using flood-excess volume, for three extreme UK and French river floods. River Research and Application, DOI:[10.1002/rra.3507](https://doi.org/10.1002/rra.3507)

As interest mounts in natural water-retention measures and alternative Nature-Based Solutions (NBS) as complementary options to civil-engineering measures, catchments and cities face a growing number of possible protection strategies to mitigate flooding. We offer a straightforward and educational protocol, for quantified flood-mitigation assessment of protection strategies, targeted for effectiveness analysis and decision-making involving stakeholder participation. It is based on the concept of flood-excess volume (FEV), i.e., volume exceeding a threshold and generating flood damage, and exemplified for recent extreme-flood events in the UK and France. The central questions are: what fraction of FEV is reduced, and at what cost, by particular flood-mitigation measures? Quantification and interpretation of cost scenarios are facilitated using a novel visualisation of flood-alleviation basins as partially filled, 2m-deep square lakes with side-lengths of ~1-2 km. We consider two 2015 floods of the River Calder in Mytholmroyd (Yorkshire, UK) and the River Brague in Biot (Alpes-Maritimes, France). Each case has different flood-mitigation measures: flow-attenuation features, tree planting and peat restoration, and reservoir storage (Calder), and; retention measures, flood-walls, and bed-widening (Brague). Our straightforward protocol enables fast, quantifiable and easy to understand exploration of protection strategies using multiple measures, and in doing so highlights the issue of NBS scalability.



Bokhove O.; Kelmanson M.A.; Kent T.; Piton G. & Tacnet JM. (under review) A cost-effectiveness protocol for flood-mitigation: a sanity check on Leeds' 2015 Boxing Day floods, Proceedings of the Royal Society A.

Flood-excess volume corresponds to the volume that a river cannot evacuate and which must be stored. An important decision-making problem consists in choosing the most effective flood-protection strategy. The goals of this paper are threefold: (i) to provide a clear and graphical cost-effectiveness analysis of flood mitigation, exemplified for a hypothetical scheme, partially based on actual flood-mitigation plans; (ii) to found such a cost-effectiveness protocol on flood-excess volume (FEV), here for the Boxing Day Flood of 2015 of the River Aire in Leeds, UK; and, (iii) to revisit the concept of flood-excess volume (FEV) as the flood volume above a chosen river-level threshold of flooding. By re-expressing FEV in terms of a 2m-deep square lake of equivalent capacity, one can visualise its dimensions and compare it with those of the river valley considered. Cost-effectiveness for flood-mitigation is expressed within the square-lake representation of FEV, which can be done either prior to or in tandem with more detailed hydrodynamic numerical and laboratory modelling of river flows. We have revisited the FEV concept and re-expressed it as a single three-panel graph, highlighting thresholds and error bounds; the resulting graphs are used to visualise different scenarios of our hypothetical flood-mitigation plan with each scenario involving a combination of higher (than existing) flood-defence walls, enhanced flood-plain storage sites, giving-room-to-the-river bed-widening and natural flood management (comprising tree planting, leaky and beaver dams), both closer to and further upstream of Leeds. For policy makers, our straightforward cost-effectiveness analysis can be used as a protocol to compare and hence to choose between flood-mitigation scenarios in a quantifiably justified, direct and visual manner, thereby offering better prospects of being understood by a wide audience, including citizens and city-council planners. Techniques employed are data analysis combined with general river hydraulics, common-sense and upper-bound estimation, making our analysis purposely straightforward and accessible, as a sanity check of flood-mitigation plans and calculations.

Recking, A.; Piton, G.; Montabonnet, L.; Posi, S. & Evette, A. "Design of fascines for riverbank protection in Alpine rivers: insights from flume experiments", Ecological Engineering, (2019) , 138:323-333, DOI:10.1016/j.ecoleng.2019.07.019; Open access: [hal-02266169](https://hal.archives-ouvertes.fr/hal-02266169)

We present the results of flume experiments specifically designed to investigate the conditions required for successful bank protection using fascines, considered in the early and critical stage of their installation (no developed root system), in the alpine context. A total of 145 runs were



performed with erodible banks, considering different combinations of protection design (no protection, rip-raps, twigs), bed mobility (with or without bedload), discharge (from low to exceptional floods), and bend curvature radius. None of the runs showed any direct fascine grabbing by the flow observed; all destruction was the consequence of bank scouring, erosion and collapse around the structure. In all cases, most destructive effects resulted from water recirculation inside the bank. Thus, we conclude that all measures aiming to reduce water circulations during the first stage of the fascine construction and development are recommended. This include large bend curvature radii (when possible), fining of the filling material, use of antiscouring twigs, optimisation of the programming of the works with consideration of the hydrology (shape of hydrographs) and regular survey of the structure. Our experiments show that anti-scouring twigs have a real protective effect by modifying the local hydraulics and promoting sediment deposition at the bank toe.

Piton, G. & Recking, A. "Steep Bedload-laden Flows: Near-Critical?", *Journal of Geophysical Research: Earth Surface*, American Geophysical Union/Wiley, 2019, [DOI:10.1029/2019JF005021](https://doi.org/10.1029/2019JF005021).
Open access: hal-02266073/

Steep gravel-bed rivers sometimes experience flood events that dramatically rework river bed structure and topography. Hazard assessments and paleo-event reconstructions require better knowledge of such phenomena. This paper explores a data set measured on a generic Froude-scaled model. Bedload-laden flood events were introduced in a narrow flume and spread into a five-times wider unconfined area with a 0.1-steep slope (m/m). Image analysis enabled measurements taken at an unprecedented level of accuracy on unconfined flows laden with bedload. A flow reconstruction procedure was used to compute depth, Froude Fr and Shields T^* numbers on millions of pixels based on a friction law and measurements of surface velocity using LSPIV, and slope and roughness using SfM. Despite the steep slope, Froude numbers proved to be mostly subcritical in all but the regions experiencing the most active sediment transport. Competent flows, identified by the transport stage higher than unity ($T^*/T_{cr}^* > 1$), were observed to be near-critical and seldom had $Fr > 1.3$ -1.5. This demonstrates that, providing that bed width and structure can adjust, hydraulic features such as standing waves, hydraulic jumps and lateral shock waves dissipate energy very efficiently in addition to adjusting channel features. These competent flows also tend to rework channels to approach the energy minimum of near-critical flows. This hypothesis was postulated by Gordon Grant (1997, *Wat. Resour. Res* 33(2), 349-358), regularly confirmed by post-disaster flow computations on a few river sections but, to the best of our knowledge, not yet demonstrated on such a large sample of very steep, unconfined flows.



Considering near-critical flows during discharges that are high enough to be clearly competent in laterally unconfined reaches therefore seems reasonable as a first approximation in steep gravel-bed channels. This result may ease discharge evaluation for paleo-flow reconstruction and can help hazard assessments by constraining flow stage - discharge relationships.

Santoro S., Pluchinotta I., Pagano A., Pengal P., Cokan B., Giordano R. (2019) Assessing stakeholders' risk perception to promote Nature Based Solutions as flood protection strategies: The case of the Glinščica river (Slovenia). Science of the Total Environment, 655, pp. 188-201. DOI:10.1016/j.scitotenv.2018.11.116

Evidences from flood risk management demonstrated that a deep understanding of the main physical phenomena to be addressed is often not enough but should be also integrated with stakeholders' knowledge and risk perception. Particularly, the effectiveness of flood risk management strategies is highly dependent on stakeholders' perception and attitudes, which play a critical role on how individuals and institutions act to mitigate risks. Furthermore, practitioners and policy-makers realized that grey infrastructures may not be the most suitable solution to reduce flood risk, and that a shift from grey solutions to Nature Based Solutions is required. Within this framework, the present work describes a methodology to enhance the Nature Based Solutions implementation by facilitating the generation, acquisition and diffusion of different stakeholders' risk perceptions. It is based on the combination of Problem Structuring Methods for the elicitation of stakeholders' risk perceptions through individual Fuzzy Cognitive Maps, and Ambiguity Analysis for the investigation of differences in risk perceptions and problem framing. The outputs of the Ambiguity Analysis, used during a participatory workshop, facilitated a dialogue aligning the divergences and promoting the social acceptance of Nature Based Solutions. These results of the implementation of this multi-step methodology in the Glinščica river basin (Slovenia) are discussed.

Pagano A., Pluchinotta I., Pengal P., Cokan B., Giordano R. (2019) Engaging stakeholders in the assessment of NBS effectiveness in flood risk reduction: a participatory System Dynamics Model for benefits and co-benefits evaluation. Science of the Total Environment, 690, pp. 543-555. DOI:10.1016/j.scitotenv.2019.07.059

There is an imperative worldwide need to identify effective approaches to deal with water-related risks, and mainly with increasingly frequent floods, as well as with severe droughts. Particularly, policy- and decision-makers are trying to identify systemic strategies that, going



beyond the mere risk reduction, should be capable to deal simultaneously with multiple challenges such as climate resilience, health and well-being, quality of life, thus providing additional benefits. In this direction, the contribution of Nature Based Solutions (NBS) is relevant, although their wider implementation is still hampered by several barriers, such as the uncertainty and lack of information on their long-term behaviour and the difficulty of quantitatively valuing their multidimensional impacts. The activities described in the present paper, carried out within the EU funded project NAIAD, mainly aim at developing a participatory System Dynamic Model capable to quantitatively assess the effectiveness of NBS to deal with flood risks, while producing a multiplicity of co-benefits. The adoption of a participatory approach supported both to increase the available knowledge and the awareness about the potential of NBS and hybrid measures (e.g. a combination of NBS and socio-institutional ones). Specific reference is made to one of the demos of the NAIAD project, namely the Glinščica river case study (Slovenia).

Giordano R., Pluchinotta I., Pagano A., Scricciu A., Nanu F. (under review). Enhancing NBS acceptance for reducing water-related risk through stakeholders' engagement in co-benefits identification.

Nature-Based Solution are increasingly recognized as a valid alternative to grey infrastructures as measures for reducing climate-related risks. On the one side, past experiences showed that grey infrastructures are capital intensive, may address only some water-related issues and often damage or eliminates biophysical processes necessary to sustain people, ecosystems and habitats, and livelihoods. On the other side, increasing evidences demonstrated that NBS can reduce risks to people and property as effectively as traditional grey infrastructures, but potentially offering many additional benefits, e.g. improving the natural habitat for wildlife, enhancing water and air quality, improving community socio-cultural conditions. The growing interests in the NBS triggered an increasing interest in developing integrated and multi-disciplinary frameworks for assessing NBS effectiveness accounting for the co-benefits production. Starting from the analysis of the existing frameworks, this work claims for a more direct engagement of stakeholders - i.e. co-benefits beneficiaries - in developing NBS assessment framework. This work demonstrates that differences in co-benefits perception and valuation might lead to trade-offs and, thus, to potential conflicts. An innovative methodology using quasi-dynamic Fuzzy Cognitive Map approach based on multiple time steps was developed in order to assess NBS effectiveness, and to detect and analyse trade-offs among stakeholders



due to differences in co-benefits perceptions. The developed methodology was implemented in the Lower Danube demo.

Coletta V.R., Pagano A., Pluchinotta I., Scricciu A., Nanu F., Giordano R. (under review). A participatory approach based on Causal Loop Diagrams for assessing Nature Based Solutions effectiveness in co-benefits production

The increasing occurrence of both droughts and floods is showing severe effects on communities, on the economy and on the built environment. There are also growing concerns on the state of ecosystems, which are likely to be seriously threatened in the near future. Both policy- and decision-makers thus acknowledge an increasing need to identify innovative strategies for supporting climate change adaptation and water-related risks reduction. In this direction, the contribution of Nature Based Solutions (NBS) could become increasingly relevant due to their multi-functionality, although their implementation is still limited by multiple barriers, both technical and socio/institutional. Starting from these premises, the present research intends to revise the process of NBS design, focusing on the identification, modelling and assessment of the most relevant benefits and co-benefits. A multi-step methodology was implemented, combining both individual and participatory activities performed with the local stakeholders. A conceptual model based on Causal Loop Diagrams (CLD) was developed, to support analysing the effectiveness of a set of NBS in achieving the selected objectives, while visualizing the key causal connections and potential mutual influences. The proposed model supports a comparative effectiveness assessment of different NBS, as well as the identification of potential related trade-offs among different benefits and co-benefits and side effects. It has been coupled with a Performance Matrix (a basic feature of Multicriteria Decision Analysis) to provide recommendations for decision-makers. The paper deals specifically with research activities performed in the Potelu Area (Lower Danube, Romania).

Pagano A., Giordano R., Pluchinotta I., Basile R., Santoro S., Scricciu A., Nanu F. (2019) Enhancing the introduction of Nature Based Solutions to deal with water-related risks using participatory approaches. Proceedings of the 2nd ICONHIC Conference, Crete (Greece), June 2019.

The increasing frequency and magnitude of water-related risks is causing growing concerns but, at the same time, raising the awareness of decision-makers about the need to identify and implement innovative strategies for adaptation and risk reduction. Traditional approaches



based on 'grey' infrastructures are being gradually integrated, or even replaced, by Nature Based Solutions (NBS), which are increasingly promoted at EU level and beyond, mainly due to their potential for producing additional positive impacts (i.e. the co-benefits) in multiple fields, besides the reduction of risk levels. However, several barriers still exist, mainly in terms of knowledge and awareness of the potential of NBS. The present work, which is being carried out within the H2020 funded project NAIAD, aims at proposing a process, mainly based on participatory approaches, for supporting a bottom-up identification and co-design of a suitable set of NBS to deal with water related risks. Starting from the analysis of stakeholders' risk perception through Fuzzy Cognitive Maps and the identification of their main risk management goals, a set of potential co-benefits is identified, and a workshop used to identify the most effective set of NBS in order to produce them. Detailed results are provided for the Lower Danube case study.

Krauze K., Włodarczyk-Marciniak R. (2018). Defining the risk to water and natural capital in cities with risk component analysis tool (DAPSET): Case study Łódź. Journal of Environmental Management 227: 62–72.

Management of water resources poses a particular challenge in cities, due to the extensive degradation of the urban ecosystem and its limited self-regulatory capacity as compared to natural systems. Effective management requires an in-depth understanding of the sources (drivers) giving rise to such risk. This paper reports on a participatory identification of such factors driving the risk to urban water resources in the city of Łódź, Poland, carried out with the aim of testing a simple risk analysis tool (DAPSET - Drivers and Pressures – Strength Evaluation Tool), intended to yield the kind of complex data able to help assist city managers in decision-making processes. In the first part of the study, a number of selected public officials, students, researchers and NGO representatives were asked to rank the key socioeconomic drivers of water resources in the city. The four drivers identified as key (a low degree of environmental awareness among citizens, low law-enforcement efficiency, the city's low economic potential and land use changes) were then scrutinized in the second part of the study, which included a self-administered questionnaire designed to create a risk profile of drivers based on the DAPSET. Each of the four key drivers were analysed with reference to eleven features. DAPSET revealed that all the key drivers share certain common features: they affect a large spatial scale, the damage they cause is persistent, and they involve either medium-high damage potential or probability of damage. The major differences between them stem from the dynamic features of the risk: societal attraction, invisibility, and availability of information.



Analysis of the risk profiles so created against risk types pointed to the desirable directions of management and a need to go beyond standard actions.

Faneca, M.; Trambauer, P.; Pescimoro, E.; García-Alcaraz, M.; Altamirano, M. and Manzano, M. (2019). Understanding the potential of Nature Based Solutions to recover the natural ecosystem services of the Medina del Campo Groundwater Body in the NAIAD EU project. 46th International Association of Hydrogeologists Congress: Groundwater Management and Governance, Coping with Water Scarcity. Málaga, Spain. 22-27 September 2019. Accepted.

The area covered by the Medina del Campo Groundwater Body (Duero River Basin, Spain) is an important agricultural production region. The zone is prone to climatic and geomorphological hazards such as floods, dry spells and landslides. Climate projections indicate that these hazards might become more frequent in the future. The main economic activity of the area is agriculture, which is also the main water user almost entirely relying on groundwater. Currently there are more than 5000 wells pumping groundwater to supply the agricultural water demand. Measurements show that groundwater levels have declined up to 20 m in some areas in the last 40 years. In the framework of the NAIAD H2020 project we developed a 3D numerical groundwater flow model with the objective to understand the dynamics of the groundwater, to evaluate the impact of climate change, and to assess the potential of some Nature Based Solutions (NBS) for recovering the original ecosystem services of the groundwater body. The model was built to simulate a pristine system without abstractions, and a system under anthropic pressure with the current abstractions. The NBS simulated include the artificial recharge of the aquifer, the change of crops, and the modification of abstraction rates and distribution. The preliminary results indicate that under a scenario of climate change with reduced precipitation, although the assessed NBS solutions can be beneficial, they are not able to totally reverse the impact caused by the abstractions, and therefore do not succeed to completely restore the original ecosystem services of the groundwater body.



Borowiecka, M.; García-Alcaraz, M and Manzano, M. (2019). Analysis of piezometric trends in the Medina del Campo Groundwater Body to understand the status and drivers of trends of groundwater-related ecosystem services. NAIAD EU project. 46th International Association of Hydrogeologists Congress: Groundwater Management and Governance, Coping with Water Scarcity. Málaga, Spain. 22-27 September 2019. Accepted.

The area covered by the Medina del Campo Groundwater Body (MCGB, Duero River Basin, Spain) is an important agricultural production region. Groundwater is the main provisioning source for irrigation, to supply many small towns and also to support surface groundwater-related ecosystems (SGRE). The area is prone to climatic and geomorphological hazards such as floods and droughts. The aquifer is formed by a thick (100 to > 500 m) accumulation of Tertiary fine-sized alluvial, Aeolian and lacustrine sediments. Groundwater levels have declined up to 20 m in some areas in the last 40 years. In the framework of the NAIAD H2020 project, we are analysing the role of groundwater-related ecosystem services (GRES) for drought hazard mitigation and to support SGRE, in a context of increasing climatic variability and testing different management strategies. This work aims to understand the evolution of some provisioning and regulating eco-services and its causes, based on the analysis of temporal piezometric trends. The Mann-Kendall test has been used to analyse piezometric temporal trends in the MCGB for the period 1985-2018. The results have been studied on a regional scale with the support of GIS. The study was based on data from 169 piezometers. Based on a widely observed change of trends, the analysis was performed for two-time intervals: 1985-2001 and 2002-2018. From 1985 to 2001 there was a clear and widespread tendency to lowering levels, which suggest a main cause and points to intensive exploitation of groundwater. Widespread piezometric drawdown reduced discharge to surface ecosystems and induced wells deepening, thus intensive withdrawal reduced quickly the GRES flow. From 2002 to 2018 only a quarter of the observation points show a clear piezometric increasing trend, while most of them just show weak and unclear tendencies. This points to diverse and localised drivers of change, the most probable being abandonment of expensive exploitations and replacement of groundwater for surface water as irrigation source. Thus, reducing groundwater exploitation induced a slow recovery of groundwater levels over the last two decades, which points to an also slow increase of GRES flow.



Gómez Martín E, Máñez Costa M, Schwerdtner Máñez K (2019) An operationalized classification of Nature Based Solutions for water-related hazards: From theory to practice. Ecological Economics. Volume 167, January 2020, 106460.

Nature Based Solutions (NBS) are currently gaining importance in the EU policy agenda as a promising approach to mitigate and adapt to environmental and climate change. The main advantage of NBS over other adaptation strategies is their capability to deliver multiple benefits. They support the resilience of natural processes and help in reducing adaptation costs. In this paper, we address the current gaps in the literature by providing a comprehensive, easy-to-use classification scheme focussing on hydrological extreme events. The classification scheme is presented as a matrix and contains a portfolio of known NBS as well as the important criteria for their selection. Specifically, we have included disservices/ barriers, and the potential impacts of climate change on NBS. The matrix provides decision-makers with a tool that will guide them through the first phase of the complex process when choosing the most appropriate NBS for a specific challenge. In that way, we aim to support the spread of NBS in the scientific literature as well as their practical application.

4 Part B: Papers in development that will be completed post NAIAD

This section provides titles and links to extended abstracts of a total of 16 papers that are being prepared for D2.6. These will be published post-NAIAD. The anticipated paper titles, authors and work packages involved are provided in table 1. The paper titles link to separate documents with extended abstracts for these papers.

Table 1. Anticipated paper titles, authors and work packages involved for papers in development.

Nr	Paper title	(lead-, co-) authors	WPs involved
1	Estimating the hydrologic and economic effects of a restored urban river nature-based solution scenario demonstrated for the city of Copenhagen	Van der Keur, P.; Kidmose, J.; Henriksen, H.J.; Jørgensen, M.E.; Joyce, J.; ... (in prep)	WP2,4,6



2	System Dynamic Model [.....] demonstrated for the case of Copenhagen	Gomez, E.; Giordano, R.;van der Keur, P.; Pagano,A; Manez, M.; Van Cauwenbergh, N (in prep)	WP 3,5 and 6
3	The challenge of assessing the biophysical and economic effect of nature-based solutions at the urban scale illustrated for the cases of Rotterdam, Lodz and Copenhagen	Krauze, K., Dartee, K., Pena, K., Joyce, J.; van der Keur, et al. (proposed)	WP2,3 and 4
4	Is groundwater active management a potential NBS tool for floods mitigation?	Marechal JC, Ladouche B., Le Coent P. , van der Keur, P.(in prep)	WP2
5	Estimating the effectiveness of NBS to reduce flood risk in Mediterranean context, the case of the Lez Basin	Marchal R., Le Coent P., Moncoulon D, Forey I, Delbar V.	WP2, 4, 6 and 7
6	The (Re)Insurance industry's roles in the integration of nature based solutions for prevention in Disaster Risk Reduction – Insights from a European survey.	Marchal, R., Piton, G., Lopez-Gunn, E, Zorrilla-Miras, P, Tacnet, J-M., Graveline, N., Altamirano, M., Matthews, J., Joyce, ., Nanu, F., Groza, I., Peña, K., Dartée, K., Pengal, P., Cokan, B., Van der Keur, P., Burke, S., and Moncoulon, D	WP7
7	EU-wide relevant multi-hazard risk and mitigation by green infrastructure	Douglas, Mulligan, van Soesbergen, Burke	WP2
8	EU-wide ecosystem service relevant socio-economic exposure	van Soesbergen, Mulligan, Douglas, Burke	WP2
9	Modelling insurance-relevant flood mitigation ecosystem services using the EcoActuary	Mulligan, Douglas, Burke, van Soesbergen	WP2
10	River channel widening during floods:	Ruiz-Villanueva, V.; Scorpio, V.;	WP2



	outcomes from a European meta-analysis	Bachmann, A.; Brousse, G.; Cavalli, M.; Comiti, F.; Crema, S.; Fernández, E.; Furdada, G.; Hajdukiewicz, H.; Hunzinger, L.; Lucia, A.; Marchi, L.; Moraru, A.; Piégay, H.; Piton, G.; Rickenman, D.; Righini, M.; Stoffel, M.; Surian, N.; Yassine, R.; Wyżga, B.	
11	Estimating the effectiveness of NBS to reduce flood risk in Mediterranean context, the case of the Brague Basin	Marchal R., Piton G., Moncoulon D.	WP2, 4, 6 and 7
12	Resilience of natural systems. A hydrogeological perspective	De la Hera-Portillo, A., López-Gutiérrez, J., Llorente-Isidro, M., Heredia-Díaz, J., Mayor-Rodríguez, B., Zorrilla-Miras, P. & Lopez-Gunn, E.	WP2 and WP6
13	An integrated modelling framework to simulate the effect of Nature Based Solutions in the Medina del Campo Aquifer, Spain	Mayor, B., Zorrilla-Miras, P., Llorente Isidro, M., de la Hera, A., Heredia, J., López-Gutiérrez, J., Manzano, M., Alcaraz, M., Robles, V., Basco, L., Faneca, M., Pescimoro, E., Gómez, E., Giordano, R., Pagano, A., Van Cauwenbergh, N. & López Gunn, E.	WP2 and WP6
14	A stakeholder engagement methodological approach for the participatory design and assessment of NBS strategies in the Medina del Campo Aquifer, Spain	Mayor, B., Zorrilla-Miras, P., López Gunn, E., Vay, L., Van Cauwenbergh, N., Altamirano, M., Basco, L., Giordano, R., Gómez, E., Mañez, de la Hera, A., Llorente, M., Benítez, C., López Angulo, M.	WP2, 4, 6, 7, 9



15	Natural Assurance Schemes canvas: a framework to describe value capture and business models to catalyse the implementation of nature based solutions for disaster risk reduction	Mayor, B., Lopez-Gunn, E., Zorrilla Miras, P., Groza, I., Nanu, F., Scriciu, A., Dartée, K., Peña, K., Graveline, N., Le Coen, P. and Marchal, R.	WP7
16	Hydrogeological model for assessing artificial recharge in Medina del Campo groundwater body (Spain)	Heredia-Díaz, J., De la Hera, A., Martínez-Santos, P.	WP6