PHUSICOS

According to nature

Deliverable D2.2

Overview of submitted and approved NBSs for implementation during months 1-14

Work Package 2 – Case study sites:
Large scale demonstrator sites and supporting concept cases

Deliverable Work Package Leader:
NGI

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Project information

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Project partners:

Summary

This report summarizes the NBSs proposed by the agencies responsible for the three large scale demonstrator sites and the two smaller concept case sites during the first 14 months of the PHUSICOS project. The report also summarises the process for submittal and evaluation of the proposals, which has been slightly changed due to experiences gained during the first year, and discussions among the consortium partners.

Proposals have been submitted from all the case study sites. One of the three demonstrator sites, the Pyrenees, has proposed 5 individual NBSs, which are currently in review. The two other demonstrator sites, Gudbrandsdalen, Norway and Serchio River Basin, Italy, have submitted one proposal each and have indicated the NBS measures for their next proposals. The concept case at Kaunertal, Austria has submitted their only proposal, which is well in line with the original project proposal, as outlined in the DoA. The other concept case, the Isar River, Germany, has proposed and hosted the first of several planned learning visits, to share experience, which is of particular importance for the demonstrator cases.

The NBSs currently in process in PHUSICOS cover a range of hydrometeorological hazards: flood protection in Gudbrandsdalen; lake salinization, erosion and ecosystem restoration in the Serchio River Basin; snow avalanches, landslides, soil erosion, rock fall and torrents in the Pyrenees; erosion and landslides in the Kaunertal; and ecosystem restoration and flood protection along the Isar River.

Stakeholder involvement is an important part of PHUSICOS with strong guidance from WP3. All proposals involve stakeholder participation in co-creation and co-design, but to various degrees. The Living Labs approach of stakeholder involvement has been tailored to the local context at each site including existing policy processes related to the selection of NBS measures. WP3 is important for all the case sites, and tools developed in this work package are being used both to facilitate the stakeholder involvement through the Living Labs approach, and to monitor and evaluate the process as well as stakeholder satisfaction. Furthermore, all NBSs will be evaluated using the comprehensive framework developed in WP4 of the project.

Site visits to all three demonstrator case sites have been performed, and short reports have been written from all these visits. These reports are not part of the official deliverables of PHUSICOS, but they have been put together and attached as an appendix to this report.

Contents

Appendices

1 Introduction

PHUSICOS will demonstrate the viability and up-scalability of nature-inspired solutions for reducing the risk of extreme weather events in rural mountain landscapes through implementation of such solutions in cases study sites in Europe. The case study sites comprise three large-scale demonstrator sites and two supporting concept cases. Together, they represented a broad range of stages with regard to the implementation of NBSs at the start of the project in 2018. Since the case studies form the backbone of PHUSICOS, over 45% of the PHUSICOS budget is dedicated to the implementation of NBSs at the case study sites. Work package 2 (WP2) is responsible for the process and procedures for selecting the NBSs to be implemented as well as for the implementation of the measures themselves.

This report, delivery D2.2 is linked to Task 2.1 (Selection of NBSs to be implemented) and Task 2.2 (Implementation of demonstration sites) and Task 2.3 (Implementation of NBS at concept sites) as described in the DoA – part A. This deliverable provides an overview of the NBSs approved for implementation during months 1-14 of the project.

2 Experience from the submittal and evaluation process

The originally suggested NBSs and the procedures to propose, evaluate and select the measures were described in delivery D2.1 (PHUSICOS, 2018). However, as more than one year of the project has passed, and experience with the process has been gained, slight revisions and modifications of the selection and evaluation process are judged as necessary and relevant. D2.1 also presented a proposal template (Table 2.1), which is simple, but with the main elements aligned with the comprehensive assessment framework of WP4.

Some of the evaluation criteria (Table 2.1) have been added relative to the DoA. These are:

- Possible negative impact
- Harmonization with other WPs
- Compliance with international agreements and EU directives.

The first was added as a result of the review process of report D2.1, and was found useful in order to make proponents, as well as other project partners consider what potential negative impact the proposed NBS could pose, and assess whether the proposed NBS really is preferable to other traditional, 'grey' solutions. The two other added points for the evaluation are to ensure good communication and cooperation across WPs, and that proponents consider if and where their proposal is aligned with international agreements such as the Sendai Framework and the UN SDGs. It is of course also important that the suggested measures do not violate any EU directive, such as the Water Framework Directive and the Floods Directive, but rather enhances the effect of these regulations. So far (June 2019) no proposal has been rejected, but there have been a number of comments and questions to all the submitted proposals. Although some comments are

due to misunderstandings, most comments have been received positively by the proponents and have improved their proposed NBS project.

Table 2.1 Scoring scheme for proposed NBSs (left part) and how it relates to the initial version of WP4's framework for NBS monitoring and evaluation (right part). (From PHUSICOS delivery D2.1.)

Evaluation of proposals					Task 4.1 - NBS evaluation
Parameter	**Weight**	**Score (Poor-good)**	**Result**	**Comments**	**Ambit (see App. B for full framework)**
External funding	2	0-5		Proponents must have relevant external funding (40%) for the proposed NBS (D2.1: Ch. 4.1.1)	N/A
Risk reduction / Resilience	3	0-5		All areas must be adressed; human life, economic value and ecological state (D2.1: Ch. 4.1.2).	Risk
Feasibility	2	0-5		The proposed NBS must be technically and economically feasible within the budget and the time frame of the project (D2.1: Ch. 4.1.3).	Technical and Feasibility Aspects
Co-benefits	3	0-5		The proposed NBS should provide environmental, societal and/or economical co-benefits. These are main factors in differentiating NBSs from traditional 'grey' solutions (D2.1: Ch. 4.1.4)	Environment Society Economy
Effectiveness	2	0-5		NBSs must be effective over decades and under varying climate, including plans for maintenance. Assess also effectiveness vs. that of other 'grey' measures. (D2.1: Ch. 4.1.5).	Technical and Feasibility Aspects
Efficiency	1	0-5		The process towards NBS implementation should be efficient, and there should be congruity between costs (D2.1: Ch. 4.1.6)	Technical and Feasibility Aspects
Possible negative impact	3	-5-0		Identify and evaluate possible negative impacts of NBS (economy, society, ecology, resilience, etc.) (D2.1: Ch. 4.1.7)	Risk, Society, Environment, Economy
Participatory process	2	0-5		The intended stakeholder involvement / Living Lab process accompanying the NBS realization should be outlined here (D2.1: Ch. 4.1.8).	Society
Harmonization with other WPs	1	0-5		NBSs should receive input from and provide output to the other WPs (D2.1: Ch. 4.1.9).	All ambits
Compliance with international agreements and EU directives	1	0-5		NBS proposals should describe how they align with the UN SDGs, Sendai Framework, COP21 - Paris Agreement, EU directives, etc. (D2.1: Ch. 4.1.10)	All ambits
Total					

Revision of the assessment process

The four first proposals (below) were evaluated following the process described above. These were from the two concept case sites, the Isar River in Germany, and the Kaunertal valley in Austria, and from two of the large Demonstrator sites, the Gudbrandsdalen valley in Norway and the Serchio River Basin in Italy. After the May 2019 consortium meeting in Vienna, however, it was decided to slightly revise the process, and the first of five NBS proposals from the demonstrator site Pyrenees is used to test the revised scheme. The revision includes a Skype meeting between all SC members, and a delayed decision for approval or disapproval, in the following steps:

- SC members review the proposal, prepare comments and questions, as before, and use the simple scoring sheet of Table 2.1 if they wish.
- Comments and questions are sent to the WP2 lead within a deadline of ca. 2 weeks, as before, but with no requirement to vote for approval or disapproval at this stage.
- WP2 lead is responsible for compiling the comments and questions, differentiated under topics, in a document that will be sent to the SC a few days before a skype meeting (below).
- A 1-2 hours SKYPE meeting is set up to discuss the most important issues regarding the proposal. The meeting is chaired by the WP2 lead.
- Following the meeting, the document is edited according to the discussions and views expressed during the skype meeting, and sent to the proponents with a request for response within roughly 2 weeks
- The response to comments and questions are sent to the SC members, who are then asked to approve or disapprove within a relatively short deadline (about 1 week).
- If approved, the proponents are informed that they can start spending PHUSICOS funds. If not a new revised proposal may be requested, and the process is repeated.

At present, this evaluation scheme is being tested, and if agreed by the SC members, it will be followed also for the other 4 proposals submitted from the Pyrenees (below), as well as for future NBS proposals within PHUSICOS.

3 NBSs at the Demonstrator and Concept Case sites

PHUSICOS aims to implement at least 3 new large-scale NBSs at each demonstrator site. Construction of the NBSs will be subcontracted to local entrepreneur(s) following the standard EU procedures, as well as following national rules for public procurement. National procurement regulations for each of the case site countries are briefly described in delivery D2.1, which also provides references to more complete documents for each country.

In addition to the large scale demonstrator sites, PHUSICOS will also test at least 2 new novel ideas for an NBS at each concept site. If the proposed NBS to be tested at the concept site has potential for up-scaling and implementation at a demonstrator site, then the process for evaluation and implementation of the NBSs will be fast-tracked.

The first main milestone for WP2 was February 28th2019, by which date all sites should have submitted at least one NBS proposal. This milestone was only partly met. By February 28th, WP2 had received NBS proposals for both concept case sites and for two of the demonstrator sites (Gudbrandsdalen and the Serchio River Basin), all with one proposal each. The agencies for the third demonstrator site (the Pyrenees) had not submitted proposals by this milestone, but were working on five proposals from the region, including comprehensive stakeholder involvement processes with the local authorities to ensure local knowledge and strengthen legitimacy of the suggested NBS. CTP, the partner for the Pyrenees, kept a tight communication with the WP2 leader, who was continuously informed about the process. By April 3rd, all five proposals from the Pyrenees were submitted.

An overview over all NBS proposals submitted to the PHUSICOS Steering Committee (SC) is provided in Table 3.1. The table includes the dates for the submission of the original proposals, revisions based on comments from the SC, as well as final approval from the SC. The status of each proposal is commented in the table and elaborated in detail below.

Table 3.1 Status of PHUSICOS NBS proposals 20 July 2019.

Site	Proposal	Submitted	Revised	Approved	Budget (kEuro) Total/PHUSICOS	Status
DS-Gudbrandsdalen, Norway	Receded green flood barrier	19.12.2018	14.01.2019	20.02.2019	1250,00 / 732,00	Out for public procurement.
DS-Serchio River Basin, Italy	Bufferstrips along canals in the area of Lake Massaciuccoli	11.03.2019	27.03.2019	08.06.2019	1282,90 / 657,70	Approved, but working on improving the measure after comments from the Steering Committee.
DS-Pyrenees, Spain	Landslides, Santa Elena (Spain)	30.04.2019	No revision	05.07.2019	571,25 / 342,75	In process within the SC
DS-Pyrenees, France	Snow avalanches, Baréges (France)	30.04.2019	To come	To come	328,00 / 196,80	Approval process to start
DS-Pyrenees, France	Torrents, Bastan River (France)	30.04.2019	To come	To come	520,00 / 312,00	Approval process to start
DS-Pyrenees, France	Rock fall, Artouste (France)	30.04.2019	To come	To come	445,50 / 267,30	Approval process to start
DS-Pyrenees, France	Torrents, Socques (France)	30.04.2019	To come	To come	522,00 / 313,20	Approval process to start
CCS-Isar River, Germany	Look and learn' visit; workshop and excursions	19.12.2018	No revision	22.01.2019	8,90 / 5,40	Visit and workshop 20.03-22.03.2019
CCS.Kaunertal, Austria	Altitude adapted and microbe assisted seed mixture to reduce erosion in high mountain environments	22.02.2019	06.03.2019	22.05.2019	854,00 / 35,00	Most work to be covered by UNIVIE and PLUS. Only small amount (35 kEuro) set off for subcontracting

All the demonstrator sites have been visited by WP2. The Gudbrandsdalen site was visited on 3 September 2018, the Serchio River Basin site on 7-9 November 2018, whereas the Pyrenees site was visited on 4-5 June 2019. Short reports were written after each of these site visits, and these reports have been compiled to be presented as appendix A in the present report.

3.1 Demonstrator site Gudbrandsdalen

The agency responsible for the Gudbrandsdalen site, the Oppland County Administration, submitted their proposal '*Receded green flood barrier*' on 19 December 2018. The proposal was slightly revised on request from WP2, resubmitted and finally approved on 20 February 2019 (Table 3.1).

The proposal originates from the 'Regional Master Plan for the Gudbrandsdalslågen and its tributaries', which is an overall plan for reducing the risk related to flooding, erosion and landslides in the whole river-course of Gudbrandsdalslågen, one of Norway's largest rivers. The proposed measure covers the lower reaches of one of the side rivers, Gausa, and is to remove the existing, 'grey' flood protection along the riverbank, and build a new green flood barrier further away from the river (Figure 3.1). This barrier will be built using only natural and local materials. The Jorekstad area consists of housing, infrastructure, agricultural land, and a relatively large sports facility with football fields and a swimming hall. The new flood barrier will be approximately 2300 meters long, and is to be located between the agricultural land and the forested floodplain (Figure 3.1). By placing the flood barrier in this location, it will protect houses, agricultural land and the football fields from flood damage, while the area closest to the river will be frequently flooded and gain an increased value as a wetland. Consequently, the measure will lead to a higher security for the society, and at the same time have a positive effect on the natural environment and the ecosystem in and close to the river. It will allow the river to expand during flood situations, creating both a river course with high water capacity, and room for natural processes in the watercourse.

The Oppland County Administration has also involved PHUSICOS partner AgenceTer in the preliminary design of the measure. AgenceTer has created some conceptual ideas of how such a barrier can be formed (Figure 3.2), and will be further involved as the plans are being detailed further. At present (June 2019), a call for tenders for the construction of the barrier has been out, in line with the Norwegian rules for public procurement. When the contractor has been chosen, the aim is to start the construction in the early fall of 2019.

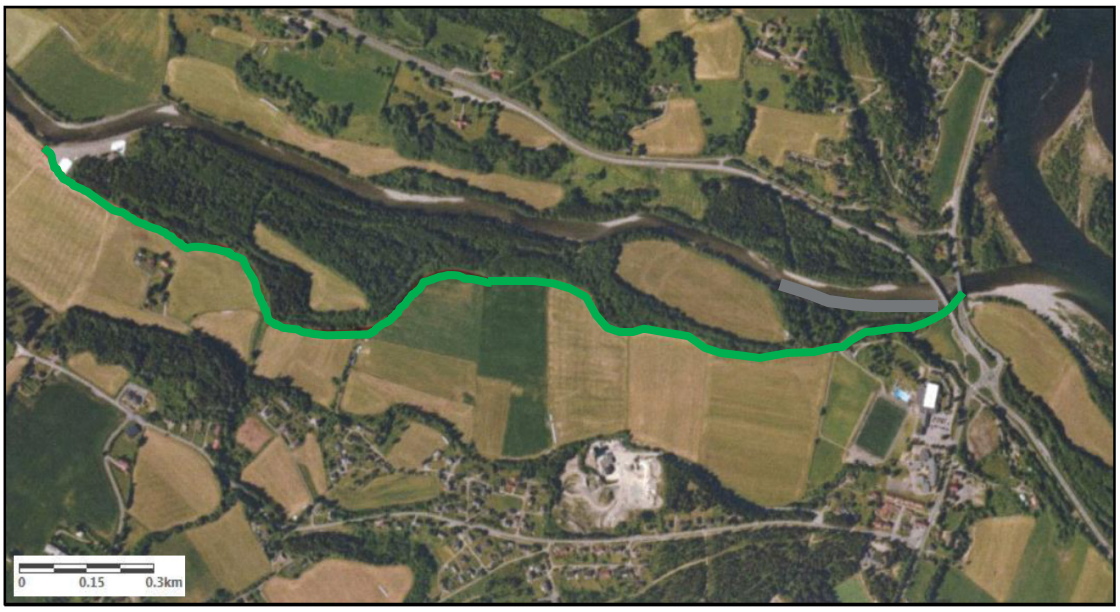

Figure 3.1 The planned location of the receded flood barrier (green) at Jorekstad. The main river Lågen is seen in the right part of the picture, and the old protection, which will be removed, is shown in grey.

Figure 3.2 Sketch of a cross section of a flood barrier, indicating how such a structure can be formed (AgenceTer, 2019).

Stakeholder involvement – Living Lab process

The work with the Regional Master Plan, has had a wide participatory process since 2013. The proposed measure at Jorekstad is one of the prioritised measures listed in this plan, and has thus undergone a participatory process including public workshops and public hearing. Furthermore, a proposed 'innovate procurement process' (following Norwegian regulations), will also serve as a participatory process by inviting subcontractors, NGOs, and other interested parties to a dialogue conference, before the contractor is chosen and the final design of the measure is carried out.

The Oppland County Administration also plans to hold a town hall meeting at the site, Jorekstad, with Lillehammer municipality as co-host, before any final design is decided and the construction starts. The invitation will go out broadly, and key stakeholders include the sports club and swimming hall, residents, and NGOs.

Future plans

The authority responsible for the Gudbrandsdalen demonstrator case has already started a Stakeholder involvement process regarding measures to prevent torrents with erosion and deposition and flooding in a side river to the main Gudbrandsdalslågen river, in the north-western part of the drainage area. The municipality of Skjåk had major flooding due to early snow-fall followed by a rapid temperature increase in October 2018. This 'spring-flood in the fall' may happen again, but is also an equivalent to extreme spring flood. A process of stakeholder involvement has started and new meetings, the first already in late August 2019, are planned with all relevant stakeholder groups, as well as individual citizens of the municipality. Hence, this will be a Living Lab process starting from scratch and include co-creation and co-design.

Furthermore, the Oppland County Administration will also propose one more NBS, related to problems of either torrents or landslides in the mid-valley. The details of this are however not finally decided yet, but several options are relevant. Some of these involve using bogs or old, more or less abandoned small reservoirs in the higher parts of the catchments for flood retention.

3.2 Demonstrator site Serchio River Basin

The proposal *'Construction of buffer strips between Fosso Boccalli and Fossa Nuova Channel in the southest of Massaciuccoli's Lake'*, was first submitted 11 March 2019. On request from WP2, a revised version was submitted 27 March 2019. The proposal received many comments and questions from the Steering Committee, and despite a 2/3 majority for approval, final approval from WP2 was not given until 8 June 2019. Then the proponents had provided adequate response to all the questions and comments, and permission to start spending project funds was given.

The proposed NBS is to establish buffer strips between the agricultural fields and channels in an area immediately to the south-east of Lake Massaciuccoli (Figure 3.3). Preliminary suggested width of the strips is 3m, but the the final width of the buffer strips will be defined more accurately based on the simulations by the VFSMOD model fulfilled by project partners UNINA and CREAF. This NBS represents one of several to be implemented in addition to a large state funded project on diverting fresh water from the Serchio River to the lake. The diversion pipeline will lead water to the start of the Fossa Nuova Canal through which it will feed into the lake. This will help decreasing the salinity of the lake, which is currently very high. The water level in the lake is at sea level, and the inflow of river water will also help keep the water level from falling below sea level during dry periods, and thereby reduce the risk from inflowing sea water in these periods.

The main function of the buffer strips (Figure 3.4) is to provide a barrier and to increase the permeability of the soil along the channel bank. In this way the runoff from the farmland is intercepted by the vegetation and infiltrated into the soil before flowing into the canal. Furthermore, the strip vegetation will act positively in the retention of eroded soil particles, can limit the water transfer of pollutants and play an important role in maintaining biodiversity and diversifying the agricultural landscape. There are three levels of channels in the area, based on their size, and the buffer strips will be implemented along the tertiary channels located between the two main Fosso Boccalli and Fossa Nuova Canals (Figure 3.3). Not least the measure is perfectly integrated with the environment of the Massaciuccoli area, which belongs to an area of great natural value within the Park of San Rossore Massaciuccoli.

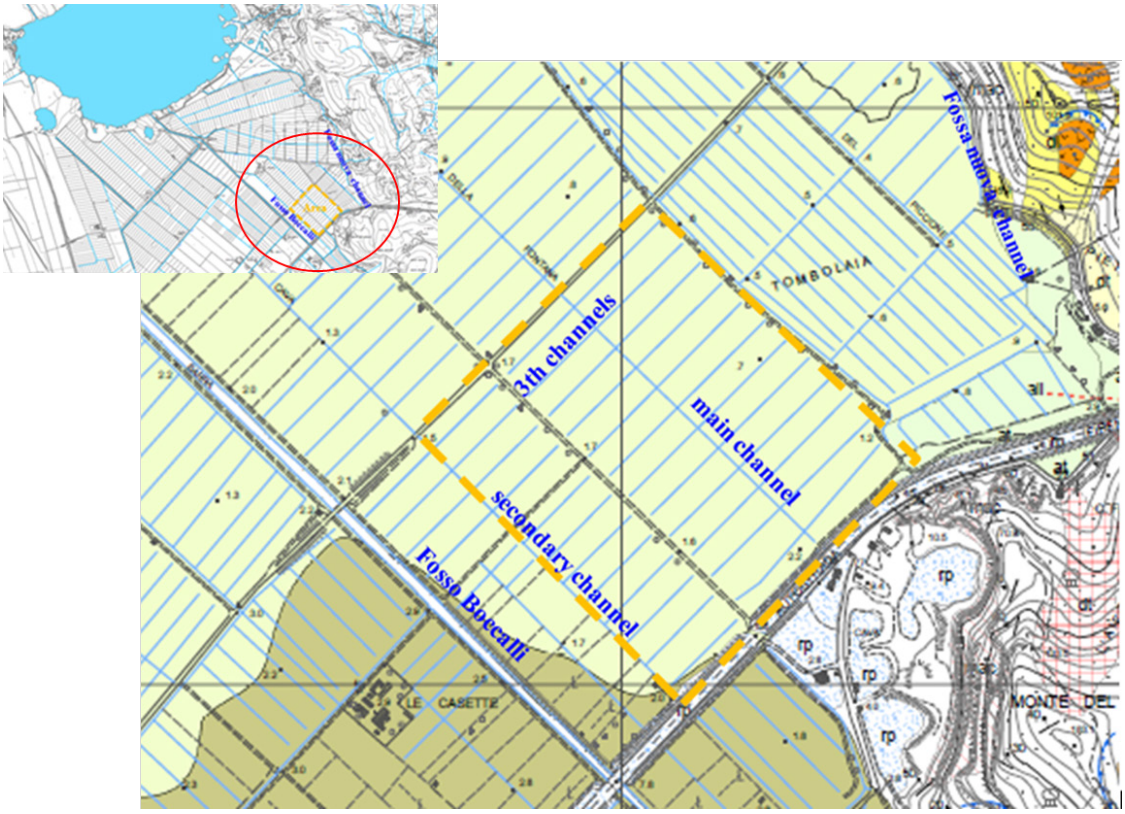

Figure 3.3 The area for the proposed buffer strips along the canals, within square marked in yellow, and the red circle in the inset map. Lake Massaciuccoli is shown in the inset map.

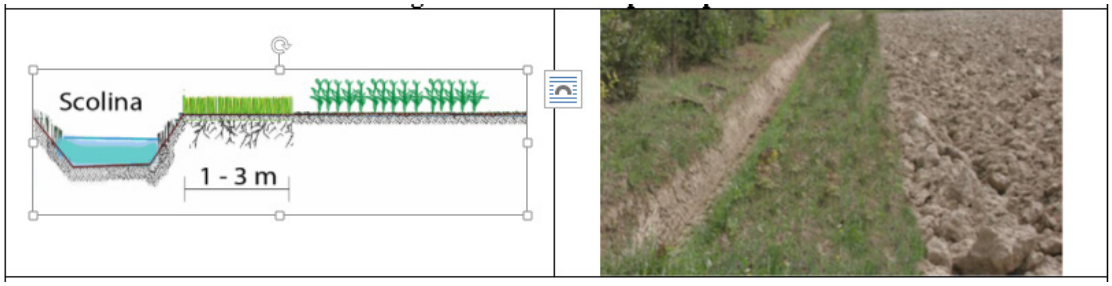

Figure 3.4 Example of buffer strips, which are to be vegetated with herbaceous plants. The final width of the strips is still to be decided.

As a whole, the implementation of the buffer strips (Figure 3.4) will slow down the process of leaching and transfer of pollutants from the agricultural land to the lake, improving the ecological state of the lake and the surrounding areas. It will also contribute to the control of surface erosion and therefore to a reduction of solid transport into the waterways, reducing the possible overflows with a consequent increase of the hydraulic resilience of the territory.

In addition to the improved ecological state and the increased hydraulic resilience, the measures will help make the area more user-friendly for various groups, and therefore is believed to have both social and economic co-benefits.

Stakeholder involvement – Living Lab process

Stakeholders have been earlier involved in the plans for the diversion pipeline. For the present NBS two meetings have been organized with participation from a number of public and private organizations, of which perhaps the most important have been from the agricultural side, farmers and agricultural authorities. The most important results of these meetings have been an agreement around the width of the buffer strips of 1-3 m (Figure 3.4). This is by many considered small, but is also approved by agricultural experts from the University of Pisa, and reported by Silvestri et al. (2017). In this regard, simulations by VFSMOD model are underway by UNINA and CREAF to define more accurately the suitable width of the buffer strips. Another important outcome is that the participants of the meetings wanted to test the effectiveness of the measures in a small experimental area, where buffer strips are to be implemented along all three levels of canals, not only the tertiary channels. As such, co-creation and co-design have been taking place through these two meetings.

Future plans

At least two more NBS proposals are expected from the ADBP, the agency responsible for the Serchio River demonstrator case. The details of these are not decided yet, but the proponents at ADBP are working on several possibilities, together with their science partner, CGT / University of Siena. Options include:

- Restoration and re-vegetation of the Serchio River Banks.
- Sediment capture ponds on the secondary hydraulic networks of the Lake Massaciuccoli's wetlands.
- Forest restoration by using multiple vegetation layers to reduce the risk of landslides and rain induced erosion, through selection of appropriate native plant species.
- Construction of retention basins to be activated in the case of high intensity events.
- Improvement of existing phytoremediation plants.

These will be decided upon during the next year.

3.3 Demonstrator site The Pyrenees

A total of five NBS proposals have been submitted from the demonstrator case Pyrenees. The proposals were all submitted 30 April 2019, and at present the evaluation and approval process has only started for two of the proposals, the one from Santa Elena and the one from Bareges (see below). However, all proposals will be in this process until mid-August 2019, and the goal is to have most decisions on approval or disapproval ready by mid-September. Four of the proposals are for measures in France, and one is from the Spanish side, the Santa Elena proposal. The proposed measures are for reduction of risk from a variety of hazards; snow avalanches, rock fall, torrents, and erosion with transport and deposition of large sediment volumes. Hence, the measures are of great interest in a wider NBS perspective, as most measures available in global databases are related to floods.

The five proposals can be divided in two groups based on regions, type of consequences and stakeholders. Two proposals are from the Bastan Valley in France, and concern snow avalanches and torrent related erosion processes with mass transport and deposition leading to change of river-course and increased flooding. The other group concerns risk along an important road, A-136 / RD-934, between France and Spain. Three hazardous spots are selected for PHUSICOS measures along this road, which has up to 1.5 mill. cars passing every year. It is the only road through this particular area and therefore has high value, both economically, for tourism, but also for security, as there are few if any possibilities for emergency units to pass if the road is closed.

Future plans

As five proposals have already been submitted from the Pyrenees, related to a variety of natural hazards, no more proposals will be submitted from this demonstrator case.

3.3.1 Erosion and rock fall from a moraine ridge, Road A-136, Santa Elena, Spain

The NBS has been proposed by the EGTC Space Portalet, through CTP and BRGM, as the site responsible PHUSICOS partners. At present, this proposal has been evaluated and has received comments from all the members of the steering committee. A skype meeting has been held among the SC members, and the comments and questions have been sent to the proponents for their response before the SC members are to vote for approval or disapproval (revised procedure, see above). The site is the southernmost of the three sites along this road (Figure 3.5), and the only NBS proposed on the Spanish side.

Figure 3.5. The three sites along the trans-border road A-136.

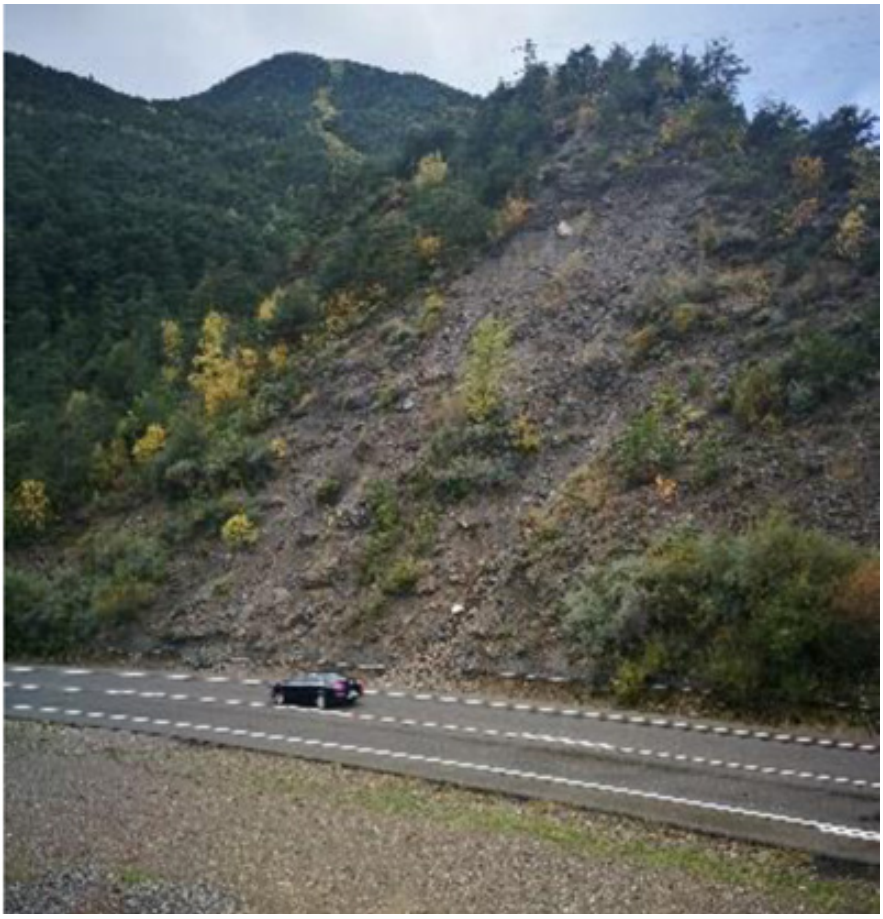

Figure 3.6 The problematic slope at Santa Elena.

Figure 3.7 The road, with low visibility immediately north of the slope. View from south

The slope (Figure 3.6) is presently secured with a net, which originally was attached to the ground. However, erosion over the last years have led to the net now being detached from the ground surface by 15-25cm. Furthermore, the net is broken at several places and is not working properly. The spot has been classified as a high risk spot in a recent consultant report.

The proposal is for reducing the rock fall hazard by establishing a terraced slope and revegetating with native species for this region (Salix sp., Pinus sp., Alnus sp., and various shrubs). The hazard is particularly great here, because the visibility is low for traffic from the north, and the probability of hitting obstacles in the road is therefore great (Figure 3.7). The terracing will be done by the use of wood and/or masonry. The overall slope will be reduced, and drainage solutions will be installed. Similar solutions were established in 1903-1905, in a large slope near the village of Biescas, not far from the Santa Elena slope. Due to dense and effective revegetation, these measures can no longer be identified from the distance, but are still working well after >110 years (Appendix A).

The 're-discovery' of such functioning, old, traditional solutions is a secondary goal of the present proposal for Santa Elena, as well as for other proposed measures in the Pyrenees (see below).

Stakeholder involvement – Living Lab process

The stakeholders involved are mainly from the administrative level, and include the EGCT, the regional road services of Aragon, Spain, the environmental administration of Aragon, the municipality of Biescas, and the French department of Pyrénées-Atlantiques as observer. Furthermore, there are plans to involve tourist associations, as well as environmental NGOs. Through the Living Lab process, the proponents aim at a certain level of co-designing the measure, in particular when it comes to detailed design of the terraces and selection of plants to be emplaced.

3.3.2 Ravine with torrential flow in Socques, Road RD-934, France

This measure is also proposed by the EGCT Space Portalet, with CTP and BRGM as the responsible PHUSICOS partners. The measure is the second of three along the same trans-national road between France and Spain. The hazard is posed by torrents in a ravine (Figure 3.8), which erodes and transports large amounts of sediments, which, after severe storms, are deposited upstream of the road. This may clog the drainage under the road (Figure 3.8) and lead to overflow and damage to this important cross-border road. A recent, not yet finalized study done by a French consultancy recognizes this spot as a high-risk spot along the road. The site is within the Pyrenees National Park (Parc National des Pyrénées-PNP), and all actions must be agreed upon and authorized by the PNP.

The proposed measure is to create a stepped river profile by establishing energy dissipating basins (Figure 3.9), both to reduce speed and erosive power of the river, and to ensure controlled deposition of the bedload carried by the river. The steps will be

constructed either by wood (Figure 3.9), or by using local rock material. Erosion protection will also be emplaced along the river immediately upstream of the road, and the capacity of the culvert under the road will be increased, in order to avoid clogging and ensure through-passing of suspended load and bedload not caught by the retention dams. An appropriate maintenance program of the culvert, particularly after extreme events, will be planned. Modelling of the torrents has been performed, and a goal is to establish a more balanced river profile.

Figure 3.8 The ravine at Socques, seen from the road, upstream (left), with easily erodible sediments seen all along the ravine, and the nearly clogged culvert under road RdD-934 (right). The culvert dimensions are 3x4m.

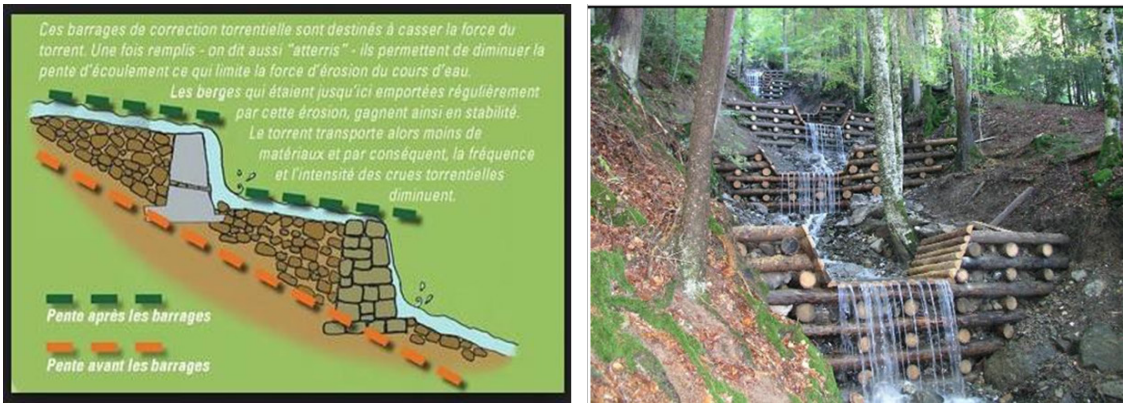

Figure 3.9 Principal sketch of the stepped solution with energy dissipating basins (left), and one possible solution sketched in the Socques proposal (right).

Stakeholder involvement – Living Lab process

The participatory process for the Socques case will be led by the EGCT Space Portalet, and coordinated with the road services of the region Pyrénées-Atlantiques, and with the Spanish region of Aragon as an observer. Other actors to be involved in the process include technical staff of the road services, the national park authorities (PNP), the National Forest Office (ONF) the association for restauration of the mountain terrains (RTM), as well as municipality of Laruns, French environmental authorities, and

environmental NGOs. These bodies will all be involved in discussion of various alternative solutions, and of the final design of the selected solution.

3.3.3 Rock fall at Artouste, Road RD-934, France

This is the third of the measures proposed by the EGCT Space Portalet, with CTP and BRGM as the responsible PHUSICOS partners, for the road between France and Spain (1-136 / RD-934). The road at Artouste has a severe rock fall problem (Figure 3.10). The main consequence is the possibility of road closure. However, this site also had a fatal accident in 2007, when a person died after a direct hit by a falling rock from the slope. A ca. 5m high retention wall is built along the road to stabilize the road cut. The slope above is roughly 40° steep, with loose blocks at several places on the slope. The main release area is a ledge about 200 m above the road. The present forest (relatively small diameter and too low tree density) is not sufficient to stop larger blocks that have been released from the ledge, caught speed, and may also move in jumps. Some blocks have been stopped, however, but may again be released as a result of falling trees. There are some relatively low fences in the lower part of the slope, but these have very little effect, as they are widely spaced and because rocks may jump over them and hit the road.

The proposed measure here is to construct innovative wooden structures (Figure 3.11) close to the ledge where most rocks are released, to prevent detachment or to stop rocks before they reach high velocity. A study will be carried out to find the most efficient structure, as well as the most resistive type of wood to use. The measures will be designed according to the local conditions such as slope, fracture pattern of the rock ledge, etc. Furthermore, the existing forest will be maintained in such a way that over time, also this will have a more protective effect than at present.

Stakeholder involvement – Living Lab process

The participatory process for the Artouste case will mainly comprise the EGCT, the regional (Conseil départemental des Pyrénées-Atlantique) road services, the regional and national environmental services, the national park services (PNP), the national forest office (ONF), the association for restoration of mountain terrains (RTM), municipality of Laruns, and relevant NGOs.

Figure 3.10 Overview of the hazardous area at Artouste (left), and one of the identified release zones for rock fall.

Figure 3.11 Example of the construction of one type of measure to be assessed at Artouste. The measures are to be constructed from local wood.

3.3.4 Snow avalanche risk at the village of Baréges, France

The village of Baréges is threatened by large snow avalanches (Figure 3.12), and were hit badly in 1897 and in 1907. The village is originally built up around a military hospital, which now serves as a military training camp. There are two main avalanche paths, which lead to the military facility and the lower parts of the village, respectively. After the accidents in 1897 and 1907, large protecting structures have been built over a number of years in several of the release areas. The structures are mainly 4-5 m high snow fences and terraces. All together there is a total of 5 km of fences in the release areas of the two main gullies. These are very maintenance demanding and a large avalanche in 2013, which hit the old military hospital, but without doing much damage,

showed that the current measures are insufficient. Partly due to heavy precipitation and partly due to snow drift, accumulation in the release areas, near the crest of the mountain, often exceeds the height of the fences. In the event in 2013, it was the snow above the fences, which detached and formed the avalanche.

The proposal for this site is to carry out reforestation in the release area of one of the avalanche paths. The reason to choose only one of the avalanche paths, is that the slope of the release area is somewhat lower, and that it has a soil cover, whereas the other is mainly characterized by bare rock faces. The vegetation to be planted will be a mix of suitable species. The most typical pine species in the region is currently being seriously affected by a disease, which causes tree death over large regions. Therefore, the proponents will plant a mixed vegetation of trees, which also are meant to adapt to climate change. The plants will be protected by wooden structures until they are strong and tall enough to withstand the pressure from snow creep (Figure 3.13). Some plants have already been planted in the area as a test, and the expected growth rate is in the order of 0,5m/year.

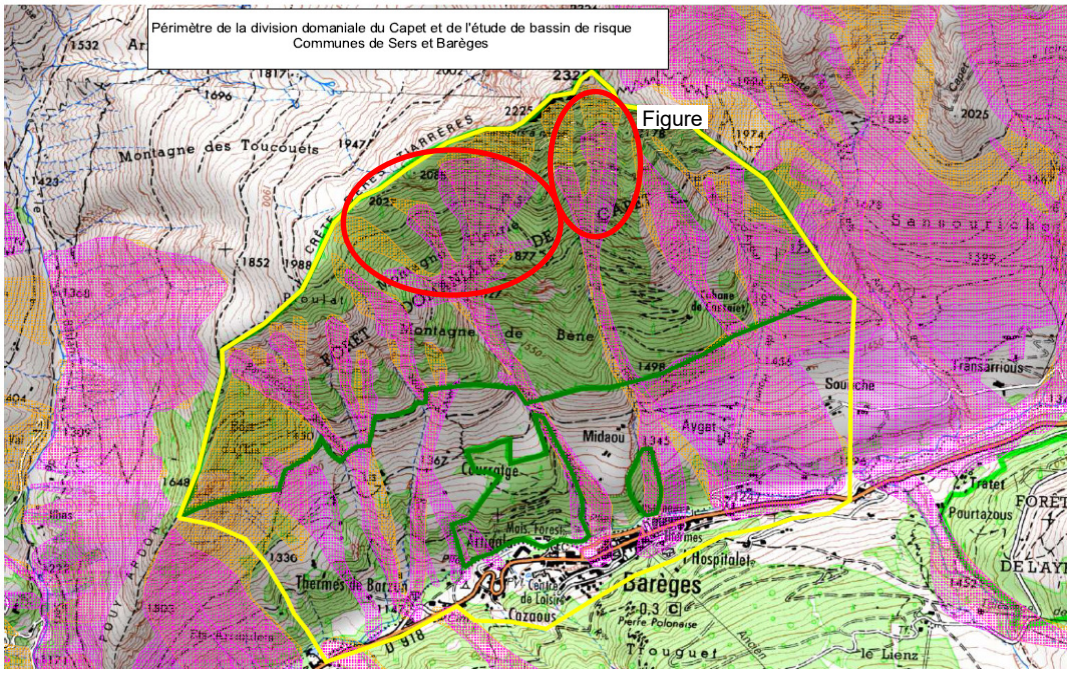

Figure 3.12 The valley side north of the village of Barèges. Avalanche paths are between the green areas and mainly follow gullies towards the valley and the village. Release areas of the two main gullies in the proposal are marked with red circles.

Figure 3.13 The type of wooden structures, made from local wood, planned for implementation to protect the plants from damage by snow creep during the first years. The structures will themselves also prevent release of snow avalanches.

Stakeholder involvement – Living Lab process

The planned participatory process comprises the municipalities of Baréges and Sers, the national park services (PNP), the National Botanic Conservatory of the Pyrenees (CBNP), representatives of the Natura 2000 zone, and the French state, represented by the territorial department and the sub-prefecture of Argelés-Gazost. The population knows the problem and is keen to find good solutions. The current measures need much maintenance, and the current estimated maintenance costs are about 300.000 Euros/year, and mainly includes repair and cleaning of the fences. An important co-benefit with the proposed NBS is therefore economic gain, through less maintenance over time.

3.3.5 Torrents in the Bastan River and its confluence with the Gavernie River, France

The torrent related measures for the Bastan River are proposed at two locations, one at the point where the smaller Bastan River meets the main Gavernie River, and another a few km upstream along the Bastan River.

The confluence between the two rivers

In 2013 a severe flood destroyed part of the road along the Bastan river (see below) and also most of the riparian zone at the confluence with the Gavernie river. After the flood the municipality built an extended river bank, made of stones (taken from the river bed) and concrete, almost 2 m high. The river bank was moved around 10 m towards the river and a playground for children was built on this prolonged zone.

The proposal for this site is to remove the constructed river bank, which currently forms an obstacle into the river, build a green barrier 10-12 m away from the river bank, and renaturalize the area with vegetation by installing a new riparian zone along the river. This will provide more space for the river and particularly during floods, and prevent sediments to be deposited at the confluence, which previously has led to increased flooding problems.

Figure 3.14 The confluence between the Bastan River (from the right) and the Gavernie River. The constructed riverbank to be removed is marked with green shading. Red lines are boundaries between municipalities.

Upstream along the Bastan River

The road along the river was destroyed during the severe flood of 2013. Satellite images from before the event show that the riverbed was smaller in width and that there was a riparian zone with trees along the river bank. The road was rebuilt and a new riverbank was made mainly using stones taken from the river, which are smooth and rounded, rather than using square blocks, usually used for these purposes. This leads to a lower stability of the road foundations. In addition houses nearby are also at risk during floods. At present, the river bed is not stable and is vulnerable to erosion and sediment transport during floods.

The main idea is to stabilize the river bed with a step-and-pool system and establish a riparian zone along the bank (Figure 3.15 and Figure 3.16). The cross-sectional shape of the river bed will also be changed to stabilize and increase the transitional zone between the riverbed and the valley, and thereby also increase the area available for grazing sheep. Moreover there are some invasive plants that will be removed and the typical species of that area will be reintroduced. The road authorities are involved in the project as a part of the proposal is to stabilize the road foundation by using solid, square blocks from the valley sides, and exchange these with the rounded blocks presently used in the foundations. The latter blocks will then be used for reshaping and stabilizing the river course. The measure is planned to be implemented in a ca. 1km long stretch of the river (Figure 3.15), but with a plan to later upscale to cover the entire 14 km of the Bastan River, when the functionality of the measures are proven.

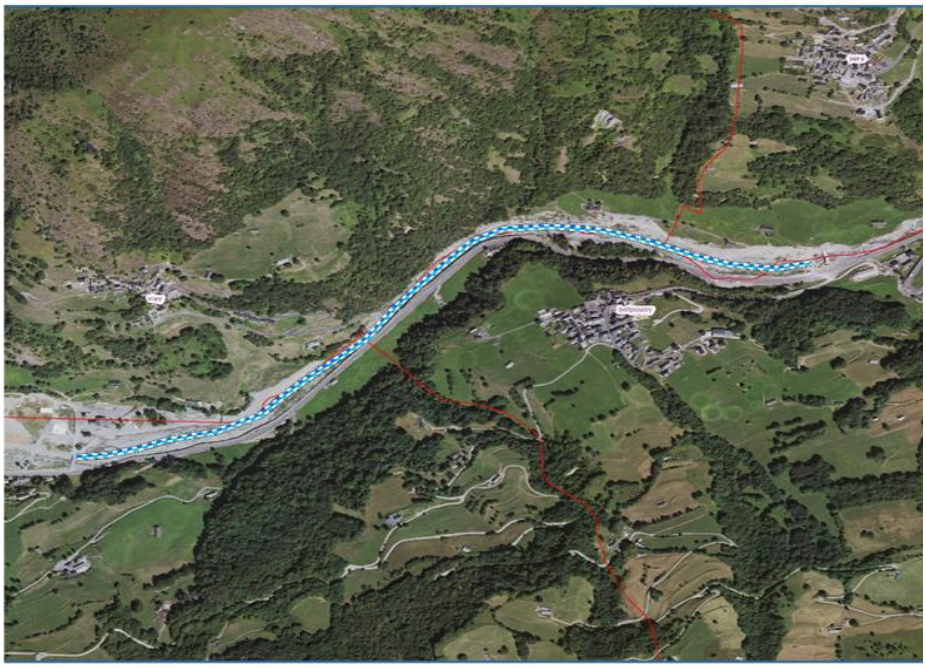

Figure 3.15 The roughly 1km stretch (blueline) of the Bastan River planned for restoration by the principles of Figure 3.16.

Stakeholder involvement – Living Lab process

The participatory process for the two proposed measures will comprise all relevant stakeholders: local political leaders, state agricultural agency, the botanical conservatory, national park authorities (PNP) the forest administration (ONF), and, perhaps most important in this case, representatives the local population and the farmers. The area at the confluence zone belongs to the municipality, whereas the area along the Bastan River is privately owned by the farmers. There is currently a general scepticism among the population regarding NBS and establishing a riparian zone along the river. Whereas the construction itself can be carried out over a relatively short time interval, the main challenge is to involve the local population in the project and thereby achieve

co-creation and co-design of the measures. The living lab process for the measures are currently being planned.

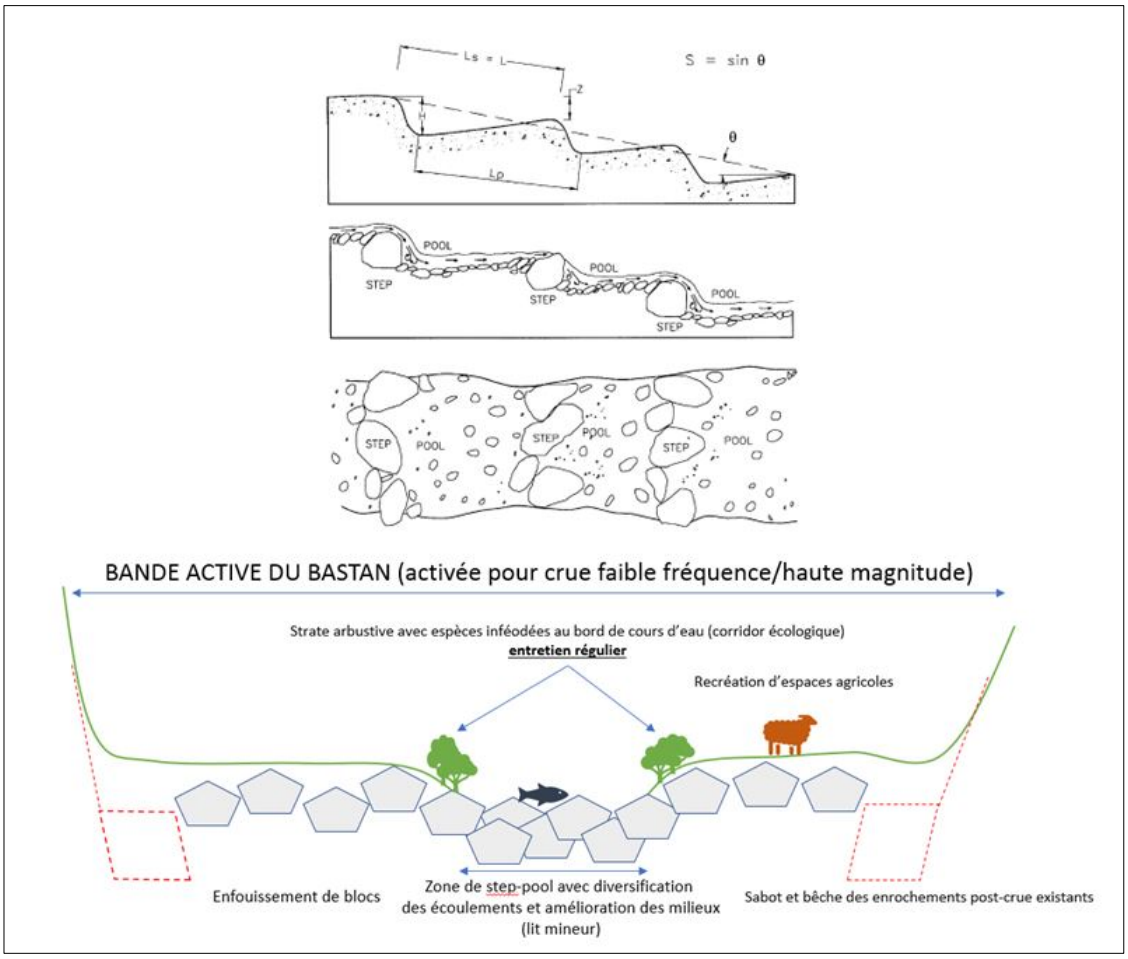

Figure 3.16 Concept drawing of the stabilizing and revegetating measures along the Bastan River.

3.4 Concept case site The Isar River, Germany

The Isar River concept case is one of measures which have been carried out and completed. The reason for including this case in PHUSICOS, is to learn from all aspects of this river restoration project, both regarding the technical implementation, and not the least, the participatory processes carried out in order to make the project a success.

Over the last two decades, the state of Bavaria in cooperation with city governments and other relevant stakeholders have implemented a wide range of local NBSs, along the Isar River. These succeeded to decrease flood risks and the river incision rate, ameliorate recreational quality and improve the ecological status of the river course and its floodplains. The post-analysis of this concept case provides a good practice framework of a successfully implemented flood risk management plan and related river restoration, enabling to identify the key factors relevant to the other PHUSICOS case study sites.

This is the background for the 'look-and-learn' visit proposed by PHUSICOS partner Technical University of Munich (TUM) on 19 December 2018 and approved on 22 January 2019. The proposal included a relatively small budget for subcontracting, and was approved without revision, but still with comments that helped improving the proposal. The visit was carried out over a three-days period in March 2019. It was held as a combination of workshops with presentations and discussions, and excursions, both along the restored Isar (Figure 3.17) into the city of Munich, and to the upper reaches of the river and the hydrological modelling laboratory, which modelled all measures as part of their final design.

On 20 March participants received input from various Isar partners, regarding two Living Labs, which had been set up during the early stages of the Isar project. Both Living Labs led to implementation of measures, and this provided valuable insights and inspiration about stakeholder processes for the facilitators and site owners of the demonstrator cases. An excursion along the Isar to the centre of Munich enabled participants to see and understand the implemented Isar-Plan project on site, which is one of the NBS implementation recognized worldwide as a good practice to follow.

On 21 March a field trip at the upper Isar presented further NBSs and negative effects of grey infrastructure on the riverine system. Furthermore, a visit to the modelling laboratory showed how innovative NBS were tested before their implementation.

On 22 March theoretical presentations on innovative NBSs were provided. A research group working on improvement of riverine retention potential presented their preliminary results and an engineering office presented the technical specifics of the Isar-Plan. The final day was also used by WP3 partners to support the different PHUSICOS cases with their next steps for their Living Lab strategies.

A professional film company was hired by TUM to do filming (Figure 3.17) and interviews during and after the visit. A short information movie about the PHUSICOS, Isar project and Nature Based Solutions in general has since been produced and is now available on the project's website (https://phusicos.eu/).

Figure 3.17 Photos from the 'Look and learn visit' to the Isar River in March 2019.

Future plans

The proponent for the Isar concept case, TUM, will propose at least one more 'look and learn' visit to the Isar, with main focus on aspects related to the stakeholder involvement, governance, funding schemes, monitoring systems, as well as policy questions. The timing of this is not yet decided.

3.5 Concept case site The Kaunertal Valley, Austria

The Kaunertal concept case is an innovative small-scale research project with the aim of revegetating barren slopes in high alpine areas, such as those left by retreating glaciers. The measures have a large upscaling potential, and the methods may also be of interest for other PHUSICOS sites, such as some of the sites in the Pyrenees (above). The proposal was submitted on 22 February 2019. There were parts which needed clarifications, in particular regarding the budget, and a revised version was submitted on 6 March 2019. Approval was given on 22 May 2019.

Revegetation activities are well known for their effectiveness in reducing erosion and to consolidate slopes. However, seed mixtures applied on unconsolidated slopes often do not establish long-lasting plant covers or do not have the desired effectiveness forcing repeated management actions. Furthermore, in high alpine regions no seed mixtures are available that are adapted to the extreme conditions. Therefore, the proponents (UNIVIE and PLUS) will 1. Test high alpine plant species for their potential in the reduction of erosion and 2. Identify microbes that assist the plants in the establishment in areas of loose soils. Effective reduction of sediment erosion by revegetation is determined by plant cover (percentage of the area covered by plants), but also by plant diversity and the functional composition of the plant assemblies. Therefore, plants with large leaf surfaces and a large root system will be favoured in the project. Agricultural applications show that microbes have the potential to affect relevant traits and to help plants to tolerate stress, such as dry and cold conditions, which the seeds may encounter in the alpine sites. The effectiveness of elevation-adapted plant species assisted by microbes in erosion reduction will be demonstrated in proof-of-concept sites. The most efficient seed-microbe mixtures will be applied in implementation sites to demonstrate the applicability and the potential for upscaling.

The first six months (May-Oct 2018) of the project were used to install sediment traps quantifying the erosion of treated and untreated sites (Figure 3.18 and Figure 3.19). Untreated sites serve as control to evaluate the effectiveness of the treatments with microbe-assisted plants. In winter 2018/2019 the plant and microbe communities at these sites were characterized in order to identify plant, bacteria and fungus species well suited for an application. Lab work to test microbial effects on plant germination and plant phenotype are well established guaranteeing an efficient progress. A plant species that was identified as a potential target species is also of economic importance for a seed propagation company suggesting the potential for a tight cooperation. The proof of concept sites are maintained with the expertise of project staff.

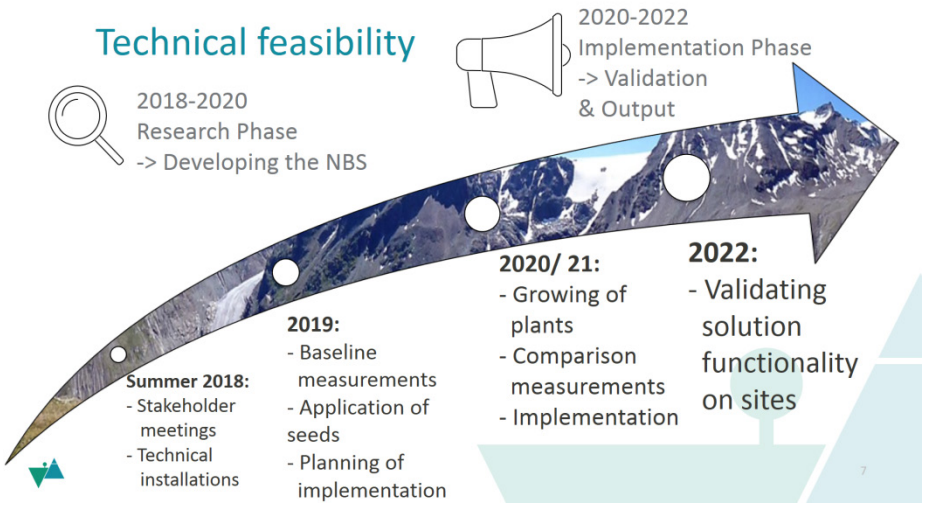

Figure 3.18 Technical plan for the concept case project in Kaunertal.

In 2019 (Figure 3.18) the proponents plan to do the baseline measurement, apply the seed mixtures and start the selection process for implementation sites with the involvement of local stakeholders (mayor, nature park CEO, the Tirolean Water company TIWAG, Ski resort responsible, shepherds and hunters) and greening companies. The aim is to deploy the seed mixture by the end of 2020 on the implementation sites to give the seed mixture a full winter of rest before they will germinate in 2021. First measurable results should be ready by 2022, still within the PHUSICOS project period.

Figure 3.19 Shallow landslide with erosion plot installations, road and reservoir in the background.

Stakeholder involvement – Living Lab process

A tight stakeholder involvement has been carried out from the early beginning of the project, and 17 personal meetings with partners in industry, government, municipality, and non-governmental organisations were carried out during the first 6 months. These partners strongly support the activities in the Kaunertal and facilitate an effective progress of the NBS. Additionally, outreach activities to broaden the awareness in the society have been implemented in 2018 (children university, regular newsletter) and are planned with the partners on site for the coming years. A four-hour workshop with all the 3rd and 4th graders of the valley were organized on 14 May 2019 in the framework of a project week on climate change and consequences for the valley. Furthermore, the involvement in a local nature exhibition has been discussed with the mayor and the CEO of the nature park and will be implemented in the coming years. All actions are well perceived in the municipality.

Future plans

The Kaunertal group, UNIVIE and PLUS, will not submit more proposals to PHUSICOS than the one described above. All subcontracting related to this experimental concept case are to be done with the funding allocated through the initial proposal.

4 Links to the PHUSICOS Work Packages

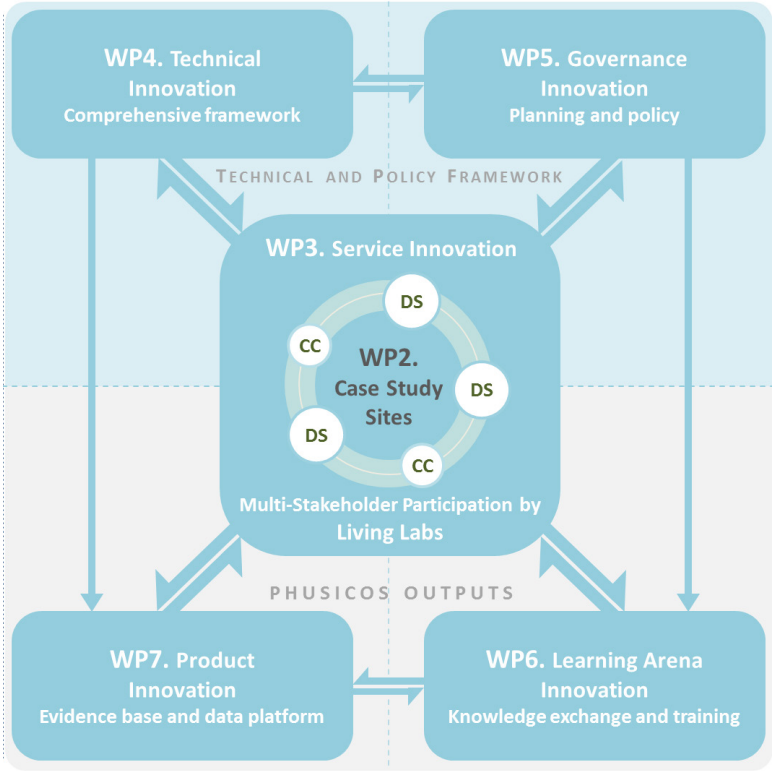

Figure 4.1 PHUSICOS work plan and project structure, (DS=demonstrator site; CC=concept case).

WP2 and the case study sites represent the core of the PHUSICOS project, with strong support from WP3 (Service innovation). All NBSs will be evaluated using the comprehensive framework developed in WP4 (Technical innovation) (PHUSICOS, 2019c), and there are close links to the three other innovation WPs (Figure 4.1).

WP3 - Stakeholder involvement through the Living Labs process (Lead partner TUM)

Stakeholder involvement through a Living Labs approach is an important part of PHUSICOS. The LL approach is supported by WP3 – 'Service innovation: stakeholder participation through Living Labs', and has been described in Deliverable D3.1, 'Guiding Framework for Tailored Living Lab Establishment at Concept and Demonstrator Case Study Sites' (PHUSICOS D3.1, 2018).

In PHUSICOS, some of the case sites have already had contact with a range of key stakeholders, and the planning of various NBSs to be proposed has reached different stages. Therefore, the LLs will have different objectives and start at different phases of selection and implementation of the proposed NBSs. It is thus important that the individual LL processes will be tailored by the case site teams to the local context at

each site, considering local needs and ambitions, physical conditions, and socio-cultural factors. This is described under the individual proposals, above.

WP3 has developed comprehensive tools for running the Living Labs process as well as for monitoring and evaluation of the stakeholder involvement in the various cases. These tools are documented in WP3 deliverables D3.2 and D3.3, respectively (PHUSICOS, 2019a and PHUSICOS 2019b). The starter toolbox of D3.2 is meant as a tool to help the local facilitators of the living labs processes, whereas the scheme of D3.3 offers tools to monitor and evaluate the stakeholder participation and user satisfaction. Both of these reports and the tools therein will be extensively used by the agencies responsible for the case sites and their local facilitators of the Living Labs processes.

WP4 - Assessment and evaluation of the NBSs (Lead partner UNINA)

WP4 has designed a comprehensive framework for assessment of NBSs in the context of natural hazard risk mitigation and ecosystem services monitoring, with the clear objective to strengthen the evidence regarding the effectiveness of NBSs. The suggested NBSs must comply with the monitoring criteria developed in WP4.

Deliverable D4.1 (PHUSICOS, 2019c) is developed as the central assessment tool for PHUSICOS. The tool is a comprehensive framework to verify the performances of NBSs in risk management processes from both technical and socio-economic points of view. The comprehensive framework assesses the beneficial role of NBSs in ecosystem services, which is a crucial metric for the overall evaluation of the implemented intervention and solutions. In addition to ecosystem services, environmental, economic and social indicators are coupled with the above-mentioned risk management indicators, defining positive co-benefits, as well as potentially undesirable side effects and social perceptions. All NBSs under the PHUSICOS project will be evaluated following the WP4 framework, which also includes evaluation of the stakeholder involvement.

The project scenarios assessment is carried out in comparison with a baseline scenario using the implemented comprehensive framework tool. Specifically, the number and typology of indicators of the framework tool are modified with reference to the site-specific hazards for which NBSs are designed. During the May 2019 consortium meeting in Vienna, WP4 provided the DCs and CCs with the customized framework tool, leaving the indicators selection open to discussion. Main differences between the customized framework tools distributed to CCs and DCs regard the performance indicators of the hazard criterion (risk ambit):

- Gudbrandsalen DC: peak flow and flooded area;
- Serchio River Basin DC: peak flow, peak volume, flooded area; standardized precipitation index, effective drought index;
- Pyrenees DC: landslide safety factor, occurred landslide area, velocity of occurred landslide; snow cover map; barrier effect index, overall rockfall protection index;
- Kaunertal CC: landslide safety factor, occurred landslide area, velocity of occurred landslide;

- Isar CC: peak flow, peak volume, flooded area.

The remaining indicators will be selected, together with the study case leaders, among the most relevant for the specific case, also taking into account the data availability. Furthermore, directions on the performance indicator calculation at the baseline scenario were provided.

At this stage, the preliminary NBS assessment for the Isar DC has been carried out by WP4 (UNINA+TUM) and the obtained results have been disseminated at international conferences.

WP5 - Governance innovation for the design and implementation of nature-based solutions (Lead partner IIASA)

WP5 will explore policy framework financial instruments to enhance the effectiveness of the design and implementation of NBS in the context of governance innovation. This will include an analysis of EU policy for enabling NBS as implemented by national, regional and local governments, and also instruments and initiatives on the part of the business community and non-governmental organizations. For this, 3-4 cases will be selected for in-depth analyses. The Isar concept case is already one of these, which will be reviewed for governance, whereas the other are to be selected from the NBS data base developed in WP7.

WP6 - Learning arena innovation to encourage knowledge exchange (Lead partner Oppland County Administration)

WP6 will facilitate closer collaboration between stakeholders using learning arena innovation to encourage knowledge exchange through the identification of possible NBSs, co-development of scenarios and modelling their impacts at the demonstrator sites, as well as training programmes for key stakeholder groups: decision-makers, technical specialists including local contractors as well as citizens. The activity of this WP has just started, and the main activity is on testing a solution using virtual reality (VR), building on the established hydrological model for the Gudbrandsdalen demonstrator case site, and for the suggested NBSs comprised by the site.

WP7 - Product innovation to develop an evidence-base and data platform (Lead partner BRGM)

WP7 aims to establish a comprehensive state-of-the-art evidence-base and data platform concerning NBSs related to extreme hydro-meteorological events in rural mountain landscapes. The established platform will be provided as a service product for the market. The current inventory includes NBSs for relevant hazards in mountain areas and the submitted and planned NBS proposals presented in this report will be added to the inventory.

WP8 - Dissemination and communication (Lead partner NGI)

The overall ambition within this work package is to design and implement strategic communication in order to demonstrate how PHUSICOS can provide adequate proof-

of-concept for the ability of NBSs to address hydro-meteorological events in sensitive rural and mountainous regions. The results of all NBSs described in this report will be communicated to a wide audience through a number of channels. This activity is well underway with dissemination through seminars, website, social media, etc., and will be further strengthened as proposed NBSs are implemented and results appear.

5 References

PHUSICOS, 2018a: Procedures for distribution of funds and tenders. PHUSICOS Deliverable D2.1, 46pp.

PHUSICOS 2018b: Guiding framework for tailored living lab establishment at concept and demonstrator case study sites. PHUSICOS deliverable D3.1, 100pp.

PHUSICOS 2019a: Starter toolbox for stakeholder knowledge mapping to co-design nature based solution at case study sites. PHUSCOS deliverable D3.2, 187pp.

PHUSICOS 2019b: Monitoring and evaluation scheme to assess stakeholder participation and user satisfaction with living lab experience, Version 1. PHUSICOS deliverable D3.3, 119pp.

PHUSICOS, 2019c: Comprehensive Framework for NBS Assessment PHUSICOS deliverable D4.1, 137pp.

Silvestri, N., Pistocchi, C., & Antichi, D. (2017). Soil and Nutrient Losses in a Flat Land Reclamation District of Central Italy. *Land degradation & development*, *28*(2), 638-647.

Appendix A

Site visits to the demonstrator case sites.

Contents

A1 Introduction

Site visits to the three large scale demonstrator sites were carried out during the fall of 2018 and the spring of 2019. The primary goal of these visits was to see all, or most off the potential case sites, which will be subject for NBS proposals. However, another aim was to have discussions with the agencies responsible for the sites, in order to discuss the planned measures, and, if necessary improve the coming proposals.

After each of the site visits, which were carried out somewhat separated in time, a short report was written, which than was reviewed by the agencies responsible for the sites. These reports, not being one of the official deliverables of PHUSICOS, are formulated somewhat differently. However, they do describe the visits and the discussions adequately, and they are therefore compiled as they originally were written and included as an appendix to deliverable D2.2.

A2 Meeting and field trip, Gudbrandsdalen Demonstrator site, 03.09.2018.

A2.1 Meeting in Oppland County administration (OFK).

Present: Anders Solheim, Mari Olsen, Turid Wulf Knutsen

Initial meeting

Solheim presented the project in general, as a background for further discussions.
OFK presented briefly the two measures they plan to propose for the project.
OFK also raised some questions, presented below, with AS' response:

- Can the 40% 'external funding' be money from e.g. the county administration itself?
    - *Solheim's response: Yes, the important thing is that only 60% of the funding comes from EU. The remaining 40% (at least) can be from any source, and can be both cash and/or in-kind.*
- Is it a problem if both the suggested measures are in the same side valley to Gudbrandsdalen, and that this is in the lower portion of the valley, and no suggested measures higher up in the Gudbrandsdalen drainage?
    - *Solheim's response: Probably not a problem. Other Demo sites, such as the Pyrenees, will also only have limited locations suggested to the project. But OFK may think of a backup location further up the valley, in which perhaps landslides and transport of sediments to the river could be the primary problem.*

A2.2 Field trip to two proposed NBS locations:

The two measures are:

- Use a small lake and two bog areas (Figure 2.1&Figure 2.2) in the hills above Follebu to delay the downstream flooding in two problematic rivers, Finna and Liumsbekken.
- Establishment of a new flood barrier away from the river near the outlet of river Gausa to Gudbrandsdalslågen. This will provide space for the river in a 100-300m belt of swamps and riparian vegetation.

The Follebu site

Mari Olsen and AS drove from Lillehammer to the administrative centre of Gausdal municipality, SegalstadBru, and met with Jon Sylte of the county administration. Sylte explained the different measures they had planned and partly started in this part of the valley of Gausdal, a tributary to Gudbrandsdalen valley proper.

The trip then went up along the stream Finna to its source, Lake Finntjern (Figure 2.3). Along the river, we were shown a number of problematic points, mainly road crossings with poor culverts and erosion problems. The municipality has already contracted a mapping project for the area to a consultant, and this mapping will focus on the problematic areas and what measures should be taken there.

All measures to be taken by the municipality were triggered by a new area of housing (family dwellings) to be built next to another, existing area of housing. Different measures, including drainage and sedimentation basins are planned in detail there. These are also interesting for PHUSICOS. The sedimentation basins will be dry and used for playground, green areas, parks, etc. during periods of no flooding.

All measures started are based on municipal funding, with some economic support from the Government thorough the Norwegian directorate for water resources and energy - NVE.

For PHUSICOS, however, the measures in the upper parts of the two streams are the most important. This involves two bog areas, both with forestry roads on the downstream side (Figure 2.1&Figure 2.2). The ideas to be proposed to the project is to lift short parts of these gravel roads to make a barrier in front of the bogs. Drainage will then be dimensioned to let the streams have normal drainage most of the time. During flooding periods, however, the bogs will fill up and delay the flooding further downstream, acting as retention basins.

A similar measure is thought of for Lake Finntjern. The lake is the water reservoir for some of the farms down in the valley, and already has a small earth dam (Figure 2.3). The idea is to build this somewhat higher, by ca. 1m, and this way further delay flooding downstream. These are relatively small catchments, and delaying flooding with some hours may make a large difference.

The Jorekstad site

The river Gausa frequently has floods and transports vast amounts of sediments into the main river Gudbrandsdalslågen. The low-lying plains on the south side of the lower parts of the river are frequently flooded, and in addition to flooding agricultural land, it threatens a sports facility, family dwellings and a military facility. After the large flood in 1995, the Energy and Water Directorate (NVE) built flood and erosion protection along the riverbanks at some locations (Figure 2.4), but this is far from sufficient.

The suggested measure for PHUSICOS is to remove the present barrier along the lowermost part of the river, and to build a new barrier 100-300m inland of the river (Figure 2.5). This will provide space for the river to move naturally during flooding, in an area where there is swamps and 'floodplain vegetation'. There are also a few farm fields, which will be flooded (Figure 2.6), but these are always flooded during floods anyway.
The existing barrier along the riverbank is ca. 400m long, but the new 'inland' barrier could be up to ca. 2,5km long.

Figure 2.1 One of the bogs to be used is to the right of the road, which will be lifted by roughly 1-2m relative to the lowest point.

Figure 2.2 The other bog area, which may be used to delay flooding downstream. The design will be similar to the one above, by lifting the road ca. 1m.

Figure 2.3 Lake Finntjern, with the original dam. The plan is to raise this by 0,5-1,0m.

Figure 2.4 The base of the original (from 1995) 400m long barrier along the river Gausa. This barrier will be removed and replaced with one 100-250m inland.

Figure 2.5 The new barrier will roughly follow the dirt road, protecting the green fields seen in the photo, but leaving fields on the other side of the trees to be flooded.

Figure 2.6 The proposed barrier will be built to the left oh these fields, which will be flooded during extreme events. The forest to the right is a strip of floodplain vegetation and the distance to the river, to the right, from the edge of the field, is ca. 30m.

A3 PHUSICOS Site visit to Serchio River Basin.

As part of a series of site visits, WP2 leader Anders Solheim visited the Serchio River Basin proposed sites and had meetings with the involved Italian parties on 7-9 November 2018. The sites are all around Lake Massaciuccoli, hereafter referred to as 'the lake' (Figure 1).

A3.1 Meeting with ADBS in Lucca, Wednesday 7.11.2018, 15:30-17:00.

Present: Anders Solheim, Nicola Del Seppia, Andrea Di Grazia, Nicola Coscini, BenedettaLenci (Head of division)

Nicola gave a presentation about the case and their plans. Key points are:

- ADBS cover a large region, all Tuscany and Liguria. They have just been merged with the northern part, with main office in Florence. Much effort has been put into work with the merger.
- The natural hazards related to the lake and areas around are:
    - Flooding, both from the lake and from the Serchio River.

  - Drought.
  - Water quality degradation and salinization. (Lake waters have a salinity not far from that of normal marine waters).
  - Subduction, from pumping of ground water and from decay of organic matter. The area around the lake is an old swamp area, and there is a high organic content in the sediments.
  - Landslides / debris flows on the east side, which is hilly. This threatens mainly the existing Fossa Nuova Channel, which is to be considered critical infrastructure for this area. A country road is also affected by the landslides.
- The population affected by flooding is ca. 31.000
- There has been an industry on silica rich sands. Sand resources have been excavated and has left depressions 20-30m deep. This activity has now stopped.
- The lake surface is roughly at sea level, while large areas around the lake are below sea level (Figure 2), and are kept dry by canals and pumps. Flooding from the sea has happened. The Serchio River is elevated relative to the lake and the areas around it (the padule). The lake is artificial, surrounded by levees.
- The proposed new diversion channel is planned as a pipe. Open channel is considered too expensive. Water will be pumped from the river, with a flux of 1,5 m^3/s.
- Main barriers include:
  - Time availability of some stakeholders. Some organizations have not responded to requests yet.
  - The role of the farmer's associations (2 main ones) is very important. The farmers are generally positive, but there are issues of discussion, such as the use of the water from the diversion pipe, and what crops to grow in the fields.
  - Landscape considerations. This is largely a national park and has special laws and regulations.
  - Some scepticism to NBSs and their effectiveness, relative to grey traditional measures.
  - Demonstration of the effect of NBSs is necessary.

A3.2 Site visit to the Lake Massaciuccoli,Thursday 8.11.2018

Participants: Anders Solheim, Nicola Del Seppia, Andrea Di Grazia, and Nicola Coscini from ADBS, Altair Pirro and Claudio Vanneschi from CGT.

The field trip (Figure 3.1&Figure 3.2) was mainly focused on the problems related to the hydraulic hazards, and included visits to canals, pumping stations, etc. However, these are also the areas where the PHUSICOS NBSs are to be implemented. The trip was very useful in order to understand better the problems faced by this area. Visited sites included also the point in the Serchio River where the diversion pipe is to start, and the point where it will enter the Fossa Nuova Channel. The planned buffer strips with forest are also planned along this and other channels.

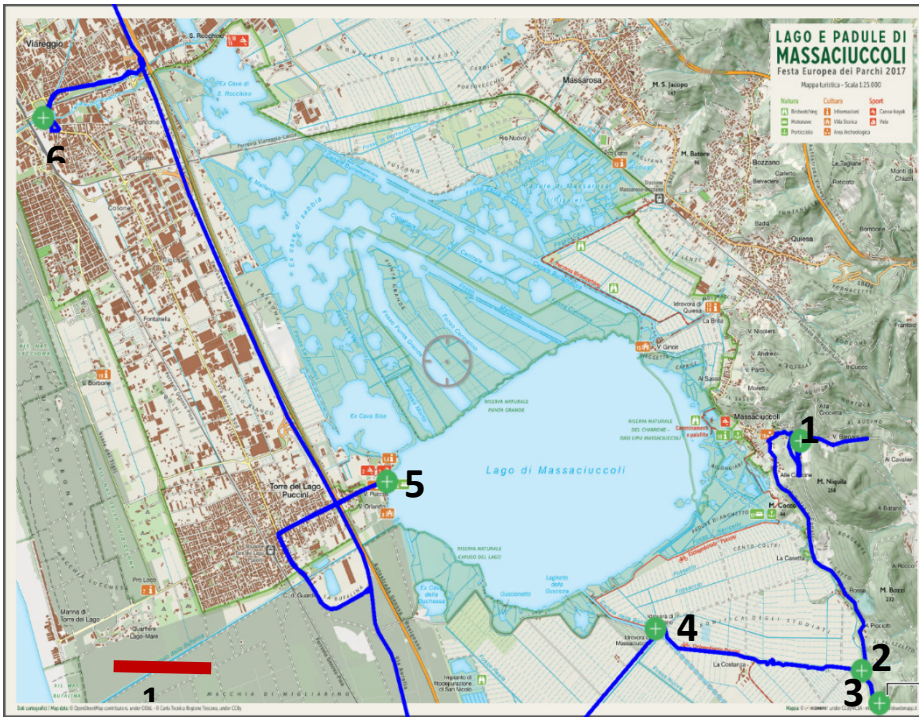

Figure 3.1 Map of the Lake Massaciuccoli area with the field trip route (blue) and stops (numbered green dots).

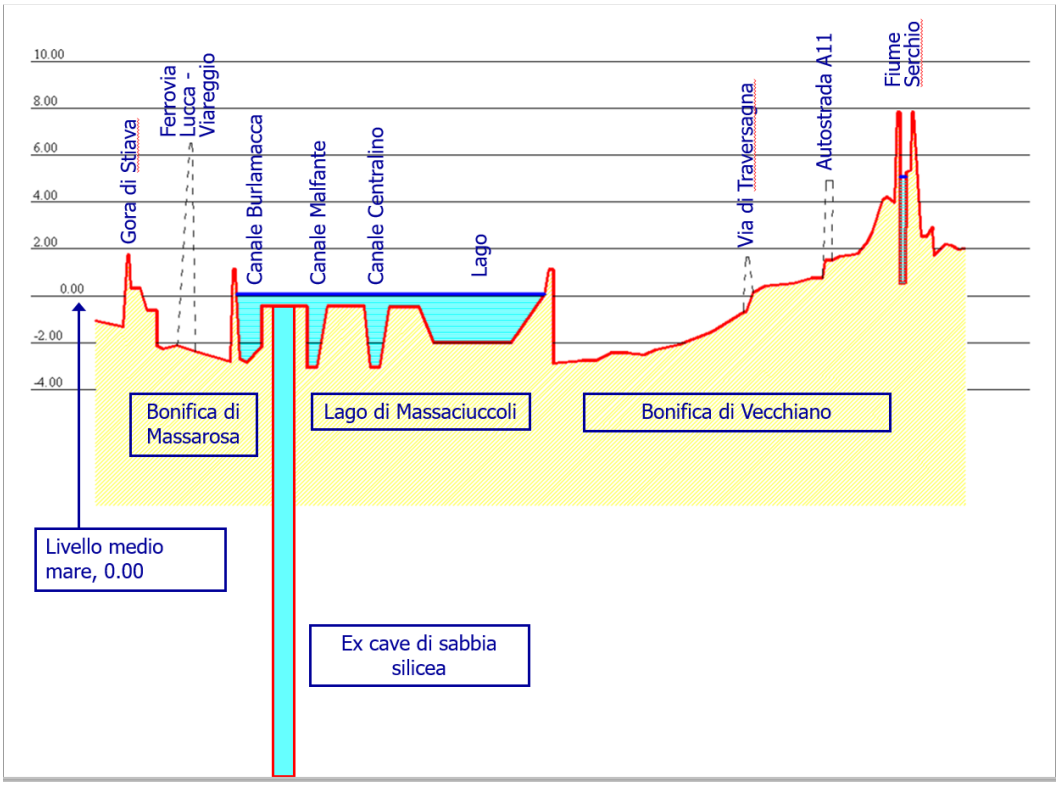

Figure 3.2 Profile roughly SSE – NNW, from the Serchio River across the lowlands and the lake towards the sea. The deep 'whole' is an abandoned pit after exploitation of the siliceous sands in the area (From ADBS).

A3.3 Notes from field trip stops (Figure 1):

Stop 1 (Figure 3.3)

This stop was to get an overview of the area. The photo (Figure 3) shows the lake and the farmlands to the south of the lake. The sea can be seen in the far distance in the photo. The main crop grown in the fields is corn. The small ponds in the foreground are abandoned rice paddies.

Stop 2 (Figure 3.4)

This is the Fossa Nuova channel, into which the diversion pipe will supply water from the Serchio River. The entry point is about 1 km to the south, upstream. The soils in the area are fertile, but pollution from the agricultural activities, feeding into the channels and then into the lake, is a serious problem.

Figure 3.3 Overview of Lake Massaciuccoli and the farmland to the south of the lake, seen from stop 1. The sea is seen in the far back of the photo. Ponds in the foreground are abandoned rice paddies.

Figure 3.4). The Fossa Nuova channel, seen downstream, which will receive and lead the water from the Serchio River.

Stop 3 (Figure 3.5)

This is roughly the entry point for the diversion pipe into the channel. The pipe will have a diameter of 600mm, and the capacity is 1,5m^3/s. This is also limited by the discharge of the Serchio River during dry periods.

A point of controversy with the farmers of the region, is that the farmers would like to use the supplied water directly for irrigation, whereas the authorities' first priority is to improve the water quality of the lake with the supply of river water.

Stop 4 (Figure 3.6)

This stop is by one of the pumping stations of the area. These are important to avoid flooding of the farmland, which is about 3m below sea level, whereas the lake is roughly at sea level. Water is pumped to the lake, from which it leaves through a main channel to the sea.

Stop 5 (Figure 3.7 & Figure 3.8)

Whereas this was more of a touristic stop, near the house of the composer Puccini, the stop provided a good view of the lake and the hills along its east side (Fig. 3.7).

Furthermore, ADBS also measures the lake water level at this site (Figure 3.8). If it goes too low, the connection to the sea is closed in order to prevent further inflow of saline seawater.

Figure 3.5 (Stop 3). This is just above the planned entry point for the diversion pipe from the Serchio River. Fossa Nuova Channel starts just behind the bushes and runs between the road and the fields.

Figure 3.6 (Stop 4). One of the pumping stations. The water in the basin is roughly at sea level, as is the lake level. The lake is right behind the trees in the distance, which mark the levee bordering the lake. The farmland between the pumping station and the lake is roughly 3m below sea level.

Figure 3.7 View from Stop 5 towards the east side of the lake.

Figure 3.8 (Stop 5). ADBS's measurement of lake water level relative to mean sea level.

Figure 3.9 (Stop 6). The lock and its upper gate (which is closed) in the channel that connects Lake Massaciuccoli to the sea.

Stop 6 (Figure 3.9)

This is the location of the main gates (including a lock) in the channel leading to the sea. The main gates are open during times of high lake level, and closed when the lake level is below sea level. During the visit, the sea level was about 20cm above the lake level, and the gates were closed.

Following the field trip, Andrea Di Grazia gave a presentation in the ADBS office. Key points here were:

- There are levees around most of the lake. Hence, the present-day lake is artificial, with a depth of around 2 m, except for one old pit after sand out-take, which is significantly deeper, roughly 25m. The whole area was mostly a swamp area before agricultural activities commenced.
- The pumping stations were first built in the 1920-30'ies. They have been flooded several times, latest during the large floods in 2009. In such cases, transportable emergency pumps are available.
- The average annual precipitation for the area of the lake is 900-1000mm/year, but there are areas in the mountains to the east (Apennines) which get 3000mm/year.
- The lowlands around the lake have been subsiding about 3m since 1935. This is due to the pumping and to decay of organic matter in the sediments. It is gradually decreasing and is expected to reach a balance in the future.
- The diversion channel will be operational only during droughts, and ADBS will set a threshold for starting the flow through the channel. The threshold will probably be when the lake level is 10-15cm below sea level.

A3.4 Visit to CTG, Friday 9 November 2018.

Friday 9 November was set off for a visit to Centre for GeoTechnologies, CGT, in San Giovanni Valdarno. CGT is the *'Centre of University of Siena (UNISI) for applied geological investigations, research and high professional training'*. Participants, in addition to A. Solheim, from ADBS were Nicola Del Seppia and Nicola Cascini, whereas Altair Pirro and Paolo Conti (CGT President) hosted the visit, which also included short presentations from several of the CGT staff.

Despite its connection to UNISI, CGT operates as a semi-independent institute, with only few of the staff full-time employed by the university. The institute performs both research and consulting in fields such as Geomatics, remote sensing, GIS and digital cartography, soil- and rock mechanics, geophysics, geomorphology, hydrology and various geo-related web services. Both MSc. and PhD students are attached to CGT projects and spend time at the centre.

The visit included a tour and short presentations by the various groups in the main CGT premises, located in a renovated industrial area in the village of San Giovanni. Solheim also gave short presentation on the overall aspects of the PHUSICOS project. CGT's geotechnical and rock mechanics laboratories (Figure 3.10), located just outside of the

town, were visited at the end of the day. These include certified laboratories for advanced soil (Figure 3.11) and rock testing in spacious and practical facilities, which also contain CGT's warehouse for field equipment, including heavy-duty equipment like a vibroseis truck and a small airplane (Figure 3.12).

Figure 3.10 CGT's laboratory and warehouse building.

Figure 3.11 From CGT's certified soil laboratory.

Figure 3.12 From CGT's equipment storage, with their aircraft and the vibroseis truck (left).

A4 Site visit to the Demonstrator case sites in the Pyrenees, 4-5 June 2019.

As part of PHUSICOS WP2, CTP organized a site visit to the proposed NBS sites in the Pyrenees on June 4 and 5. Anders Solheim and Vittoria Capobianco from NGI represented PHUSICOS WP2. In addition to CTP and NGI, the visit involved a number of participants from various involved organizations (Table 4.1). The five sites represent several different hazards, such as snow avalanches, torrents, landslides, rock fall and erosion.

The five proposals from the Pyrenees are located in two main regions. Two of the sites are in the Bastan Valley, whereas the three others are along the important trans-national Portalet Road A-136 (Spain) / RD-934 (France). The sites in the Bastan Valley were visited on Tuesday 4. June, whereas the trans-national road was the focus of the site visit on Wednesday 5. June. In addition to the proposed NBS sites, two sites with old NBSs were also visited on Wednesday 5. June. These were both constructed more than 100 years ago in Biescas and Canfranc, Spain, and consist of terraced and re-vegetated valley sides. They have been serving their purpose ever since, but are no longer visible from the distance. These measures may serve as inspiration for other NBSs both in the Pyrenees and elsewhere.

Table 4.1List of participants during the two days site visit to the Pyrenees.

Contact	Partner	Email	4th June 2019 - Bastan Valley	5th June 2019
Anders Solheim	NGI	anders.solheim@ngi.no		
Vittoria Capobianco	NGI	vittoria.capobianco@ngi.no		
Isabelle Bouroullec	BRGM	i.bouroullec@brgm.fr		
Eric Leroi	R&D	eric.leroi@risques-developpement.fr		
Idoia Arauzo	CTP	i.arauzo@ctp.org		
Juan Terrádez	CTP	j.terradez@ctp.org		
Roberto Molowny	CREAF	roberto@creaf.uab.cat		
Enrique Doblas Miranda	CREAF	e.doblas@creaf.uab.cat		
Santiago Fabregas	ECGT	sfabregas@espalet.eu		
Servando González García	DGA - Portalet EGTC	sgonzalezg@aragon.es		
Jerome Darré	PA-D64 - Portalet EGTC	jerome.darre@le64.fr		
Jean-Marc Bonnemason	PA-D64 - Portalet EGTC	jean-marc.bonnemason@le64.fr		
Patrick Carassou	PA-D64 - Portalet EGTC	Patrick.Carassou@le64.fr		
Alain Bruzy	ONF RTM	alain.bruzy@onf.fr		
Alain Masy	PLVG	alain.masy@plvg.fr		
Benjamin MAZERY	PLVG	benjamin.mazery@plvg.fr		
Pierre Escale	DDTM64	pierre.escale@pyrenees-atlantiques.gouv.fr		
Olivier Fryzou	PLVG	olivier.frysou@plvg.fr		
TOTAL			**12**	**15**

A4.1 The Bastan Valley, 04.06.2019

Site 1a: Bastan Valley – Sassis village

Description: This site is at the confluence of the smaller Bastanriver and the bigger Gavarnie river (Figure 4.1Confluence point of Bastan river with Gavarnie river.).

Figure 4.1 Confluence point of Bastan river with Gavarnie river.

There was a vegetated riparian zone (mostly with trees) along the river. In 2013 a severe flood destroyed part of the road passing along the Bastanriver (site 1b) and also most of the riparian zone at the confluence with the Gavarnie river. In that spot, after the flood the municipality decided to build a big stream bank made of stones (taken from the river bed) and concrete almost 2 m high (Figure 4.2). The river bank was moved around 10 m towards the river and a playground for children was built on this prolonged zone (Fig. 4.3).

Figure 4.2 Embankment made with stones and cement after the 2013 flood event

Figure 4.3 The constructed point with playground along the river

Proposal: The main idea of the proponents (PLVG) is to remove the constructed river bank, which currently forms a point into the river (Figure 4.3&Figure 4.4), build a green barrier 10-12 m away from the river bank, and renaturalize the area with vegetation by installing a new riparian zone along the river. This is a public zone belonging to the municipality, but the population is reluctant about the efficiency of a riparian zone along the streambank, since it did not survive the 2013 flood event. There is also a discussion with particularly the local farmers along the river concerning the type of vegetation. They in principle do not want large trees, as they believe these will cause more damage.

Figure 4.4 Part of the embankment to be removed and renaturalized

The maximum water depth in the relevant part of the river does not exceed 3 m. The proponents claim that the technical part of the project will not take too much time itself, whereas the process of involving the stakeholders (population, mayor of the city etc.) will take more efforts in terms of both time and motivation. The challenge is to convince them about the potential benefit of renaturalizing the area with a riparian zone and move the river bank backwards. Hopefully it will start next year (September), but this depends also on the local up-coming elections, which may lead to a further delay.

Site 1b: Bastan Valley – road on the riverside (Betpoy and Villa cities)

Description: This part of the road was destroyed during the severe flood of 2013. Satellite images before the event show that the riverbed was smaller in width and that there was a riparian zone with trees along the river bank. The road was rebuilt and a new riverbank was made mainly using rounded stones taken from the river (Figure 4.5). These are generally smooth and rounded, which leads to a lower stability of the road foundations, rather than square blocks usually used for these purposes. At present, the river bed is not stable and is vulnerable to erosion and sediment transport during floods.

Figure 4.5 Road rebuilt after the 2013 event and sediment transportation into the river

Proposal: The main idea is to stabilize the river bed with a step pool system and make a riparian zone along the bank, which protects the nearby houses from extreme floods. The shape of the river bed should be changed as they want to stabilize and increase the transitional zone between the riverbed and the valley, and thereby also increase the area available for grazing sheep (Figure 4.6). Moreover there are some invasive plants that will be removed and the typical species of that area will be reintroduced. Also here, the population is reluctant regarding this solution, because they remember the event of 2013 and need to be convinced that the suggested solutions will work. PLVG wants to also involve the road constructors for an appropriate rebuilding of the road by taking the stones from the slope that are more appropriate for building the road, and make the step pools by using the local stones transported by the river. At this site, the social involvement is considered more important to address than the technical aspects. This is one of the reasons why they want to engage an external facilitator to handle the LL. Since the area of interest is 14 km long, the proposed measures will be a pilot site of 1 km length, which will serve as an example for later upscaling the full length of the river.

Figure 4.6 Unstable riverbank to be renaturized to create a transitional zone

Site 2: Baréges – reforestation

Description: The village of Baréges is threatened by large snow avalanches, and was hit badly in 1897 and in 1907. The village is originally built up around a military hospital, which now serves as a military training camp. There are two main avalanche paths, which lead to the military facility and the lower parts of the village, respectively. After the accidents in 1897 and 1907, large protecting structures have been built over a number of years in several of the release areas. The structures are mainly 4-5 m high snow fences and terraces (Figure 4.7).

Figure 4.7 Existing protection works in the snow avalanche release area above the village of Baréges.

The two main gullies (Figure 4.8) forming the avalanche paths are the Theil, leading towards the old hospital, and the Midaou, leading to the lower part of the village. All together there are a total 3 and 2 km of fences, respectively in the release areas of the Theil and Midaou gullies. These are very maintenance demanding and a large avalanche in 2013, which hit the old military hospital, but without doing much damage, showed that the current measures are insufficient. Partly due to heavy precipitation and partly due to snow drift, accumulation in the release areas, near the crest of the mountain, often exceeds the height of the fences. In the event in 2013, it was the snow above the fences, which slid and formed the avalanche.

Figure 4.8. Left: The Midaou and Theil catchments are numbered 6 and 7, respectively. Right: Where the Midaou avalanche path ends in the valley.

Proposal: The proposal for this site is to carry out reforestation in the release area of the Midaou avalanche path. The reason to choose this and not the other avalanche path, is

that the slope of the release area is somewhat lower, and that it has enough soil (about 1 m) for the trees to grow, whereas the other, the Theil, is mainly characterized by bare rock faces. The vegetation to be planted will be a mix of suitable species. The most typical pine species in the region is currently being seriously affected by a disease, which causes tree death over large regions. Therefore, the proponents will plant a mixed vegetation of trees, which also are meant to adapt to climate change. The plants will be protected by wooden structures until they are strong and tall enough to withstand the pressure from snow creep. Some plants have already been planted in the area as a test, and the expected growth rate is in the order of 0,5m/year.

In this case the participatory process is expected to less of a challenge than along the Bastan River. The population knows the problem and is keen to find good solutions. The current measures need much maintenance, and after a helicopter accident in 2006, all helicopter transport of operators to the fences are forbidden. Hence, much has to be done on foot and by hand. The current estimated maintenance costs are about 300.000 Euros/year, and mainly includes repair and cleaning of the fences. An important co-benefit with the proposed NBS is therefore economic gain, through less maintenance over time.

A4.2 The Portalet Road, 05.06.2019

Site 3: Portalet Road - Santa Elena

Description: This is the southernmost of the three proposed sites along the Portalet Road, and it is the only site on the Spanish side of the border. The concern at this site is a slope of an end moraine ridge. The spot is identified as a high risk point along the road, because of a number of registered detachment and erosion events over the last few years. Because of the curvature and inclination of the road, the visibility is limited for traffic from the north, and the potential for hitting obstacles in the road is therefore high. The slope is about 35-40°, and somewhat steeper near the top (Figure 4.9). At present there are nets mounted on the slope, but the nets do not provide effective protection, and are partly broken. Erosion of the slope during particularly the last 5-10 years has also lead to the nets being detached 15-25cm from the soil surface. The problematic slope has a width of roughly 80-100m along the road, and is about 40m high.

Figure 4.9 The rock fall prone slope at Santa Elena

Proposal: The proposed measure at the Santa Elena slope is to adjust the slope by constructing terraces, and to revegetate by using low-growing local bushes and shrubs. The terracing will also reduce the overall slope angle, and a system for drainage of excess water will also be established. The work will start with a detailed Lidar scanning of the slope, and the measures will be designed based on the shape of the slope and the variable degree of erosion. The measures can be implemented over a period of 2-4 months. A small barrier will be constructed to prevent rocks to fall into the road during the construction period.

The >100 years old terraced and revegetated valley side in Biescas (see below) is an example of a similar, but much larger measure, which has been working since 1905. This serves as an inspiration for similar measures, and re-discovering such old, traditional measures should be considered a co-benefit.

Site 4: Torrent at Portalet Road - Soques

Description: The second site along the Portalet Road is the ravine at Socques, where torrents regularly affect the road (Figure 4.10). The ravine has large volumes of erodible glacial sediments, and after an event in 2013, as much as 10.000 m^3 of deposits had to be removed. The road passes the torrent on an embankment built up of stones and concrete, and as a culvert with dimensions of 3x4m (Figure 4.10). The culvert is easily blocked by sediments eroded and transported by the torrents. In fact, the passage under

the road is almost blocked at present. This situation may lead to overflow and severe damage to the road in coming events.

Figure 4.10 The torrent at Soques. Erosion in easily erodible deposits (left), and the partly blocked culvert (right).

Proposal: The proposed measure at Socques is to establish check dams made of wood and/ or local rock material to create a step-pool river profile, with sedimentation basins behind the dams. This will reduce the erosive force of the torrents, and prevent sediments from clogging the culvert. In addition, the plans include widening of the culvert, and establish erosion protection along the most exposed banks, using local rock material. Maintenance of the system will mainly be removal of sediments after events, to maintain efficiency of the dams. The site is located within the Pyrenees National Park and the proponent, EGCT, works with the road authorities and the park administration to find sustainable solutions. The area is also grazing land for sheep (Figure 4.11), and the local farmers and shepherds are stakeholder to include in the participatory process.

Figure 4.11 Downstream from where Portalet Road crosses the ravine at Socques. The area is part of a national park, and is heavily used for grazing sheep.

Site 5: Rockfall Portalet Road - Artouste

Description: The third and northernmost site along the Portalet Road has a rockfall problem. The main consequence is also here the possibility of road closure. However, this site also had a fatal accident in 2007, when a person died after a direct hit by a falling rock from the slope. A ca. 5m high retention wall is built along the road to stabilize the road cut (Figure 4.12). However, the slope above is roughly 40° steep, with loose blocks several places on the slope. The main release area is a ledge about 200 m above the road. The present forest (relatively small diameter and too low tree density) is not sufficient to stop larger blocks that have been released from the ledge (Figure 4.12), caught speed, and may also move in jumps. Some blocks have been stopped, however, but may again be released as a result of falling trees. There are some relatively low fences in the lower part of the slope (Figure 4.12), but these have very little effect, as they are widely spaced and because rocks may jump over them and hit the road.

Figure 4.12. Retaining wall at the base of the slope, along the road (left), and protective fences, also near the base of the slope (right).

Proposal: The proposed measure here is to construct innovative wooden structure close to the ledge where most rocks are released, to prevent detachment or to catch rocks before they reach high velocity. A study will be carried out to find the most efficient structure, as well as the most resistive type of wood to use. The measures will be designed according to the local conditions such as slope, fracture pattern of the rock ledge, etc. Furthermore, the existing forest will be maintained in such a way that over time, also this will have a more protective effect than at present.

A4.2.1 Visit to historic NBS sites

In addition to the sites for PHUSICOS NBS proposals, the field trip included visits to two sites where measures in the form of terraced and reforested valley sides had been implemented in the beginning of the 20th century, and has been working well ever since. These sites are important inspirations for the new proposals; they are efficient over long time intervals, need little maintenance, and are not visible unless one is close to or at the mitigated slope itself.

Biescas, Spain

This is an example of a NBS implemented more than 100 years ago, as it was built between 1903 and 1905. The slope, with its cover of glacial till, had problems with landslides, debris flows and rock fall, as the valley side at that time was almost deforested due to the need for timber and grazing animals. The risk was related to consequences for agricultural land at the base of the slope. The measures consist of a system of densely spaced terraces, built with dry masonry (no cement) using local rock material, and with drainage channels in between the terraces (Figure 4.13). Vegetation was planted, and the slope is now completely covered with forest. The soil has become gradually richer over the >100 years, as the terraces also prevent organic matter from the vegetation and animals from being eroded. The measures are no longer visible unless one is in between the terraces, but still serve its function very well.

Figure 4.13 Terraces and drainage system, completed in 1905, in Biescas

Canfranc, Spain

The measures at Canfranc are quite similar to those at Biescas, and consist of terracing and reforestation, with controlled drainage routes down the slope (Figure 4.14 right). The mitigated valley side at Canfranc is larger than that at Biescas, and is most likely the largest example of NBS mitigation against landslides in Europe. The measures were implemented at the beginning of the 20th century to protect the railway line and the famous Canfranc railway station in the valley bottom. The station itself has a dramatic and interesting history, particularly in relation to World War 2, when it served an important function. At Canfranc, studies were also conducted to find the right mix of plants for the purpose of stabilizing the slope. The plants to use were grown in plant 'nurseries' in various places in the slope itself before being planted out on the slope. At present, the forested valley side at Canfranc has popular hiking trails, and one of the pilgrimage routes to Santiago de Compostella passes through the slope.

The Canfranc village and train station is also threatened by hazards from the other side, in particular snow avalanches through two main gullies leading towards the village. This hazard has been mitigated by traditional dams and barriers in the gully, to reduce the runout of the avalanches (Figure 4.14 left).

Figure 4.14 Dams for snow avalanche protection (left) and reforestation in terraces (right) in Canfranc.

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