NBS selection and engineering, permitting paths
Part 1

OPERANDUM

OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

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RINA -C
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OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

1. Introduction
2. Integration of NBS technologies with conventional engineering approaches
3. Design Process Actual Implementation

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1 Introduction

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SUSTAINABILITY MANAGER - Real Estate & Infrastructure

- Civile Engineer
- 20+ years of experience
- Active on several (10+) EU funded research projects on sustainability and energy efficiency
- BREEAM Assessor New Construcion and In-Use
- Head of a multidicplinary group dedicated to sustainability of infrastructures and urban developments
- Trying to come up with new ideas

Who we are

Energy & Mobility
Energy solutions from O&G to renewables, taking care of sustainability and environmental impacts

Marine
Rules, technologies and innovative services to manage transport and pleasure vessels

Certification
Solutions to support products, people and processes on their way to excellence

Real Estate & Infrastructure
The path to the next generation of infrastructure and buildings by ensuring their safety and efficiency

Industry
Industry 4.0, innovation & research, Space & Defence, Cyber Security

RINA today

4,600
colleagues

200
offices

70
countries

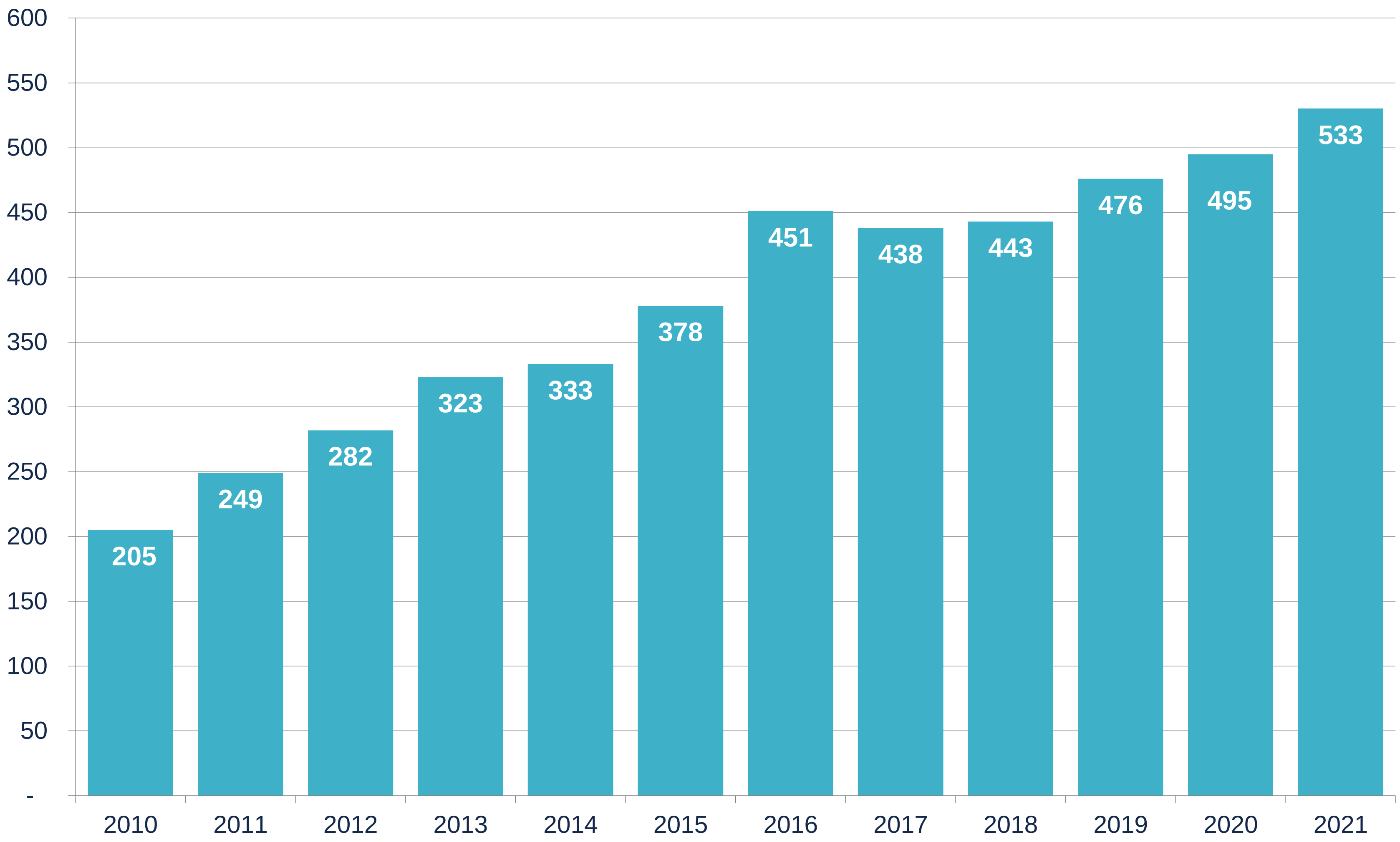
Our people

More than **90 nationalities**

70%+
educated to degree level

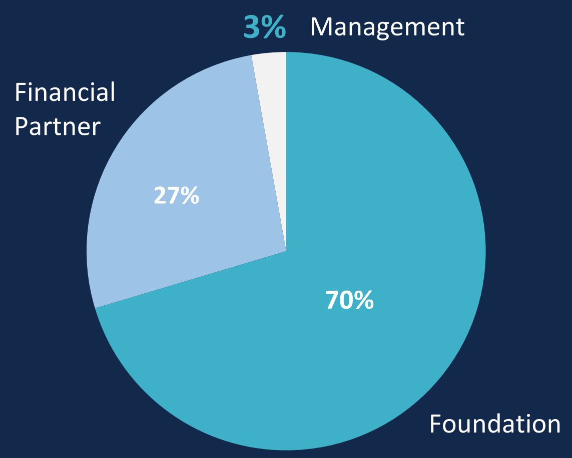
43
average age

Successful growth*



*official budget data

Current structure

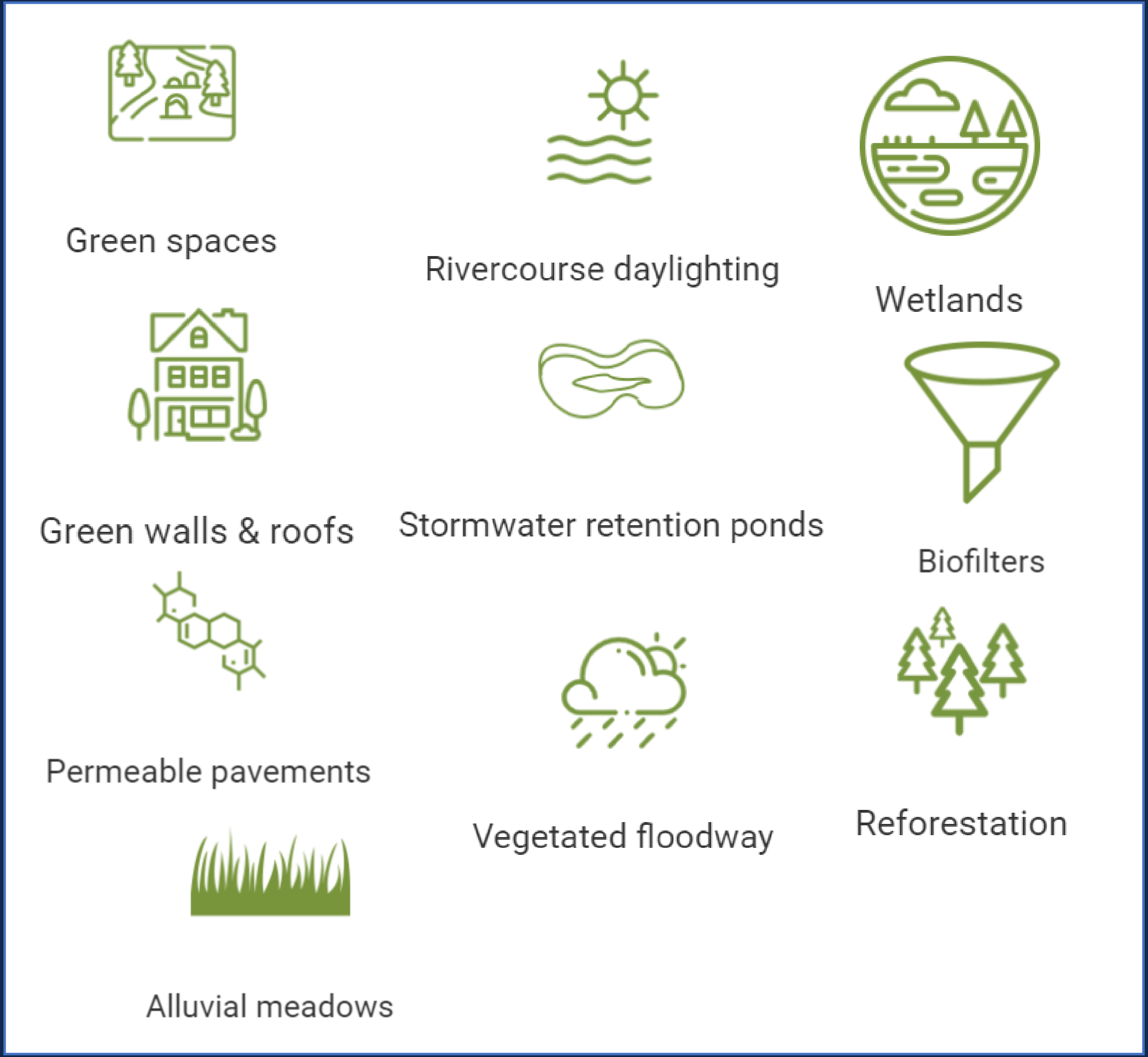


WHY NBSs are important for engineers?

- The climate change challenges will increasingly require **reliable**, **affordable** and sustainable solutions.
- The employment of **Nature Based Solutions** (NBS) to mitigate the impact of hydro meteorological events is still sporadic due to lack of specific guidelines, scientific evidence of performances, readiness of technical solutions.
- RINA Consulting is currently working on industrial projects involving NBSs for specific needs

RINA is developing **services** for the **design** and **implementation** of NBS in **compliance with current regulations and standards**, integrating NBS with **conventional engineering approaches**.

Definition of Nature Based Solutions



"Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience."

NBS engineering in OPERANDUM

Creation of a **catalogue of available NBS solutions**, including basic information on how to approach their **design** in a general case of application

Flooding

Deep rooting plants, bioswales, bioretention, green rooftops, grazing of the foreland

Coastal Erosion

Artificial dune, marine sea grasses

Nutrient and sediment loading

Constructed wetlands, overland flow area, sedimentation ponds and pits, peak flow control structures, submerged dams, riparian buffer zones, continuous cover forestry and a decision support protocol.

Drought

Natural water retention measures and water storage management

Landslide

Sealing streams and channels, optimized forest management, snow accumulation control, drainage trenches, live fascines and brush layers, live pole draining, live crib walls and slope grids

25 NBSs

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OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

2 Integration of NBS technologies with conventional engineering approaches

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Integration of NBS technologies with conventional engineering approaches

“Traditional” engineering approaches, are intended as processes based on **data and calculations** (e.g definition of loads, analysis of the structural behaviour, local calculations and numerical assessment) rather than on empirical/expert judgement approaches.”

1. **Problem definition**
2. Identification of the **input parameters**
3. **Solution behaviour modelling**
4. **Calculations and checks**
5. **Analysis and assessment** of calculations results

1 PROBLEM DEFINITION

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What is the problem to be solved?

This refers to the general **understanding of a specific event or process** which generates **negative impacts** on a given area. The target is the definition of the **problem to be solved** or, in a wider sense, **the aspects to be improved**, and the **comprehension** of the **main causes** involved in the event in order to **define the possible solutions** able to mitigate their negative effects.

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1 PROBLEM DEFINITION

- **How can the problem be solved?**

Once the general context of the problem is defined, **a solution strategy can be defined**, evaluating the potential best ways to mitigate the negative effects related to such problem. Of course, a problem may have many different solutions and to select the most appropriate one, the **boundary conditions (**external factors such as economic resources availability, timing of the solution deployment, environmental impacts, regulatory framework and logistics) are important. These boundary conditions influence indirectly the effectiveness of the solution: for instance, **an ideal optimal solution** could be **too expensive** or have a **huge impact on the local context**; for this reason an apparently less efficient solution could be preferred, **considering a complex balances between pros and cons**.

1 PROBLEM DEFINITION

- **Which is the best location to deploy the solution in order to better tackle the problem?**

According to **different boundary conditions**, **the scale, size and location of the solution may change significantly**. In addition, two different approaches affecting the selection of the best location can be followed:

- **an active system** solution **targeting the actions** generating the negative impact
- **a passive system** solution **targeting the negative effects** only (e.g. local protection or reinforcement).

In this first step the **rough layout for the solution deployment can be defined**, while the final and detailed configuration can be determined only downstream of the detailed analysis and calculations

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1 PROBLEM DEFINITION

- **When is the best time for the deployment of the solution?**

A **correct schedule** is a very relevant aspect because of **natural and/or anthropic actions changing during the year** (e.g. seasonal variations of natural events or different anthropic presence) that may **influence the feasibility or the effectiveness of the proposed solution**.

2 INPUT PARAMETERS IDENTIFICATION

Identification of the required input parameters, necessary to the definition of the solution configuration.

- **topographical conditions** (or bathimetric conditions when required);
- **hydraulic conditions** (e.g. river flow, meteocean conditions, water levels, permeability etc.);
- **geotechnical parameters** (e.g. stratigraphy and geotechnical parameters of the in situ soils);
- **natural conditions** (i.e. presence and characteristics of vegetation and fauna);
- **anthropic variables** (e.g. presence of interfering structures, underground services, anthropic activities that may be relevant for the design).

3 SOLUTION BEHAVIOUR MODELLING

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This step is the conceptual core of the approach

The overall site conditions and the solutions selected in the previous steps have now to be linked by one or more models representing the **global behavior** of the solution **in the actual environment**; **a model is an analytical representation of the reality**.

The way the actual parameters are translated in a model in terms of action and capacity of the system is the main critical aspect of this step. In some cases, the model has been already defined in literature and is standardized by regulations, literature studies and guidelines. In other cases, modelling through specialistic software may allow to simulate the interaction between natural actions and the system.

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4 CALCULATIONS AND CHECKS

An appropriate model of the system shall be developed, correctly representing the structure or system, the materials used, the forces acting

The model could be a **simplified model**, defined by formulas implemented for instance through an excel sheet, **or a more complex model**, built using specialistic software. In the preliminary phase, simplified formulas or simplified models may be used to define the general geometry. In the next stages the level of detail should increase, reaching also very high level of detail and accuracy, in case of critical aspects to be studied.

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5 ANALYSIS AND ASSESSMENT OF CALCULATION RESULTS

The results of the calculation and checks phase have to be analysed in detail

In order to reach a longer lifespan of the solution, specific care should be given on the **maintenance and monitoring aspects**. For this reason, durability aspects should be studied already during the design stages, providing a maintenance plan, describing the **schedule and type of inspections and maintenance intervent**ions. Another way to validate the effectiveness of installed solution is the implementation of a monitoring system, and comparing these values to threshold levels. The **combination of good monitoring plan and maintenance** systems allows to identify possible issues in the early stages and consequently to intervene promptly repairing the failures.

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3 Design Process Actual Implementation

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1 : IT, Lido di Volano artificial dune

1. Definition of the **engineering problem:** to reduce coastal erosion impacting on a protected area, by means of a passive erosion protection system, consisting in a vegetated embankment realized using natural materials.

2. Identification of the **required input parameters:** topographical conditions, meteocean conditions, bathimetric conditions, geotechnical parameters, seismic parameters, vegetation conditions, anthropic variables, Soil thrust, Wave loads, Anthropic loads, Seismic actions

3. Model of **the solution behaviour**, in terms of engineering/calculations: slope stability, structural strenght of materials, geotechnical stability of the bulkhead

4. Detailed **calculations and check** : use of tools such as Excel spreadsheets, specialistic software (e.g. SLIDE, Paratie Plus)

5. Calculation results and interpretation: definition of final geometric features and position of the dune, maintenance and monitoring plan, expected behaviour of the beach protected by the dune…..

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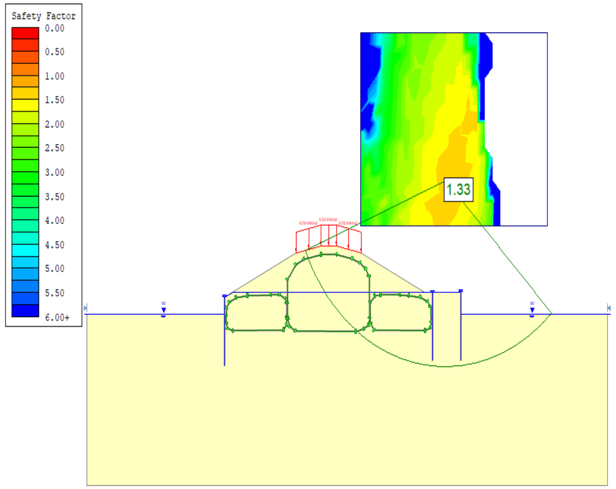
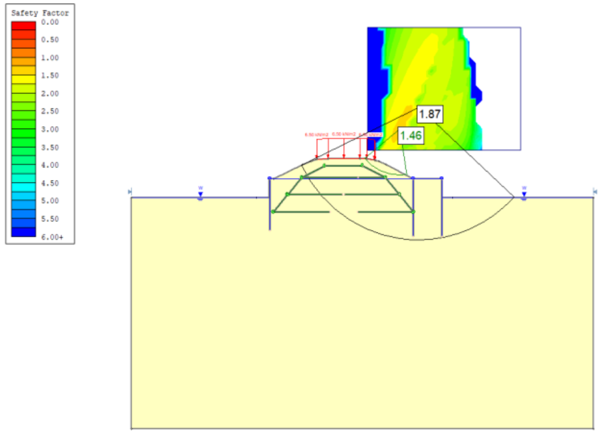
Example 1 : IT, Lido di Volano artificial dune



Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Material 1		17	17	Mohr-Coulomb	1	23.9	Water Surface	Custom	1



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Material 1		17	17	Mohr-Coulomb	1	23.91	Water Surface	Custom	1

4. VERIFICHE						
4.1 Verifiche a trazione (Rif 4.4.8.1.1)						
				K_s		
Tensione di calcolo a trazione parallela alla fibra	$\sigma_{t,0,d}$	0.09	[MPa]	88.74		*Verificato*
4.2 Verifiche a compressione parallela alla fibra (Rif. 4.4.8.1.3)						
Tens di calcolo a compressione parallela alla fibra	$\sigma_{c,0,d}$	-0.88	[MPa]	12.67		*Verificato*
4.3 Verifiche a compressione perpendicolare alla fibra (Rif 4.4.8.1.4)						
Tense di calcolo a compressione perp alla fibra	$\sigma_{c,90,d}$	-0.20	[MPa]	6.67		*Verificato*
4.4 Verifiche a flessione (Rif 4.4.8.1.6)						
Tensione di calcolo a flessione nella direzione forte			$\sigma_{m,y,d}$	10.02	[MPa]	
Tensione di calcolo a flessione nella direzione debole			$\sigma_{m,z,d}$	0.00	[MPa]	
Coefficiente k_m per ridistribuzione tensioni e disomogeneità			k_m	1.00	[-]	
	$\sigma_{m,y,d}/f_{m,y,d}+k_m\,\sigma_{m,z,d}/f_{m,z,d}=$			0.75	≤1	*Verificato*
	$k_m\,\sigma_{m,y,d}/f_{m,y,d}+\sigma_{m,z,d}/f_{m,z,d}=$			0.75	≤1	*Verificato*
4.5 Verifiche a tensoflessione (Rif 4.4.8.1.7)						
	$\sigma_{t,0,d}/f_{t,0,d}+\sigma_{m,y,d}/f_{m,y,d}+k_m\,\sigma_{m,z,d}/f_{m,z,d}=$			0.76	≤1	*Verificato*
	$\sigma_{t,0,d}/f_{t,0,d}+k_m\,\sigma_{m,y,d}/f_{m,y,d}+\sigma_{m,z,d}/f_{m,z,d}=$			0.76	≤1	*Verificato*
4.6 Verifiche a pressoflessione (Rif 4.4.8.1.8)						
	$(\sigma_{c,0,d}/f_{c,0,d})^2+\sigma_{m,y,d}/f_{m,y,d}+k_m\,\sigma_{m,z,d}/f_{m,z,d}=$			0.75	≤1	*Verificato*
	$(\sigma_{c,0,d}/f_{c,0,d})^2+k_m\,\sigma_{m,y,d}/f_{m,y,d}+\sigma_{m,z,d}/f_{m,z,d}=$			0.75	≤1	*Verificato*
4.7 Verifiche a taglio (Rif 4.4.8.1.9)						
Verifica nel caso di sezione rettangolare						
$\tau_d=VS/(Jb)$	τ_d		[MPa]			
Rapporto tra resisitenza a taglio e tensione tangenziale			$f_{d,v}/\tau_d$			
Verifica nel caso di sezione circolare						
Raggio della sezione			R	60.00	[mm]	
$\tau_d=4V/(3\pi R^2)$	τ_d	0.42	[MPa]			
Rapporto tra resisitenza a taglio e tensione tangenziale			$f_{d,v}/\tau_d$	3.14		*Verificato*
Verifica nel caso di altro tipo di sezione						
$\tau_d=VS/(Jb)$	τ_d		[MPa]			
Rapporto tra resisitenza a taglio e tensione tangenziale			$f_{d,v}/\tau_d$			

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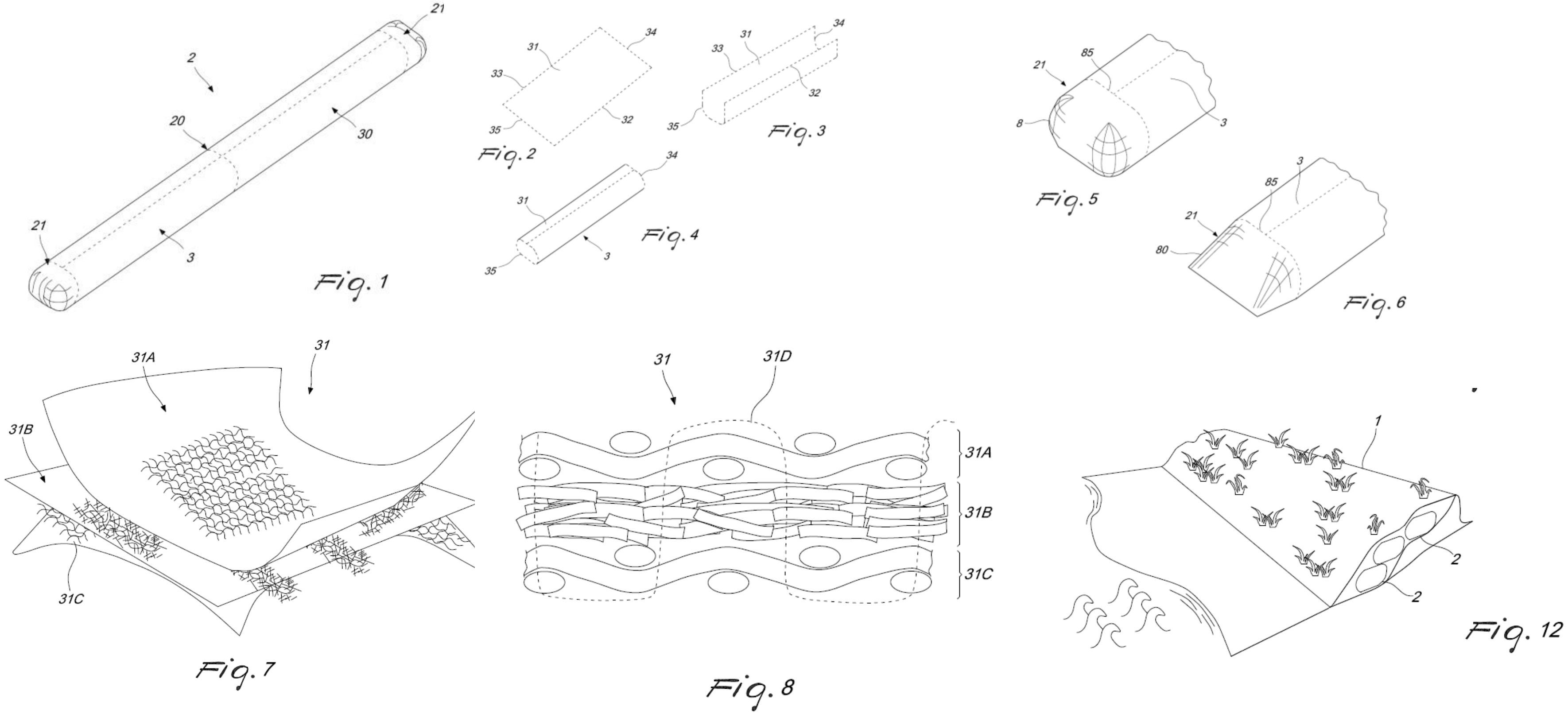
Example 1 : IT, Lido di Volano artificial dune

- **Patent filed:** Geotube for coastal protection barrier and coastal protection barrier comprising the Geotube (https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2020229253)



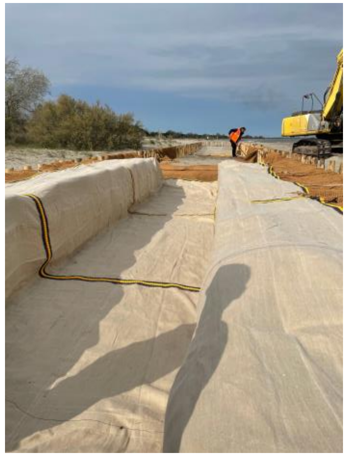
1 : IT, Lido di Volano artificial dune

Some photos from the construction site









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1 : IT, Lido di Volano artificial dune

Some photos from the construction site

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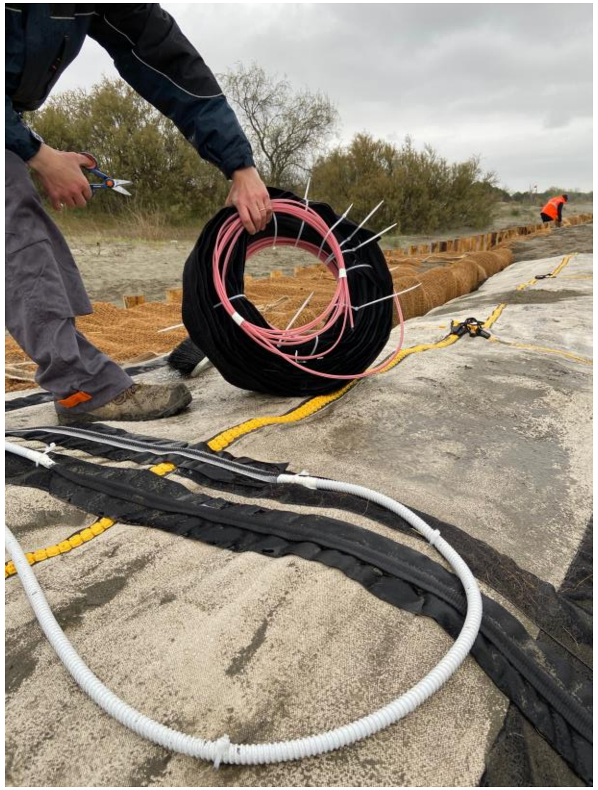
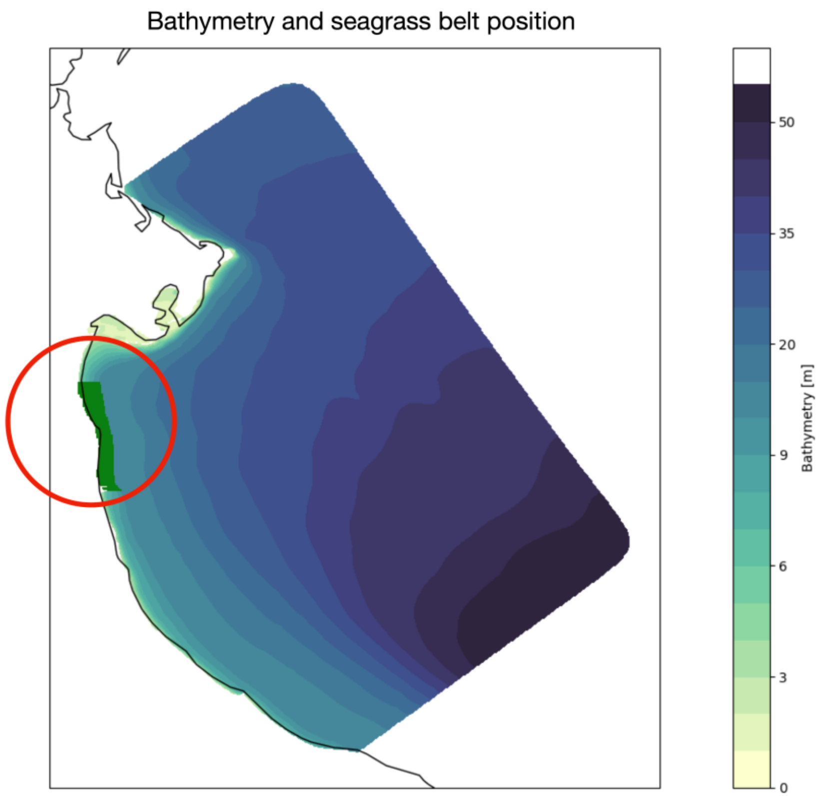
Some photos from the construction site


1 : IT, Lido di Volano artificial dune

Integrated efficiency of the dune and seagrass were also investigated with simulations for both present (2010-2019) and future scenario (2040-2049)



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2: DE, Flood plain management

1. Definition of the **engineering problem:** active and targeted grazing with the aim of restricting the growth of vegetation in the foreland that impedes runoff and thus ensuring a defined minimum runoff effectiveness of the foreland areas.

2. Identification of the **required input parameters:** available animal species, (e.g. sheep, cattle), determination of the grazing period and area during the year

3. Model of **the solution behaviour**, in terms of engineering/calculations: determination of the stocking density on the area (number of animals per ha

4. Detailed **calculations and check:** Excel spreadsheets

5. Calculation **results and interpretation:** most suitable animal species, stocking density, input for procurement models

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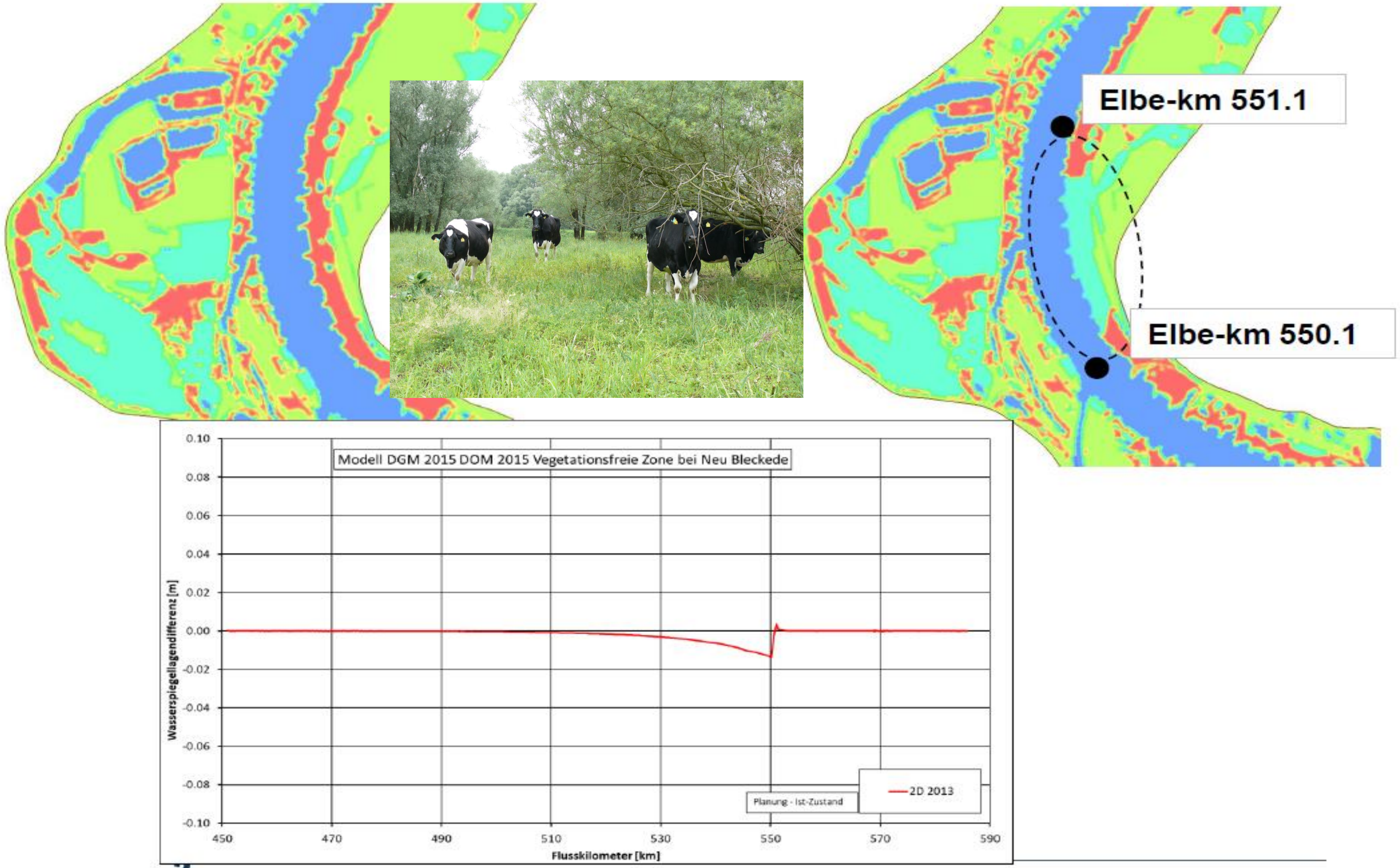
2: DE, Flood plain management

3 Modellrechnungen

Beispeil: Modellrechnungen durch Entfernen von Bewuchs (lokal)



h2 Hochschule Magdeburg • Stendal

- Hochschule Magdeburg - Forschungs- und Entwicklungszentrum (FEZ) - Breitscheidstraße 51 - 39114 Magdeburg -

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2: DE, Flood plain management

Example 2: DE, Flood plain management

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2: DE, Flood plain management

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2: DE, Flood plain management

HOME MADE VEGETATION MANAGEMENT

3: IE, Dublin - Smart IoT Green Roof

1. Definition of the **engineering problem:** Reduction of rainfall-fed runoff to control floods in an urban environment using green roofs. Enhancement of the green roof NBS with technology to have an hybrid NBS in the form of a smart IoT green roof.

2. Identification of the **required input parameters:** Meteorological variables (rainfall, temperature, wind speed, solar radiation, humidity), types and nature of vegetation used, soil moisture content. All the parameters are monitored and visualised in real time with smart IoT technology

3. Model of **the solution behaviour**, in terms of engineering/calculations: Estimation of reduction in runoff due to green roofs using modelling as well as monitoring approaches. The modelling approach requires a relationship between rainfall, runoff, soil moisture content and relative humidity, while the monitoring approach will measure the runoff with and without the green roofs for comparison.

4. Detailed **calculations and check:** Runoff from a storm event is equal to the amount of rainfall without the losses. The primary loss is evaporation/evapo-transpiration. In situations where the green roof is absent, evapo-transpiration won't be present, while presence of green roof will contribute to considerable evapo-transpiration.

5. Calculation **results and interpretation:** Based on the modelling, the percentage of runoff reduction from a building can be estimated. Accuracy of the model can be evaluated using monitored data.

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3: IE, Dublin - Smart IoT Green Roof

3: IE, Dublin - Smart IoT Green Roof

#	NBS technologies	Linked activities
1	**Bioswales** receive runoff and has vegetation and organic matter holds water, reduce infiltration and filter out pollutants.	Green infrastructure could significantly reduce heat leading to greater thermal comfort.
2	**Rainwater harvesting** involves collection of rainwater from roofs and hard pavement surfaces on a much larger scale.	Collected water can be used for irrigation and other household activities.
3	**Tree pit systems** are porous surfaces that are laid around the base of trees in urban areas. These porous systems allow water, air and nutrients to reach tree roots and thereby use evapotranspiration process to reduce stormwater runoff.	Increate amenity value of the surrounding area.
4	**Attenuation tanks** are used to temporarily store stormwater for a period, normally until the peak storm has passed. The water is then released to the sewer network at a controlled rate using a flow control device.	Space above the tank can be used for other purposes.
5	**Infiltration trenches** are excavations that are filled wit void-forming materials, typically rubble or stone, that allow temporary storage of water before it soaks into ground.	Can be constructed along pavement or parks to increase aesthetic value.
6	**Green roofs** are used to increase evapotranspiration and store water at the roof, leading to reduced flow from the roof to the ground via stormwater drainage system.	Has potential to reduce noise, heat, air pollution and increase aesthetic values.

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3: IE, Dublin - Smart IoT Green Roof

4: GR, Retention basins in Komma

1. Definition of the **engineering problem:** Artificial basins built in an adjacent river, stream, lake, or bay to manage stormwater are called retention basinsThe design feature of retention basins that differentiates them from detention and infiltration basins is that they always keep a percentage of their water capacity. They can also provide stormwater attenuation and treatment as well as fostering aquatic vegetation along their shores. Apart from flood protection, these basins and ponds are also beneficial in terms of other ecosystem services such as water quality improvement, groundwater recharge, flood protection and aesthetic improvement.

2. Identification of the **required input parameters:** Ability to absorb flood flows up to 2,167 m3/s (T=50 years), average water reservoir ~ 600,000 m3, nullify water scarcity issues for Anthili and Roditsa irrigation networks,

3. Model of **the solution behaviour**, in terms of engineering/calculations: Provide information of the impact that the Nature Based Solution on the flood levels and the flood mapping outputs. To achieve this, the TUFLOW hydraulic model is used. Flood extents have been produced for the 20% and 10% annual exceedance probability (AEP) events.

4. Detailed **calculations and check:** Measuring the effectiveness of the solution via model results and actual measurements

5. Calculation **results and interpretation:** model outputs

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4: GR, Retention basins in Komma

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4: GR, Retention basins in Komma

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5: AT, Sealing of leaky streams

1. Definition of the **engineering problem:** The OAL lanslide activity has been analyzed in detail, evaluating that the main driver of the landslide is the presence of incoming groundwater at the lower part of the slope. The presence of a stream prone to infiltration losses into the underground, contributes to groundwater recharge.

2. Identification of the **required input parameters:** Hydraulic conductivity, discharge, initial water level, regolith depth, slope angle, specific storage, soil water content and characteristic curve

3. Model of **the solution behaviour**, in terms of engineering/calculations: For representing the governing infiltration processes at the NBS-site a 1D pore pressure diffusion model was appliedThese two options were exploited to reproduce the conditions with and without the implemented nature-based solution (bio-degradable multi-component clay liner as an impermeable layer). The model allows to estimate the proportion of water prevented from deep seepage and hence, the improvements due to the NBS compared to the original conditions.

4. Detailed **calculations and check:** The dynamic model was applied in the experiment OAL site for the duration of one day with hourly outputs of pore pressure distributions over the considered depth.

5. Calculation **results and interpretation:** The comparison of the original conditions at the experiment site in OAL-AT and the conditions after implementing a prototype of the bio-degradable multi-component clay liner generally show the expected results. However, the model is based on assumptions considering homogeneous, anisotropic material characteristics and does not account for preferential flow. In the light of ongoing investigations and monitoring activities a more accurate comparison may be achieved.

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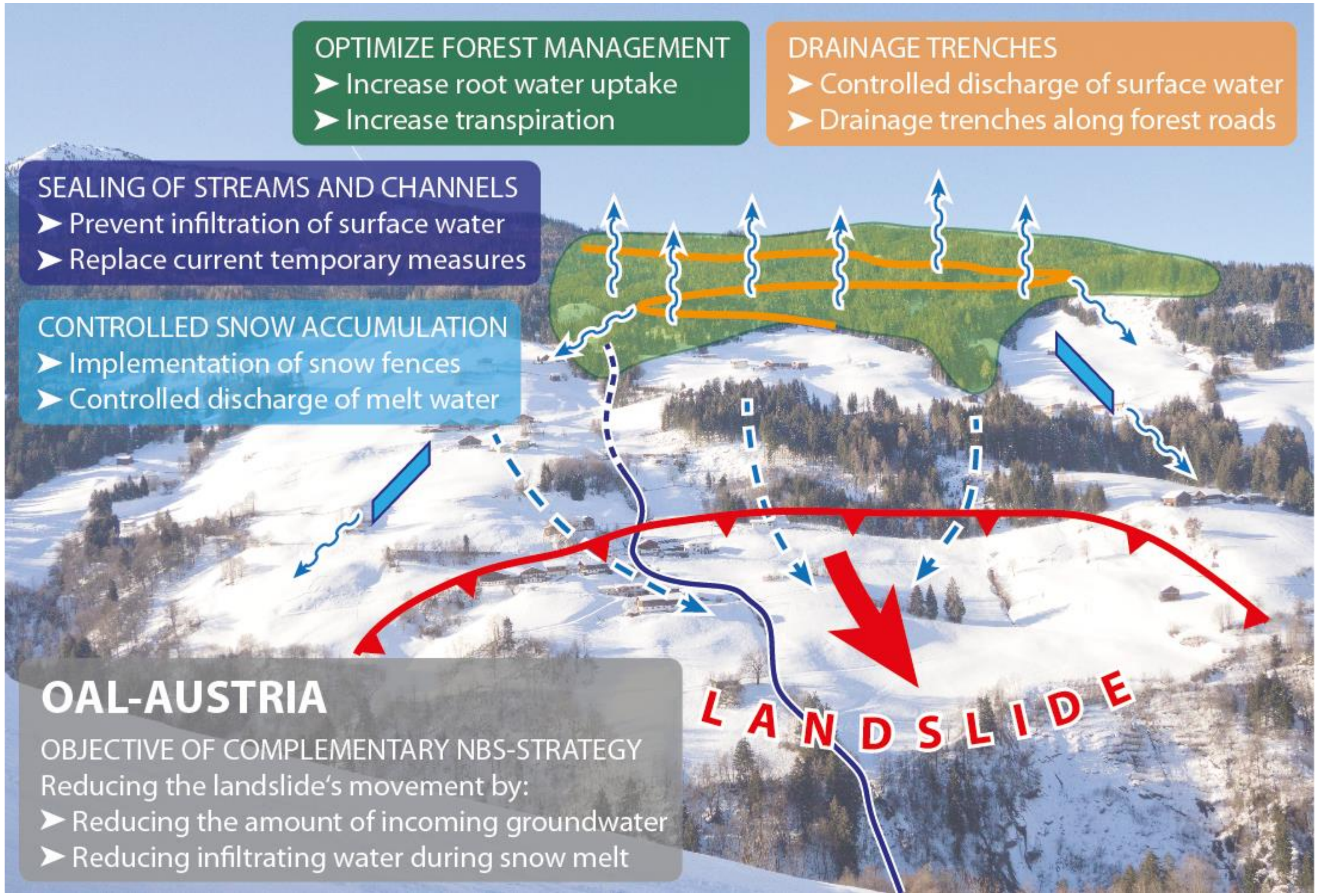
5: AT, Sealing of leaky streams



5: AT, Sealing of leaky streams