SPECIALIZATION PROCESS FOR THE BIOENGINEERING SECTOR IN THE MEDITERRANEAN ENVIRONMENT. ECOMED PROJECT

According to the EFIB (European Federation of Soil Bioengineering) soil bioengineering is a discipline that combines technology biology, and sociology making use of plants and plant communities to help protect and develop land uses and infrastructures, and contribute to landscape development, particular in the domain of slope stability and erosion control.

The promotion and greater adoption of soil bioengineering in the Mediterranean ecoregion is the main aim of the Erasmus + ECOMED project. This aim is being achieved by generating sector-specific theoretical and practical materials and tools essential for the specialization process and enhancement of this sector in the region of interest which is at the core of the ECOMED project strategy and approach. The lack of specialized training, a collection of analysed case studies and shortage of specialized staff in soil bioengineering in most of the Mediterranean countries makes it a necessity to develop training courses and a handbook on soil and fluvial soil bioengineering implementation, along with hazard assessment methods and effective selection of soil bioengineering methods specific to the Mediterranean environment.

Book Topics:

Part I

- Introduction to soil and water bioengineering.
- Soil and water bioengineering and geological engineering.
- Hydrology, Hydraulics and water bioengineering techniques.
- Geographic Information Systems (GIS) for soil and water.
- Environmental Impact Assessment and Planning.
- E-Learning, Data Management and Technical Drawing.

Part II

- Protocols and Case Studies.

Co-funded by the Erasmus+ Programme of the European Union

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PART II. PROTOCOLS AND CASE STUDIES

Editors

García R., José L.; Sangalli, Paola; Tardío, Guillermo; Mickovski, Slobodan; Fernandes, Joao; Giménez, Martín

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SPECIALIZATION PROCESS FOR THE ECOENGINEERING SECTOR IN THE MEDITERRANEAN ENVIRONMENT. ECOMED PROJECT. PART II. PROTOCOLS AND CASE STUDIES.

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Designed by
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This book is intended for educational and scientific purposes only

PART II.
PROTOCOLS AND CASE STUDIES

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PROLOGUE

The main objective of ECOMED promoters was the development of a clear site analysis strategy and structure, identifying all different components to be included within the field work analysis. Particular attention was given to the fact that the main purpose on this task was to generate new design tools adapted to the Mediterranean bioengineering design needs and limitations.

The importance of the maintenance and monitoring stage of soil and water bioengineering works is clearly highlighted within this handbook. Particularly, Different protocols were produced in order to analyse a set of selected soil and water bioengineering works and projects and a detailed case studies section was developed. The case studies analysed throughout the Mediterranean area are included. In these reports both the project and the soil and water bioengineering work throughout their service life are analysed. Apart from that information, recommendations and improvement proposals are also highlighted.

Construction site analysis procedures template. Monitoring stage parameter and field work definition.

The aims of the construction site analysis template are the following:

- This template offers a possibility to show and share the main information and conclusions of the bioengineering work analysis. This template is readily connected to the protocol 2 and 3 aims and contents.
- The contents of the bioengineering work analysis collected throughout the ECOMED project, will allow the generation of improvements at the different levels of analysis. These improvements will both be used in the generation of sector specific tools and an improved training modules contents and support the specialisation process of the Mediterranean bioengineering sector.

The generation of the template for the construction site analysis report and the protocols 1, 2 and 3 were simultaneously developed.

By means of the use of the before mentioned protocols, all the questions to be answered throughout the construction site analysis were defined. The information to be generated for addressing the preceding questions was also defined within the protocols.

The main structure of the construction site analysis report template is the following:

- Analysis of the general information about the associated project and the construction site.
- Analysis related to project itself.
- Analysis of the information related to the construction stage and the work service life.
- Analysis of the work performance.
- Conclusions and improvement proposals.

Sector specific routines and procedures for the Mediterranean bioengineering sector.

As part of the sector specific tools, the protocols for defining the selection process of the bioengineering works and the definition of the analyses to be performed have already been generated.

Particularly:

Protocol 1: definition of the construction site analysis selection. In this protocol the criteria to be followed to efficiently select a case studies set is defined. Four different scenarios were defined: slope, fluvial, coastal and failed work scenario. Those work cases with abundant information associated to their service life development will be prioritized.

Protocol 2: Case study analysis definition. In this protocol, the different levels of analysis to be carried out in order to generate useful information for the ECOMED project objectives fulfilment are defined. Both the project stage as well the work service life development is included in the analysis.

Protocol 3: definition of the field work variables and the field work procedures and methodologies to be followed during the *in situ* construction site analyses.

Implementation of the protocols on case studies across all the participating countries.

A total of 21 case studies all over the Mediterranean ecoregion were analysed. The criteria included in protocol 1 (case studies selection protocol) was utilized and a suitable set of soil and water bioengineering works were included. Besides, different service life lengths were included which gave us the opportunity to analyse the bioengineering works at the different stage/level of analysis included in the protocol 2. A summary of the preceding information is shown in the following table:

Nº	CASE STUDY NAME	Type	Service life	COUNTRY
1	L'Hers river	Fluvial	18 years	France
2	L'Arize river	Fluvial	10 years	
3	LoguesAygues	Fluvial	6 years	
4	Garonne river	Fluvial	In progress	
5	Marble quarry restoration	Slope	3 years	Greece
6	Wild fire erosion Thassos	Slope	2 years	
7	Rio de Couros	Fluvial	11 years	Portugal
8	Albergaria-a-Velha	Slope	7 years	
9	Alverca	Fluvial	5 years	
10	Carvalha/Argoncilhe	Fluvial	7 years	
11	Praia do Guincho	Coastal	7 years	
12	A1 E75 Highway	Slope	13 years	FRYMC
13	Negotino	Slope	4 years	
14	Kartaltepe	Slope	30years	Turkey
15	Terkos	Coastal	31 years	
16	Orlando Mount	Slope	8 years	Italy
17	Melfa	Slope	8 years	
18	Ripe	Slope	1 year	
19	Santa Eulalia	Fluvial	7 years	Spain
20	Artia	Fluvial	14 years	
21	Baztan	Fluvial	less than 1 year	

Protocols 2 and 3 were utilized throughout the analysis and field work of the selected bioengineering works. All the collected information and the work analyses were included in the detailed case studies reports. For this task, the bioengineering work analysis report template was utilized. This allowed us to present and structure the generated information in an effective and useful fashion for achieving the ECOMED project aims and objectives.

Image from ECOMED webpage (ecomedbio.eu). Distribution of case studies analysed on Mediterranean countries

Useful information is available in the detailed case studies. In each analysed case study the following information was generated:

- bioengineering techniques used,
- variables that were calculated,
- main strategy followed within the intervention,
- Collected fieldwork data, etc.

Short description of the case studies analysed:

FRANCE: four case studies were analysed, all of them in fluvial scenarios. Particularly:

- L'Hers river: the objective was the protection of a road embankment
- Arize river: the objective was the protection of urban land lots
- Aygues Longues river: the objective was the protection of a residential area (housing protection)
- Garonne river: the objective was the protection of a residential area (housing protection)

FYROM: Two case studies were analyzed, all of them with the objective of slope stabilization. Particularly:

- Skopje - Gevgelija (A1) highway case study and the
- Railway Negotino - Demir Kapija case study.

GREECE: two case studies were analyzed, both related to slope stabilization scenarios. Particularly:

- Drama case study: the objective is the restoration of a marble quarry exploitation
- Thassos case study: the objective is the erosion control in a post fired scenario.

ITALY: three case studies were analyzed, one in fluvial scenario and two in slope scenarios. Particularly:

- Melfa river case study: the objective was the stabilization of fluvial slopes
- Ripe case study: the objective was the stabilization on a slope
- Orlando mount case study: The objective was the restoration of a slope

PORTUGAL: five case studies were analyzed, one in coastal scenario, two in slope scenario and three in fluvial scenario. Particularly:

- Rio de Couros case study: the objectives were the restoration and stabilization of fluvial slopes.
- Albergaria-a´Velha: the objective was the stabilization of a slope
- Alverca case study: the objectives were the runoff erosion control and the stabilization of a slope.
- Argoncilhe case study: the objectives were the stabilization of a fluvial slope and the ecological restoration of a river stretch.
- Praia do Guincho case study: the objective was the stabilization of sand dunes.

TURKEY: two case studies were analyzed, one in slope scenario and one in coastal scenario. Particularly:

- Terkos case study: the objective was the stabilization of sand dunes.
- Kartaltepe case study: the objectives were the runoff erosion control and the stabilization of a slope.

SPAIN: Three case studies were analyzed, all of the in fluvial scenario. Particularly:

- Artia case study: the objectives were the renaturalization and restoration of a river stretch.
- Baztan case study: the objectives were the flooding protection and stabilization of fluvial slopes in a river stretch.
- Santa Eulàlia case study: the objectives were the flooding protection and fluvial restoration of several river stretches.

PROTOCOLS

PROTOCOL I

1. THE AIM OF THIS TEMPLATE

- This template offers a possibility to show and share the main information and conclusions of the bioengineering work analysis. This template is readily connected to protocols 2 and 3 aims and contents.
- The contents of the bioengineering work analysis collected throughout the ECOMED project, will allow the generation of improvements at the different levels of analysis. These improvements will both be used in the generation of sector specific tools and improved training modules contents and support the specialisation process of the Mediterranean bioengineering sector.

For the generation of the bioengineering work analysis report, please follow the below sections and questions.

2. GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

- Please, provide in your analysis the following information with your remarks:

Work location / project title:

UTM coordinates:

Completion date of the design stage:

Completion date of the construction stage:

Client: (e.g. private or public person or industrial company)

Decision criteria for this type of construction: (e.g. ecological restoration; prevention; erosion control; landslide to restore; etc.).

3. GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

In this stage we are looking for information regarding the project and the way the work was done.

3.1 LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

The information we are seeking here is: What was done by the soil- and water- bioengineer during the analysis stage and before the beginning of the designing stage? Here we will analyse all the preliminary analyses and studies related to the site carried out before proposing concrete solutions into the project.

This preliminary analysis stage occurs before the planning/design stage and includes researching and collecting all kind of information available related to the site. Examples of this are the following:

- Project key objectives? (Erosion control, slope stability, habitat restoration -for species-, landscape restoration, etc.).
- Site appraisal: reconnaissance, desk/office studies, and inspections for biodiversity, dendrology, inspections for ecology covering:
  - Climatic aspects (rainfall, temperature, potential evapotranspiration, exposure, aspect)
  - Soil physical aspects (grading, density, water regime)
  - Soil chemical aspects (pH, conductivity, nutrients, organic matter, exchange capacity, acid toxicity)
  - Soil engineering aspects (strength, permeability, aggregate stability)
- Native vegetation analysis
- Landscape features
- Problems, risks and hazards that were addressed by the project including but not limited to:
  - Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)
  - Geotechnical risks (mass movement, liquefaction, seismicity)
  - Fire risk
  - The extent and nature of potential failure of vegetation
  - Implications of the loss of function (temporarily or permanently) the vegetation is performing
  - Costs of repair and making good any consequent damage
  - Risks to life, health or property
- Visual soil/rock classification. Geotechnical analysis (preliminary assessment of ground/slope stability, etc.)
- Hydraulic/hydrographic analysis including flooding risk assessment
- In case of river works, the characteristics of flood events that had affected the job site (data, flow rate, equivalent return period, speeds and shear boundary stress)

- Maps, photographs with the purpose of collecting historical information
- Site topography and site surveying (geomatics)
- Cadastral data, parcel ownership.
- Interviewing people for collecting historical information
- Collection of urban planning processes and information showing current or future impacts with the work/site
- Other construction sites planned close to the site
- Calculations and drawings related to this preliminary stage
- Existing information in Regulatory Agencies (e.g. sustainability initiatives, resilience initiatives)
- ……

3.2 LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

In this level the planning/designing stage established by the soil- and water- bioengineer is analysed. This stage follows the preliminary analysis stage (analysed in the preceding level 1). The design documents and information (the project itself) are now analysed and assessed.

Some examples of the type of information analysed in his level are the following:

- Is there a clear criterion for the plant species selection? Which is the criteria follow for selecting the plant species included in the project? Do the plants that belong to the first successional stage of the intervention area well represented?
- Was a phytosociological approach used in both the plant species selection process and the intervention strategy?
- Are there clear criteria for the project strategy implementation?
- Are there clear criteria for the bioengineering techniques selections?
- Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear?
- Functional requirements of vegetation (select all that apply to the project):
    - Soil reinforcement and enhancement of soil strength
    - Soil water removal
    - Surface protection against traffic
    - Surface protection against wind/water erosion
    - Bank and channel reinforcement
    - Shelter or screening
- Which improvements would you propose, at the design stage, regarding:
    - Plant selection:
    - Strategy implementation

- Bioengineering techniques selection
- Calculations
- etc.

Please indicate your main conclusions after the analysis of the bioengineering work at the design stage:

4. INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

4.1 LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

The question to answer here is: how was the work carried out by the contractor (Construction Company) during the construction stage?

The construction stage corresponds to the construction of the client's project by a contractor (construction company) based on design documents approved by the client. Examples of the issues to be analyzed here are the following:

General issues, problems and defects.

- Problems/defects/issues recorded during the construction stage (information retrieved from the construction company).
- Detected flaws regarding the construction stage. E.g.
  - increasing bed or river bank erosion in upstream or downstream areas adjacent to the work,
  - Incorrect harvest method and transport conditions of the living material
  - Incorrect use and placement of the living material,
  - Incorrect storage conditions of the living material
  - Incorrect machinery selection
  - etc.
- Please give your opinion about disturbing/destabilizing elements present between the design stage and the construction stage:
  - Insufficient budget
  - Construction stage too short
  - Lack of a competent (effective) supervision during the construction stage
  - Lack of and affective monitoring stage after the construction stage
  - Machinery utilised in the work
  - Other (detail)………………

- Please, indicate the construction standards used in the work:
- Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied: …………..

Issues related to construction features:

- Where there any plantation techniques used to better attain and/or preserve soil humidity? (e.g. tree pit formation, mulching, etc.).
- Was there any mycorrhizae used in the utilised plants?
- Were there any changes in terms of the plant species used in comparison with those included at the design stage? If so, how those changes were justified?
- Were the utilised plants regionally distinctive/characteristic of the intervention area?
- Were there any quality control for the materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed?
- Information regarding quality control for the inert materials (grey materials). Related normative (standard).
- Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard).
- Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard).
- Plant density. In case of herbaceous species: seeding rate.
- bad connections/junctions between the logs,
- bad lateral connection of the work edges with the slope,
- Insufficient or missing soil compaction
- Adverse climate conditions
- Other (detail)…..

Miscellaneous:

- Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques?
- Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)?
- Were there any adherent polluting matters or residues on inherent construction material?
- Groundwater appearance?
- Sanitation failure?
- Natural landslide impact?
- Destruction by local residents (or vandalism) observed?
- Other (detail)…..

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

Please, include here the main conclusions of your analysis at this stage.

Which improvements would you propose for the analysed bioengineering work at the construction stage?

4.2 LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Please, provide information regarding the bioengineering work monitoring and maintenance tasks carried out.

- Was there a maintenance contract?
- Comparison between specification/design and 'as built' measure
- Information on any maintenance work during monitoring phase. If applicable, conduct a characterisation of the maintenance tasks in terms of their performance and suitability
- Analyse all the available information regarding the bioengineering work monitoring tasks carried out
- Was there any monitoring specified? If so, was it installed/performed as planned? If not, please note any reasons
- Was any instrumentation left in situ for monitoring? Detail?
- Were inspections carried out? How regularly? Who carried out the inspections (qualifications?)
- Were there any defects noted after the defect correction period? What was the nature of the defects? Who noted them? Who corrected them? Who paid for them? Value (as percentage of the total contract)?
- Were there any emergency works carried out? What was the nature of the works? Who carried them out? Who paid for them? Value (as percentage of the total contract)?
- Etc.

4.3 LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

This level is directly related to the field work protocol (protocol 3). In this level we will analyse the data related to the operation stage (or work service life stage) of the work. This is the stage in which the construction site field work takes place.

4.3.1 IN SITU FIELD WORK VARIABLES SELECTION

Please, show the selected set of field work variables used for the bioengineering work field work analysis. Please, recall that the selected set of field work variables should include those able to effectively reflect the bioengineering work evolution, performance, and beneficial effects.

Justify the set of field work variables you finally chose. Please, explain the criteria followed in this process. The field work variables can be classified according to the following categories:

- WOODEN ELEMENTS
- PLANTS (IN/OUT THE BIOENGINEERING WORK)
- SOILS
- WATER/TEMPERATURE/CLIMATE

- OTHER UTILISED GREY AND GREEN MATERIALS

A more detailed information can be found in Protocol 2 and 3.

4.3.2 BIOENGINEERING WORK CURRENT STATE DESCRIPTION

Include in this section the field work variables description from a statistical point of view (number of samples, average, variance, variation coefficient, etc.).

Please indicate the field work procedures followed in your work.

COMPARISONS WITH REFERENCE SCENARIOS

PRE-RESTORED SCENARIO:

A complementary analysis of an adjacent or nearby area without bioengineering intervention must also be accomplished (if possible) in order to assess the overall beneficial effects of the bioengineering intervention.

- Location:
- Field work variables measured:
- Number of samples taken and field work variables average values:

Please indicate the main differences found between the bioengineering work area and the pre-restored scenario:

Please, give your opinion in a justified manner, about the main effects of the soil bioengineering work:

TARGETED SCENARIO (END-POINT SCENARIO):

The targeted scenario is a study area similar to the intervention area, but not in need of stabilisation. This site represents the study area if it were undisturbed or stable. Conditions at the reference site represent the conditions that are the goals of the intervention.

- Location:
- Field work variables measured:
- Number of samples taken and field work variables average values:

Please indicate the main differences found between the bioengineering work area and the targeted scenario:

What is the effectiveness level of the intervention compared to the targeted situation. Which is the level of fulfilment of the restoration objectives? Is the work evolving at an adequate pace from a restoration performance point of view?

Please indicate the presence of plants belonging to different successional stages in the intervention area, the pre-restored conditions and the targeted conditions (the end point scenario):

Is Climate Change affecting the achievement of the targeted conditions? In which variables this influence is more intense?

4.4 LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

In this section we should be able to do the following:

- Analysis of the gap between the planned (designed) work and the 'as built' work

- Work performance and beneficial effect analysis
- Which are the achieved functions or targets? For example, Ecological functions: such as biotope connectivity, habitat improvements (in number and in quality), plant community development, hydrologic and hydraulic functions, geotechnical functions, landscape functions, socio-economic functions, etc.

Particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done. Examples of this are the following:

- Suitability of the plant species utilised in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?
- Were the seeds used for the hydro-seeding appropriately selected?
- Problems related to the lack or abundance of water
- Problems related to an excessive plant density
- Problems related to soil fertility
- Problems related to slope aspect/angle/topography
- Problems with availability and adequacy of workforce with relevant qualifications
- Problems with access to the work site
- Problems with health/safety (e.g. invasive species)
- Problems related to a maintenance contract failure
- Problems related to a missing maintenance contract
- Engineering/Stability performance of the works
- Sustainability performance of the works

4.5 LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Please, show here your conclusions obtained after combining the different levels analysed (design, construction, /maintenance and monitoring).

Please, include in this section your opinion to describe the result of the work, in terms of the pursued objectives. You may use the following approach:

- Very successful evolution of the work (all the main objectives were achieved) during 1 to 2 or 3 years after its completion
- The successful evolution of the work (all the main objectives were achieved) after more than 5 years after its completion
- Acceptable evolution and results (the main objectives were partially achieved) after more than 5 years after its completion
- Long-term failure (after more than 5 years after its completion): slope failure, erosion problems, etc.
- Short-term failure (within 2 or 3 years after its completion): slope failure, erosion problems, etc.

Please, indicate how the initial risks that were present in the intervention area have decreased because of the bioengineering work beneficial effects.

Is the climate change affecting the performance of the bioengineering intervention? If so, please indicate how.

Finally, include in this section your opinion, in a justified manner, about why the work succeeded and/or failed in achieving its objectives. Include your proposals for improving the work performance and efficiency.

ECOMED is an ERASMUS+ co-founded programme promoted by Universidad Politecnica Madrid which aims to improve the specialisation level of the ecoengineering sector in Mediterranean areas and within this context, this project offers to provide a sound and practical knowledge based on the accumulated experience in order to offer to the next generation of practitioners and managers a solid and well suited training in ecoengineering restoration techniques in Mediterranean scenarios.

For further information

www.ecomedbio.eu

PROTOCOL II

1. THE AIM OF THIS PROTOCOL

- This Protocol 2 is about defining the existing project information and the set of variables to be measured in the eco-engineering work analysis and field work. For the generation of the bioengineering work analysis report, please follow the below sections and questions.

2. GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Please, provide in your analysis the following information with your remarks:

- Work location / project title:
- UTM coordinates: In case of river works, explain the characteristics of flood events that had affected the job site (data, Flow rate, equivalent return period, speeds and shear boundary stress).
- Completion date of the design stage:
- Completion date of the construction stage:
- Client: (e.g. private or public person or industrial company)
- Decision criteria for this type of construction: (e.g. ecological restoration; prevention; erosion control; landslide to restore;………)
- Your opinion in describing the result of the work, in terms of the pursued objectives, is:
    - Successful evolution of the work (all the main objectives were achieved) during 1 to 2 or 3 years after completion
    - Still successful evolution of the work (all the main objectives were achieved) after more than 5 years after completion
    - Acceptable evolution and results (the main objectives were partially achieved) after more than five years after completion
    - Failure during 2 or 3 years after completion: slope failure, erosion problems, etc.
    - Failure after more than 5 years after completion: slope failure, erosion problems, etc.
    - Etc.

Please give your opinion about disturbing elements present between the design stage and the construction stage:

- Not enough budget
- Construction stage too short
- Lack of a competent (effective) supervision during the construction stage
- Lack of and affective monitoring stage after the construction stage
- Etc.

Please, indicate the construction standards used in the work:

Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied: ……….

3. INFORMATION RELATED TO THE ANALYSIS WITHIN THE PROJECT

In this stage we are looking for information regarding the project and the way the work was done.

In this section, the questions are structured into two different levels:

Level 1: What information was considered and collected for doing the project.

Level 2: What was calculated and included within the project?

3.1 Level 1. What information was considered and collected for doing the project?

The information we are seeking here is: What was done by the soil- and water- bioengineer during the analysis stage and before the beginning of the designing stage? Here we will analyse all the preliminary analyses and studies related to the site carried out before proposing concrete solutions into the project.

This preliminary analysis stage occurs before the planning/design stage and includes researching and collecting all kind of information available related to the site. Examples of this are the following:

- Project key objectives? (Erosion control, slope stability, habitat restoration -for species-, landscape restoration,..).
- Site reconnaissance, desk studies, and inspections for biodiversity, dendrology, inspections for ecology
- Native vegetation analysis
- Landscape features
- Problems, risks and hazards that were addressed by the project
- Visual soil/rock classification. Geotechnical analysis (preliminary assessment of ground/slope stability, etc.)
- Hydraulic/hydrographic analysis
- In case of river works, the characteristics of flood events that had affected the job site (data, Flow rate, equivalent return period, speeds and shear boundary stress)
- Maps, photographs with the purpose of collecting historical information
- Site topography
- Cadastral data, parcel ownership.
- Interviewing people for collecting historical information
- Collection of urban planning processes and information showing current or future impacts with the work/site
- Other construction sites planned close to the site
- Calculations and drawings related to this preliminary stage
- Existing information in Regulatory Agencies
- Etc.

3.2 Level 2. What was calculated and included into the project?

In this level the planning/designing stage established by the soil- and water- bioengineer is analysed. This stage follows the preliminary analysis stage (analysed in the preceding level 1). The design documents and information (the project itself) are now to be analysed and assessed.

Some examples of the type of information analysed in his level are the following:

- **Materials selection and specification** (timber, plant species-native or exotic species, plantation techniques, stored topsoil, compost, seeds, rocks, soils/fill, geosynthetics, other materials, etc.).
- **Calculations, models, and drawings** related to obtain accurate designing documents, including all relevant input parameters for the calculations

- **Justification of the bioengineering techniques selection** – which engineering problem(s) has been solved
- **Which aspects are improvable at the design stage?**
- Etc.

4. INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND ITS SERVICE LIFE

In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Level 4: (optional) Decommissioning.

4.1 Level 1. Construction stage analysis (Construction Company's work!)

The question to answer here is: how was the work carried out by the contractor (Construction Company) during the construction stage?

The construction stage corresponds to the construction of the client's project by a contractor (construction company) based on design documents approved by the client. Examples of the issues to be analysed here are the following:

General issues, problems and defects.

- Problems/defects/issues recorded during the construction stage (information retrieved from the construction company).
- Detected flaws regarding the construction stage. E.g.
  - increasing bed or river bank erosion in upstream or downstream areas adjacent to the work,
  - Incorrect harvest method and transport conditions of the living material
  - Incorrect use and placement of the living material,
  - Incorrect storage conditions of the living material
  - etc.

Issues related to construction features:

- Where there any plantation techniques used to better attain and/or preserve soil humidity? (E.g. tree pit formation, mulching, etc.).
- Was there any mycorrhizae used in the utilised plants?
- Were there any quality control for materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed?
- Information regarding quality control for the inert materials (grey materials). Related normative (standard).
- Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard).
- Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard).
- Plant density. In case herbaceous species: seeding rate.
- Bad connections/junctions between the logs,
- Bad lateral connection of the work with the slope in its extremes,
- Insufficient or missing soil compaction
- Adverse climate conditions
- Etc.

Miscellaneous:

- Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques?
- Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)?
- Were there any adherent polluting matters or residues on inherent construction material?
- Groundwater appearance?
- Sanitation failure?
- Natural landslide impact?
- Destruction by local residents observed?

4.2 Level 2. Maintenance and monitoring stage analysis

Please, provide information regarding the bioengineering work monitoring and maintenance tasks carried out.

- Was there a maintenance contract?
- Comparison between specification/design and 'as built' measure
- Information on any maintenance work during monitoring phase. If applicable, characterisation of the maintenance tasks in terms of their performance and suitability
- Analyse all the available information regarding the bioengineering work monitoring tasks carried out
- Etc.

4.3 Level 3. Analysis of the current state of the bioengineering work

This level is directly related to the field work protocol (protocol 3). In this level we will analyse the data related to the operation stage (or work service life stage) of the work. This is the stage in which the construction site field work takes place.

The following sections will be included in this analysis:

1. Current state of working area
2. Current state of reference scenarios (see protocol 3 and construction site analysis report template for their definitions)
3. In situ field work variables analysis.

4.3.1 Current state of working area

Analysis of the current state of the bioengineering work:

- Stability: as expected; signs of failure but stable; undesirable problem
- Durability: as expected; signs of failure but stable; undesirable problem
- Ageing: as expected; signs of failure but stable; undesirable problem
- Deterioration: no signs of failure; as expected
- State of "Flexible construction evolution": observed during completion; after completion; soil refixing process ongoing

4.3.2 Current state of reference scenarios (pre-restored scenario and targeted scenario)

A complementary analysis of the reference scenarios (see protocol 3 and construction site analysis report template) must also be accomplished in order to assess the overall beneficial effects of the bioengineering intervention:

- Erosion processes observed: YES/NO
- Slope instabilities observed: YES/NO

- Vegetation properties (trees, shrubs, heights, diameters, land cover, biodiversity indexes, survival rates, etc.)
- Soil properties
- Etc.

4.3.3 In situ field work variables analysis

The field work variables to analyse can be classified according to their nature:

WOODEN ELEMENTS

- Tree species used for the timber utilized in the work
- Diameters used
- Mechanical properties measures of both the deteriorated logs and green samples of the same tree species
- Cross sectional loss: comparison between the initial and current diameter values
- Deterioration of the wooden elements near the nails (pilot holes are zones with higher vulnerability risk to the pathogen actions)
- Etc.

PLANTS (IN/OUT THE BIOENGINEERING WORK)

- Plant species (tree, shrub and herbaceous)
- Heights and diameters
- Land cover rate
- Biodiversity index (nº of species)
- Evolution of plant composition: number and quantity of the different species.
- Invasive allochthones plants affecting the area
- Root depth
- Root spread
- Root tensile strength
- Root pull out strength
- Etc.

SOILS

- Soil moisture
- Soil pore pressure
- Organic matter content
- Aggregate stability
- Shear strength
- Etc.

WATER/TEMPERATURE/CLIMATE

- Precipitation amount evolution
- Insolation amount evolution
- Snow period evolution
- Temperature (air/soil)
- Ground water appearance interacting or not
- Air moisture content/humidity
- Drainage (runoff, drains, etc.)
- Storm water management(in Mediterranean climate the success can be related to storm water management)

OTHER UTILISED GREY AND GREEN MATERIALS

- Geotextiles biodegradable
- Geosynthetics (e.g., geogrids)
- Rocks
- Steel rods, wire, etc.
- Etc.

Please note this: All the field work variables will be measured according to the protocol 3 (field work protocol).

5. ANALYSIS OF THE WORK PERFORMANCE

The In this section we should be able to do the following:

- Analysis of the gap between the planned (designed) work and the ‘as built’ work
- Comparisons between needs for design and construction vs. level of assumptions and stability
- Work performance and beneficial effect analysis

Particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done. Examples of this are the following:

- Suitability of the plant species utilized in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?
- Were the seeds used for the hydroseeding appropriately selected?
- Problems related to the lack or abundance of water
- Problems related to an excessive plant density
- Problems related to soil fertility
- Problems related to slope aspect/angle/topography
- Problems with availability and adequacy of workforce with relevant qualifications
- Problems with access to site
- Problems with health/safety (e.g. invasive species)
- ... related to a maintenance contract failure
- … related to a missing maintenance contract
- Etc.

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ECOMED is an ERASMUS+ co-founded programme promoted by Universidad Politecnica Madrid which aims to improve the specialisation level of the ecoengineering sector in Mediterranean areas and within this context, this project offers to provide a sound and practical knowledge based on the accumulated experience in order to offer to the next generation of practitioners and managers a solid and well suited training in ecoengineering restoration techniques in Mediterranean scenarios.

For further information

www.ecomedbio.eu

PROTOCOL III

1. PREFACE

This field protocol describes the methods that will be employed by the field teams under the ECOMED project. The field protocol aims to encourage the standardisation that is necessary to enable data from the construction site analysis to be pooled for generating improvements at the following levels:

- Design of the eco-engineering works
- Constructive procedures of eco-engineering works
- Monitoring, maintenance, and long term performance (resilience) of eco-engineering works

The descriptions of the methods are intended to be a reference to the best practice for the Mediterranean region and to highlight any pitfalls that might impair the quality of the data. In many cases, detailed descriptions of recommended procedures are readily available in other manuals, handbooks or international standards. Those who have difficulty in finding or applying these methods should contact the WP3 co-leaders.

1.1 List of contributors

The Ecomed field manual has been compiled by Guillermo Tardio.

The EcoMed field manual contains contributions from:

1. Guillermo Tardio
2. Alejandro Gonzalez-Ollauri
3. Kristina Dimovska
4. George Zaimes
5. Joao Paulo Fernandes

Some parts of the described methodology have been taken from the ECOSLOPE field manual (2002).

2. CONSTRUCTION SITES SELECTION

A set of case studies (soil and water bioengineering work examples) has been selected according to the Protocol 1. This set comprises a representative sample of different scenarios incorporating soil- and water- bioengineering works within the Mediterranean environment (slope, fluvial and coastal conditions, and failed work).

3. REFERENCE SYSTEM

In order to describe and recover data from different places, a general reference system is needed. It is advised that grid references are made with respect to UTM co-ordinates, which fully comply with GPS measurements.

4. SLOPE PROFILE DESCRIPTION

The equipment for measuring the slope could be a spirit level, angle ruler, linen tape, ranging poles, protractor, etc.

The measurement should be presented in the form of slope profile along the steepest gradient. A number of characteristic profiles covering the whole slope length should be described for a good characterisation of the slope and to ensure an adequate number of measurements within the study. For this, marking several longitudinal transects of similar width (e.g. 10 m) should be ideal.

The slope aspect within each transect should be expressed with a reference to the North. The slope curvature should be described in terms of concave or convex, but it can be also described numerically. In addition to this attributes, it is also of interest to evaluate hill shade or radiation indices to evaluate the degree of sunlight hitting a given slope transect or zone. The topographical description of the slope could be carried out using GIS software (e.g. Q-GIS, ESRI ArcGIS) in which different points on the slope are recorded with a GPS and then processed using functions related to spatial analyst tool of GIS.

5. SOIL PROFILE DESCRIPTION

Soil classification:

The classification of the mineral soil profile should be based on the standard F.A.O. (1990) or the Unified Soil Classification System (USCS) (ASTM, 1985; Head, 1980). The latter permits to classify the soil on the basis of the particle size distribution (i.e. gravel, sand, silt and clay). The former, however, permits a more detailed soil profile description. Three field guides are recommended: (i) Field book for describing and sampling soils (Schoeneberger et al., 2012); (ii) Guidelines for soil description (FAO, 2006); and (iii) World reference base for soil resources manual on soil profile classification (Driessen et al., 2001). Aspects related to soil texture, colour, fauna occurrence, hydromorphic traits or stones content can be readily described onsite. The presence of carbonates can be evaluated by adding a drop of HCl to the soil. It is also recommended to provide the soil classification on the basis of local/national soil classification systems, if any.

Soil colours are described by using the Munsell scale handbook.

A third soil classification should also be made using the national soil classification system.

Organic soil profile classification (cf. Green et al., 1993):

The ectorganic horizons should be classified using an adapted method of Green et al. (1993) and its revised version (Klinka, 1997). This can be found at www.forestry.ubc.ca/klinka/sci_sil/sses/sses009.pdf .The description of the underlying horizons can be carried out according to Green et al. 1993). To identify the forms of humus within the organic soil horizons, the key from Klinka (1997) can be used.

Engineering soil classification:

It is proposed to use the **EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil.**

Other codes can be proposed and arranged by the project partners.

The firmness or strength of the in-situ soil can be assessed by simple index tests (see Table below).

Soil type	Term	Test
Sand and gravels	Loose	Can be excavated with a spade; 50 mm wooden peg can easily be drive into the soil
	Dense	Requires pick for excavation; 50 mm peg is hard to drive into the soil
	Slightly cemented	Soil is excavated with pick in lumps. Lumps cannot easily be broken but particles can be

		abraded
Silt	Loose	Easily moulded or crushed with fingers
	Dense	Strong pressure required to mould material
Clays	Very soft	Extrudes between fingers when squeezed
	Soft	Moulded without pressure
	Firm	Can be moulded with pressure
	Stiff	Cannot be moulded but can be indented with thumb
	Very stiff	Cannot be indented except with the thumb nail
Organic	Firm	Fibres compressed together
	Spongy	Open and compressible structure
	Plastic	Mouldable and smears the hands

Information on the consistency limits of cohesive materials can be obtained by means of the Atterberg limits, while the grading of cohesion less soils can be obtained by means of particle size distribution (sieving) analysis. Both properties are determined in the laboratory and used to classify the soils according to the above standard or to the Unified Soil Classification System (ASTM, 1985).

6. GEOLOGY

The parent material (if proven) should be described as adequately as possible. For this, the use of national geologic maps (e.g. 1:50000) and their corresponding guides is recommended. These can normally be found in the geologic survey institutions (e.g. Spain: IGME; UK: BGS) websites and public libraries.

7. SITE HISTORY AND CLIMATE

The climate of the site should be described from existing data (total annual rainfall, mean maximum and minimum temperature ,insolation, prevalent wind direction, etc.) from the closest weather station, etc. This information should preferably reflect long-term averages (e.g. 30 years). Anyhow, the time period used to generate the information related to the climatic features of a given site should be specified, as the climate is changing. On the basis of rainfall and temperature values, the climate should be classified according to Köppen (1884).

Site history with regard to land use changes or extreme events (wind, precipitation, avalanching and rock fall, flooding, land sliding, storms, waves, etc.) should also be described, too, as this can provide important information about changes in vegetation and soil properties. Historic maps and aerial images can be used for this purpose.

8. ABIOTIC SITE DESCRIPTION

8.1 Gravimetric soil moisture content ($g.g^{-1}$) (destructive method)

The gravimetric soil moisture determination is based on the loss of the mass of water from a sample that is oven-dried at 105°C for 24 hours. Two methods are suggested, the core method for soils that are not too dry or stony (Blake and Hartke, 1986), and the excavation method for stony soils (Goudie, 1981; Huntington et al., 1989). The core method can be also used to determine the related properties of void ratio, bulk density, specific volume, degree of saturation, etc. (i.e. phase relationships). It is worth noting that the gravimetric soil moisture content is synonymous with the water content, w.

Core method: Field: standard stainless steel rings (50 mm diameter, 100 cm^3 volume), a ring driver, hydraulic pressure apparatus for driving cores into the soil (optional), trowel and/or spade, metal saw, plastic ring covers to prevent evaporation and disturbance, tape for sealing the samples.

Laboratory equipment: oven, digital scale (accurate to 0.01 g), desiccator.

Procedure: Drive the ring slowly into the ground, disturbing the soil as little as possible. A hammer should not be used. Inserting the ring with a hydraulic press should be preferred. Remove the soil around the ring with the trowel or knife, without disturbing the soil in the core. Remove the ring with the containing core carefully from the soil, by cutting at least at 2 cm from the core bottom. Soil protruding from the ring should be carefully cut away with a small metal saw, cutting perpendicular to the core edge. Cutting with a knife parallel to the ring edge will smear the sample.

Put the plastic lids on the top and bottom of the ring immediately after sampling.

In the laboratory, weigh the ring with the core (wW; g) as soon as possible, dry it in the oven at 105°C for 24 hours, cool it in a desiccator and reweigh (dW; g). The weight of the clean sampling ring is determined (rW; g) after drying in the oven.

Calculation: Gravimetric soil moisture content, w

$w = M_w/M_s$

where M_w – mass of water [g]

M_s – mass of dry solids [g]

Note: for soils with stones the excavation method should be used (Hanson and Blevins; 1979).

8.2 Volumetric soil moisture content (cm^{-3} cm^{-3}) continuous, non-destructive

Non-destructive tests for the volumetric soil moisture content usually use the relationship between the dielectrical constant of the sample volume and the proportion of air and water in the pore space. TDR (time domain reflectometry) and derived methods are preferred. TDR uses probes of various sizes that determine the moisture content for various soil volumes depending on the probe size.

Figure 8. TDR device

8.3 Organic matter content (O, $g.g^{-1}$)

The organic matter content is the gravimetric fraction of the soil comprising C-rich organic substances (e.g., living and decomposing organic matter, particulate OM). It is suggested that the roots of living vegetation are excluded from this characterisation as roots are covered in the vegetation description section.

A rapid assessment of the soil organic matter content can be done through the quantification of the soil total organic carbon with the loss on ignition (LOI) test. This test quantifies the loss in sample weight when ignited at 450°C to 500°C for ca. 1 hour in a muffle. The soil mass loss is attributed to the combustion of the organic carbon.

8.4 Void ratio and porosity

The void ratio (e) and the porosity (n) represent the proportion of soil pore space in relation to the total volume and to the volume of solids in the soil, respectively. The variables can be expressed in terms of each other,

e = n/(1-n) and n = e/(1+e)

The void ratio can be derived from the dry bulk density (i.e. mass of solids/total soil volume; dry bulk density = dry soil weight (g)/soil volume (cm^3)) or from the gravimetric moisture content (w) and degree of saturation (Sr) if the particle density (ρ_s) is known

$$e = \frac{w \cdot \rho_s}{Sr \cdot \rho_w}$$

Where ρ_s is the particle density (g/cm^3), ρ_w is the density of water ($1\ g \cdot cm^{-3}$), w is the gravimetric moisture content and Sr is the relative degree of saturation ($m^3 \cdot m^{-3}$), which is the volume of water over the total volume of voids. It is worth noting that ρ_s is normally assumed to be equal to 2.65 g cm^{-3}.

The preceding equation is readily applicable when it can be assumed that the sample is saturated (Sr= 1). In that case, the void ratio is the product of the particle density with the gravimetric moisture content.

8.5 Soil chemistry

The analysis of the soil chemistry should be carried out according to the standards specified by Page et al (1982).

A basic characterisation of the soil chemical properties should include pH, TKN and plant available P, soil ReDox potential (Eh) and CEC (cation exchange capacity). Soil pH and CEC may regulate soil water relationships. These two variables can be used within pedotransfer functions along with information related to particle size distribution and soil organic matter to obtain soil hydrological attributes –e.g. field capacity, wilting point, matric suction of wetting front, saturated hydraulic conductivity, etc. TKN and available P regulate plant growth and performance. Information related to these variables may contribute to evaluate the potential establishment of vegetation on a particular site or slope section. ReDox potential regulate the release and speciation of microelements to the soil solution, which, more oftent than not, regulate plant performance. Rapid tests can be carried out with the use of field kits http://www.lamotte.com/en/soil/agricultural/5029.html. For more accurate outcomes, it is advisable to carry out these analyses in the laboratory following the protocols described below.

pH: Soil pH can be measured in the soil and in the saturation extract. In both cases, a glass electrode conveniently calibrated with pH 7 and 4 buffer solution standards is employed. In the first procedure (soil pH; 1: 2.5)), a 20 g of soil per replicate is mixed with 50 ml of distilled water in a 100 ml plastic glass. The mixture is stirred with a glass rod and left to stand for half an hour followed by further stirring prior to reading the pH. In the second procedure the pH measurement is performed directly on the saturation extract with the same type of electrode.

Available P: Method retrieved from MAPA (1986). Weigh 2.5 g of soil sample, add one tablespoon of active carbon and 50 ml of $NaHCO_3$ 0.5M. Shake for half an hour in a mechanical arms shaker. Filter the suspension with Whatman # 40. Take a 5 ml aliquot from the filtered solution in a 100 ml beaker and add 5 ml of ammonium molybdate. Stir manually the mixture to provide a suitable evolution of CO_2. Thereafter, add 14 ml of distilled water and 1 ml of diluted Cl_2Sn. This will develop a bluish colour in case of containing phosphorus. After 10 minutes, proceed to the colorimetric analysis in a UVV spectrophotometer (e.g. Perkin-Elmer). It should be noted that the former mixture is only stable for 20 minutes, so the reading must be performed in this time interval.

To obtain the calibration curve, the following solutions are needed:

(Mix the different reagents in the order indicated in the table; volumes in ml)

P concentration	0.04 ppm	0.12 ppm	0.20 ppm	0.40 ppm	0.60 ppm	0.80 ppm	1 ppm
P (2 ppm)	0.5 ml	1.5	2.5	5	7.5	10	12.5
CO_3HNa	5 ml	5	5	5	5	5	5
Molybdate	5 ml	5	5	5	5	5	5
H_2O	13.5 ml	12.5	11.5	9	6.5	4	1.5
Diluted Cl_2Sn	1 ml	1	1	1	1	1	1

The blank was prepared by mixing 14 ml of distilled water, 5 ml of $NaHCO_3$ 0.5 M, 5 mL of ammonium molybdate and 1 ml of diluted Cl_2Sn.

The absorbance of the solution is measured at a wavelength of 660 nm. The reading values are used in the following formula to calculate the Phosphorus content:

$$P\left(\frac{mg}{kg}\right) = \frac{reading\left(\frac{mg}{mL}\right)}{kg\ Sample}$$

[illegible]

TKN: After Bremner, J.M. (1965)

<u>Materials</u>

- Analytical balance
- Watchglass
- Fume hood
- Digestion tubes (250 ml)
- Digestor or heating unit with temperature regulator adapted to digestion tubes
- Catalyser: Tecator Kjeltabs: 5g potassium sulphate + 0.005 g selenium
- Sulphuric acid (96%)
- Dispenser
- Automated distiller
- Borate buffer solution: Add 88 mL of 0.1 N Sodium hydroxide (4g NaOH/L) to 500 mL 0.025M Sodium tetraborate (Na2B4O7) solution (5.0 g Na2B4O7/L) and dilute to 1 L.
- Baker
- Automated colorimetric device or titrator

- Solution of sulphuric acid 0.5 N
- Acid resistant gloves
- Goggles

Protocol

Adjust the temperature of the heating unit (i.e. digester) to 420 C. Weigh 1g of sieved (<2mm) soil on a watch glass and add it to the digestion tube. Add a tablet of catalyser followed by 10 ml of sulphuric acid (96%) with the dispenser. Place the digestion tube into the heating unit located in a fume hood. It is desirable to leave two free spaces within the tubes set unit for a blank and a sample of known concentration, respectively. Digest the content of the set of tubes at 420 C for 90 minutes. Take the set of tubes out of the digester and allow them to cool down. Place each tube in the automated distiller where the ammonia generated during the digestion will be absorbed by 50 ml of boric acid. Empty the distillate into a beaker and measure the volume of sulphuric acid 0.5N spent until change of pH of the distillate in a titrator.

Calculations:

%N = 14.01* (Lm-Lb)*N*f /g*10

Where:

Lm: volume (ml) of sulphuric acid spent in the titration

Lb: volume (ml) of sulphuric acid spent in the titration of the blank

N: sulphuric acid normality

f: sulphuric acid factor

g: mass (g) of soil sample

Eh: Shake 25 g of the soil sample with 50 mL distilled water in an Erlenmeyer flask for 5min. After this time, immerse the Eh electrode in the suspension and measure the redox potential. It is important to stir the sample during the measurement to keep the suspension from settling. Depending on the composition of the soil, the final value will be reached after 30 ... 50 min. For this reason the reading should, on principle, only be taken after 50 min have elapsed. The electrode is to be checked from time to time (i.e. calibration with adequate buffer solutions) and cleaned, if necessary.

CEC: After Chapman (1965). The soil sample is mixed with an excess of sodium acetate solution, resulting in an exchange of the added sodium cations for the matrix cations. Subsequently, the sample is washed with isopropyl alcohol. An ammonium acetate solution is then added, which replaces the adsorbed sodium with ammonium. The concentration of displaced sodium is then determined by atomic absorption, emission spectroscopy, or an equivalent means.

REAGENTS: (i) Sodium acetate (NaOAc), 1.0 N: Dissolve 136 g of $NaC_2H_2O_2$ @$3H_2O$ in water and dilute it to 1,000 mL. The pH of this solution should be 8.2. If needed, add a few drops of acetic acid or NaOH solution to bring the reaction of the solution to pH 8.2; (ii) Ammonium acetate (NH_4OAc), 1 N: Dilute 114 mL of glacial acetic acid (99.5%) with water to a volume of approximately 1 liter. Then add 138 mL of concentrated ammonium hydroxide (NH_4OH) and add water to obtain a volume of about 1,980 mL. Check the pH of the resulting solution, add more NH_4OH, as needed, to obtain a pH of 7, and dilute the solution to a volume of 2 liters with water.

PROCEDURE (i) Weigh 4 g of medium- or fine-textured soil or 6 g of coarse-textured soil and transfer the sample to a 50-mL, round-bottom, narrow-neck centrifuge tube; (ii) Add 33 mL of 1.0 N NaOAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear; (iii) Decant the liquid, and repeat it three more times; (iv) Add 33 mL of 99% isopropyl alcohol, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear; (v) Repeat the procedure described in iv two more times; (vi) Add 33 mL of

NH4OAc solution, stopper the tube, shake it in a mechanical shaker for 5 min, and centrifuge it until the supernatant liquid is clear. Decant the washing into a 100-mL volumetric flask; (vii) Repeat the procedure described in vi two more times; (viii) Dilute the combined washing to the 100-mL mark with ammonium acetate solution and determine the sodium concentration by atomic absorption, emission spectroscopy, or an equivalent method.

8.6 Undrained and effective shear strength & Root strength

Undrained shear test: it will be measured with a vane shear test (EN 1997-2, Eurocode 7 part 2; https://www.iso.org/obp/ui/#iso:std:iso:22476:-9:dis:ed-1:v1:en).

Root reinforcement is only apparent when soil samples are tested both with and without roots. The following gives a brief description of the commonly used direct shear test.

Effective shear strength without root reinforcement

Equipment: Direct shear apparatus and shear box; soil sieved 2mm and lower.

Method: A detailed description of the direct shear test can be found in Head and Epps (2011), or national standards such as BS1377. The aim of the direct shear test is the determination of the soil cohesion and friction angle. Several test runs carried out at different normal loads are required (a minimum of three soil samples must be tested) to portray the so-called Mohr-Coulomb failure envelope, in which the intercept stands for the cohesion, and the slope angle stands for the angle of internal friction. Undisturbed samples for direct shear tests are usually saturated in advance. This test can be performed under drained or undrained conditions, depending on the shear apparatus employed. The same test can be implemented to evaluate the soil-root reinforcement under laboratory conditions (see below).

Root reinforcement:

In situ shear test. *It will depend upon the availability of the in situ shear test equipment. Vane can be used or in situ shearbox (e.g. Mickovski and van Beek, 2009).*

Direct shear tests in the laboratory should only be used to characterise the contribution of the smaller root systems (root diameters up to 2 mm).

8.7 Aggregate stability

Equipment: sieves with 2.8 mm, 4mm and 5 mm mesh diameter, droplets generating apparatus, 1.0 pF tray

Method: An adapted method of Low is used, as described by Imeson and Vis, (1984). It is important that 0.1 g drops are used and that the fall height is standardised at 1 m. A set of 40 aggregates of a size ranging between 4 to 5 mm is used. These can be separated during the aggregate size distribution analysis. It is very important that they are analysed as quickly as possible after sampling as aggregate stability changes during storage. Alternatively, soil samples can be stored in a refrigerator at 4^{0}C prior testing. A comparison of pre-wetted and dry aggregates is recommended. One set of 20 aggregates is pre-wetted during 24 hours at pF= 1.0. The other set of 20 is used after being air-dried. Each aggregate is positioned on the 2.8 mm mesh sieve. Let drops of water fall exactly on the middle of the aggregate until its falls apart, and it is washed down through the mesh. Count the number of drops until the aggregate is falling apart. Repeat this analyses for the two sets of 20 aggregates (air-dry and at pF= 1.0).

8.8 Estimation of slope soil erosion

A common way to measure soil erosion can be accomplish by using the Gerlach method (Morgan, 1986). In this method, small plots with boundaries (called troughs) are used. They consist of a small collecting gutter which is let into the soil surface and connected to a small collecting container on the downstream side

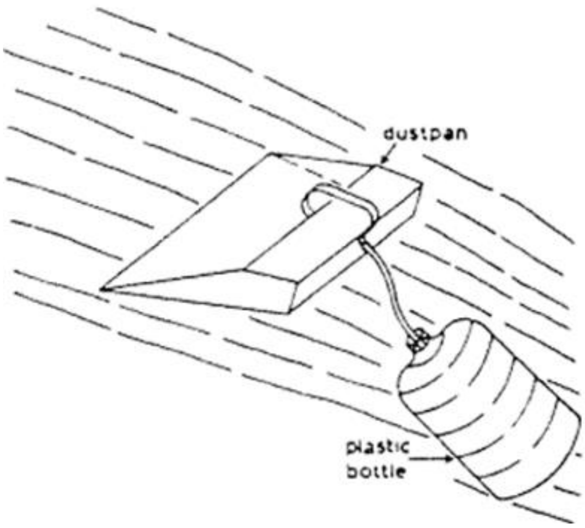


Figure 1 Gerlach method (from Morgan, 1986)

Figure 3 Example of installation of collecting boxes (from de Assunçao Alho, 2006)

The size of the plots is related to the purpose of the trial. In the bioengineering field work case, microplots of one or two square meters may be appropriate because the objective is a simple comparison of two treatments and the treatments are not influenced by scale. The two scenarios to compare are the bioengineered slope and the pre-restored scenario (represented by a similar area without bioengineering techniques). By performing several replications (e.g., 10) it is possible to attain useful comparisons of the effects/benefits of the bioengineering techniques in the intervention area.

Soil erosion can also be measured by using stainless steel rods or pins (Hudson, 1982). In case the selected site had those elements installed, the methodology for calculating the soil loss rate is explained in the following paragraphs. If an extra field work is planned to be done in the pilot site within the Ecomed project length, these elements could also be installed for collecting erosion measurements.

Soil erosion by the continual (gradual or intense) loss of topsoil may eventually lead to the inhibition of plant growth as well as to deterioration of the slope stabilisation structure. The importance of soil erosion has been pronounced in numerous occasions since it often goes undetected for long periods of time. The measurement/estimation of topsoil loss (in mm/year) for each site will yield valuable information when comparing different eco-engineering approaches within the slope scenario.

The use of erosion pins in measuring soil erosion rates has been extensively practiced as indicated by Boardman & Favis-Mortlock (2016). The technique is based on simple insertion of a thin metal pin (preferably a number of pins) into the ground with the top of the pin being exposed above ground. Upon insertion, the aboveground exposed length of the pin is measured, this being the starting point of the measurement. After a period of time the exposed length is again measured, and the increase in this length indicates erosion whereas the decrease indicates deposition. These measurement can be performed repeatedly and frequently over e fixed period of time. Boardman & Favis-Mortlock (2016) furthermore point out that this is a simple and a rather inexpensive method which can also be easily adapted in relation to the aim of the project.

There are no geographical restraints for the applicability of the technique. The method of erosion pins for the measurement of erosion rates has also been used in the Mediterranean climatic region as well (Scoging 1982, Benito et al. 1991, Sirvent et al. 1997).

Equipment: Mild steel or stainless steel rods, usually 300 mm long and 5 mm in diameter. Painted rods may be used for and ease in localisation after a period of time.

Vernier calliper, Vernier depth gage or a Depth micrometer gauge for precise measurement of the exposed length of the pin (in mm).

Method: The methodology follows in great detail Hancock & Lowry (2015). The pins can be located in a linear transect/s along the slope or within a grid (which will be representative of the area studied). Depending on the area of the site the pins can be located at 1 m distance within the transect and the transects distanced 2-3 m from each other. The pins should be inserted into soil between gaps in the surface armour.

The pins can be inserted into the ground by placing a wooden block on top and then hammered down. The height of the exposed length should be measured for reference. Usually this height is 50 mm.

Measurement of the exposed length of the pins can be performed every month (for a period of three months, six months, a year). In every case more reliable results are more likely to be obtained with longer time periods of measurement. Two measurements can be taken at each pin to avoid measurement bias. Hancock & Lowry (2015) give details on how the measurements should be performed.

Figure 4 Example of installation of collecting boxes (from de Assunçao Alho, 2006)

Calculation: The result for each pin will be the average of the two measurements performed. The arithmetic mean of the measured change in the exposed length of the pins is then used to quantify the net erosion or net deposition on the site. The changes in the exposed length of all pins are summed and divided by the duration of the observations, giving an average rate of net erosion or net deposition (in mm/year) for the area covered by the pins and for the period of measurement.

As an alternative method, a geodetic laser measurement can be utilised for an extremely precise measurement of topsoil loss. Leica Scanstation is commonly used for such measurements, which is characterised with a precision of ± 2.00 mm

8.9 Assessment of the deterioration of the wooden elements

The purpose of assessing the current state of the wooden elements is for retrieving information about the way the wooden material will evolve with time in the conditions present in the intervention area. Being able to foresee this process will improve the capacity for both designing the wooden structures and erring on the safe side in the internal stability checks (Tardio and Mickovski, 2016).

The first stage will consist in collecting information about:

- the tree species used in the work
- the natural durability of the tree species.
- Were the trunks debarked when used in the work? Is it treated or untreated timber the one used in the work?
- The age of the trunks used in the intervention. Depending on the age the percentage of sapwood will be lower or higher. Generally juvenile wood has a higher sapwood percentage and therefore a lower natural durability (higher deterioration rates can be assumed).
- the initial diameters used in the work
- gathering information about the most common fungi and insect attacks in the intervention area will be very valuable as well. Sometimes the attack is not from outside to the inside but the other way around.

As with the assessment of wooden girders and columns of old structures, the following methodology will be used:

1. Use a bodkin for a general check of the wooden elements. Use the bodkin to try to find weak zones over the wooden structure.

2. In case of detecting some weak areas (with lower rigidity), use a penetrometer (e.g. pylodin) for having a first assessment of the damage. See Giuriani and Gubana (1994) for the pylodin use.
3. If the depth of the affected area is longer than the penetrometer range (generally 40 mm) then use the resistograph for analysing the extent of the rot area. See Ouis (2003) for the resistograph use.

With the preceding information, an assessment of the cross sectional loss of the wooden element will be calculated. Based on the latter, the deterioration rate will be calculated according to:

$r = \frac{(d_{initial} - d_{current})}{2} \cdot \frac{1}{t}$ (mm/year) (see below figure)

Where:

$d_{initial}$ = initial diameter of the wooden piece

$d_{current}$= equivalent diameter after t years; current equivalent diameter of the wooden piece (take two perpendicular measurement of the diameters and make an arithmetic average)

t = time lag (in years)

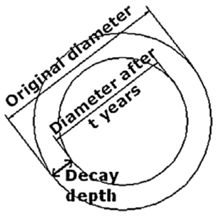


Figure 5 Example of decay process in a log used in a bioengineering work (from Tardio and Mickovski, 2016)

4. If available, use a microsecond timer for assessing the general state of the wooden element
5. Take a slice of the affected area in order to both analyse and study the type of pathology that affected the wooden elements. A sewing machine or a saw will be used for this purpose

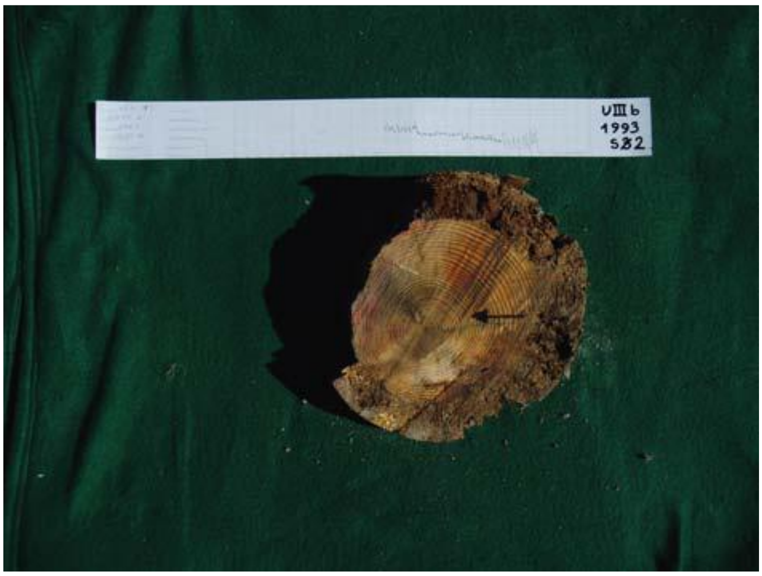


Figure 6 Slice of a wooden element. The resistograph reading is placed on the top of the wooden piece

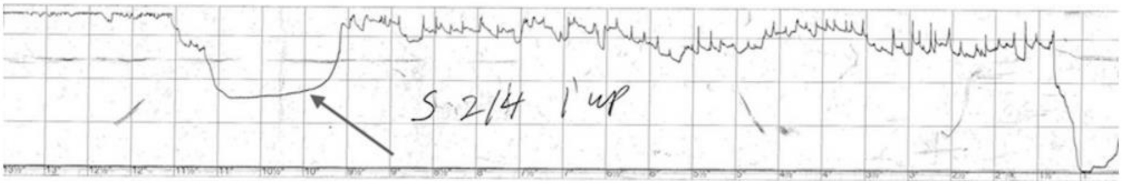


Figure 7 Resistograph reading. The dip in the line shows a zone with decay deep in a trunk

The unaffected cross sectional area will be assumed to keep its original mechanical properties. The latter maybe updated according to the current level of moisture of the wooden elements according to EN 384:2010. The moisture will be measured by using a wood hygrometer.

In the case of failed works, the following approaches will be analysed:

- Did the work fail because of a bad design (e.g., a wrong calculation of the necessary diameters to withstand the existing forces, a wrong choice of the bioengineering technique, etc.?)
- Did the work fail because of the loss of cross sectional area of the wooden elements (intense fungi or insect attack)?
- A combination of the preceding two approaches

The necessary apparatus and tools will be:

- a measuring tape (for measuring diameters)
- a bodkin
- a penetrometer (e.g. pylodin)
- a resistograph
- a driller: use this tool only if a resistograph or a microsecond timer is not available. You will have to detect when the drilling resistance increases, then you will stop drilling and measure the depth. Do this in different directions around the detected weak zone.
- a microsecond timer (use it when a resistograph is not available)
- a wood hygrometer

Figure 8 Wood hygrometer

Figure 9 Microsecond timer. The device is designed to measure stress wave propagation time in trees

Special attention will be paid in the analysis near the junctions since these are usually weak points (pathogens have a better access to inner parts of the wooden pieces).

9. DETAILED CHARACTERIZATION OF THE VEGETATION

The vegetation analysis will allow us to characterise the vegetation structure and its floristic composition. For the former, variables such as ground over, heights and diameter will be used while for the latter, variables such as number of species, seedling, etc will be utilised.

9.1 Vegetation cover per unit area of ground and vegetation height ($m^2.m^2$); (m)

The determination of the vegetation cover can be carried out using a stratified haphazard design (Gonzalez-Ollauri and Mickovski, 2017). This protocol consists of dividing the slope section into different strata (e.g. slope toe, slope middle, slope crest) and collecting random samples of vegetation by throwing randomly a 0.5/1.0 m2 quadrat. All the vegetation found within the frame is either harvested for further processing (e.g. dry biomass determination by drying the collected vegetation at 70C until constant mass) or counted in terms of individuals (i.e. density; number of individuals per unit area of ground). On zones where vegetation cover is sparse, the fraction of the frame covered by vegetation can be estimated. In this case, vegetation cover scales can be used (e.g. Domin scale). The following categories provide a rapid assessment of the vegetation cover, which provide an average value for each quadrat from grids (e.g. 5x5 cm; 10x10cm) established within a given quadrat.

A minimum of 30 repeats per stratum is recommended. Please, note that the former protocol is for herbaceous vegetation. For woody vegetation, the size of the quadrat must increase –e.g. 10x10 m. For the later, aerial images can be used and processed in a GIS software

Estimates of vegetation cover per grid square
0%
Around 25%
Around 50%
Around 75%
100%

The area without vegetation is either bare or covered by litter. Here, a further distinction can be made (note that the classes should be established per quadrant):

- Bare soil: no cover of dead or living vegetation or canopy and hence fully exposed to the sky;
- No litter present but sheltered by overhanging canopy
- Litter covered without canopy
- Litter covered with canopy

9.2 Plant species

Plant species will be identified for trees, shrubs and herbaceous vegetation. Invasive plant species present in the intervention area will be indicated in the study case report.

9.3 Vegetation height estimation

Estimate heights per plant species using manual measurements (http://www.wikihow.com/Measure-the-Height-of-a-Tree), clinometer, laser measure (e.g. Leica Disto) or smartphone (https://gabrielhemery.com/2011/05/15/how-to-calculate-tree-height-using-a-smartphone/). These measurements are based on trigonometric and Pythagoras principles.

For the case of herbaceous vegetation, plant height measurements can be obtained using rulers, sticks or meter tapes, starting the measurements from the ground level always

9.4 Tree location and dimensions

When trees are present on a site, it is important to map their position. Common tree traits measurements are tree height (see above), projected canopy area and diameter at breast height (DBH) must be measured. In the case of coppiced trees, the stump position, maximum height and diameter of the newly re-sprouted crown, should also be measured. It is vital to obtain information about the stand history (tree age, planting regime, year of coppicing etcetera). The compilation of measuring protocols compiled by Blozan (2006) is recommended.

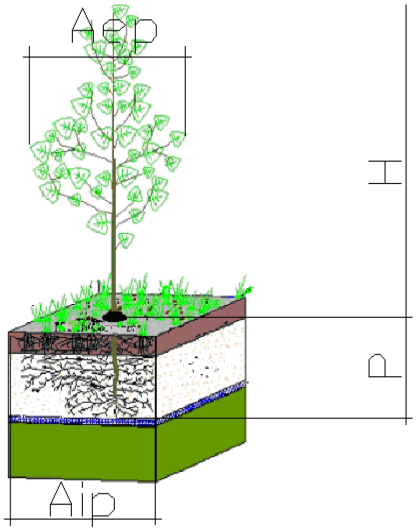
Equipment: Tachymeter or GPS, measuring tapes (2), Abney level or Vertex instrument, ranging staff, 4 pegs and poles, rope

Procedure: Map tree locations using either a tachymeter or a high resolution GPS system. X, Y, and Z-co-ordinates of each tree should be recorded.

Measure the circumference of the tree (DBH, [m]) at breast height (1.5 m). If the shape of the tree trunk is very irregular, measure three times, at 1.5 m and at a small distance above and below this height, and average. Alternatively, LiDAR-based methods can be used to geolocate and measure the above mentioned tree features (https://www.e-education.psu.edu/geog481/l8_p4.html).

9.5 Synthetic parameters (Cornelini et al., 2008)

The following parameters are based on the next figure:



Adimensional index of root architecture:

Index of root semi-sphericity:

A=1/2*(P/Aip) = 1/2*(root depth/root amplitude)

Adimensional indexes of stability and solidity

Index of relative stability: S=P/H = root depth/height above ground

Index of potential stablity: Sp=L/H = (length of main root / height above ground)

Index of relative solidity: s= Aip/Aep = Root amplitude / Plant amplitude above ground

Global stability indexes

Index of root stability: R=S*s = relative stability*relative solidity

Index of global stability: P = S*s^2 = (relative stability)*(relative solidity^2)

NOTE:

Comparisons of vegetation structure and floristic composition between the pilot area and both the pre-operational situation and a reference site (endpoint condition) will be very valuable for assessing the overall performance and progress of the bioengineering intervention.

GENERAL NOTE:

For the assessment of the overall intervention performance, the assessment should also be done in the following scenarios:

- Pre-restored conditions: In case of lacking the pre-restored information of the intervention area, a nearby area with similar conditions and similar instabilities can be used.

- Reference site: this is a study area similar to the project area, but not in need of stabilisation. This site represents the study area if it were undisturbed or stable. Conditions at the reference site represent the conditions that are the goals of the intervention.

Pre- and post-construction evaluations can measure the change or impact from the project, but the level of success can be judged only relative to reference system (NRCS, 2007).

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11. APPENDIX 1: RAPID ASSESSMENT FORM FOR WATER BIOENGINEERING ASSESSMENT

Project title:

Date of construction:

Date of repairs (if any):

Primary goal of the project:

Secondary goal of the project:

Other goal (s):

Please indicate if the detected problems were solved and to what extent:

Description of stream prior to construction (if available):

Evaluation information:

Date of assessment:

Assessment team:

List of materials tools used for the assessment:

RAPID ASSESSMENT METHOD

For qualitative assessments rate the variable from 1 to 5 (where 1 is the worst condition).

Landscape context:

- Landscape connectivity: riparian corridor connectivity
- Buffer width: average with in meters
- Buffer condition: degree of disturbance, quality of buffer

Hydrology:

- Water source: anthropogenic inputs.
- Channel stability: equilibrium, aggradation or degradation
- Hydrologic connectivity. Connection to floodplain

Physical structure:

- Physical patch richness. Richness of habitat structures:
  - Spawning gravel
  - Instream cover
  - Shade
  - Pool/riffle ratio
  - Amount and size of distribution of large woody debris
- Topographic complexity. Variation in elevation and moisture gradients.

Biotic structure:

Plant community:

- Number of plant layers. Number of height classes.
- Species richness. Number of co-dominant species
- % Invasion. % of co-dominants that are invasive
- Horizontal interspersion and zonation. Inter-fingering of plant community zones in plan view.
- Vertical Biotic structure. Degree of vertical overlap of plant height classes.

For a rapid assessment of the overall intervention performance, the rapid assessment should be also done in the following scenarios:

- Pre-restored conditions: In case of lacking the pre-restored information of the intervention area, a nearby area with similar conditions and similar original problems can be used.
- Reference site: this is a study area similar to the project area, but not in need of stabilisation. This site represents the study area if it were undisturbed or stable. Conditions at the reference site represent the conditions that are the goals of the intervention.

Pre- and post-construction evaluations can measure the change or impact from the project, but the level of success can be judged only relative to reference system (NRCS, 2007).

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ECOMED is an ERASMUS+ co-founded programme promoted by Universidad Politecnica Madrid which aims to improve the specialisation level of the ecoengineering sector in Mediterranean areas and within this context, this project offers to provide a sound and practical knowledge based on the accumulated experience in order to offer to the next generation of practitioners and managers a solid and well suited training in ecoengineering restoration techniques in Mediterranean scenarios.

For further information

www.ecomedbio.eu

CASE STUDIES

CASE STUDIES.
FRANCE

CASE STUDY - FLUVIAL

RIVER LONGUES AYGUES CONSTRUCTION SITE REPORT 2012/2015

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

82000 Nègrepelisse, France/ Steep slope river bank rehabilitation work by application of "Soil and Water Bioengineering techniques"

UTM coordinates:

44° 04' 20.32'' N, 01° 314 40.04" E

Completion date of the design stage:

2011

Completion date of the construction stage:

2015 after sagging in 2013 and soil refixing by high capacity of Salix root system

Client: (e.g. private or public person or industrial company):

Public (office of mayor)

SUMMARY

10 m high bank erosion some meters in front of residential buildings needs stabilization and restoring riparian vegetation with Biological Engineering Techniques.

Perfect development of Salix spec. with well-established root systems regardless to a slope sagging about 1 to 2m height.

Contents

✓ >>IF THIS SIGN APPEARS IN THE BOX THIS MEANS "YES" OR "TRUE"

>>IF NO SIGN APPEARSIN THE BOX THIS MEANS "NOT AT ALL"

ALL INFORMATIONS PROVIDED ARE VERIFIED AND RELATED EXCLUSIVELY TO THE PERFORMED CASE STUDIES

ALLINFORMATIONS RELATED TO CASE STUDY "2018 GARONNE STREAM – WORK IN PROGRESS"ARE SO FAR PLANIFIED, YET OBSERVED OR DETERMINEDELEMENTS; THE COMPANY'S QUALIFICATIONSARE KNOWN

THE AIM OF PROTOCOL N°2

This protocol 2 is about defining the existing project information and the set of variables to be measured in the eco-engineering work analysisfield work protocols n°1 and n°3.

1 GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

- In this section is provided information regarding the general informations of construction sites

GENERAL INFORMATION ABOUT THE PROJECT AND CONSTRUCTION SITES

Criterions	Case study data			
				
Work location /UTM coordinates				F-13600 Saubens 43°28'38.65"N 01°20'40.30"E
Delivering dates: preliminary stage P/design stage D/construction stage C				P 2012/D 2016/ C expected dates 2018 to '19
Final delivery date, river name and project title				2019Garonne Stream (expecteddate, work in progress) "Protection of residential areas in front of the stream"
Client(e.g. private or public person or industrial company)				Public (office of mayor)
Decision criterion for this type of construction (e.g. ecological restoration; prevention; erosion control; landslide to restore ;………)				Sustainable and residential area safety measures after lateral riverbank shifting

Site area and bioengineering work type				500m right riverbank restoration by living riprap, log crib wall and other techniques on 10m bankheight
Opinion about disturbing elements present between the design stage and/or the construction stage				
Final Final delivery date, river name and project title				2019 Garonne Stream (expected date, work in progress) “Protection of residential areas in front of the stream”
1 - Not enough budget				
2 - Construction stage too short				unconcerned
3 - Lack of a competent (effective) supervision during the construction stage				unconcerned
4 - Extreme climate event (e.g. storm, flood, landslide or similar) disturbed profoundly the work				unconcerned
5 - Lack of monitoring stage after the construction stage				unconcerned
6 – Other to describe				

Construction standards used in the work

Final delivery date, river				2018 Garonne Stream (expected

name and project title				date, work in progress) “Protection of residential areas in front of the stream”
Rip-rap/Living rip-rap				✓
Fascine type cocofibres				
Living log cribwall				✓
3D greened steel structure				✓
Brush layers				✓
Brush mattresses				✓
Hydrodynamic 3D parabolic coarse rock ramp with integrated fishway				
Seeding under coconut fibre erosion control blanket				✓
Large tree planting				✓
Insurance type required for design stage/construction stage				
Kind of insurance “10 years warranty bonds” requiredfor both designer and company required				✓
Only designer required				
Only company required				

2 INFORMATION RELATED TO THE ANALYSIS STAGE WITHIN THE PROJECT

- In this section is provided information regarding the project and the way the work was doneduring the analysis stage

- In following, the analysis is structured into two different levels:

  Level 1: What information was considered and collected for doing the project?

  Level 2: What was calculated and included within the project?

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

- The information providedare the following: What was done by the soil and water- bioengineer during the analysis stage and before the beginning of the design stage? Followingareanalyzed all the preliminary analyses and studies related to the site carried out before proposing determined solutions into the project.

Definition: The preliminary analysis stage occurs before the planning/design stage and includes researching and collecting all kind of information available related to the site.

LEVEL 1. WHAT KIND OF INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

Project key objectives	Case study data			
				
Final delivery date, river name and project title				2019 Garonne Stream (expecteddate, work in progress) “Protection of residential areas in front of the stream”
Erosion control				✓
Slope stability				✓
Habitat restoration for species				
Landscape restoration				✓
Road restoration				✓

Realization of hiking trail				
Site appraisal: reconnaissance, desk studies, inspections for biodiversity, dendrology, inspections for ecology covering				
Climatic aspects (rainfall, temperature, potention evapotranspirations, exposure)				Rainfall, exposure
Soil physical aspects (grading, density, water regime)				Grading, water regime
Soil chemical aspects (ph, conductivity, nutrients, organic matter, exchange capacity, acid toxity)				nutrients, organic matter
Soil engineering aspects (strength, permeability, aggregate stability)				✓
Landscape features				✓
Native vegetation analysis				✓
Problems, risks and hazards that were addressed by the project:				
Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)				rain erosivity, soil erodibility, overland flow, channel discharge
Fire risk				
Extent and nature of potential failure of vegetation				
Implications of the loss of function (temp'y or perm'y) the vegetation is forming				
Costs of repair and making good any consequent damage				
Risk to life, health or property				✓

Geotechnical analysis/rock classification (preliminary assessment of ground/slope stability, etc.)				✓
Hydraulic/hydrographic analysis				✓
Maps, photographs with the purpose of collecting historical information				✓
Site topography/surveying (geomatics)				✓
Cadastral data, parcel ownership				✓
Interviewing people for collecting historical information				✓
Collection of urban planning processes and information showing current or future impacts with the work/site				✓
Other construction sites planned close to the site impacting the bioengineering workflow				✓ Sewer restoration , urban housing existing, public traffic way
Calculations and drawings related to this preliminary stage				✓
Existing information in Regulatory Agencies (e.g. Biotope classifying/protection)				✓
Specific river works criterions				
Characteristically of flood events that had affected the site (return period Q = flowrate m^3/velocity m/s /others)				Q_{100}=2.780m^3/3.8m/s/natural phenomena of lateral bedshifting

Expected boundary shear stress τ = N/m²				300 N/m²

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT?

- In this level the planning/designing stage established by the soil and water bioengineer is analyzed. This stage follows the preliminary analysis stage (analyzed in the preceding level 1).

Definition: In this stage the design documents and informations are now to be analyzed and assessed; the future project itself becomes his shape.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?				
Material selection and specification	Case study data			
				
Final delivery date, rivername and project title				2019 Garonne Stream (expecteddate, work in progress) “Protection of residential areas in front of the stream”
Plant species-selection criterion applied				Regional native plants by seeking in the area
Clear justification of techniques design provided?				Preliminary investigation report normalized mission G2 delivered, construction stage mission G3 will be ordered by client
Project strategy implementation				Implementationin progressconformabl

criterions provided?				e to the French construction implementation law
Clear structural and geotechnical calculations provided?				In progress
Functional requirements of vegetation by following items:				
Soil reinforcement and enhancement of soil strength				✓
Soil water removal				✓
Surface protection against traffic				✓
Surface protection against water erosion				✓
Bank and channel reinforcement				✓
Shelter of screening				
Rocks				✓
Geosynthetics incorporated				In log cribwall and draining works
Timber applied				✓
Stored topsoil applied				✓
Soils/fill delivered				
Compost applied				
Plant species exotic applied				
Plantation techniques applied:				
Industrial seeds				Adapted to riverbanks

Other materials				3D greened steel structure
Calculations, models and drawings applied:				
Calculation type approach				Hydraulic and geotechnical
Modeling				2D hydraulic and experience
Justification of the bioengineering techniques selection:				
Engineering onsite problem has been solved				✓
Aspects that are improvable at the design stage				
Plant selection				
Strategy implementation				
Bioengineering techniques selection				
Calculations				

The main conclusion related to the design stage is:

The well trained designer has to take enough time to visit the site and all his surroundings in order to establish an adapted and sound site analysis. If so, all his following work like diagnostics, calculation and modeling will be well prepared and optimized for the bioengineering construction stage.

Only a holistic approach helps to find out the best site adapted Eco-technical solution and this is the precondition to get the most adapted final technical solution from the assortment of bioengineering technics.

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3 INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND ITS SERVICE LIFE

- In this section the bioengineering work will be analyzed throughout its service life.

Here we provide the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Level 4: (optional) Decommissioning

LEVEL 1. CONSTRUCTION STAGE ANALYSIS

- The information provided here is: how was the work carried out by the construction company) during the construction stage?

Definition: The construction stage corresponds to the span of time of the realization of the client's project by a contractor (Construction Company). His work is based exclusively on the design documents previously approved by the client.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS				
General issues, problems and defects	Case study data			
				
Final delivery date, river name and project title				2018Garonne Stream (expecteddate, work in progress) "Protection of residential areas in front of the stream"

Problems/defects/issues recorded during the construction stage (information retrieved from the construction company):				unconcerned
Detected flaws regarding construction stage:				
Increasing bed or river bank erosion in upstream or downstream areas adjacent to the work				unconcerned
Incorrect harvest method and transport conditions of the living material				unconcerned
Incorrect use and placement of the living material				unconcerned
Incorrect storage conditions of the living material				unconcerned
Incorrect machinery selection				unconcerned
Disturbing elements present between design stage and construction stage:				
Insufficient budget				
Construction stage too short				
Lack of a competent (effective) supervision during the construction stage				
Lack of affective monitoring stage after the construction stage				✓
Machinery utilized in the work				
Construction standards used:				
EFIB standards				✓
Own long term standards				✓

Issues related to construction features:				
Plantation techniques used to better attain and/or preserve soil humidity (e.g. tree pit formation, mulching, etc.)				unconcerned
Mycorrhizae used in the utilized plants				unconcerned
Changes in terms of plant species used in comparison with those included at the design stage? If so, how those changes were justified				
Utilised plants regionally distinctive/characteristic of the intervention area?				
Quality control for materials, plants (quality and origin) used				unconcerned
Normative (standard) followed				unconcerned
Information regarding quality control for the living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard):				
Inert materials (grey materials) and related normative (standard) followed				Rip-Rap EN 13383 1 and 2
Living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard) followed				unconcerned
Used hormone treatment for improving plant rooting capacity and root system development and related normative (standard) followed				
Plant density applied in log crib wall				8 to 10u/m
Plant density applied in brush				8 to 10u/m

layers				
Plant density applied in brush mattresses				20 to 25u/m
Herbaceous species seeding rate				30g/m²
Insufficient connections/junctions between the logs				unconcerned
Insufficient bad lateral connection of the work with the slope in its extremes				unconcerned
Insufficient or missing soil compaction				unconcerned
Adverse climate conditions				Strong exposition to flood peaks
Miscellaneous				
Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques				Experienced company
Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)				sufficient
Adherent polluting matters or residues on inherent construction material observed				
Detected groundwater appearance				✓
Detected sewerage failure				✓

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Natural landslide impact during construction stage				
Destruction by local residents observed?				

The main conclusion related to the construction stage is:

Surveying company’s work is a primordial matter; often the company’s, during the work, are needing both expert monitoring and professional tips.

Proposal of improvements for analyzed SWB work

Training modules and onsite courses adapted to less skilled workers have to improve the knowledge and the quality of company’s work.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

- In following level is provided information regarding the bioengineering work monitoring and maintenance tasks carried out

Definition: This level is related to the monitoring stage during the lifetime of bioengineering works after final delivery date

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Available information regarding the bioengineering work monitoring tasks carried out	Case study data

				
Maintenance contract required and executed				✓
Kind of maintenance contract before all over final delivery date				1 year full site maintenance with 10 years warranty clause
Kind of maintenance contract after Final delivery date				No professional maintenance carried out by client
Comparison between specification/design and 'as built' measure: from accurate to failed				unconcerned
Characterization of the maintenance tasks in terms of their performance				Soaking, pruning, crop protection, fertilizing
Characterization of the maintenance tasks in terms of their suitability				All tasks are regularly obliged to be executed
Maintenance after delivery of site maintenance contract				Very probably: No professional riparian forest managing will be provided by client
Monitoring instrumentation provided:				
Inspections carried out				unconcerned
Noted defects				unconcerned

Defects noted by				unconcerned
Nature of defect				unconcerned
Correction of defect				unconcerned
Payment of defect by				unconcerned
Value as % of total construction costs				unconcerned
Kind of emergency works				unconcerned
Emergency work realized by				unconcerned

The main conclusion related to the monitoring stage is:

It's essential that no professional monitoring (riparian forest management) was provided during the lifetime period. Clients are forgetting bioengineering works if they are well integrated in the natural environment. Sometimes nonprofessional pruning activities was observed. The consequence of this lack isan important decreasing of ecological quality and mechanical soil resistance after a 15/20 year period whichaffects the well planned sustainability of bioengineering works.

Proposal of improvementsrelated to the monitoring stage

To institute a compulsory riparian forest management in the context of public projects.

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

- This level is directly related to the field work protocol (protocol 3). In this level is analyzed the data related to the operation stage (or work service life stage) of the work
- The in situ field work variables to analyze are classified according to their nature in "wooden elements", "plants", "soils", "water/temperature/climate" and other utilized grey and green materials.

Definition: This is the stage (lifetime in process) in which the construction site field work takes place in his specific environment.

The following sections will be included in this analysis:

- 3.1 In situ field work variables analysis
- 3.2Current state (June 2018) of the analyzed bioengineering work area
- 3.3 Targeted scenario (end-point scenario)

LEVEL 3. ANALYSIS OF THE CURRENTSTATE (JUNE 2018) OF THE BIOEGINEERING WORK

3.1 Current state of in situ field work - variable analysis measured according to the "field work protocol n°3"

Slope profile description (in ° along the steepest gradient)				45 up to 50°
Slope exposition (top of image is North) and curvature of slope (river bed thalweg)				
Geological and soil type description:				
Geological underground maps available				

Geological underground description				Alluviums of the major bed and the low plains; upper Stampien with molasse debris
Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil:				
Sand and gravel*loose*				✓
Sand and gravel*dense*				✓
Sand and gravel*slightly cemented*				
Silt (Lehm) *loose*				Argillaceous silt
Silt*dense*				
Clays (Ton) *very soft*				
Clays *soft*				
Clays *firm*				
Clays *stiff*				
Clays *very stiff*				
Organic matter				
Aggregate stability				
Other				Bedrock flush
Water, temperature and climate information:				
Precipitation amount				638mm

evolution				
Insolation [h] amount evolution				2032
Snow period evolution				
Air temperature [°] max/min in january/july				10/2jan//28/17jul
Ground water appearance interacting or not				✓
Air moisture content				
Drainage (runoff, drains, etc)				
Plants in and out of the bioengineering work:				
Root depth[1]				
Root spread[2]				
Root tensile strength[3]				
Root pull out strength[4]				
Wooden elements:				
Logs for piles and cribwall construction				Larix decidua
Other utilized grey and green materials:				
Non treated biodegradable geotextiles				Jute and coco fiber

1 Slope protection work in lifetime stage: No laboratory work therefore no destructive investigation possible

[2]Idem 1

[3] Idem 1

[4]Idem 1

Geosynthetics (e.g., geogrids)				✓
Rocks				✓
3.2 Current state (June 2018) of the analyzed bioengineering work area				
Available information regarding the bioengineering work monitoring tasks carried out	Case study data			
Stability: as expected				unconcerned
Stability:with signs of failure but still stable				unconcerned
Stability:insufficient by undesired phenomenon				unconcerned
Stability: other				unconcerned
Durability: as expected				unconcerned
Durability: with signs of failure but still stable				unconcerned
Durability: insufficient by undesired phenomenon				unconcerned
Durability: other				unconcerned
Aging: as expected				unconcerned
Aging: with signs of failure but still stable				unconcerned
Aging: insufficient by undesired phenomenon				unconcerned

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Aging: other				unconcerned
State of "Flexible construction"[5]: observed during construction or before final delivery date				Flexible construction is stipulated
State of "Flexible construction": observed after final delivery date				unconcerned
State of "Flexible construction": The auto-refixing process is running				unconcerned
State of "Flexible construction": evolution as expected				unconcerned
3.3 Current state of the nearby area				
Erosion processes observed				✓
Slope instabilities observed				✓
Vegetation properties (trees, shrubs, heights), initial vegetation survival rate				Canopy height/shrub height 15to18m/5to8m Initial survival rate ≥ slide processing
3.3 Targeted scenario (End-point scenario)				
Regular riparian forest's rejuvenation process				unconcerned

4 ANALYSIS OF THE WORK PERFORMANCE

- In this section are provided the following elements:
  - ✓ Analysis of the gap between the planned (designed) work and the 'as built' work

[5]"Flexible construction"[5] (work partially failed but refixing was self-recovered by the growing root system)

- Comparisons between needs for design and construction vs. level of assumptions and stability
- Work performance and beneficial effect analysis

✓ In particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done.

4 ANALYSIS OF THE WORK PERFORMANCE

Available information	Case study data			
Suitability of the plant species used in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?				unconcerned
Seeds used for the hydroseeding/manual seeding were appropriately selected?				unconcerned
Problems related to the lack or abundance of water				unconcerned
Problems related to an excessive plant density				unconcerned
Problems related to soil fertility				unconcerned
Problems related to slope aspect/angle/topography				unconcerned
Problems with availability and adequacy of workforce with relevant qualifications				unconcerned

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Problems with access to site				unconcerned
Problems with health/safety (e.g. invasive species)				✓
Problemsrelated to a maintenance contract failure				unconcerned
Problems related to a missing maintenance contract(lifetime period after final delivery date)				Very probably

5 CONCLUSIONS - WORK PERFORMANCE

Available informations with description of the result of the work in terms of the pursued objectives	Case study and his evolution of vegetation efficiency in graduation from 1 "best" to 6 "worst"			
1 –**Very successful evolution** of the work (all the main objectives were achieved) <u>during 1 to 2 or 3 years</u> after final delivery date				unconcerned
2 - **Successful evolution** of the work (all the main objectives were achieved) <u>after more than 5 years</u> after final delivery date				unconcerned
3 - **Acceptable evolution and results** (the main objectives were partially achieved) after <u>more than five years</u> after final delivery date				unconcerned

4 –**Short term failure within 2 or 3 years** after final delivery date: slope failure, erosion problems, etc				unconcerned
5 –**Long term failure after more than 5 years**after final delivery date: slope failure, erosion problems, etc.				unconcerned
6 – **Failure during construction stage**				Unconcerned
Additional information: Recovery effect by auto-refixing observed				Unconcerned
Description of decreasing of initial risks in the intervention area in response of bioengineering work's beneficial effect				It is expected: slowing down lateral bed shifting and bank slide
The climate change is affecting the bioengineering work performance by ….				
The bioengineering work succeeded due to …				unconcerned
The bioengineering work failed due to …				unconcerned

In view of a general approach: Following should be important in nearfuture to increase notoriety and quality of SWB works:

Main proposal of improvementsrelated toanalyzed SWB works

- ✓ Establishing a multiyear European communication process to inform stakeholders about the technical possibilities of bioengineering works (they don't have informations of this discipline)
- ✓ Establishing training courses to educate future skilled personal is urgent

Main conclusion related toanalyzed SWB works

- ✓ A holistic and site adapted ecological/social/technical approach including students, designers, technicians and company's qualified persons during the design and construction stages is the guarantor of high probability of bioengineering work success.

Annexes

Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil

Test method applied on jobsite:

Soil type	***Term***	***Test***
Sand and gravels	Loose	Can be excavated with a spade; 50 mm wooden peg can easily be drive into the soil
	Dense	Requires pick for excavation; 50 mm peg is hard to drive into the soil
	Slightly cemented	Soil is excavated with pick in lumps. Lumps cannot easily be broken but particles can be abraded
Silt (Lehm)	Loose	Easily moulded or crushed with fingers
	Dense	Strong pressure required to mould material
Clays (Ton)	Very soft	Extrudes between fingers when squeezed
	Soft	Moulded without pressure
	Firm	Can be moulded with pressure
	Stiff	Cannot be moulded but can be indented with thumb
	Very stiff	Cannot be indented except with the thumb nail
Organic	Firm	Fibres compressed together
	Spongy	Open and compressible structure

	Plastic	Mouldable and smears the hands

>>Click to obtain further information related to «Soil and Fluvial Bioengineering»:

www.ecomedbio.eu

www.efib.org

www.aeip.org

http://www.agebio.org

Twitter: @ecomedbio

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ECOMED Team France in June 2018

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CASE STUDY - FLUVIAL

RIVER LONGUES AYGUES CONSTRUCTION SITE REPORT 2012/2015

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

82000 Nègrepelisse, France/ Steep slope river bank rehabilitation work by application of "Soil and Water Bioengineering techniques"

UTM coordinates:

44° 04' 20.32'' N, 01° 314 40.04" E

Completion date of the design stage:

2011

Completion date of the construction stage:

2015 after sagging in 2013 and soil refixing by high capacity of Salix root system

Client: (e.g. private or public person or industrial company):

Public (office of mayor)

SUMMARY

10 m high bank erosion some meters in front of residential buildings needs stabilization and restoring riparian vegetation with Biological Engineering Techniques.

Perfect development of Salix spec. with well-established root systems regardless to a slope sagging about 1 to 2m height.

Contents

✓ >>IF THIS SIGN APPEARS IN THE BOX THIS MEANS "YES" OR "TRUE"

>>IF NO SIGN APPEARSIN THE BOX THIS MEANS "NOT AT ALL"

ALL INFORMATIONS PROVIDED ARE VERIFIED AND RELATED EXCLUSIVELY TO THE PERFORMED CASE STUDIES

THE AIM OF PROTOCOL N°2

This protocol 2 is about defining the existing project information and the set of variables to be measured in the eco-engineering work analysisfield work protocols n°1 and n°3.

1 GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

- In this section is provided information regarding the general informations of construction sites

GENERAL INFORMATION ABOUT THE PROJECT AND CONSTRUCTION SITE

Criterions	Case studydata
	 
Work location /UTM coordinates	F-82000 Nègrepelisse 44° 04’ 20.32’’ N 01° 314 40.04” E
Delivering dates: preliminary stage P/design stage D/construction stage C	P 2011/D 2011/ C 2012
Final delivery date, river name and project title	2015 Longues Aygues River “Protection of existing public housing project” after refixing cycle
Client(e.g. private or public person or industrial company)	Public (office of mayor)

Decision criterion for this type of construction (e.g. ecological restoration; prevention; erosion control; landslide to restore ;………)	Sustainable public housing project; safety measure after riverbank erosion
Site area and bioengineering work type	35m right riverbank restoration by 10m high riparian rehabilitation
Opinion about disturbing elements present between the design stage and/or the construction stage	
1 - Not enough budget	
2 - Construction stage too short	
3 - Lack of a competent (effective) supervision during the construction stage	
4 - Extreme climate event (e.g. storm, flood, landslide or similar) disturbed profoundly the work	
5 - Lack of monitoring stage after the construction stage	✓
6 – Other to describe	Sagging in 2013 and refixing in 2015
Construction standards used in the work	
Rip-rap/Living rip-rap	EN 13383 parts 1 and 2
Fascine type cocofibres	
Living log cribwall	
3D greened steel structure	✓
Brush layers	✓
Brush mattresses	
Hydrodynamic 3D parabolic coarse rock ramp with integrated fishway	

Seeding under coconut fibre erosion control blanket	✓
Large tree planting	
Insurance type required for design stage/construction stage	
Kind of insurance "10 years warranty bonds" requiredfor both designer and company required	✓
Only designer required	
Only company required	

2 INFORMATION RELATED TO THE ANALYSIS STAGE WITHIN THE PROJECT

- In this section is provided information regarding the project and the way the work was doneduring the analysis stage
- In following, the analysis is structured into two different levels:

Level 1: What information was considered and collected for doing the project?

Level 2: What was calculated and included within the project?

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

- The information providedare the following: What was done by the soil and water- bioengineer during the analysis stage and before the beginning of the design stage? Followingareanalyzed all the preliminary analyses and studies related to the site carried out before proposing determined solutions into the project.

Definition: The preliminary analysis stage occurs before the planning/design stage and includes researching and collecting all kind of information available related to the site.

LEVEL 1. WHAT KIND OF INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

Project key objectives	Case study data
Géotechnical survey mission G2	 
Erosion control	✓
Slope stability	✓
Habitat restoration for species	
Landscape restoration	✓
Road restoration	
Realization of hiking trail	
Site appraisal: reconnaissance, desk studies, inspections for biodiversity, dendrology, inspections for ecology covering	
Climatic aspects (rainfall, temperature, potentionevapotranspirations, exposure)	Rainfall, exposure
Soil physical aspects (grading, density, water regime)	Grading, water regime

Soil chemical aspects (ph, conductivity, nutrients, organic matter, exchange capacity, acid toxity)	nutrients, organic matter
Soil engineering aspects (strength, permeability, aggregate stability)	✓
Landscape features	✓
Native vegetation analysis	✓
Problems, risks and hazards that were addressed by the project:	
Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)	rain erosivity, soil erodibility, overland flow, channel discharge
Fire risk	
Extent and nature of potential failure of vegetation	
Implications of the loss of function (temp'y or perm'y) the vegetation is forming	
Costs of repair and making good any consequent damage	
Risk to life, health or property	
Geotechnical analysis/rock classification (preliminary assessment of ground/slope stability, etc.)	✓
Hydraulic/hydrographic analysis	✓
Maps, photographs with the purpose of collecting historical information	
Site topography/surveying (geomatics)	

Cadastral data, parcel ownership	✓
Interviewing people for collecting historical information	✓
Collection of urban planning processes and information showing current or future impacts with the work/site	✓
Other construction sites planned close to the site impacting the bioengineering workflow	Urban housing existing
Calculations and drawings related to this preliminary stage	✓
Existing information in Regulatory Agencies (e.g. Biotope classifying/protection)	
Specific river works criterions	
Characteristically of flood events that had affected the site (return period Q = flowrate m^3/velocity m/s /others)	+/- Q_{10}=120m^3/s; +/- v=3m/s/vortex located
Expected boundary shear stress τ = N/m^2	+/- 220 N/m^2

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT?

- In this level the planning/designing stage established by the soil and water bioengineer is analyzed. This stage follows the preliminary analysis stage (analyzed in the preceding level 1).

Definition: In this stage the design documents and informations are now to be analyzed and assessed; the future project itself becomes his shape.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

Material selection and specification	Case study data
Site after cleaning and discovering hanging sewers	 
Plant species-selection criterion applied	Regional native plants by seeking in the area
Clear justification of techniques design provided?	Only preliminary normalized mission G2 delivered to supervisor, mission G3 not delivered , verification during construction stage impossible
Project strategy implementation criterions provided?	Lack of implementation conformable to the French construction implementation law

Clear structural and geotechnical calculations provided?	Geotechnical construction stage report was not executed by the company
Functional requirements of vegetation by following items:	
Soil reinforcement and enhancement of soil strength	✓
Soil water removal	✓
Surface protection against traffic	
Surface protection against water erosion	✓
Bank and channel reinforcement	✓
Shelter of screening	
Rocks	✓
Geosynthetics incorporated	In 3D greenable steel structure
Timber applied	✓
Stored topsoil applied	✓
Soils/fill delivered	
Compost applied	
Plant species exotic applied	
Plantation techniques applied:	
Industrial seeds	Adapted to riverbanks
Other materials	3D greened steel structure
Calculations, models and drawings applied:	
Calculation type approach	Hydraulic and geotechnical
Modeling	Peak water level was supplied

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Justification of the bioengineering techniques selection	
Engineering onsite problem has been solved	✓
Aspects that are improvable at the design stage	
Plant selection	✓
Strategy implementation	
Bioengineering techniques selection	✓
Calculations	Hydraulic approach

The main conclusion related to the design stage is:

The well trained designer has to take enough time to visit the site and all his surroundings in order to establish an adapted and sound site analysis. If so, all his following work like diagnostics, calculation and modeling will be well prepared and optimized for the bioengineering construction stage.

Only a holistic approach helps to find out the best site adapted Eco-technical solution and this is the precondition to get the most adapted final technical solution from the assortment of bioengineering technics.

3 INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND ITS SERVICE LIFE

- In this section the bioengineering work will be analyzed throughout its service life.

Here we provide the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Level 4: (optional) Decommissioning

LEVEL 1. CONSTRUCTION STAGE ANALYSIS

- The information provided here is: how was the work carried out by the construction company) during the construction stage?

Definition: The construction stage corresponds to the span of time of the realization of the client's project by a contractor (Construction Company). His work is based exclusively on the design documents previously approved by the client.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS	
General issues, problems and defects	Case study data
During construction stage	 
Problems/defects/issues recorded during the construction stage (information retrieved from the construction company):	Surveyor didn't receive geotechnical report related to the slope stability during construction stage

Detected flaws regarding construction stage:	
Increasing bed or river bank erosion in upstream or downstream areas adjacent to the work	
Incorrect harvest method and transport conditions of the living material	
Incorrect use and placement of the living material	
Incorrect storage conditions of the living material	
Incorrect machinery selection	✓
Lack of geotechnical investigation	✓
Disturbing elements present between design stage and construction stage:	
Insufficient budget	
Construction stage too short	
Lack of a competent (effective) supervision during the construction stage	
Lack of affective monitoring stage after the construction stage	✓
Machinery utilized in the work	
Construction standards used:	
EFIB standards	✓
Own long term standards	✓
Issues related to construction features:	
Plantation techniques used to better attain and/or preserve	

soil humidity (e.g. tree pit formation, mulching, etc.)	
Mycorrhizae used in the utilized plants	
Changes in terms of plant species used in comparison with those included at the design stage? If so, how those changes were justified	
Utilised plants regionally distinctive/characteristic of the intervention area?	Local Salix species
Quality control for materials, plants (quality and origin) used	✓
Normative (standard) followed	Long term experience of site supervisor

Information regarding quality control for the living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard):

Inert materials (grey materials) and related normative (standard) followed	Rip-Rap EN 13383 1 and 2
Living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard) followed	Long term experience of site supervisor
Used hormone treatment for improving plant rooting capacity and root system development and related normative (standard) followed	
Plant density applied in log crib wall	
Plant density applied in brush layers	10u/m
Plant density applied in brush mattresses	

Herbaceous species seeding rate	
Insufficient connections/junctions between the logs	
Insufficient bad lateral connection of the work with the slope in its extremes	
Insufficient or missing soil compaction	✓
Adverse climate conditions	✓
Miscellaneous:	
Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques	Acceptable; onsite training and constant monitoring was necessary
Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)	insufficient
Adherent polluting matters or residues on inherent construction material observed	
Detected groundwater appearance	✓
Detected sewerage failure	✓
Natural landslide impact during construction stage	
Destruction by local residents observed?	✓

The main conclusion related to the construction stage is:

Surveying company's work is a primordial matter; often the company's, during the work, are needing both expert monitoring and professional tips.

Proposal of improvements for analyzed SWB work

Training modules and onsite courses adapted to less skilled workers have to improve the knowledge and the quality of company's work.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

- In following level is provided information regarding the bioengineering work monitoring and maintenance tasks carried out

Definition: This level is related to the monitoring stage during the lifetime of bioengineering works after final delivery date

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Available information regarding the bioengineering work monitoring tasks carried out	Case study data

Vegetation cycle 2016	 
Maintenance contract required and executed	✓
Kind of maintenance contract before all over final delivery date	1 year full site maintenance with 10 years warranty clause
Kind of maintenance contract after Final delivery date	No professional maintenance carried out by client
Comparison between specification/design and ‘as built’ measure: from accurate to failed	Accurate after refixing and recovery period
Characterization of the maintenance tasks in terms of their performance	Soaking, pruning, crop protection, fertilizing
Characterization of the maintenance tasks in terms of their suitability	All tasks are regularly obliged to be executed
Maintenance after delivery of site maintenance contract	No professional riparian forest managing provided by client

Monitoring instrumentation provided:

Inspections carried out	Irregular by own means
Noted defects	Pruning non-professional
Defects noted by	Designer/supervisor
Nature of defect	
Correction of defect	
Payment of defect by	
Value as % of total construction costs	
Kind of emergency works	
Emergency work realized by	

The main conclusion related to the monitoring stage is:

It's essential that no professional monitoring (riparian forest management)is providedsince final delivering in 2015. After delivering it seems that clients are forgetting bioengineering works if they are well integrated in the natural environment. Non-professional pruning activities are observed.In case of longterm non-professional activity, the consequence of this lack will be an important decreasing of ecological quality and mechanical soil resistance after a 10 upt to 20 year period whichaffects the well planned sustainability of bioengineering works.

Proposal of improvementsrelated to the monitoring stage

To institute a compulsory riparian forest management in the context of public projects.

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

- This level is directly related to the field work protocol (protocol 3). In this level is analyzed the data related to the operation stage (or work service life stage) of the work
- The in situ field work variables to analyze are classified according to their nature in “wooden elements”, “plants”, “soils”, “water/temperature/climate” and other utilized grey and green materials.

Definition: This is the stage (lifetime in process) in which the construction site field work takes place in his specific environment.

The following sections will be included in this analysis:

3.1 In situ field work variables analysis

3.2Current state (June 2018) of the analyzed bioengineering work area

3.3 Targeted scenario (end-point scenario)

LEVEL 3. ANALYSIS OF THE CURRENTSTATE (JUNE 2018) OF THE BIOEGINEERING WORK

3.1 In situ field work variables analysis measured according to the “field work protocol n°3”

Slope profile description (in ° along the steepest gradient)	50° up to 55°
Slope exposition (top of image is North) and curvature of slope (river bed thalweg before work)	

Geological and soil type description:	
Geological underground maps available	
Geological underground description	Alluviums of River Aveyronin downstream fromMontricoux, current alluviums of the low plain (posterior than the Gallo-Roman): pebbles, gravels, sands and flood silt
Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil:	
Sand and gravel*loose*	✓
Sand and gravel*dense*	✓
Sand and gravel*slightly cemented*	
Silt (Lehm) *loose*	
Silt*dense*	Graveled silt
Clays (Ton) *very soft*	
Clays *soft*	
Clays *firm*	
Clays *stiff*	

Clays *very stiff*	
Organic matter	
Aggregate stability	
Other	Bedrock flush
Water, temperature and climate information:	
Precipitation amount evolution	712mm
Insolation [h] amount evolution	2066
Snow period evolution	
Air temperature [°] max/min in january/july	9/2jan//28/16jul
Ground water appearance interacting or not	✓
Air moisture content	
Drainage (runoff, drains, etc)	
Plants in and out of the bioengineering work:	
Root depth[1]	
Root spread[2]	
Root tensile strength[3]	

1 Slope protection work in lifetime stage: No laboratory work therefore no destructive investigation possible

[2]Idem 1
[3] Idem 1

Root pull out strength[4]	
Wooden elements:	
Logs for piles and cribwall construction	
Other utilized grey and green materials:	
Non treated biodegradable geotextiles	Jute and coco fiber
Geosynthetics (e.g., geogrids)	✓
Rocks	✓ Coarse particels on river bed edge
3.2 Current state (June 2018) of the analyzed bioengineering work area	
Available information regarding the bioengineering work monitoring tasks carried out	Case study data
	 

[4]Idem 1

Stability: as expected	✓
Stability: with signs of failure but still stable	
Stability: insufficient by undesired phenomenon	
Stability: other	
Durability: as expected	✓
Durability: with signs of failure but still stable	
Durability: insufficient by undesired phenomenon	
Durability: other	
Aging: as expected	✓
Aging: with signs of failure but still stable	
Aging: insufficient by undesired phenomenon	
Aging: other	
State of "Flexible construction"[5]: observed during construction or before final delivery date	Sagging in 2013 refixed in 2015
State of "Flexible construction": observed after final delivery date	
State of "Flexible	Refixing process ended after 2 vegetation cycles

[5]"Flexible construction"[5] (work partially failed but refixing was self-recovered by the growing root system)

construction": The auto-refixing process is running	
State of "Flexible construction": evolution as expected	

3.3 Current state of the nearby area

Erosion processes observed	
Slope instabilities observed	
Vegetation properties (trees, shrubs, heights), initial vegetation survival rate	Canopy height/shrub height 1,8m/none Initial survival rate 95%

3.3 Targeted scenario (End-point scenario)

Regular riparian forest's rejuvenation process	Not yet accomplished

4 ANALYSIS OF THE WORK PERFORMANCE

- In this section are provided the following elements:
  - ✓ Analysis of the gap between the planned (designed) work and the 'as built' work
    - o Comparisons between needs for design and construction vs. level of assumptions and stability
    - o Work performance and beneficial effect analysis
  - ✓ In particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done.

4 ANALYSIS OF THE WORK PERFORMANCE

Available information	Case study data

Pictures during the site monitoring in 2016	
Suitability of the plant species used in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?	✓
Seeds used for the hydroseeding/manual seeding were appropriately selected?	No site adapted mix available
Problems related to the lack or abundance of water	
Problems related to an excessive plant density	
Problems related to soil fertility	
Problems related to slope	Compaction failure but refixing

aspect/angle/topography	
Problems with availability and adequacy of workforce with relevant qualifications	Delivering of geotechnical survey failed
Problems with access to site	
Problems with health/safety (e.g. invasive species)	
Problemsrelated to a maintenance contract failure	
Problems related to a missing maintenance contract (lifetime period after final delivery date)	✓

5 CONCLUSIONS - WORK PERFORMANCE

Available informations with description of the result of the work in terms of the pursued objectives	Case study and his evolution of vegetation efficiency in graduation from 1 “best” to 6 “worst”

	 
1 –**Very successful evolution** of the work (all the main objectives were achieved) <u>during 1 to 4 years</u> after final delivery date	No: failure by sagging Yes: subsequently refixing process successful 2 years after first delivering
2 - **Successful evolution** of the work (all the main objectives were achieved) <u>after more than 5 years</u> after final delivery date	✓
3 - **Acceptable evolution and results** (the main objectives were partially achieved) after <u>more than five years</u> after final delivery date	✓
4 –**Short term failure within 2 or 3 years** after final delivery date: slope failure, erosion problems, etc	no
5 –**Long term failure after more than 5 years**after final delivery date: slope failure, erosion problems, etc.	
6 – **Failure during construction stage**	Sagging due to soil compaction and sewer failure
Additional information: Recovery effect by auto-refixing observed	Yes: Normal evolutionby recovery effect

Description of decreasing of initial risks in the intervention area in response of bioengineering work's beneficial effect	Complete eliminating lateral bed shifting and bank slide; protection of residential area
The climate change is affecting the bioengineering work performance by ….	
The bioengineering work succeeded due to …	Enough time spent on the preliminary and analysis stage; the auto refixing capacity of high quality green materials
The bioengineering work failed due to …	Partially failed due to absence of geotechnical and compaction survey report
Salix brush layers during lifetime refixing cycle 2013 up to 2015	

In view of a general approach: Following should be important in nearfuture to increase notoriety and quality of SWB works:

Main proposal of improvementsrelated toanalyzed SWB works

- ✓ Establishing a multiyear European communication process to inform stakeholders about the technical possibilities of bioengineering works (they don't have informations of this discipline)
- ✓ Establishing training courses to educate future skilled personal is urgent

Main conclusion related toanalyzed SWB works

- ✓ A holistic and site adapted ecological/social/technical approach including students, designers, technicians and company's qualified persons during the design and construction stages is the guarantor of high probability of bioengineering work success.

Annexes

Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil

Test method applied on jobsite:

Soil type	***Term***	***Test***
Sand and gravels	Loose	Can be excavated with a spade; 50 mm wooden peg can easily be drive into the soil
	Dense	Requires pick for excavation; 50 mm peg is hard to drive into the soil
	Slightly cemented	Soil is excavated with pick in lumps. Lumps cannot easily be broken but particles can be abraded
Silt (Lehm)	Loose	Easily moulded or crushed with fingers
	Dense	Strong pressure required to mould material
Clays (Ton)	Very soft	Extrudes between fingers when squeezed
	Soft	Moulded without pressure
	Firm	Can be moulded with pressure
	Stiff	Cannot be moulded but can be indented with thumb
	Very stiff	Cannot be indented except with the thumb nail
Organic	Firm	Fibres compressed together
	Spongy	Open and compressible structure
	Plastic	Mouldable and smears the hands

>>Click to obtain further information related to «Soil and Fluvial Bioengineering»:

www.ecomedbio.eu

www.efib.org

www.aeip.org

http://www.agebio.org

Twitter: @ecomedbio

Facebook: Ecomedbio-Erasmus+

ECOMED Team France in June 2018

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CASE STUDY - FLUVIAL

RIVER LONGUES AYGUES CONSTRUCTION SITE REPORT 2012/2015

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

82000 Nègrepelisse, France/ Steep slope river bank rehabilitation work by application of "Soil and Water Bioengineering techniques"

UTM coordinates:

44° 04′ 20.32′′ N, 01° 314 40.04″ E

Completion date of the design stage:

2011

Completion date of the construction stage:

2015 after sagging in 2013 and soil refixing by high capacity of Salix root system

Client: (e.g. private or public person or industrial company):

Public (office of mayor)

SUMMARY

10 m high bank erosion some meters in front of residential buildings needs stabilization and restoring riparian vegetation with Biological Engineering Techniques.

Perfect development of Salix spec. with well-established root systems regardless to a slope sagging about 1 to 2m height.

ECOMED

Contents

✓ >>IF THIS SIGN APPEARS IN THE BOX THIS MEANS "YES" OR "TRUE"

>>IF NO SIGN APPEARSIN THE BOX THIS MEANS "NOT AT ALL"

ALL INFORMATIONS PROVIDED ARE VERIFIED AND RELATED EXCLUSIVELY TO THE PERFORMED CASE STUDIES

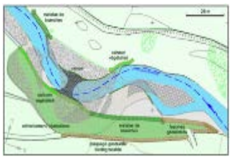
THE AIM OF PROTOCOL N°2

This protocol 2 is about defining the existing project information and the set of variables to be measured in the eco-engineering work analysisfield work protocols n°1 and n°3.

1 GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

- In this section is provided information regarding the general informations of construction sites

GENERAL INFORMATION ABOUT THE PROJECT AND CONSTRUCTION SITE

Criterions	Case study data			
				
Work location /UTM coordinates		F-09240 Labastide de Sérou, 43°00'29.27"N 01°25'54.02"E		
Delivering dates: preliminary stage **P**/design stage **D**/construction stage **C**		P 2006/D 2007/ C 2008		
Final delivery date, river name and project title		2008 Arize River “Urban area protection”		
Client(e.g. private or public person or industrial company)		Public (office of mayor)		
Decision criterion for this type of construction (e.g. ecological restoration; prevention; erosion control; landslide to restore ;………)		Sustainable urban land safety measures after riverbank erosion		
Site area and bioengineering work type		160m riverbed and left bank’s restoration by recreation of meander and hydraulic 3D		

		coarse ramp		
Opinion about disturbing elements present between the design stage and/or the construction stage				
Final Final delivery date, river name and project title		2008 Arize River “Urban area protection”		
1 - Not enough budget				
2 - Construction stage too short				
3 - Lack of a competent (effective) supervision during the construction stage				
4 - Extreme climate event (e.g. storm, flood, landslide or similar) disturbed profoundly the work				
5 - Lack of monitoring stage after the construction stage		✓		
6 – Other to describe				

Construction standards used in the work

Final delivery date, river name and project title		2008 Arize River “Urban area protection”		
Rip-rap/Living rip-rap		✓		
Fascine type cocofibres				
Living log cribwall		✓		
3D greened steel structure				

Brush layers		✓		
Brush mattresses				
Hydrodynamic 3D parabolic coarse rock ramp with integrated fishway		✓		
Seeding under coconut fibre erosion control blanket		✓		
Large tree planting				
Insurance type required for design stage/construction stage				
Kind of insurance "10 years warranty bonds" requiredfor both designer and company required		✓		
Only designer required				
Only company required				

2 INFORMATION RELATED TO THE ANALYSIS STAGE WITHIN THE PROJECT

- In this section is provided information regarding the project and the way the work was doneduring the analysis stage
- In following, the analysis is structured into two different levels:

Level 1: What information was considered and collected for doing the project?

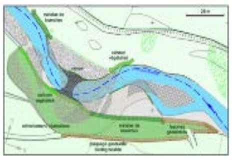
Level 2: What was calculated and included within the project?

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

- The information providedare the following: What was done by the soil and water- bioengineer during the analysis stage and before the beginning of the design stage? Followingareanalyzed all the preliminary analyses and studies related to the site carried out before proposing determined solutions into the project.

Definition: The preliminary analysis stage occurs before the planning/design stage and includes researching and collecting all kind of information available related to the site.

LEVEL 1. WHAT KIND OF INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

Project key objectives	Case study data			
				
Final delivery date, river name and project title		2008 Arize River “Urban area protection”		
Erosion control		✓		
Slope stability		✓		
Habitat restoration for species				
Landscape restoration				
Road restoration				
Realization of hiking trail				

Site appraisal: reconnaissance, desk studies, inspections for biodiversity, dendrology, inspections for ecology covering

Climatic aspects (rainfall, temperature, potentionevapotranspirations, exposure)		Rainfall, exposure		
Soil physical aspects (grading, density, water regime)		Grading, water regime		
Soil chemical aspects (ph, conductivity, nutrients, organic matter, exchange capacity, acid toxity)		nutrients, organic matter		
Soil engineering aspects (strength, permeability,		✓		

aggregate stability)				
Landscape features		✓		
Native vegetation analysis		✓		
Problems, risks and hazards that were addressed by the project:				
Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)		rain erosivity, soil erodibility, overland flow, channel discharge		
Fire risk				
Extent and nature of potential failure of vegetation				
Implications of the loss of function (temp'y or perm'y) the vegetation is forming				
Costs of repair and making good any consequent damage				
Risk to life, health or property		✓		
Geotechnical analysis/rock classification (preliminary assessment of ground/slope stability, etc.)				
Hydraulic/hydrographic analysis		✓		
Maps, photographs with the purpose of collecting historical information	Not available in 1999	✓		
Site topography/surveying (geomatics)	Not available in 1999	Not available in 2008		
Cadastral data, parcel ownership		✓		
Interviewing people for collecting historical information		✓		
Collection of urban planning processes and information		✓		

showing current or future impacts with the work/site				
Other construction sites planned close to the site impacting the bioengineering workflow		✓ Urban housing project		
Calculations and drawings related to this preliminary stage		✓		
Existing information in Regulatory Agencies (e.g. Biotope classifying/protection)		✓		
Specific river works criterions				
Characteristically of flood events that had affected the site (return period Q = flowrate m^3/velocity m/s /others)		Q_{50}=190m^3/2m/s/vortex expected		
Expected boundary shear stress τ = N/m²		60 N/m²		

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT?

- In this level the planning/designing stage established by the soil and water bioengineer is analyzed. This stage follows the preliminary analysis stage (analyzed in the preceding level 1).

Definition: In this stage the design documents and informations are now to be analyzed and assessed; the future project itself becomes his shape.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?				
Material selection and specification	Case stud data			
				

Final delivery date, rivername and project title		2008 Arize River "Urban area protection"		
Plant species-selection criterion applied		Regional native plants by seeking in the area		
Clear justification of techniques design provided?		✓		
Project strategy implementation criterions provided?		All stages implemented conformable to the French project construction implementation law		
Clear structural and geotechnical calculations provided?		On site decisions after ground inspection		
Functional requirements of vegetation by following items:				
Soil reinforcement and enhancement of soil strength		✓		
Soil water removal				
Surface protection against traffic		✓		
Surface protection against water erosion		✓		
Bank and channel reinforcement		✓		
Shelter of screening				
Rocks		✓		
Geosynthetics incorporated				
Timber applied		✓		
Stored topsoil applied		✓		
Soils/fill delivered				

Compost applied				
Plant species exotic applied				
Plantation techniques applied:				
Industrial seeds		Adapted to riverbanks		
Other materials				
Calculations, models and drawings applied:				
Calculation type approach		Hydraulic		
Modeling		1D hydraulic and experience		
Justification of the bioengineering techniques selection:				
Engineering onsite problem has been solved		✓		
Aspects that are improvable at the design stage				
Plant selection				
Strategy implementation				
Bioengineering techniques selection				
Calculations				

The main conclusion related to the design stage is:

The well trained designer has to take enough time to visit the site and all his surroundings in order to establish an adapted and sound site analysis. If so, all his following work like diagnostics, calculation and modeling will be well prepared and optimized for the bioengineering construction stage.

Only a holistic approach helps to find out the best site adapted Eco-technical solution and this is the precondition to get the most adapted final technical solution from the assortment of bioengineering technics.

3 INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND ITS SERVICE LIFE

- In this section the bioengineering work will be analyzed throughout its service life.

Here we provide the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Level 4: (optional) Decommissioning

LEVEL 1. CONSTRUCTION STAGE ANALYSIS

- The information provided here is: how was the work carried out by the construction company) during the construction stage?

Definition: The construction stage corresponds to the span of time of the realization of the client’s project by a contractor (Construction Company). His work is based exclusively on the design documents previously approved by the client.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS				
General issues, problems and defects	Case study data			
				

Problems/defects/issues recorded during the construction stage (information retrieved from the construction company):		Company's lack of knowledge and experience to realize main parts of the construction		
Detected flaws regarding construction stage:				
Increasing bed or river bank erosion in upstream or downstream areas adjacent to the work				
Incorrect harvest method and transport conditions of the living material				
Incorrect use and placement of the living material				
Incorrect storage conditions of the living material				
Incorrect machinery selection				
Disturbing elements present between design stage and construction stage:				
Insufficient budget				
Construction stage too short				
Lack of a competent (effective) supervision during the construction stage				
Lack of affective monitoring stage after the construction stage		✓		
Machinery utilized in the work				
Construction standards used:				
EFIB standards		✓		
Own long term standards		✓		

Issues related to construction features:				
Plantation techniques used to better attain and/or preserve soil humidity (e.g. tree pit formation, mulching, etc.)				
Mycorrhizae used in the utilized plants				
Changes in terms of plant species used in comparison with those included at the design stage? If so, how those changes were justified				
Utilised plants regionally distinctive/characteristic of the intervention area?				
Quality control for materials, plants (quality and origin) used		✓		
Normative (standard) followed		Long term experience of site supervisor		
Information regarding quality control for the living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard):				
Inert materials (grey materials) and related normative (standard) followed		Long term experience of site supervisor		
Living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard) followed		Long term experience of site supervisor		
Used hormone treatment for improving plant rooting capacity and root system development and related normative (standard) followed				
Plant density applied in log crib wall		15u/m		

Plant density applied in brush layers		15u/m		
Plant density applied in brush mattresses				
Herbaceous species seeding rate		30g/m²		
Insufficient connections/junctions between the logs				
Insufficient bad lateral connection of the work with the slope in its extremes				
Insufficient or missing soil compaction				
Adverse climate conditions				
Miscellaneous:				
Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques	I	Acceptable; onsite training and constant monitoring was necessary		
Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)		sufficient		
Adherent polluting matters or residues on inherent construction material observed				
Detected groundwater appearance				
Detected sewerage failure				
Natural landslide impact during				

construction stage				
Destruction by local residents observed?		✓		

The main conclusion related to the construction stage is:

Surveying company's work is a primordial matter; often the company's, during the work, are needing both expert monitoring and professional tips.

Proposal of improvements for analyzed SWB work

Training modules and onsite courses adapted to less skilled workers have to improve the knowledge and the quality of company's work.

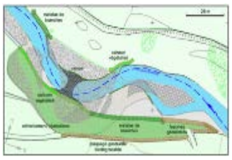
LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

- In following level is provided information regarding the bioengineering work monitoring and maintenance tasks carried out

Definition: This level is related to the monitoring stage during the lifetime of bioengineering works after final delivery date

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Available information regarding the bioengineering work monitoring tasks carried out	Case study data

				
Maintenance contract required and executed		✓		
Kind of maintenance contract before all over final delivery date		2 years full site maintenance with 10 years warranty clause		
Kind of maintenance contract after Final delivery date		No professional maintenance carried out by client		
Comparison between specification/design and 'as built' measure: from accurate to failed		Accurate after recovery period		
Characterization of the maintenance tasks in terms of their performance		Soaking, pruning, crop protection, fertilizing		
Characterization of the maintenance tasks in terms of their suitability		All tasks are regularly obliged to be executed		
Maintenance after delivery of site maintenance contract		No professional riparian forest managing provided by client		
		Monitoring instrumentation provided:		
Inspections carried out		Irregular by own means		
Noted defects		No leave sprout		
Defects noted by		Designer		

Nature of defect		Lack of fencing; sheep have damaged vegetation		
Correction of defect				
Payment of defect by				
Value as % of total construction costs				
Kind of emergency works				
Emergency work realized by				

The main conclusion related to the monitoring stage is:

It's essential that no professional monitoring (riparian forest management) was provided during the lifetime period. Clients are forgetting bioengineering works if they are well integrated in the natural environment. Sometimes nonprofessional pruning activities was observed. The consequence of this lack isan important decreasing of ecological quality and mechanical soil resistance after a 15/20 year period whichaffects the well planned sustainability of bioengineering works.

Proposal of improvementsrelated to the monitoring stage

To institute a compulsory riparian forest management in the context of public projects.

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

- This level is directly related to the field work protocol (protocol 3). In this level is analyzed the data related to the operation stage (or work service life stage) of the work
- The in situ field work variables to analyze are classified according to their nature in “wooden elements”, “plants”, “soils”, “water/temperature/climate” and other utilized grey and green materials.

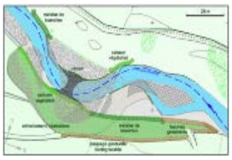
Definition: This is the stage (lifetime in process) in which the construction site field work takes place in his specific environment.

The following sections will be included in this analysis:

- 3.1 In situ field work variables analysis
- 3.2Current state (June 2018) of the analyzed bioengineering work area
- 3.3 Targeted scenario (end-point scenario)

LEVEL 3. ANALYSIS OF THE CURRENTSTATE (JUNE 2018) OF THE BIOEGINEERING WORK

3.1 In situ field work variable analysis measured according to the "field work protocol n°3"

				
Final delivery date, river name and project title		2008 Arize River "Urban area protection"		
Slope profile description (in ° along the steepest gradient)		40		
Slope exposition (top of image is North) and curvature of slope (river bed thalweg)				
		Geological and soil type description:		
Geological underground maps available				

Geological underground description		Post-Würm and current alluviums of the pyrenean rivers with pebbles, gravels, sands		
Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil:				
Sand and gravel*loose*		✓		
Sand and gravel*dense*				
Sand and gravel*slightly cemented*				
Silt (Lehm) *loose*		Argillaceous silt		
Silt*dense*				
Clays (Ton) *very soft*				
Clays *soft*				
Clays *firm*				
Clays *stiff*				
Clays *very stiff*				
Organic matter				
Aggregate stability				
Other				
Water, temperature and climate information:				

Precipitation amount evolution		+/- 950mm		
Insolation [h] amount evolution		+/- 1930		
Snow period evolution				
Air temperature [°] max/min in january/july		10/0jan//26/15jul		
Ground water appearance interacting or not				
Air moisture content				
Drainage (runoff, drains, etc)				
Plants in and out of the bioengineering work:				
Root depth[1]				
Root spread[2]				
Root tensile strength[3]				
Root pull out strength[4]				
Wooden elements:				
Logs for piles and cribwall construction		Larix decidua		
Other utilized grey and green materials:				
Non treated biodegradable		Jute and coco fiber		

1 Slope protection work in lifetime stage: No laboratory work therefore no destructive investigation possible

[2] Idem 1
[3] Idem 1
[4] Idem 1

geotextiles				
Geosynthetics (e.g., geogrids)				
Rocks		✓		
3.2 Current state (June 2018) of the analyzed bioengineering work area				
Available information regarding the bioengineering work monitoring tasks carried out	Case study data			
				
Final delivery date, river name and project title		2008 Arize River “Urban area protection”		
Stability: as expected		✓		
Stability:with signs of failure but still stable				
Stability:insufficient by undesired phenomenon				
Stability: other				
Durability: as expected		✓		
Durability: with signs of failure but still stable				
Durability: insufficient by undesired phenomenon				
Durability: other				

Aging: as expected		✓		
Aging: with signs of failure but still stable		✓		
Aging: insufficient by undesired phenomenon				
Aging: other		Insufficient rejuvenation process due to inaccurate riparian forest managing		
State of "Flexible construction"[5]: observed during construction or before final delivery date				
State of "Flexible construction": observed after final delivery date				
State of "Flexible construction": The auto-refixing process is running				
State of "Flexible construction": evolution as expected				
3.2 Current state of the nearby area				
Erosion processes observed				
Slope instabilities observed				
Vegetation properties (trees, shrubs, heights), initial vegetation survival rate		Canopy height/shrub height 12/6m Initial survival rate 60 to 65%		

[5] "Flexible construction"[5] (work partially failed but refixing was self-recovered by the growing root system)

3.3 Targeted scenario (End-point scenario)				
Regular riparian forest's rejuvenation process		Not accomplished		

4 ANALYSIS OF THE WORK PERFORMANCE

- In this section are provided the following elements:
  - ✓ Analysis of the gap between the planned (designed) work and the 'as built' work
    - o Comparisons between needs for design and construction vs. level of assumptions and stability
    - o Work performance and beneficial effect analysis
  - ✓ In particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done.

4 ANALYSIS OF THE WORK PERFORMANCE

Available information	Case study data			
				
Final delivery date, river name and project title		2008 Arize River "Urban area protection"		
Suitability of the plant species used in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?		✓		
Seeds used for the		No site adapted mix		

hydroseeding/manual seeding were appropriately selected?		available		
Problems related to the lack or abundance of water				
Problems related to an excessive plant density				
Problems related to soil fertility				
Problems related to slope aspect/angle/topography				
Problems with availability and adequacy of workforce with relevant qualifications				
Problems with access to site				
Problems with health/safety (e.g. invasive species)				
Problemsrelated to a maintenance contract failure				
Problems related to a missing maintenance contract(lifetime period after final delivery date)		✓		

5 CONCLUSIONS - WORK PERFORMANCE

Available informations	Case study and his evolution of vegetation efficiency in graduation

with description of the result of the work in terms of the pursued objectives	from 1 “best” to 6 “worst”			
				
Final delivery date, river name and project title		2008 Arize River “Urban area protection”		
1 –**Very successful evolution** of the work (all the main objectives were achieved) during 1 to 2 or 3 years after final delivery date		✓		
2 - **Successful evolution** of the work (all the main objectives were achieved) after more than 5 years after final delivery date		No		
3 - **Acceptable evolution and results** (the main objectives were partially achieved) after more than five years after final delivery date		✓		
4 –**Short term failure within 2 or 3 years** after final delivery date: slope failure, erosion problems, etc		Yes: Non adapted mowing has damaged Salix cuttings		
5 –**Long term failure after more than 5 years**after final delivery date: slope failure, erosion problems, etc.		Yes: Non adapted sheep-run installation has reduced Salix cuttings		
6 – **Failure during construction stage**		no		
Additional information: Recovery effect by auto-		Yes: Normal evolutionby recovery effect		

refixing observed				
Description of decreasing of initial risks in the intervention area in response of bioengineering work's beneficial effect		Complete eliminating lateral bed shifting and bank slide; protection of residential area		
The climate change is affecting the bioengineering work performance by				
The bioengineering work succeeded due to ...		Enough time spent on preliminary and analysis stage; company's open mindedness realizing the work; enough time spent by the engineer during construction stage		
The bioengineering work failed due to ...		No failing observed	P	
During construction stage		image		
During lifetime cycle		image		

In view of a general approach: Following should be important in nearfuture to increase notoriety and quality of SWB works:

Main proposal of improvementsrelated toanalyzed SWB works

- ✓ Establishing a multiyear European communication process to inform stakeholders about the technical possibilities of bioengineering works (they don't have informations of this discipline)
- ✓ Establishing training courses to educate future skilled personal is urgent

Main conclusion related toanalyzed SWB works

- ✓ A holistic and site adapted ecological/social/technical approach including students, designers, technicians and company's qualified persons during the design and construction stages is the guarantor of high probability of bioengineering work success.

Annexes

Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil

Test method applied on jobsite:

Soil type	***Term***	***Test***
Sand and gravels	Loose	Can be excavated with a spade; 50 mm wooden peg can easily be drive into the soil
	Dense	Requires pick for excavation; 50 mm peg is hard to drive into the soil
	Slightly cemented	Soil is excavated with pick in lumps. Lumps cannot easily be broken but particles can be abraded
Silt (Lehm)	Loose	Easily moulded or crushed with fingers
	Dense	Strong pressure required to mould material
Clays (Ton)	Very soft	Extrudes between fingers when squeezed
	Soft	Moulded without pressure
	Firm	Can be moulded with pressure
	Stiff	Cannot be moulded but can be indented with thumb
	Very stiff	Cannot be indented except with the thumb nail
Organic	Firm	Fibres compressed together
	Spongy	Open and compressible structure
	Plastic	Mouldable and smears the hands

>>Click to obtain further information related to «Soil and Fluvial Bioengineering»:

www.ecomedbio.eu

www.efib.org

www.aeip.org

http://www.agebio.org

Twitter: @ecomedbio

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ECOMED Team France in June 2018

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CASE STUDY - FLUVIAL

RIVER LONGUES AYGUES CONSTRUCTION SITE REPORT 2012/2015

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

82000 Nègrepelisse, France/ Steep slope river bank rehabilitation work by application of “Soil and Water Bioengineering techniques”

UTM coordinates:

44° 04’ 20.32’’ N, 01° 314 40.04’’ E

Completion date of the design stage:

2011

Completion date of the construction stage:

2015 after sagging in 2013 and soil refixing by high capacity of Salix root system

Client: (e.g. private or public person or industrial company):

Public (office of mayor)

SUMMARY

10 m high bank erosion some meters in front of residential buildings needs stabilization and restoring riparian vegetation with Biological Engineering Techniques.

Perfect development of Salix spec. with well-established root systems regardless to a slope sagging about 1 to 2m height.

Contents

✓ >>IF THIS SIGN APPEARS IN THE BOX THIS MEANS "YES" OR "TRUE"

>>IF NO SIGN APPEARS IN THE BOX THIS MEANS "NOT AT ALL"

ALL INFORMATIONS PROVIDED ARE VERIFIED AND RELATED EXCLUSIVELY TO THE PERFORMED CASE STUDIES

ALLINFORMATIONS RELATED TO CASE STUDY "2018 GARONNE STREAM – WORK IN PROGRESS"ARE SO FAR PLANIFIED, YET OBSERVED OR DETERMINEDELEMENTS; THE COMPANY'S QUALIFICATIONSARE KNOWN

ECOMED Team France

Partner 13 I.C.E Klaus Peklo

THE AIM OF PROTOCOL N°2

This protocol 2 is about defining the existing project information and the set of variables to be measured in the eco-engineering work analysisfield work protocols n°1 and n°3.

1 GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

- In this section is provided information regarding the general informations of construction sites

GENERAL INFORMATION ABOUT THE PROJECT AND CONSTRUCTION SITE

Criterions	Case study data			
				
Work location /UTM coordinates	F-09700 Gaudies, 43°10'28.52"N 01°43'51.08"E			
Delivering dates: preliminary stage **P**/design stage **D**/construction stage **C**	P 1999/D 1999/ C 2000			
Final delivery date, river name and project title	2000 L'HersVif River"Protection of the entrance of Gaudiès village"			
Client(e.g. private or public person or industrial company)	Public (office of mayor)			
Decision criterion for this type of construction (e.g. ecological restoration; prevention; erosion control; landslide to restore ;………)	Sustainable road safety measures after riverbank erosion			
Site area and bioengineering work type	230m riverbed and left bank's riparian restoration; creation of hydraulic 3D			

	coarse ramp			
Opinion about disturbing elements present between the design stage and/or the construction stage				
Final Final delivery date, river name and project title	2000 L'HersVif River "Protection of the entrance of Gaudiès village"			
1 - Not enough budget				
2 - Construction stage too short				
3 - Lack of a competent (effective) supervision during the construction stage				
4 - Extreme climate event (e.g. storm, flood, landslide or similar) disturbed profoundly the work	Severe flooding some weeks after final delivery date			
5 - Lack of monitoring stage after the construction stage	✓			
6 – Other to describe				
Construction standards used in the work				
Final delivery date, river name and project title	2000 L'HersVif River "Protection of the entrance of Gaudiès village"			
Rip-rap/Living rip-rap	✓			
Fascine type cocofibres	✓			
Living log cribwall	✓			
3D greened steel structure				
Brush layers	✓			

Brush mattresses	✓			
Hydrodynamic 3D parabolic coarse rock ramp with integrated fishway	✓			
Seeding under coconut fibre erosion control blanket	✓			
Large tree planting	✓			
Insurance type required for design stage/construction stage				
Kind of insurance "10 years warranty bonds" requiredfor both designer and company required	✓			
Only designer required				
Only company required				

2 INFORMATION RELATED TO THE ANALYSIS STAGE WITHIN THE PROJECT

- In this section is provided information regarding the project and the way the work was doneduring the analysis stage
- In following, the analysis is structured into two different levels:

  Level 1: What information was considered and collected for doing the project?

  Level 2: What was calculated and included within the project?

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

- The information providedare the following: What was done by the soil and water- bioengineer during the analysis stage and before the beginning of the design stage? Followingareanalyzed all the preliminary analyses and studies related to the site carried out before proposing determined solutions into the project.

Definition: The preliminary analysis stage occurs before the planning/design stage and includes researching and collecting all kind of information available related to the site.

LEVEL 1. WHAT KIND OF INFORMATION WAS CONSIDERED AND COLLECTED FOR DOING THE PROJECT?

Project key objectives	Case study data			
				
Erosion control	✓			
Slope stability	✓			
Habitat restoration for species				
Landscape restoration	✓			
Road restoration	✓			
Realization of hiking trail				
Site appraisal: reconnaissance, desk studies, inspections for biodiversity, dendrology, inspections for ecology covering				
Climatic aspects (rainfall, temperature, potentionevapotranspirations, exposure)	Rainfall, exposure			
Soil physical aspects (grading, density, water regime)	Grading, water regime			
Soil chemical aspects (ph, conductivity, nutrients, organic matter, exchange capacity, acid toxity)	nutrients, organic matter			
Soil engineering aspects (strength, permeability, aggregate stability)	✓			
Landscape features	✓			

Native vegetation analysis	✓			
Problems, risks and hazards that were addressed by the project:				
Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)	rain erosivity, soil erodibility, overland flow, channel discharge			
Fire risk				
Extent and nature of potential failure of vegetation				
Implications of the loss of function (temp'y or perm'y) the vegetation is forming				
Costs of repair and making good any consequent damage				
Risk to life, health or property	✓			
Geotechnical analysis/rock classification (preliminary assessment of ground/slope stability, etc.)				
Hydraulic/hydrographic analysis	✓			
Maps, photographs with the purpose of collecting historical information	Not available in 1999			
Site topography/surveying (geomatics)	Not available in 1999			
Cadastral data, parcel ownership	✓			
Interviewing people for collecting historical information	✓			
Collection of urban planning processes and information showing current or future impacts with the work/site	✓			

Other construction sites planned close to the site impacting the bioengineering workflow	✓ Public traffic way			
Calculations and drawings related to this preliminary stage	✓			
Existing information in Regulatory Agencies (e.g. Biotope classifying/protection)				
Specific river works criterions				
Characteristically of flood events that had affected the site (return period Q = flowrate m^3/velocity m/s /others)	Q_{10}=590m^3/v=2.5m/s/ vortex located			
Expected boundary shear stress τ = N/m²	160N/m²			

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT?

- In this level the planning/designing stage established by the soil and water bioengineer is analyzed. This stage follows the preliminary analysis stage (analyzed in the preceding level 1).

Definition: In this stage the design documents and informations are now to be analyzed and assessed; the future project itself becomes his shape.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

Material selection and specification	Case study data			
				
Final delivery date, rivername and project title	2000 L'HersVif River"Protection of the entrance of Gaudiès village"			
Plant species-selection criterion applied	Regional native plants by seeking in the area			
Clear justification of techniques design provided?	✓			
Project strategy implementation criterions provided?	All stages implemented conformable to the French construction implementation law			
Clear structural and geotechnical calculations provided?	On site decisions after ground inspection			
Functional requirements of vegetation by following items:				
Soil reinforcement and enhancement of soil strength	✓			
Soil water removal	✓			
Surface protection against traffic	✓			
Surface protection against water erosion	✓			

Bank and channel reinforcement	✓			
Shelter of screening				
Rocks	✓			
Geosynthetics incorporated				
Timber applied	✓			
Stored topsoil applied	✓			
Soils/fill delivered	✓			
Compost applied				
Plant species exotic applied				
Plantation techniques applied:				
Industrial seeds	Adapted to riverbanks			
Other materials	KUFBiorolls made of coconut fibres			
Calculations, models and drawings applied:				
Calculation type approach	Hydraulic			
Modeling	1D hydraulic and experience			
Justification of the bioengineering techniques selection:				
Engineering onsite problem has been solved	✓			
Aspects that are improvable at the design stage				
Plant selection				

Strategy implementation				
Bioengineering techniques selection				
Calculations	Hydraulic approach			

The main conclusion related to the design stage is:

The well trained designer has to take enough time to visit the site and all his surroundings in order to establish an adapted and sound site analysis. If so, all his following work like diagnostics, calculation and modeling will be well prepared and optimized for the bioengineering construction stage.

Only a holistic approach helps to find out the best site adapted Eco-technical solution and this is the precondition to get the most adapted final technical solution from the assortment of bioengineering technics.

3 INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND ITS SERVICE LIFE

- In this section the bioengineering work will be analyzed throughout its service life.

Here we provide the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Level 4: (optional) Decommissioning

LEVEL 1. CONSTRUCTION STAGE ANALYSIS

- The information provided here is: how was the work carried out by the construction company) during the construction stage?

Definition: The construction stage corresponds to the span of time of the realization of the client's project by a contractor (Construction Company). His work is based exclusively on the design documents previously approved by the client.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS

General issues, problems and defects	Case study data			
				
Final delivery date, river name and project title	2000 L'HersVif River"Protection of the entrance of Gaudiès village"			
Problems/defects/issues recorded during the construction stage (information retrieved from the construction company):	Company's lack of knowledge and experience to realize main parts of the construction			

Detected flaws regarding construction stage:

Increasing bed or river bank erosion in upstream or downstream areas adjacent to the work				
Incorrect harvest method and transport conditions of the living material				
Incorrect use and placement of the living material				
Incorrect storage conditions of the living material				
Incorrect machinery selection				

Disturbing elements present between design stage and construction stage:

Insufficient budget				

Construction stage too short				
Lack of a competent (effective) supervision during the construction stage				
Lack of affective monitoring stage after the construction stage	✓			
Machinery utilized in the work				
Construction standards used:				
EFIB standards	✓			
Own long term standards	✓			
Issues related to construction features:				
Plantation techniques used to better attain and/or preserve soil humidity (e.g. tree pit formation, mulching, etc.)				
Mycorrhizae used in the utilized plants				
Changes in terms of plant species used in comparison with those included at the design stage? If so, how those changes were justified				
Utilised plants regionally distinctive/characteristic of the intervention area?				
Quality control for materials, plants (quality and origin) used	✓			
Normative (standard) followed	Long term experience of site supervisor			
Information regarding quality control for the living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard):				

Inert materials (grey materials) and related normative (standard) followed	Long term experience of site supervisor			
Living material (vegetation, stakes, seeds, live branches, etc.) and related normative (standard) followed	Long term experience of site supervisor			
Used hormone treatment for improving plant rooting capacity and root system development and related normative (standard) followed				
Plant density applied in log crib wall	15u/m			
Plant density applied in brush layers	15u/m			
Plant density applied in brush mattresses	20 to 25u/m			
Herbaceous species seeding rate	30g/m^2			
Insufficient connections/junctions between the logs				
Insufficient bad lateral connection of the work with the slope in its extremes				
Insufficient or missing soil compaction				
Adverse climate conditions	✓			

Miscellaneous

Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques	Insufficient; onsite training and constant monitoring was necessary			

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Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)	insufficient			
Adherent polluting matters or residues on inherent construction material observed				
Detected groundwater appearance	✓			
Detected sewerage failure				
Natural landslide impact during construction stage				
Destruction by local residents observed?				

The main conclusion related to the construction stage is:

Surveying company's work is a primordial matter; often the company's, during the work, are needing both expert monitoring and professional tips.

Proposal of improvements for analyzed SWB work

Training modules and onsite courses adapted to less skilled workers have to improve the knowledge and the quality of company's work.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

- In following level is provided information regarding the bioengineering work monitoring and maintenance tasks carried out

Definition: This level is related to the monitoring stage during the lifetime of bioengineering works after final delivery date

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Available information regarding the bioengineering work monitoring tasks carried out	Case study data			
				
Maintenance contract required and executed	✓			
Kind of maintenance contract before all over final delivery date	2 years full site maintenance with 10 years warranty clause			
Kind of maintenance contract after Final delivery date	No professional maintenance carried out by client			
Comparison between specification/design and 'as built' measure: from accurate to failed	accurate			
Characterization of the maintenance tasks in terms of their performance	Soaking, pruning, crop protection, fertilizing			
Characterization of the maintenance tasks in terms of their suitability	All tasks are regularly obliged to be executed			

Maintenance after delivery of site maintenance contract	No professional riparian forest managing provided by client			
Monitoring instrumentation provided:				
Inspections carried out	Irregular by own means			
Noted defects	no completion planting when partial failure			
Defects noted by	Designer			
Nature of defect	No professional pruning and riparian management;			
Correction of defect				
Payment of defect by				
Value as % of total construction costs				
Kind of emergency works				
Emergency work realized by				

The main conclusion related to the monitoring stage is:

It's essential that no professional monitoring (riparian forest management) was provided during the lifetime period. Clients are forgetting bioengineering works if they are well integrated in the natural environment. Sometimes nonprofessional pruning activities was observed. The consequence of this lack isan important decreasing of ecological quality and mechanical soil resistance after a 15/20 year period whichaffects the well planned sustainability of bioengineering works.

Proposal of improvementsrelated to the monitoring stage

To institute a compulsory riparian forest management in the context of public projects.

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

- This level is directly related to the field work protocol (protocol 3). In this level is analyzed the data related to the operation stage (or work service life stage) of the work
- The in situ field work variables to analyze are classified according to their nature in "wooden elements", "plants", "soils", "water/temperature/climate" and other utilized grey and green materials.

Definition: This is the stage (lifetime in process) in which the construction site field work takes place in his specific environment.

The following sections will be included in this analysis:

3.1 In situ field work variables analysis

3.2Current state (June 2018) of the analyzed bioengineering work area

3.3 Targeted scenario (end-point scenario)

LEVEL 3. ANALYSIS OF THE CURRENTSTATE (JUNE 2018) OF THE BIOEGINEERING WORK

3.1 In situ field work variables analysismeasured according to the "field work protocol n°3"

Slope profile description (in ° along the steepest gradient)	45

Slope exposition (top of image is North) and curvature of slope (river bed thalweg)				
Geological and soil type description:				
Geological underground maps available				
Geological underground description	Post-Würm and current alluviums of the pyrenean rivers with pebbles, gravels, sands			
Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil:				
Sand and gravel*loose*	✓			
Sand and gravel*dense*				
Sand and gravel*slightly cemented*				
Silt (Lehm) *loose*	Argillaceous silt			
Silt*dense*				
Clays (Ton) *very soft*				
Clays *soft*				

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Clays *firm*				
Clays *stiff*				
Clays *very stiff*				
Organic matter				
Aggregate stability				
Other	Bedrock flush			
Water, temperature and climate information:				
Precipitation amount evolution	+/- 950mm			
Insolation [h] amount evolution	+/- 1930			
Snow period evolution				
Air temperature [°] max/min in january/july	10/0 jan//26/14 jul			
Ground water appearance interacting or not	✓			
Air moisture content				
Drainage (runoff, drains, etc)				
Plants in and out of the bioengineering work:				
Root depth[1]				

1 Slope protection work in lifetime stage: No laboratory work therefore no destructive investigation possible

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Root spread[2]				
Root tensile strength[3]				
Root pull out strength[4]				
Wooden elements:				
Logs for piles and cribwall construction	Larix decidua			
Other utilized grey and green materials:				
Non treated biodegradable geotextiles	Jute and coco fiber			
Geosynthetics (e.g., geogrids)				
Rocks	✓			
3.2 Current state (June 2018) of the analyzed bioengineering work area				
Available information regarding the bioengineering work monitoring tasks carried out	Case study data			
				
Stability: as expected	✓			
Stability:with signs of failure	✓ Since			

[2]Idem 1
[3] Idem 1
[4]Idem 1

but still stable	2018			
Stability:insufficient by undesired phenomenon				
Stability: other	Being in decreasing process			
Durability: as expected	✓			
Durability: with signs of failure but still stable	Being in decreasing process			
Durability: insufficient by undesired phenomenon				
Durability: other	Being in decreasing process due to the lack of riparian forest managing			
Aging: as expected	✓			
Aging: with signs of failure but still stable	✓			
Aging: insufficient by undesired phenomenon				
Aging: other	Insufficient rejuvenation process due to inaccurate riparian forest managing			
State of "Flexible construction"[5]: observed during construction or before final delivery date				
State of "Flexible construction": observed				

[5]"Flexible construction"[5] (work partially failed but refixing was self-recovered by the growing root system)

after final delivery date				
State of "Flexible construction": The auto-refixing process is running				
State of "Flexible construction": evolution as expected				
3.3 Current state of the nearby area				
Erosion processes observed	✓ downstream			
Slope instabilities observed	✓ upstream			
Vegetation properties (trees/shrubs heights), initial vegetation survival rate	Canopy height/shrub height 15/8m Initial survival rate 60%			
3.3 Targeted scenario (End-point scenario)				
Regular riparian forest's rejuvenation process	Not accomplished			

4 ANALYSIS OF THE WORK PERFORMANCE

- In this section are provided the following elements:
  - ✓ Analysis of the gap between the planned (designed) work and the 'as built' work
    - Comparisons between needs for design and construction vs. level of assumptions and stability
    - Work performance and beneficial effect analysis
  - ✓ In particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done.

4 ANALYSIS OF THE WORK PERFORMANCE

Available information	Case study data			
				
Final delivery date, river name and project title	2000 L'HersVif River"Protection of the entrance of Gaudiès village"			
Suitability of the plant species used in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?	✓			
Seeds used for the hydroseeding/manual seeding were appropriately selected?	No site adapted mix available			
Problems related to the lack or abundance of water				
Problems related to an excessive plant density				
Problems related to soil fertility				
Problems related to slope aspect/angle/topography				
Problems with availability and adequacy of workforce	Onsite training was provided			

with relevant qualifications				
Problems with access to site				
Problems with health/safety (e.g. invasive species)				
Problemsrelated to a maintenance contract failure				
Problems related to a missing maintenance contract(lifetime period after final delivery date)	✓			

5 CONCLUSIONS - WORK PERFORMANCE

Available informations with description of the result of the work in terms of the pursued objectives	Case study and his evolution of vegetation efficiency in graduation from 1 "best" to 6 "worst"			
				
Final delivery date, river name and project title	2000 L'HersVif River"Protection of the entrance of Gaudiès village"			
1 –Very successful evolution of the work (all the main objectives were achieved) during 1 to 2 or	✓			

3 years after final delivery date				
2 - **Successful evolution** of the work (all the main objectives were achieved) after more than 5 years after final delivery date	✓			
3 - **Acceptable evolution and results** (the main objectives were partially achieved) after more than five years after final delivery date	✓			
4 –**Short term failure within 2 or 3 years** after final delivery date: slope failure, erosion problems, etc	no			
5 –**Long term failure after more than 5 years**after final delivery date: slope failure, erosion problems, etc.	Lower bank erosion signs occurred in 2018 due to the lack of maintenance			
6 – **Failure during construction stage**	no			
Additional information: Recovery effect by auto-refixing observed	Unconcerned			
Description of decreasing of initial risks in the intervention area in response of bioengineering work's beneficial effect	Complete eliminating vortex erosion in meander, prevention of bank erosion for nowadays nearly 20 years; protection of public traffic way			
The climate change is affecting the bioengineering work performance by				
The bioengineering work succeeded due to ...	Enough time spent on preliminary and analysis stage; onsite training;			

	company's open mindedness byrealizing the work; enough time spent by the engineer during construction stage			
The bioengineering work failed due to …	No failing but soil stability actually is decreasing due to absence of long term riparian forest managing			
During construction stage				
During lifetime cycle		  		

In view of a general approach: Following should be important in nearfuture to increase notoriety and quality of SWB works:

Main proposal of improvementsrelated toanalyzed SWB works

- ✓ Establishing a multiyear European communication process to inform stakeholders about the technical possibilities of bioengineering works (they don't have informations of this discipline)
- ✓ Establishing training courses to educate future skilled personal is urgent

Main conclusion related toanalyzed SWB works

- ✓ A holistic and site adapted ecological/social/technical approach including students, designers, technicians and company's qualified persons during the design and construction stages is the guarantor of high probability of bioengineering work success.

Annexes

Engineering soil classification applied according to EN ISO 14688-1/2:2002 Geotechnical investigation and testing - Identification and classification of soil

Test method applied on jobsite:

Soil type	***Term***	***Test***
Sand and gravels	Loose	Can be excavated with a spade; 50 mm wooden peg can easily be drive into the soil
	Dense	Requires pick for excavation; 50 mm peg is hard to drive into the soil
	Slightly cemented	Soil is excavated with pick in lumps. Lumps cannot easily be broken but particles can be abraded
Silt (Lehm)	Loose	Easily moulded or crushed with fingers
	Dense	Strong pressure required to mould material
Clays (Ton)	Very soft	Extrudes between fingers when squeezed
	Soft	Moulded without pressure

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	Firm	Can be moulded with pressure
	Stiff	Cannot be moulded but can be indented with thumb
	Very stiff	Cannot be indented except with the thumb nail
Organic	Firm	Fibres compressed together
	Spongy	Open and compressible structure
	Plastic	Mouldable and smears the hands

>>Click to obtain further information related to «Soil and Fluvial Bioengineering»:

www.ecomedbio.eu

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ECOMED Team France in June 2018

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CASE STUDIES.
FYROM

CASE STUDY - SLOPE

CUT SLOPES ON RAILWAY LINE, SECTION NEGOTINO - DEMIR KAPIJA, R. MACEDONIA

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Railway Negotino - Demir Kapija, R.Macedonia, cut slopes, km 544+550 – km 544+850

UTM coordinates:
4599052.70; 592803.39

Completion date of the design stage:
2014

Completion date of the construction stage:
2014

Client: (e.g. private or public person or industrial company):
Macedonian railways – public agency

Erosion control and rehabilitation of the current cut slopes.

SUMMARY

The objective of the project is to provide engineering solution for stabilization and erosion control of the existing cut slopes at section km 544+550 – km 544+850. Another important aspect of the project was application of environment friendly construction materials. The project was implemented in 2014.

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RAILWAY NEGOTINO - DEMIR KAPIJA CASE STUDY REPORT

Authors: Geing Krebs und Kiefer

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title :

Railway Negotino - Demir Kapija, R.Macedonia, cut slopes, km 544+550 – km 544+850

UTM coordinates:

4599052.70; 592803.39

Completion date of the design stage: 2014

Completion date of the construction stage: 2014

Client: (e.g. private or public person or industrial company)

Macedonian railways – public agency

Decision criteria for this type of construction: (e.g. ecological restoration; prevention; erosion control; landslide to restore; etc.)

Erosion control and rehabilitation of the current cut slopes.

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

- Project key objectives? (Erosion control, slope stability, habitat restoration -for species-, landscape restoration, etc.).

  The main objective of the project is stabilization of the cut slopes by applying erosion control and run-off water control measures. Applying such measures will resolve the main concern regarding traffic conditions on the railway and stability of the slopes.

  Also one of the project objectives was application of environment friendly construction materials.

- Site reconnaissance, desk Site appraisal: reconnaissance, desk/office studies, and inspections for biodiversity, dendrology, inspections for ecology covering:
    - Soil physical aspects (grading, density, water regime)

According to the established results from geomechanical laboratory tests (additional soil samples are taken in November 2017) the water content in the surficial soil layer is 10,02%. The Average of density of the soil particles is ranging between 2,583-2,586 Mg/m^3. Summary of the established results is given in Appendix 4.

- Soil engineering aspects (strength, permeability, aggregate stability)

Following material properties of the soil and rock formations encountered on site were adopted for the stability analyses:

	Bulk density [kN/m^3]	Cohesion [kN/m^2]	Angle of internal friction [°]	Compressibility modulus [kPa]	Poisson's ratio [/]
Flysch sedimentary rock	25,00	100,00	15,00	25.000	0,30
Local soil material	18,00	25,00	15,00	5.000	0,30

- Problems, risks and hazards that were addressed by the project including but not limited to:
    - Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)

Having in mind that the site geology is consisted of flysch sedimentary rock formation which at the ground surface are highly weathered erosion is developed on the cut slopes. This is one of the major problems for proper functioning of the railway.

- Geotechnical risks (mass movement, liquefaction, seismicity)

Typical landsliding is not detected on the considered section. Rock falls are detected which can endanger the regular traffic conditions and can cause damages to the railway infrastructure.

- Visual soil/rock classification. Geotechnical analysis (preliminary assessment of ground/slope stability, etc.)

According to the geological map and visual inspection the project site is composed of Eocene and Pliocene sediments (flysch deposits);

The surficial soil layers are consisted of soil materials which are classified as clays with low plasticity (CL). The erosion control measures are installed on the surficial soil layer. The geological map of the site is shown in Attachment 1 of this report.

- Maps, photographs with the purpose of collecting historical information

Geological map is enclosed in the attachments of this report.

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- Calculations and drawings related to this preliminary stage

  During the preliminary stage slope stability analysis were carried out. Having in mind that the objective of the project is to provide long terms stability of the slopes and long term erosion control measures stability analysis are conducted.

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

General issues, problems and defects.

- Construction stage too short

The time period for completion of the construction stage was tight. Probably the reason for this was that urgent rehabilitation of the cut slopes had to be done.

- Lack of and affective monitoring stage after the construction stage

According to the available informations inspection of the rehabilitated is done properly by the Client's maintenance service.

- Please, indicate the construction standards used in the work:

  The construction was carried out according to the local standards (MK standards) and local law on construction.
- Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied: NONE

Issues related to construction features:

Miscellaneous:

- Groundwater appearance?

  Ground water is not detected on the site.
- Natural landslide impact?

For the most part the railway section Nogaevci - Negotino is constructed on low embankment and runs in flat ground. On some sections the railway is constructed in cut. From slope stability point of view three critical sections are detected. On these sections the cut slopes are formed in the immediate vicinity of the railway structure. The inclination of the cut slopes varies between 45° and 65° with maximum height of the cut slopes between 8,00 and 12,00 m.

The ground of certain railway sections is consisted of flysch sedimentary rock formations which are very prone to weathering when they are exposed on atmospheric influence. The thin layers of the rock formations which are more susceptible to weathering are initially decomposed and then during the intensive rainfalls they are washed away and transported to the toe of the cut slope. With continuous process of weathering of the weak rock formations a fissures and cracks develop in the solid rock which are surrounding the weak rock layers. Over the time this process lead to formation of large rock boulders which are falling downslope to the railway structure. Considering the fact that so far, during the operational period of the railway, surface erosion has occurred and eroded material was deposited in the toe of cut slopes and behind the existing retaining wall. Over the time the eroded material filled up the space between the existing retaining wall and the cut slope which caused instability of the retaining wall. In general, the erosion of the cut slopes continuously cause difficulties for maintenance of the railway. Falling of the large rock boulders can endanger the serviceability of the railway and can cause major accidents.

-

Before commencement of the works for implementation of the erosion control measures instability of the existing retaining wall occurred. Excessive displacement of the wall were detected which further led to total collapsing of a 50 m long section of the retaining wall.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

- Was there a maintenance contract?

A According to the gained informations the maintenance of the particular cut slopes is responsibility of the Client “Macedonian railways” - state company. Hence other company was not engaged in the maintenance of the cut slopes.

Comparison between specification/design and ‘as built’ measure

The design requirements were partially implemented on cut slopes. Namely, the grassing of the cut slopes was not performed. All other measures proposed in the Design were implemented - side channels, reshaping of the slopes, installation of the geogrid etc.

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LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

Both case study projects from Macedonia fall within the “Slope stabilisation scenario”. These case study projects are titled: a.) Erosion control measures on cut slopes with biocompatible materials on Highway E75; and b.) Rehabilitation and erosion control measures on cut slopes on railway Negotino – Nogaevci.

IN SITU FIELD WORK VARIABLES SELECTION

At both case study sites from Macedonia the following field work variables were selected (grouped in accordance to Protocol 3):

SITE DESCRIPTION

1. Slope profile description

   The profile of the cut slopes is formed as per design for erosion control (Attachment no.3). The inclination of the cut slopes is 1 :1. The inclination of the cut slopes is proposed on a basis of conducted slope stability analyses.

SOIL PROFILE DESCRIPTION

2. Soil classification

   The surfical soil layer is composed of clays with low plasticity (geomechanical simbols CL) which is final natural grade for installation of the proposed erosion control measures.

3. Engineering soil classification
4. Geology

   As per geological map (Attachement no.1) and site classification of the ground the site is composed of Eocene and Pliocene sediments (flysch deposits and Diluvium deposits).

ABIOTIC SITE DESCRIPTION

5. Gravimetric soil moisture content
6. Organic matter content
7. Void ration and porosity

   The summary of the above listed soil properties is enclosed in appendix no.4

SOIL CHEMISTRY

8. pH
9. Total Kjeldahl Nitrogen
10. Plant available phosphorus
11. ReDox potential
12. Cation Exchange Capacity

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CHARACTERISATION OF VEGETATION

The selected set of variables has been chosen in regard to each variable's applicability in at least one of the case study sites from Macedonia. Factors as site accessibility, time of the year, seasonality, duration of the sampling technique, time available and time required for the laboratory procedure as well as available background data and affordability have all been considered when selecting the set of field work variables

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

SOIL CHEMISTRY

In regard to the chemical characteristics of the soil at both study sites the following parameters have been analysed: pH, total Kjeldahl Nitrogen, plant available phosphorus, ReDox potential and cation exchange capacity.

The obtained results for both sites are given in the following table:

Value	pH	Total Kjeldahl Nitrogen	Available phosphorus	ReDox potential	Cation Exchange Capacity
Units (*)	/	[mg/g]	[mg/100 g]	(mV)	(meq/100 g)
Method	ISO 10390:2015	ISO 11261	Al method		Kappen
Site					
Highway A1 (E75)	8.43	0.137 %	12.15		21.84 cmol/kg
Railway Negotino - Nogaevci	8.45	0.49	5.46	-71.5	49.47

(*) unless otherwise stated.

CHARACTERISATION OF VEGETATION

13. Estimation of vegetation cover/area

The slope site of the Negotino – Nogaevci railway section (project title: Rehabilitation and erosion control measures on cut slopes on railway Negotino –

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Nogaevci) has only recently been constructed, thus the vegetation cover is still under development.

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Figure 1a. Rehabilitated cut slopes

Figure 1b. Rehabilitated cut slopes

On 10th of November 2017 visual inspection on the project site was held. Most of cut slopes are rehabilitated and erosion control measures are successfully implemented (see Figure 1a and Figure 1b). The proposed erosion control measures were not fully implemented on the cut slopes. It was detected that the vegetation

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was not developed and the slopes were not grassed at all. Obviously the stabilization measures were not fully implemented.

CASE STUDY - SLOPE

SKOPJE - GEVGELIJA (A1) HIGHWAY, SECTION NEGOTINO-DEMIR KAPIJA R. MACEDONIA

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

Skopje - Gevgelija (A1) highway, section Negotino-Demir

Kapija km 116+990 to km 123+521, R.Macedonia

UTM coordinates:

Site at km 118+64374.

4587134.850; 7600082.280

Site at km 118+562.03

4586970.686; 7600172.978

Site at 119+634.49

4586529.507; 7601101.335

km 120+242.64

4586717.562; 7601682.062

Completion date of the design stage:

2005

Completion date of the construction stage:

2005

Agency for state roads of Republic of Macedonia (state agency)

SUMMARY

The objective of the project is to provide engineering solution for stabilization and erosion control of the highway cut slopes at section km 116+990 to km 123+521. Another important aspect of the project was application of environment friendly construction materials. The project was implemented in 2005.

ECOMED - *Ecoengineering in the Mediterranean Environment*

SKOPJE - GEVGELIJA (A1) HIGHWAY CASE STUDY REPORT

Authors: Geing Krebs und Kiefer

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title:

Skopje - Gevgelija (A1) highway, section Negotino-Demir Kapija km 116+990 to km 123+521, R.Macedonia

UTM coordinates:

Site at km 118+374.64

4587134.850; 7600082.280

Site at km 118+562.03

4586970.686; 7600172.978

Site at 119+634.49

4586529.507; 7601101.335

km 120+242.64

4586717.562; 7601682.062

Completion date of the design stage: *2005*

Completion date of the construction stage: *2005*

Client: (e.g. private or public person or industrial company)

Agency for state roads (state agency)

Decision criteria for this type of construction: (e.g. ecological restoration; prevention; erosion control; landslide to restore; etc.)

Erosion control of the highway cut slopes and rehabilitation of the current cut slopes.

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

- In this stage we are looking for information regarding the project and the way the work was done.

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LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

- Project key objectives? (Erosion control, slope stability, habitat restoration -for species-, landscape restoration, etc.).

  The main objective of the project is erosion control of the cut slopes by applying erosion control measures. Applying such measures will resolve the slope stability problems of the cut slopes of this highway section (km 116+990 to km 123+521). Also one of the project objectives is application of environment friendly construction materials.

- Site appraisal: reconnaissance, desk/office studies, and inspections for biodiversity, dendrology, inspections for ecology covering:

  Before commencement of the Design works a site visit on the (A1) E-75 Motorway, Negotino - Demir Kapija section, (km 116+990 to km 123+521). In the report is stated that on the existing cut slopes the erosion and ground instabilities are detected. Based on the findings from the site visit and the Client's requirements a design involving biodegradable erosion control blankets and 3D geogrid for erosion control is developed.

  - Soil physical aspects (grading, density, water regime)

  According to the established results from geomechanical laboratory tests (additional soil samples are taken in November 2017) the water content in the surficial soil layer ranging between 7,46% - 13,73%. The bulk density of the soil ranging between 2,38-2,45 Mg/m^3. Summary of the established results is given in Attachment 4.

- Visual soil/rock classification. Geotechnical analysis (preliminary assessment of ground/slope stability, etc.)

  According to the geological map and visual inspection the project site is composed of:

  Eocene and Pliocene sediments (flysch deposits);

  Diluvium deposits;

-


Figure 1. Site geology

The surficial soil layers are consisted of soil materials which are classified as clays with intermediate and high plasticity (CI, CL). The erosion control measures are installed on the surficial soil layer. The geological map of the site is shown in Attachment 1 of this report.

- Maps, photographs with the purpose of collecting historical information

  Geological map is enclosed in the attachments of this report.

- Calculations and drawings related to this preliminary stage

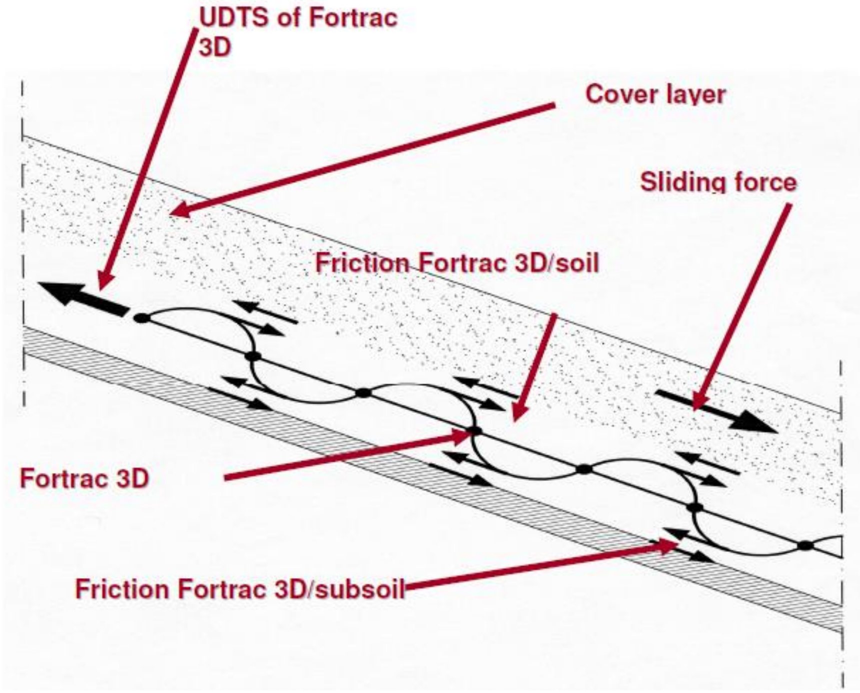

Figure 2. Scheme for dimensioning of geogrid type

- *During the design and planning stage several different type of analyses and calculations are performed:*
  - *Slope stability analysis*
  - *Calculations for soil loss,*
  - *Calculations for dimensioning of the erosion control measures*
  - *Hydraulically calculations*

The design drawings are enclosed in the attachments of this report.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

In this level the planning/designing stage established by the soil- and water-bioengineer is analyzed. This stage follows the preliminary analysis stage (analyzed in the preceding level 1). The design documents and information (the project itself) are now analyzed and assessed.

Some examples of the type of information analyzed in his level are the following:

- Is there a clear criteria for the plant species selection? Which is the criteria follow for selecting the plant species included in the project? Do the plants that belong to the first successional stage of the intervention area well represented?
- Was a phytosociological approach used in both the plant species selection process and the intervention strategy?
- Are there clear criteria for the project strategy implementation?
- Are there clear criteria for the bioengineering techniques selections?
- Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear?
- Functional requirements of vegetation (select all that apply to the project):
    - Soil reinforcement and enhancement of soil strength
    - Soil water removal
    - Surface protection against traffic
    - Surface protection against wind/water erosion
    - Bank and channel reinforcement
    - Shelter or screening
- Which **improvements** would you propose, at the design stage, regarding:
    - Plant selection:
    - Strategy implementation
    - Bioengineering techniques selection
    - Calculations
    - etc.

Please indicate your main conclusions after the analysis of the bioegineering work at the design stage:

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

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LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

General issues, problems and defects.

- Construction stage too short

The time period for completion of the construction stage was tight. Probably one of the reasons for problems on some of the rehabilitated cut slopes.

- Lack of and affective monitoring stage after the construction stage

According to the available informations inspection of the rehabilitated was not done properly.

- Please, indicate the construction standards used in the work:

The construction was carried out according to the local standards (MK standards) and local law on construction.

- Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied: *NONE*

Miscellaneous:

- Groundwater appearance?

On certain portions of the cut slopes ground water is detected. The ground water on the slopes appears and it has a negative impact on the slope stability. Considering the fact that the slopes are mostly composed of clayey materials weakening of the soil is very common for such materials which can trigger local failure of the slopes.

- Sanitation failure?

- Natural landslide impact?

As noted in the beginning of this report before commencement of the design works several slope instabilities and erosion gullies are detected on the site. Such slope conditions had adverse impact on the traffic conditions and could lead to development of slope landslides.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

- Was there a maintenance contract?

  According to the gained informations the maintenance of the particular cut slopes is responsibility of the state company which is engaged in maintenance of all state roads. Hence other company was not engaged in maintenance of the cut slopes.

- Comparison between specification/design and 'as built' measure

  The design requirements were successfully implemented on most of the cut slopes. On some cut slopes seems that the proposed erosion control measures were not implemented at all. On the portions of the slopes where the erosion control measures were not applied erosion and some local instabilities were detected. If rehabilitation on these slopes is not undertaken immediately then over the time the erosion probably will progress in more advanced form and will trigger instability on wider area of the slope.

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

Both case study projects from Macedonia fall within the "Slope stabilisation scenario". These case study projects are titled: a.) Erosion control measures on cut slopes with biocompatible materials on Highway E75; and b.) Rehabilitation and erosion control measures on cut slopes on railway Negotino – Nogaevci.

IN SITU FIELD WORK VARIABLES SELECTION

At both case study sites from Macedonia the following field work variables were selected (grouped in accordance to Protocol 3):

SITE DESCRIPTION

1. Reference system
2. Slope profile description

The profile of the cut slopes is formed as per design for erosion control (Attachment no.3). The inclination of the cut slopes is variable and it ranges between 1 :2 to 1 :2,8. The inclination of the cut slopes is proposed on a basis of conducted analyses listed in this report.

SOIL PROFILE DESCRIPTION

3. Soil classification

The surfical soil layer is composed of clays with intermediate and high plasticity (geomechanical simbols CI and CH) which is final natural grade for installation of the proposed erosion control measures.

4. Engineering soil classification
5. Geology

As per geological map (Attachement no.1) and site classification of the ground the site is composed of Eocene and Pliocene sediments (flysch deposits) and Diluvium deposits.

ABIOTIC SITE DESCRIPTION

6. Gravimetric soil moisture content
7. Organic matter content
8. Void ration and porosity

The summary of the above listed soil properties is enclosed in appendix no.4

SOIL CHEMISTRY

9. pH
10. Total Kjeldahl Nitrogen
11. Plant available phosphorus

12. ReDox potential
13. Cation Exchange Capacity

CHARACTERISATION OF VEGETATION

14. Vegetation cover/area
15. Vegetation height estimation

The selected set of variables have been chosen in regard to each variable's applicability in at least one of the case study sites from Macedonia. Factors as site accessibility, time of the year, seasonality, duration of the sampling technique, time available and time required for the laboratory procedure as well as available background data and affordability have all been considered when selecting the set of field work variables.

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

SOIL CHEMISTRY

In regard to the chemical characteristics of the soil at both study sites the following parameters have been analysed: pH, total Kjeldahl Nitrogen, plant available phosphorus, ReDox potential and cation exchange capacity.

The obtained results for both sites are given in the following table:

Value	pH	Total Kjeldahl Nitrogen	Available phosphorus	ReDox potential	Cation Exchange Capacity
Units (*)	/	[mg/g]	[mg/100 g]	(mV)	(meq/100 g)
Method	ISO 10390:2015	ISO 11261	Al method		Kappen
Site					
Highway A1 (E75)	8.43	0.137 %	12.15		21.84 cmol/kg
Railway Negotino - Nogaevci	8.45	0.49	5.46	-71.5	49.47

(*) unless otherwise stated.

CHARACTERISATION OF VEGETATION

Estimation of vegetation cover/area

In regard to the time and resources available rapid field assessment of the vegetation cover was performed. The vegetation cover was estimated in quadrat samples of 0.5 m2. For this purpose one wooden frame (having dimensions of 0.5 m x 1.0 m) was used. This wooden frame was further divided in a grid, each square of the grid being 10.0 x 10.0 cm. The sampling locations in each slope site were selected by randomly placing the wooden frame within the slope area, nevertheless about 1.0 m distanced from the edges of the slope. Due to the area of the slope investigated, 20 repeats have been performed. Estimates of vegetation cover in each grid square of the quadrat were classified as: 0%; ~25%; ~50%; ~75% and 100%. These provided the average value for each quadrat (sample) location.

The average vegetation cover for the slope site of the Highway E75 (project title: Erosion control measures on cut slopes with biocompatible materials on Highway E75) was estimated to be about 75 %.

Plant species

For this particular location the following seed mixture has been used:

Lolium perenne	15%
Festuca arundinacea	70%
Poa pratensis	15%

This mixture can sustain large summer temperatures and low winter temperatures. The need for seed is about 25 g/m². A minimal topsoil of 5 cm is necessary.

Poa pratensis L.

Kentucky Bluegrass is a perennial sod-forming grass that spreads by strong rhizomes and seeds. The species germinates (6-12 days) and establishes slowly. Therefore Kentucky Bluegrass is often used in combination with a faster-growing grass, such as Perennial Ryegrass, which will provide cover while the bluegrass establishes itself.

Kentucky Bluegrass can withstand frequent mowing and intensive wear, and is widely used for sports fields, fairways, lawns, and turf production.

Common varieties often suffer from summer heat or from too close mowing and are more prone to diseases. However, breeding has resulted in newly improved varieties with better characteristics - including disease resistance, color, texture, density, close mowing, and environmental tolerances.

Festuca arundinacea Schreb. 1771

Tall Fescues are a species for warmer and drier climates. This species has very good heat tolerance and requires less nitrogen and irrigation than perennial ryegrass, but is slower to establish. The variety's broad leaves keep a green color very well under dry conditions.

Tall Fescue requires a high seeding rate due to seed weight and size. Improved, dwarf varieties are finer leafed and have improved tolerance to low cutting and to wear. Used in combination with other species, the Tall Fescue content should be at least 60% of the mixture.

Festuca perennis (L.) Columbus & J.P.Sm 2010

Basionym: *Lolium perenne* L. 1753

Perennial Ryegrass is used all over the world as a valuable species for turf. Its general characteristics of excellent wear tolerance, fast germination, and quick establishment are highly valued. On the other hand, its limited drought tolerance and demand for good management (including fertilization and frequent cutting) restrict the usage of the species in certain regions and for certain purposes.

Skillful breeding has led to a wide range of varieties which differ in such characteristics as wear tolerance, winter-hardiness, color, disease resistance, sod density, growth rate, and heat and drought tolerance.

Vegetation height estimation

Since grass species have been planted at this case study site the vegetation height estimation was performed by measuring the height of individual plants. Nearly 100 individual plant stems have been measured. At this site the vegetation height varied between 45 – 55 cm.

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

– Which are the achieved functions or targets? For example, **Ecological functions**: such as biotope connectivity, habitat improvements (in number and in quality), plant community development, …., **hydrologic and hydraulic functions**, **geotechnical functions**, **landscape functions**, **socio-economic functions**, etc.

According to the findings from site inspection it was obvious that some of the designed measures are not fully implemented therefore on some sections local slope failures and erosion are detected.

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LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Figure 3a. Rehabilitated cut slopes

Figure 3b. Rehabilitated cut slopes

On 10th of November 2017 visual inspection on the project site was held. Most of cut slopes are rehabilitated and erosion control measures are successfully implemented (see Figure 3a and Figure 3b). It seems that the proposed erosion control measures were not fully implemented on the cut slopes. The cover soil on some sections is washed out, so the vegetation is not fully developed and it should be regenerated in order to prevent further deterioration of the slopes. Also rehabilitation of the erosion gullies and local slope failures should be done. Considering the fact that the ground on some section is composed of high plasticity clays which are sensitive on variation of the moisture local failures very *easily can occur. Variation of water content in clays leads to swelling and shrinking which trigger the failure mechanism by cracking of the ground. Such conditions will lead to global instability of the slopes.*

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CASE STUDIES. GREECE

CASE STUDY - SLOPE

Wildfire Erosion Control, Thasos, GREECE

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Wildfire Erosion Control, Thasos

UTM coordinates:
X: 551872.776 Y:4507153.179

Completion date of the design stage:
October 2017

Completion date of the construction stage:
November 2017

Client: (e.g. private or public person or industrial company):
Private Company for the Forest Service

SUMMARY

Wildfires frequently occur in Greece and can lead to severe erosion and flooding events.

In this case study showcase cost effective soil and water bioengineering works to reduce erosion with simple structures while utilized the burned material

ECOMED - ECOENGINEERING IN THE MEDITERRANEAN ENVIRONMENT

WILDFIRE EROSION CONTROL, THASSOS, GREECE

Authors: George N. Zaimes, Valasia Iakovoglou, Georgios Giatas & Georgios Pagonis

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title : Thasos, GRRECE / Wildfire Erosion Control

UTM coordinates: X: 551872,776 Y:4507153,179

Completion date of the design stage: October 2017

Completion date of the construction stage: November 2017

Client: Private Company for the Forest Service

Decision criteria for this type of construction: Erosion control

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

Introduction:

Wildfires are a natural part of Mediterranean ecosystems and should be expected every summer. Unfortunately do to anthropogenic activities their frequency and intensity has increased causing even eth loss of human lives. While wildfires are part of the Mediterranean ecosystems large scale and intense wildfires can cause irreversible damage to these ecosystems if certain measures are not taken. In these cases soil and water bioengineering appear to be the best solution since they are nature-based and cause the least anthropogenic disturbances and aesthetically pleasing.

The purpose of this study was the control of soil in watershed that was burned the previous year. These works are there for 2-3 years until vegetation is re-established and provide the necessary cover to reduce erosion.

In this study the erosion control efforts for the burned area are presented. The techniques used include hydro seeding and planting of seedlings.

- *Project key objectives? (Erosion control, slope stability, habitat restoration -for species-, landscape restoration, etc.).* Erosion Control
- *Site appraisal: reconnaissance, desk/office studies, and inspections for biodiversity, dendrology, inspections for ecology covering:*

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- *Climatic aspects (rainfall, temperature, potential evapotranspiration, exposure, aspect):* The mean annual precipitation is 638,8 mm, the mean annual temperature is 16 C°
- *Soil physical aspects (grading, density, water regime):* Bare areas after the wildfires that are steep and are susceptible to erosion.
- *Soil chemical aspects (pH, conductivity, nutrients, organic matter, exchange capacity, acid toxicity):* No soil laboratory tests were carried out
- *Soil engineering aspects (strength, permeability, aggregate stability):* No soil l engineering aspects tests were carried out

- *Native vegetation analysis:* Most vegetation was burned.
- *Landscape features:* Steep slopes that are bare of vegetation.
- *Problems, risks and hazards that were addressed by the project including but not limited to:*
  - Erosion risk (rain erosivity, soil erodibility, overland flow, channel discharge, wind erosivity)
  - Geotechnical risks (mass movement, liquefaction)
  - Risks to life, health or property because of flash flooding events
- *Maps, photographs with the purpose of collecting historical information:* Photos were taken before the restoration efforts took place.
- *Site topography and site surveying (geomatics):* Topographic measurements and visual inspections took place to find the optimal for the placement of the works.
- *Cadastral data, parcel ownership:* The intervention area is owned by the State, Forest Service
- *Existing information in Regulatory Agencies (e.g. sustainability initiatives, resilience initiatives):* Required by law to implemented erosion mitigation efforts

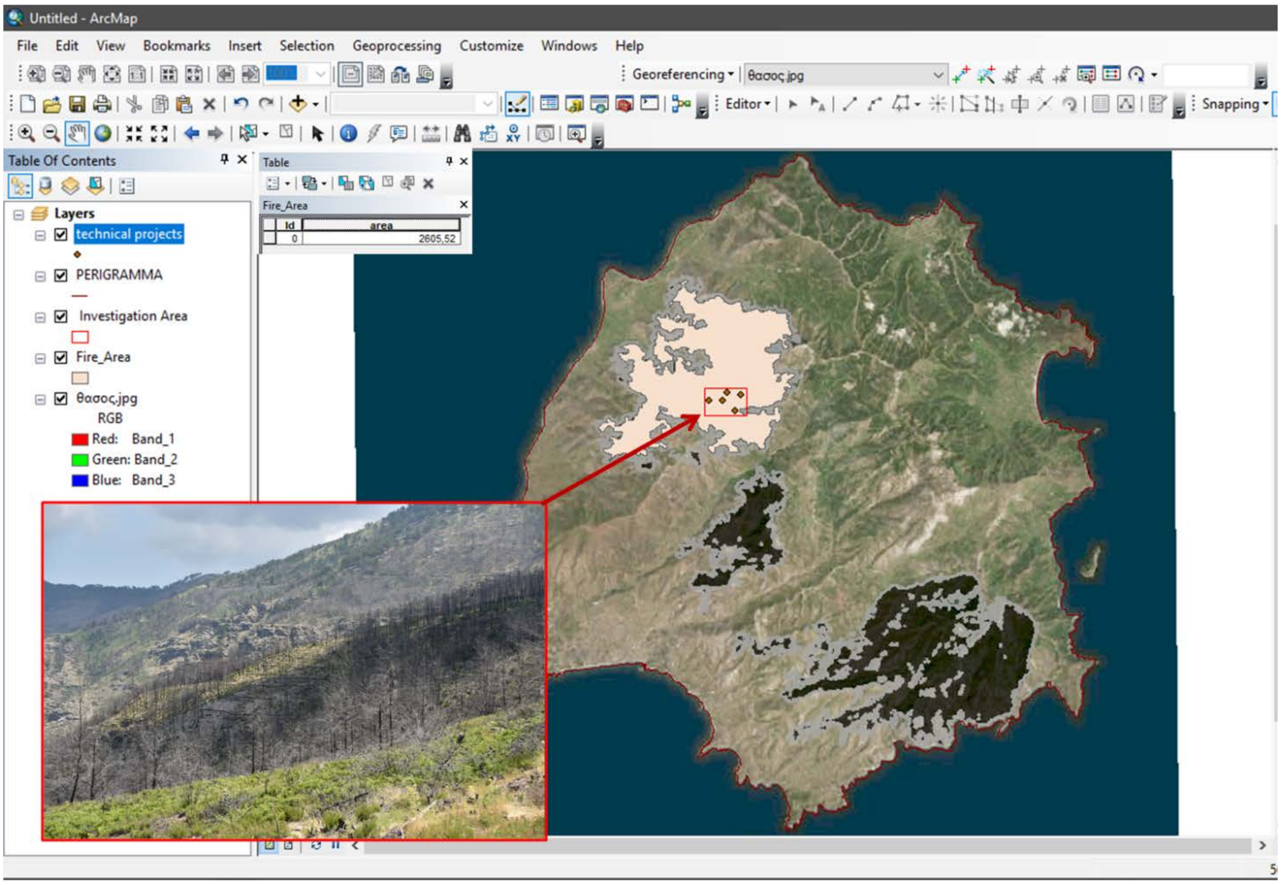
Description of the project:

On the burned slopes soil bioengineering works were installed:

- Log barriers were implemented. The total land burned in the area is 8732.37 hectares, but at the site where our study area is located, the burned area is estimated to be about 3485.13 hectares.

These activities should help reduce soil erosion on these slopes until the vegetation is re-established. The re-established should minimize erosion from surface runoff

IMAGE of the entire area burned.



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LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

Few field measurements were taken. The activities suggested were based on the past experiences and the current conditions that posed the greatest risk of soil erosion..

- *Is there a clear criteria for the plant species selection? Which is the criteria follow for selecting the plant species included in the project? Do the plants that belong to the first successional stage of the intervention area well represented?* NOT APPLICABLE
- *Was a phytosociological approach used in both the plant species selection process and the intervention strategy?* NOT APPLICABLE
- *Are there clear criteria for the project strategy implementation?* Yes, the soil and water bioengineering approach is well reflected in the project.
- *Are there clear criteria for the bioengineering techniques selections?* This is based on previous soil erosion control works but there are no explanations or justifications about it.
- *Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear?* The justification was clear but the calculations would depend on the burned logs that were found in the field.
- *Functional requirements of woody structures (select all that apply to the project):*
    - o Soil reinforcement and enhancement of soil strength
    - o Surface protection against wind/water erosion
- *Which **improvements** would you propose, at the design stage, regarding:*
    - o *Plant selection:* NOT APPLICABLE
    - o *Strategy implementation:* More details on techniques used and their proper implementation. Specific location of their implemetation
    - o *Bioengineering techniques selection:* Great diversity of technique not just one type.
    - o *Calculations:* Slope estimation and soil variable measurement would help in the selection of the dimension of the bioengineering works and their proper spacing of the plantings.

Please indicate your main conclusions after the analysis of the bioegineering work at the design stage:

The design was done with few field measurements. Only one method was selected. More techniques could have been selected to be more efficient and effective in mitigating soil erosion. Finally the location could have been more specific with more field measurements and with the use of new technologies and software (GIS).

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

- The question to answer here is: how was the work carried out by the contractor (Construction Company) during the construction stage?

In the following picture, the post-operational stage is shown:

In the preceding picture, the following features can be seen:

- The log barriers cover the majority of slope
- Many dead trees have still been left and were not used.
- Only one technique was used.

General issues, problems and defects.

Problems/defects/issues recorded during the construction stage (information retrieved from the construction company).

- Detected flaws regarding the construction stage. E.g.
  - Not many large burned trees were present to be used as log barriers.

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- Emphasis was given primarily on the downslope area and with minimal work done in the upslope areas of the burned area

- *Please give your opinion about disturbing/destabilizing elements present between the design stage and the construction stage:*
  - *Insufficient budget:* NOT APPLICABLE
  - *Construction stage too short:* Yes since the works need to be completed before winter.
  - *Lack of a competent (effective) supervision during the construction stage:* Supervision was sufficient
  - *Lack of and affective monitoring stage after the construction stage*: Monitoring has been limited.
  - *Machinery utilised in the work:* The machinery was adequate.
  - *Other:* Better distribution of the works that were emphasized n one area and the use of other methods since the large logs required for log barriers were limited.
- *Please, indicate the construction standards used in the work:* National construction standards.
- *Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied:* None

Issues related to construction features:

- *Were there any plantation techniques used to better attain and/or preserve soil humidity? (e.g. tree pit formation, mulching, etc.).* NOT APPLICABLE
- *Was there any mycorrhizae used in the utilised plants?* NO
- *Were there any changes in terms of the plant species used in comparison with those included at the design stage? If so, how those changes were justified?* NOT APPLICABLE
- *Were the utilised plants regionally distintive/characteristic of the intervention area?* NOT APPLICABLE
- *Were there any quality control for the materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed?* NOT APPLICABLE

- *Information regarding quality control for the inert materials (grey materials). Related normative (standard).* NOT REALLY
- *Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard).* NOT APPLICABLE
- *Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard).* NOT APPLICABLE
- *Plant density. In case of herbaceous species: seeding rate.* NOT APPLICABLE
- *bad connections/junctions between the logs:* YES
- *bad lateral connection of the work edges with the slope:* YES
- *Insufficient or missing soil compaction:* Could have been improved
- *Adverse climate conditions:* NOT APPLICABLE

Miscellaneous:

- *Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques?* The qualifications documents were adequate
- *Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)?* YES
- *Were there any adherent polluting matters or residues on inherent construction material?* NO
- *Groundwater appearance?* NOT APPLICABLE
- *Sanitation failure?* NOT APPLICABLE
- *Natural landslide impact?* NO
- *Destruction by local residents (or vandalism) observed?* No

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

Please, include here the main conclusions of your analysis at this stage.

Which improvements would you propose for the analysed bioengineering work at the construction stage?

Most of works were limited only in a specific area of the entire burned area. This was done probably because this area had a paved road and some residencies. Still a more holistic approach should have been taken. Finally different types of works should also been conducted. Specifically a series of wooden dam should have been built in the torrent that runs through the burned area.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Please, provide information regarding the bioengineering work monitoring and maintenance tasks carried out.

- *Was there a maintenance contract?* NO but it is mandatory by national law to have maintenance for the next three years
- *Comparison between specification/design and 'as built' measure:* The construction company carried out the intervention according to the project but with smaller diameter trees since larger diameter trees were missing.
- *Information on any maintenance work during monitoring phase. If applicable, conduct a characterisation of the maintenance tasks in terms of their performance and suitability:* There was no maintenance conducted.
- *Analyse all the available information regarding the bioengineering work monitoring tasks carried out*: NOT APPLICABLE
- *Was there any monitoring specified? If so, was it installed/performed as planned. If not, please note any reasons.* NO
- *Was any instrumentation left in situ for monitoring? Detail?* NO
- *Were inspections carried out? How regularly? Who carried out the inspections (qualifications?)* Inspection was carried out after the completion by the Forest Service.
- *Were there any defects noted after the defect correction period? What was the nature of the defects? Who noted them? Who corrected them? Who paid for them? Value (as percentage of the total contract)?* NO
- *Were there any emergency works carried out? What was the nature of the works? Who carried them out? Who paid for them? Value (as percentage of the total contract)?* NO

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LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

IN SITU FIELD WORK VARIABLES SELECTION

Five randomly plots were selected throughout the study area.

The variables measured can be categorized in two main categories.

1. **General characteristics of the plot**. This included weather conditions, slope vegetation cover and evidence of soil erosion.
2. **Log barrier characteristics**. Specifically the length height of the entire work were measured along with the diameter and length of the log utilized.
3. **Soil characteristics of the plot**. The variable measure for soil were vegetation cover, soil pH above and below the works, soil texture above and below the works, soil structure above and below the works and carbonate concentration above and below the works

At each plot five different measurements were taken for each of the log barrier and soil characteristics.

General field measurements.

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

Following is a summary table of the log barrier measurements

A/A	Bioengineering work	Height (m)	Width (m)	Legnth (m)	Material	Tree species	Diamter (m)	Slope		Sediment Deposits	Erosion			
								Above	Below		Rills	Bare	Re-vegetation	None
1	Log Barriers	0.38	0.20	23.00	Burned Logs	Pinus brutia	0,17 μ.	42%	40%	No	Yes	No	Yes	No
2	Log Barriers	0.52	0.30	25.00	Burned Logs	Pinus brutia	0,18 μ.	52%	51%	No	No	No	Yes	Yes
3	Log Barriers	0.32	0.47	20.00	Burned Logs	Pinus brutia	0,06 μ.	50%	48%	No	No	No	Yes	Yes
4	Log Barriers	0.40	0.35	25.00	Burned Logs	Pinus brutia	0,10 μ.	60%	57%	No	Yes	No	Yes	No
5	Log Barriers	0.43	0.50	22.00	Burned Logs	Pinus brutia	0,15 μ.	44%	45%	No	No	No	Yes	Yes

Photos of the log barrier measurements.

Following is a summary table of the soil measurements

A/A	pH		$CaCO_3$		Vegetetaion Cover		Structure	Soil				Organic Matter	Soil Type	Geology
	Πριν	Μετά	Πριν	Μετά	Πριν	Μετά		Gravel (>2mm)	Sand (2-0.02mm)	Silt (0,02-0,002mm)	Clay (< 0,002mm)			
1	6	6	Weak	Weak	80%	80%	Granular	35%	15%	10%	40%	70%	Loamy	Gneiss
2	6	5	Weak	Weak	90%	90%	Granular	30%	10%	20%	30%	50%	Loamy	Gneiss
3	6	6	Weak	Medium	80%	75%	Granular	25%	25%	10%	40%	60%	Clay-Loamy	Gneiss
4	7	6	Weak	Weak	70%	65%	Platey	30%	10%	25%	35%	60%	Loamy	Shale
5	6	6	Medium	Medium	80%	85%	Granular	20%	15%	20%	45%	60%	Loamy	Gneiss

Photos of the log barrier measurements.

Based on the field measurements made in the study area, there were minimal changes in the environment around the erosion works (Log barriers). The Log Barriers were placed on the slopes of the drainage basins parallel to the contour lines. The logs average dimensions were: length 23 meters, height 0.50 meters and

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wide 0.20 meters the distance between the logs is 6 - 10 meters. Overall, throughout the study area there was minimal erosion present and physical regeneration. This was also the situation throughout the entire burned area.

COMPARISONS WITH REFERENCE SCENARIOS

PRE-RESTORED SCENARIO:

The pre-restored scenario will to compare it with would be the surrounding forested areas. This was how the area was before the wildfire took place.

Based on the pre-restored scenario the restored area is still very different. It will take at least a decade to have large diameter tress in the area. The main objective of the project is to reduce soil erosion. This is necessary because of the top soil is eroded deeply it is unlikely that pine forest will be able to be re-established as quickly or might lead to a different type of ecosystem, with more shrubs. Reducing erosion and surface runoff will also reduce the likelihood of flash floods and that could be devastating in the community downstream from the burned area.

The main effects of the soil bioengineering works up till appear to have been accomplished. Still up to this point no very intensive rainfall vents have occurred. Still the fact that most works were concentrated in an area could be problematic in the future since erosion can occur in other part so the burned area. In addition that fact that the log barriers were built with small diameter trees might be problematic if they are not able to withstand the surface runoff volumes of the area. Finally climate change might be a major concern for achieving the targeted conditions of it leads to extreme precipitation events that could destroy the works or drought periods are very long and the vegetation is not re-established in the next 3-4 years.

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

The actual work conducted by the company was what had been planned (designed) work. The main issue was that the diameter of the log barriers were small because of the burned trees were of small age. They appear up till know to achieve the targeted function. Specifically the geotechnical functions (e.g. erosion control) are met since erosion was not evident at excessive rates..

Particularly, the assessment of the bioengineering work elements performance indicates the following problems:

- The diameter of the trees used in the log barriers is relatively small compared to what is typically used.
- PHOTO log barriers

- The location of the works is very localized.
- The location of the works would have been more effective with more field measurements and the use of new technologies and software (GIS)
- More holistic application of the works should have been done
- Different types of works should have implanted to better guarantee the achievement of the targeted function.
- Works should have been applied in the torrent of the burned area (e.g. wooden dams).
- PHOTO wooden dam

- Some roads are eroding despite the works that were implemented.
- PHOTO of road eroding

- There was not true maintenance contract and monitoring was not that frequent.
- More extensive calculations could have improved the engineering/Stability performance of the works

- A more holistic approach with different types of works would enhance the sustainability performance of the works

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Please, show here your conclusions obtained after combining the different levels analysed (design, construction, /maintenance and monitoring).

The bioengineering work is fulfilling its pursued objectives but the successful evolution of the work will be better assessed after more than 3-5 years after its completion. If you look at the surrounding landscape the extensive erosion cannot be seen and there no major landslides although. The area was burned with minimal vegetation covering the ground leaving extremely susceptible to raindrop impacts. The true test of the effectiveness of the works if intensive rainfall events occur that could lead to excessive surface runoff, erosion rates, flash floods and even landslides.

Climate change should be a major concern for achieving the targeted conditions. In the Mediterranean it is expected that more extreme precipitation events will be occurring that could destroy the works with longer drought periods not allowing the vegetation to be re-established in the next 3-4 years.

Hydro-seeding should also been included. Another issue was the plant density of the planting. It should have been denser. We also suggest that a greater diversity of plant should have been selected and we disagree with the planting of a non-native species. Since the soils are very poor soil fertilizer might be required or the plants that are planted should be of greater age. Finally disturbances especially grazing probably led to the mortality of the seedlings. Fencing might be required to reduce disturbances. In regard to climate we do not believe that it affected the performance of the bioengineering intervention.

Overall the works appear to be successful. Still with certain activities we strongly believe that they could have been more efficient and effective. A more holistic approach should have been taken looking at the entire area and implementing works in all areas. In this case the majority were placed on slopes that were above villages. This is logical since the main purpose is to have no fatalities if erosion, and landslides or flash flood events occurred. From en ecosystem-based approach this is very problematic because if excessive erosion occurs in certain areas it might impossible to restore them. In addition we believe that other soil and bioengineering methods could have been used for example brush mattress and wooden dams. Since the diameters of the logs in the barriers are by standard too small, the alternative would be to use brush mattresses. In addition the torrent is major threat that has had many flash floods in the past that destroyed infrastructure. In this case wooden dams with the burned material throughout the length of the torrent would help reduce erosion and high flows. This might not been feasible because of the small diameter trees that were burned.

CASE STUDY - SLOPE

MARBLE QUARRY RESTORATION, DRAMA, GREECE

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Marble Quarry Restoration, Drama, GREECE

UTM coordinates:
x: 41.250983, y: 24.213930

Completion date of the design stage:
Spring 2015

Completion date of the construction stage:
Fall 2015

Client: (e.g. private or public person or industrial company):
The mining was done by a Marble private company that rented the land from Forest Service. Another private company was hired for the restoration efforts.

SUMMARY

Marbles are used very frequently in Greece for construction. This is why there are many quarries.

Once the quarry is not utilized there is an immediate need for restoration. A restoration example is provide whose purpose was to stabilize the slope and improve aesthetics.

ECOMED - Ecoengineering in the Mediterranean Environment

MARBLE QUARRY RESTORATION, DRAMA, GREECE

Authors: George N. Zaimes, Valasia Iakovoglou, Georgios Giatas & Georgios Pagonis

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title: Drama, GREECE / Marble Quarry Restoration

x: 41.250983, y: 24.213930

Completion date of the design stage: Spring 2015

Completion date of the construction stage: Fall 2015

Client: The mining was done by Lazaridis (private company) that rented the land from Forest Service.

Decision criteria for this type of construction: Ecological Restoration

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

Introduction:

Marbles are very commonly used in Greece in construction. The main reason is their abundance in Greece along with the fact that are available in large quantities and also because they are very resistant material.

The purpose of this study was the restoration of a marble quarry that is no longer in operation. The excavation of the land to extract marble cause very serious damages as it removes large portion of the land. This areas is left with any subsequent restoration efforts also pose many risks and threats.

In this study the restoration efforts for the restoration of marble quarry are presented. The technique used were planting of seedlings.

- *Project key objectives? (Erosion control, slope stability, habitat restoration -for species-, landscape restoration, etc.):* Landscape restoration

- *Site appraisal: reconnaissance, desk/office studies, and inspections for biodiversity, dendrology, inspections for ecology covering:*
    - *Climatic aspects (rainfall, temperature, potential evapotranspiration, exposure, aspect):* the mean annual precipitation is 637,6 mm, the mean annual temperature is 14.20º
    - *Soil physical aspects (grading, density, water regime):* Bare rocks lefts after the mining of the marble.
    - *Soil chemical aspects (pH, conductivity, nutrients, organic matter, exchange capacity, acid toxicity):* No soil laboratory tests were carried out
    - *Soil engineering aspects (strength, permeability, aggregate stability):* No soil l engineering aspects tests were carried out
- *Native vegetation analysis:* No vegetation was present.
- *Landscape features:* Steep slopes
- *Problems, risks and hazards that were addressed by the project including but not limited to*: Implications of the loss of function (temporarily or permanently) the vegetation was performing, Geotechnical risks
- *Maps, photographs with the purpose of collecting historical information:* Photos were taken before the restoration efforts took place.
- *Cadastral data, parcel ownership:* The intervention area is owned by the State.
- *Existing information in Regulatory Agencies (e.g. sustainability initiatives, resilience initiatives):* Required by law to restore the area

Description of the project:

The excavated slopes were:

- planted with seedlings of *Robinia pseudoacacia* and *Fraxinus excelsior* to re-establish woody vegetation. The seedlings were place 2 x 2 meters in an area 6.261 m^2.

These activities should help stabilize the slope. In addition the growth of the vegetation should improve the aesthetic of the area through time.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

No real field measurements were taken. The activities were based on the climatic conditions of the area and the current highly degraded conditions. This determined the type of vegetation that would be used.

- *Is there a clear criteria for the plant species selection? Which is the criteria follow for selecting the plant species included in the project? Do the plants that belong to the first successional stage of the intervention area well represented?*

The criteria were to be use species, in the first successional stage, fast growing and be able to withstand the current conditions

- *Was a phytosociological approach used in both the plant species selection process and the intervention strategy?* This approach was not used.
- *Are there clear criteria for the project strategy implementation?* Yes, the soil and water bioengineering approach is well reflected in the project.
- *Are there clear criteria for the bioengineering techniques selections?* This is based on previous quarry restoration projects but there are no explanations or justifications about it.
- *Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear?* Not really.
- *Functional requirements of vegetation (select all that apply to the project):*
  - Soil reinforcement and enhancement of soil strength
  - Surface protection against wind/water erosion
- Which **improvements** would you propose, at the design stage, regarding:
  - *Plant selection:* Greater diversity of species that should promote more natural restoration. To use only native species.
  - *Strategy implementation:* More details on techniques used and their proper implementation.
  - *Bioengineering techniques selection:* The use of more complex techniques that would provide more slope stabilization and faster restoration of the site
  - *Calculations:* Slope estimation and soil variable measurement would help in the selection of the plants species and the proper spacing of the plantings.
  - *Plantation schemes or drawings showing the distribution of the different plant species would be very beneficial.*

Please indicate your main conclusions after the analysis of the bioegineering work at the design stage:

The design was done with few field measurements. The most simplistic method was selected (planting of seedling). More advanced techniques could have been selected but this might be feasible because of the budget that was allocated. Finally *Robinia pseudoacacia,* one of the selected trees, is a non-native species but can grow fact and effectively in degraded areas. It would be preferred to have selected a native species.

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

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LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

- The question to answer here is: how was the work carried out by the contractor (Construction Company) during the construction stage?

In the following picture, the post-operational stage is shown:

In the preceding picture, the following features can be seen:

- Many areas are still bare
- The seedlings have not developed and grown as much as expected.
- The aesthetics of the area have not significantly improved.

General issues, problems and defects.

- *Detected flaws regarding the construction stage. E.g.*
  - Spacing of the tree seedlings could have been closer
  - Older age trees could have been used
  - Hydro-seeding could have been used to establish grass vegetation.
- *Please give your opinion about disturbing/destabilizing elements present between the design stage and the construction stage:*

- *Insufficient budget*: Yes an increase in the budget would allow for more effective works
- *Construction stage too short:* Not applicable
- *Lack of a competent (effective) supervision during the construction stage:* Supervision was sufficient
- *Lack of and affective monitoring stage after the construction stage*: More affective monitoring was needed.
- *Machinery utilized in the work:* The machinery was adequate.

- *Please, indicate the construction standards used in the work:* National construction standards.
- *Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied:* NONE

Issues related to construction features:

- *Were there any plantation techniques used to better attain and/or preserve soil humidity?* NO
- *Was there any mycorrhizae used in the utilised plants*? NO
- *Were there any changes in terms of the plant species used in comparison with those included at the design stage? If so, how those changes were justified?* NO
- *Were the utilised plants regionally distintive/characteristic of the intervention area?* One was (*Fraxinus excelsior*) one was non-native (*Robinia pseudoacacia*)
- *Were there any quality control for the materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed?* NOT REALLY
- *Information regarding quality control for the inert materials (grey materials). Related normative (standard).* NOT APPLICABLE
- *Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard).* NOT APPLICABLE
- *Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard).* NO
- *Plant density. In case of herbaceous species: seeding rate.* 2 x 2 meters

- *bad connections/junctions between the logs,* NOT APPLICABLE
- *bad lateral connection of the work edges with the slope,* NOT APPLICABLE
- *Insufficient or missing soil compaction,* NOT APPLICABLE
- *Adverse climate conditions,* NOT APPLICABLE

Miscellaneous:

- *Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques?* The qualifications documents were adequate
- *Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)?* YES
- *Were there any adherent polluting matters or residues on inherent construction material?* NO
- *Groundwater appearance?* NOT APPLICABLE
- *Sanitation failure?* NOT APPLICABLE
- *Natural landslide impact?* NOT APPLICABLE
- *Destruction by local residents (or vandalism) observed?* NO
- *Other*. Grazing by goats and sheep take place in the surrounding area and could have impacted the seedlings that were planted.

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

Please, include here the main conclusions of your analysis at this stage.

Which improvements would you propose for the analysed bioengineering work at the construction stage?

Native species should have used. The density of the planting could have been increased. Hydro-seeding should also have been conducted. Fencing should have been implemented around the entire restore area to protect from grazing.

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LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

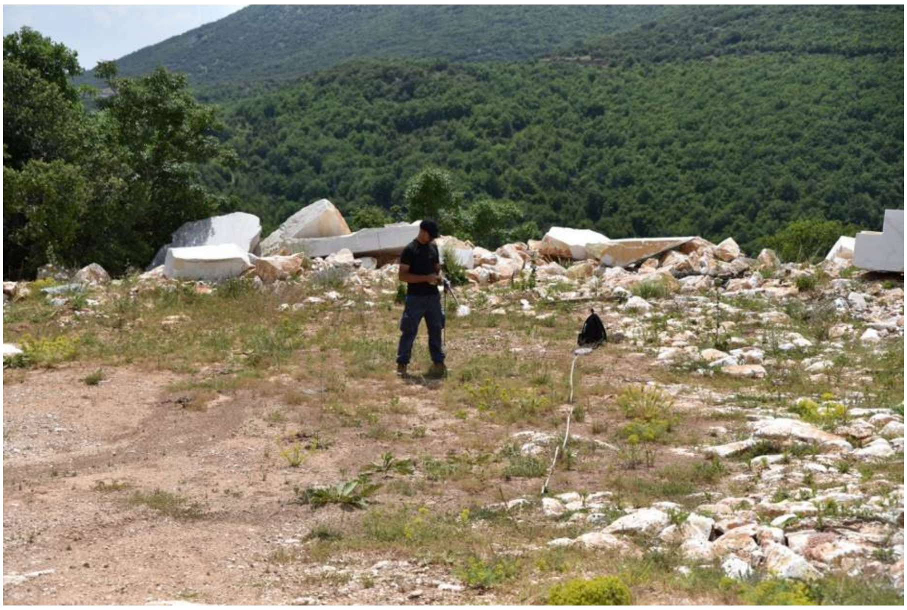
Please, provide information regarding the bioengineering work monitoring and maintenance tasks carried out.

- *Was there a maintenance contract?* NO but it is mandatory by national law to have maintenance for the next three years
- *Comparison between specification/design and 'as built' measure.* The construction company carried out the intervention according to the project.
- *Information on any maintenance work during monitoring phase. If applicable, conduct a characterisation of the maintenance tasks in terms of their performance and suitability.* There was no maintenance conducted.
- *Analyse all the available information regarding the bioengineering work monitoring tasks carried out.* NOT APPLICABLE
- *Was there any monitoring specified? If so, was it installed/performed as planned. If not, please note any reasons.* NO
- *Was any instrumentation left in situ for monitoring? Detail?* NO
- *Were inspections carried out? How regularly? Who carried out the inspections (qualifications?).* Inspection was carried out after the completion by the Forest Service.
- *Were there any defects noted after the defect correction period? What was the nature of the defects? Who noted them? Who corrected them? Who paid for them? Value (as percentage of the total contract)?* NO
- *Were there any emergency works carried out? What was the nature of the works? Who carried them out? Who paid for them? Value (as percentage of the total contract)?* NO

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

Our case study is located in the northeast Greece in the prefect of Drama.

The study of concern is an inactive marble quarry. For the restoration of the area we took 5 measurement plots in the area of the mind. The sampling surface had a radius of 5 meters.



For the collection of the measurements we recorded were:

- General characteristics (weather conditions, coordinates)
- Vegetation characteristics (plant species, diameter etc.)
- Soil characteristics (PH, calcium carbonate, soil structure etc.)

The table with general characteristic measurements.

GENERAL					
Date		Weather conditions		Prefecture	
Region		sample surface		samplers	
		POINT X		POINT Y	
Technical gps points					

The table with soil characteristic measurements.

SOIL				
PH				
CaCO3				
Plant cover				
Structure	Pebble (>2 mm)	%	Sand (2-0,02 mm)	%
	Alluvium (0,02-0,002 mm)	%	Clay (<0,002 mm)	%
Filtration				
Soil type				
texture				

The table with vegetation characteristic measurements.

PLANT FEATURES					
DIAMETER	< 2 mm	2,1-5 mm	5,1-10mm	9 mm <	
HEIGHT					
GROUND COVERAGE	%				
PLANT SPECIES					

IN SITU FIELD WORK VARIABLES SELECTION

During the field work we separate the measurements to three different types in purpose to evaluate better the different characteristics of the study area. At first we collected the general characteristics of the study area. Secondly we identified the different plant species that exist on the area, recorded their height and diameter (Picture 1, 2) and calculated the vegetation coverage.

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VEGETATION MEASUREMENTS

Picture 1: Plant height measurements

Picture 2: Plant species identification

Soil measurements

Secondly we analyzed the soil in purpose to estimate some basic characteristics. Specifically, we meaured the pH (Pitcure 3) and calcium carbonate content (Picture 4) of the study area separate. Finally we assessed the type of soil (Picture 5).

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Picture 3: Measuring soil pH

Picture 4: Calcium Carbonate concentration

Picture 4: Assesing Soil Type

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

After the data were collected they were analysed. The summary of the analysis is in the following tables.

The results of general characteristics of in the summary table below.

GENERAL					
Date	6 JUNE 2018	Weather conditions	SOLIDARITY	Prefecture	DRAMA
Region	DRAMA	sample surface	1	samplers	
			POINT X		POINT Y
Technical gps points			41,250983		24,21393

The results of the vegetation characteristics are in the summary table below.

PLANT FEATURES						
A/A		1	2	3	4	5
DIAMETER		2 mm	2,1-5 mm	5,1-10 mm	2 mm	2 mm
HEIGHT		55-90 cm	45-65 cm	15-25 cm	20-50 cm	15-20 cm
PLANT SPECIES		5	2	2	1	2

The results of the soil characteristics are in the summary table below.

SOIL						
A/A		1	2	3	4	5
PH		7	7	7	7	7
$CaCO_3$		intense	intense	intense	intense	intense
Plant cover		10%	12%	5%	10%	15%
Structure	Pebble (>2 mm)	75%	70%	60%	80%	75%
	Sand (2-0,02 mm)	10%	15%	15%	5%	5%
	Alluvium (0,02-	5%	5%	10%	10%	5%
	Clay (<0,002 mm)	10%	5%	15%	5%	15%
corrosion		medium	medium	medium	medium	medium
Soil type		clay	clay	clay	clay	clay
Filtration		moderately-nil	moderately-nil	moderately-nil	moderately-nil	moderately-nil

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COMPARISONS WITH REFERENCE SCENARIOS

PRE-RESTORED SCENARIO:

The pre-restored scenario to compare with would be the surrounding areas. This was how the area was before the mining activities took place.

Based on the pre-restored scenario the restored area is very different. This has to do with the fact that the area was restored in 2015 while the trees and vegetation are of greater age and more developed. This is why it is also too early to the different successional stages. Still it was expected that the re-vegetation and survival rate of the trees to be substantially higher.

The main effects of the soil bioengineering work were as effective as expected. There are many bare areas and many of the seedlings have died. Non-native species were used that could have negative impacts on the entire area. Additional soil and water bioengineering should be implemented. Initially hydro-seeding should take place and the seedlings and maybe even larger tree should be planted in closer densities. Fencing of the restored areas should also take place to stop disturbances (e.g. grazing). Finally climate change is no a major concern for achieving the targeted conditions.

The typical habitat in the region before the quarry mining operation

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

The actual work conducted by the company was what had been planned (designed) work. Unfortunately the work performance did not achieve the targeted function. Specifically the ecological functions (e.g. habitat improvements) plant community development and landscape function were not met.

Particularly, the assessment of the bioengineering work elements performance indicates the following problems:

- The planting of *Fraxinus excelsior* is recommended since it is well adapted to the site conditions and native to the areas.
- An invasive species *Robinia pseudoacacia* was planted that could cause serious future problems
- Hydro-seeding should have been conducted but was not.
- The plant density of the seedlings was to low
- The soil fertility is low so actions could be taken to improve e it.
- The works site is quite remote difficult to reach since it is only connected with steep gravel roads
- There was not true maintenance contract and monitoring was not that frequent.

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LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Please, show here your conclusions obtained after combining the different levels analysed (design, construction, /maintenance and monitoring).

The bioengineering work has not fulfilled the pursued objectives in year 3 after its implementation and landscape restoration and plant re-establishment. If you look at the surrounding landscape there is s a great difference and this landscape has not been fully restored although it is improving. This is related to the fact that only seedlings were planted in the area. Hydro-seeding should also been included. Another issue was the plant density of the planting. It should have been denser. We also suggest that a greater diversity of plant should have been selected and we disagree with the planting of a non-native species. Since the soils are very poor soil fertilizer might be required or the plants that are planted should be of greater age. Finally disturbances especially grazing probably led to the mortality of the seedlings. Fencing might be required to reduce disturbances. In regard to climate we do not believe that it affected the performance of the bioengineering intervention.

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CASE STUDIES.
ITALY

CASE STUDY - SLOPE

BIOENGINEERING EDUCATIONAL CONSTRUCTION SITE IN THE PARK OF MOUNT ORLANDO IN GAETA

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

GAETA (CENTRAL ITALY) REGION LAZIO

UTM coordinates:

Latitude: 41° 12' 50.69'' N

Longitude: 13° 34' 14.95'' E

Completion date of the design stage:

September 2010

Completion date of the construction stage:

October 2010

Client: (e.g. private or public person or industrial company):

Public Company: Regional Park of Riviera di Ulisse

SUMMARY

The slope was caused by rainfalls.
The aim was to stabilize and create conditions for the establishing of the vegetation.

ECOMED

ECOMED - *Ecoengineering in the Mediterranean Environment*

ORLANDO MOUNT CASE STUDY REPORT

Authors: Istituto Tecnico Costruzioni Ambiente e Territorio 'B.Tallini'. Formia

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title :

UTM coordinates:

Latitude: 41° 12' 50.69" N

Longitude: 13° 34' 14.95" E

Completion date of the design stage: December 2017

Completion date of the construction stage: December 2017

Client: Regione di Lazio. Ente Parco Regionale Riviera di Ulisse

Decision criteria for this type of construction: Erosion control, Slope stability, Habitat restoration, Landscape restoration.

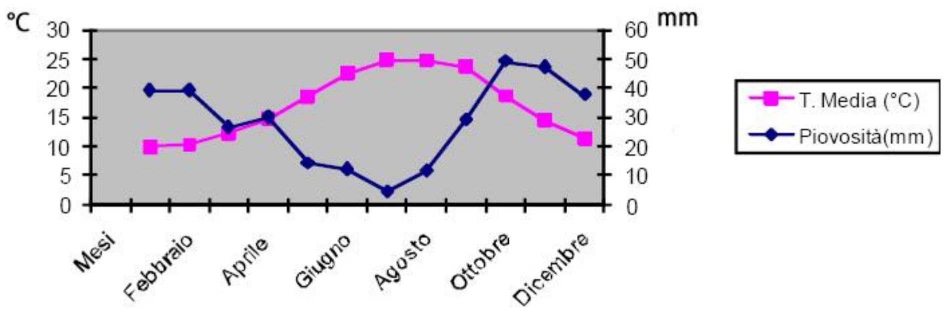
INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

SITE APPRAISAL:

- Climatic Aspects:
- The Gulf of Gaeta extends from the promontory of Circeo to Cape Miseno in Campania.
- The mountains are of great environmental interest given the peculiarity of being the junction between a typical flora of the mountains of the south and those of central Italy, as well as very close to the sea.
- The binomial gulf to the south, mountains to the north strongly characterizes the climate of the cities of Formia and Gaeta.
- Repaired by the strong wind of the north, Formia and Gaeta are more exposed instead to the cold and dry north-east wind.
- The mildness that characterizes the cities of the gulf means that there are no significant thermal extremes in any sense. Winter presents rare nights with temperatures below zero.



Soil physical aspects:

- The nature of the rocks is entirely carbonatic.
- The rock walls are made up of large "banks" of clear and stratified limestone that date back to the Upper Cretaceous, the oldest one, dates 144 million years ago.

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Native vegetation analysis:

- The vegetation of the Park consists of different associations:
- Holm Oak Wood in the north-western area
- Mediterranean scrub: consists of the typical evergreen Shrubs sclerofilli, Alaterno Shrubs, Lentisk Myrtle, Common and Thorny Broom, Arboreal Heather

Crags:

- on the walls of cliffs unexpectedly grow plants despite the exceptional inhospitable environment: here we find very rare species, including the Malvone of the Cliffs, the Sicilian Vilucchio, the arboreal Alfalfa or the Glandulous Asplenio, and the Dwarf Palm .

Botanical analysis of the study area

Intervention area

- In the escarpment of the area of intervention there are shrub specimens of Quercus ilex (holm oak), Pistacia lentiscus (lentisk) and Laurus nobilis (laurel).

List of possible species to be implanted

SPECIE	SOLE	OMBRA	ESPOSIZIONE
Pistacia lentiscus	x	x	NE - W
Rhamnus alaternus	x	x	NE - W
Crataegus monogyna	x	x	NE
Myrtus communis	x	x	NE - W
Cistus monspeliensis	x		NE - W
Erica arborea	x		W
Erica multiflora	x		W
Calicotome villosa	x		W
Rosmarinus officinalis	x		W
Laurus nobilis		x	N

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

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CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

Botanical project

The choice of floristic species and vegetation types required a careful ecological study of the intervention area (**botanical staging analysis**).

The species were chosen were the following:

• consistent with the native flora of the Riviera d'Ulisse - Monte Orlando park;

• ecologically compatible with microstational characters (microclimate, substrate, morphology, etc.) of the intervention area, taking particular account of the scarcity of light;

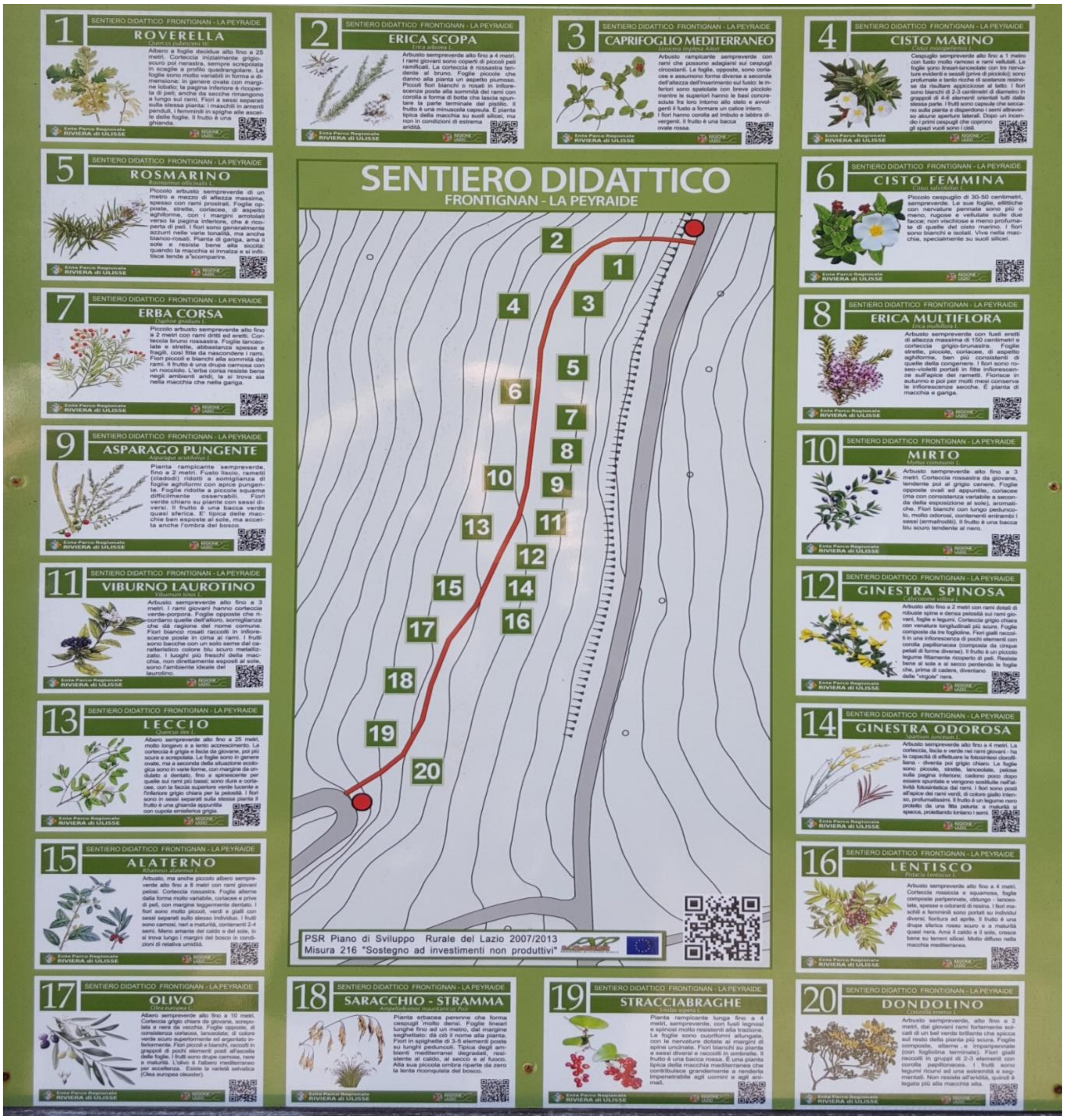
• with maximum biodiversity;

• with the necessary biotechnical characteristics

SPECIE	OMBRA
Pistacia lentiscus	x
Rhamnus alaternus	x
Crataegus monogyna	x
Myrtus communis	x
Laurus nobilis	x



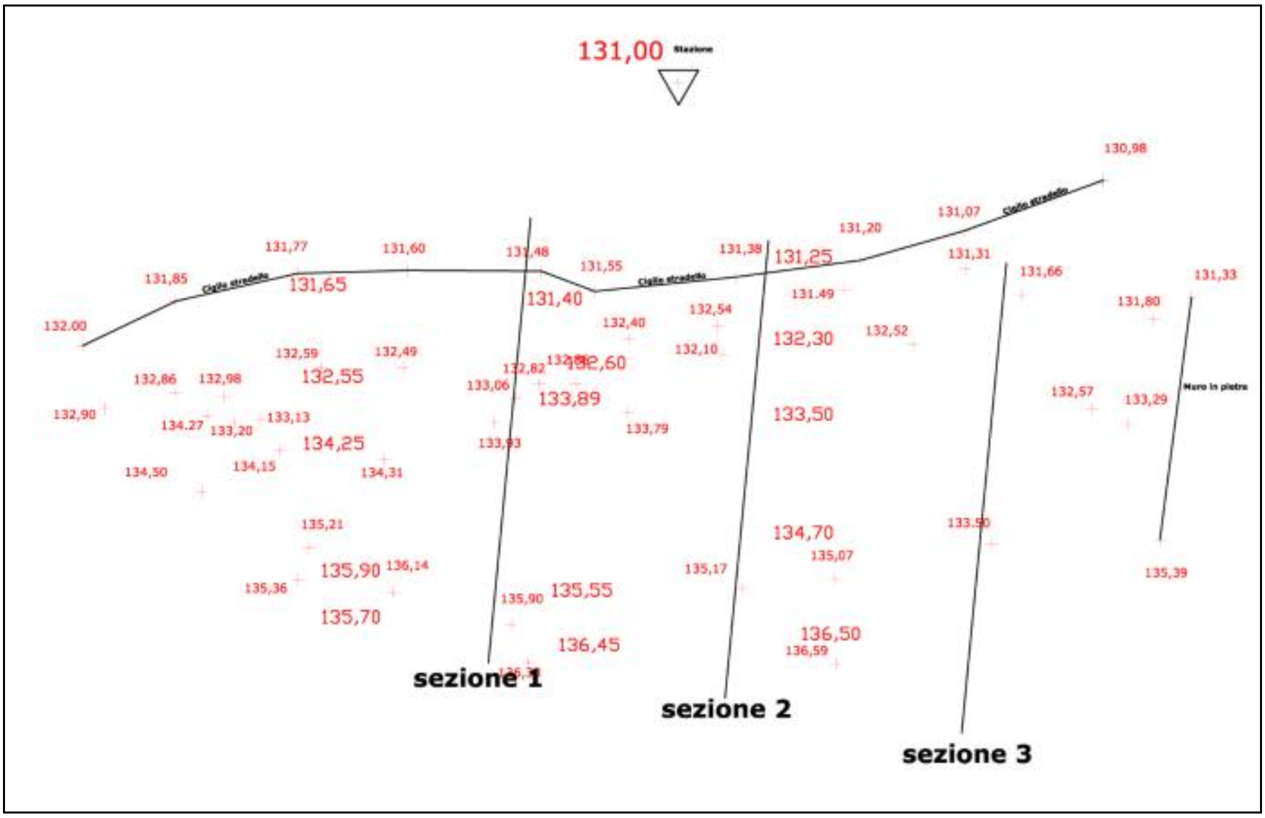
Abacus of the main shrubby plants present on the site

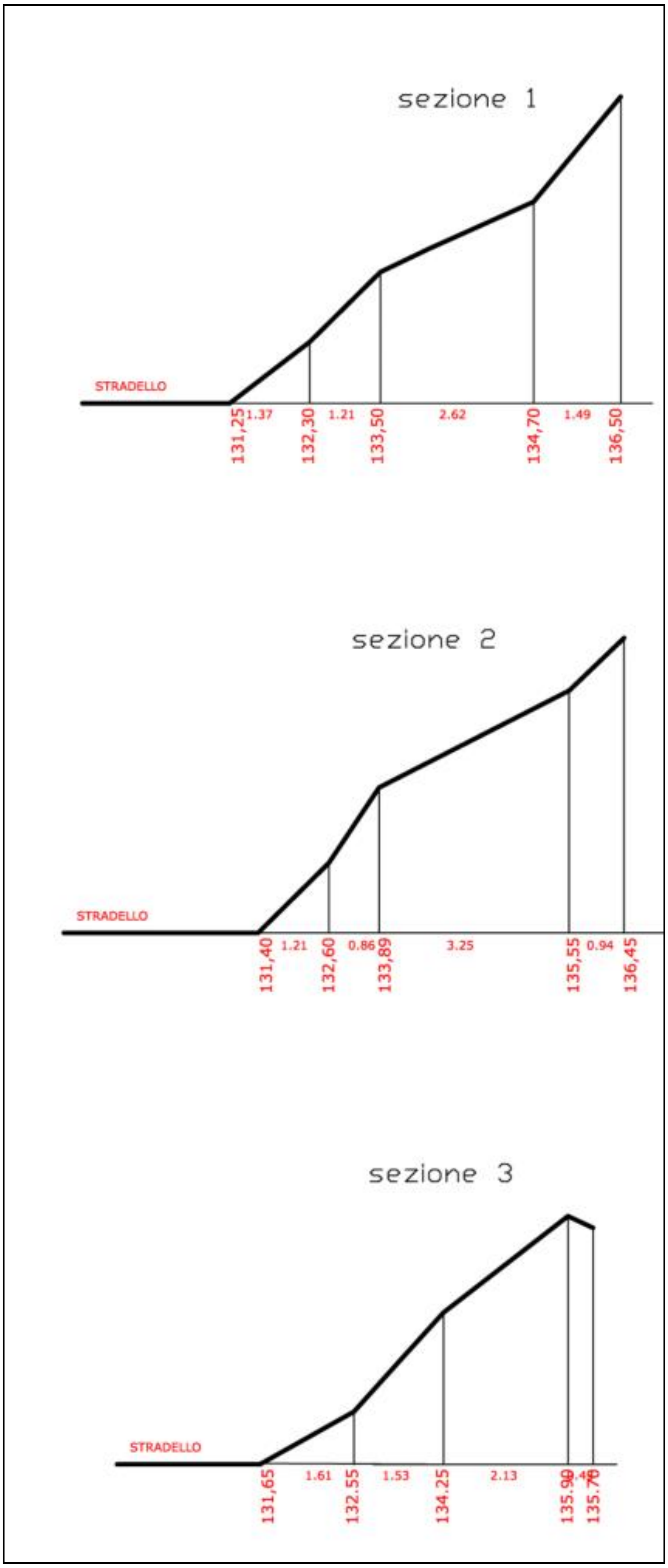


Topographic survey of the site

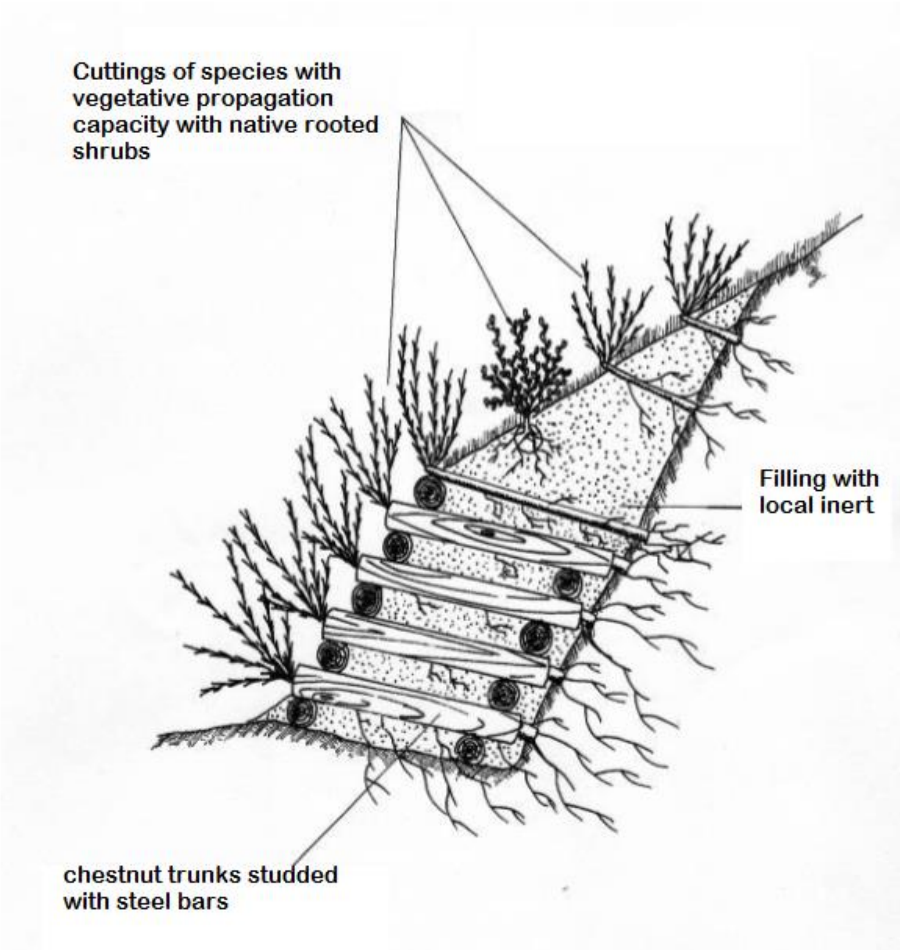
The topographic survey of the intervention area was carried out with electronic theodolite and prism.

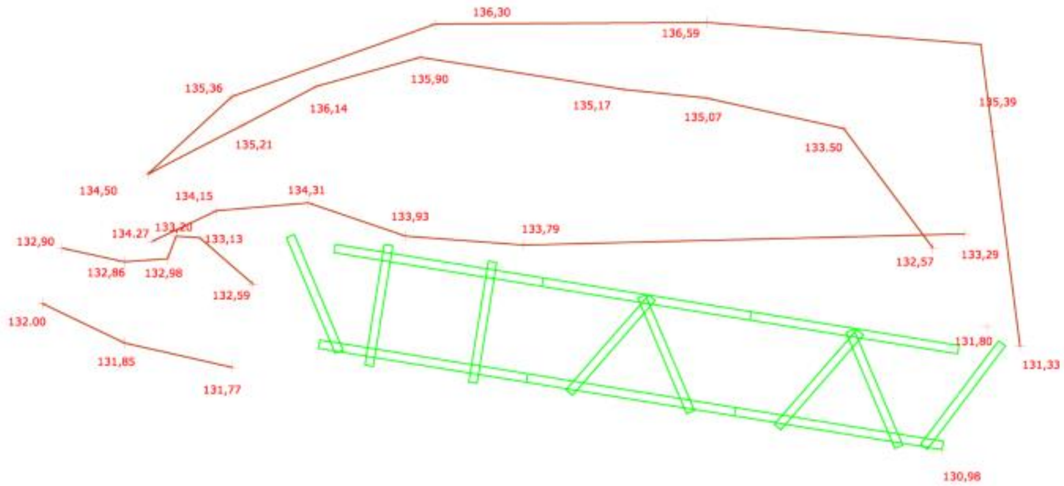
The survey of the plan and the sections are shown below.


131,00
Stazione
Ciglio stradello
Muro in pietra
sezione 1
sezione 2
sezione 3

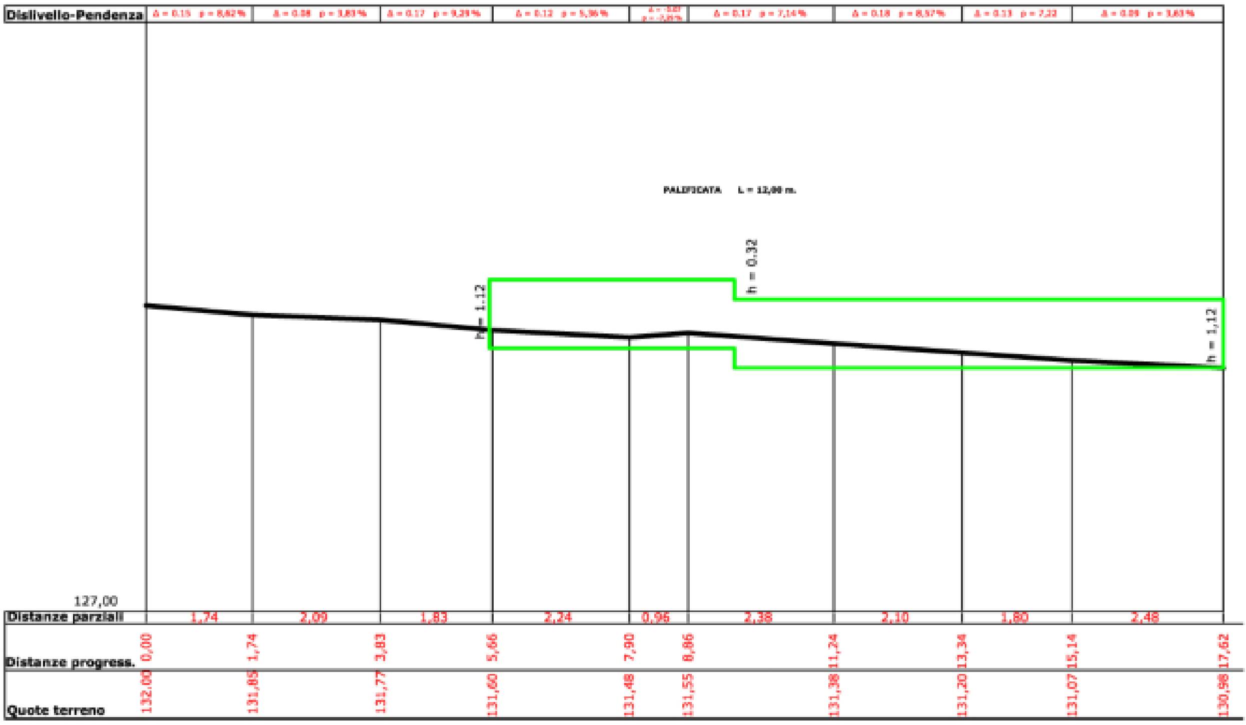

sezione 1
STRADELLO
1.37
1.21
2.62
1.49
131,25
132,30
133,50
134,70
136,50
sezione 2
STRADELLO
1.21
0.86
3.25
0.94
131,40
132,60
133,89
135,55
136,45
sezione 3
STRADELLO
1.61
1.53
2.13
131,65
132.55
134.25

Latina living crib wall



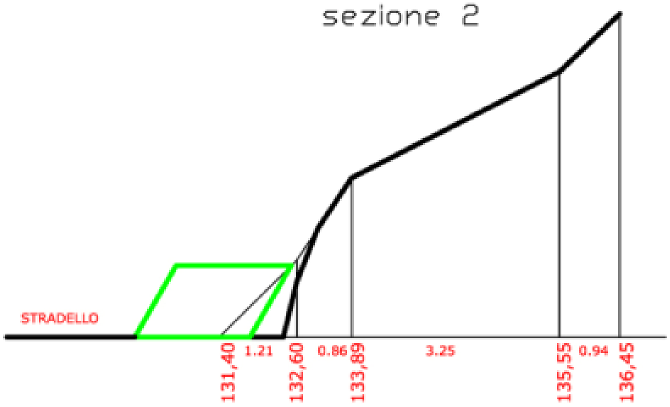


Longitudinal profile of the intervention

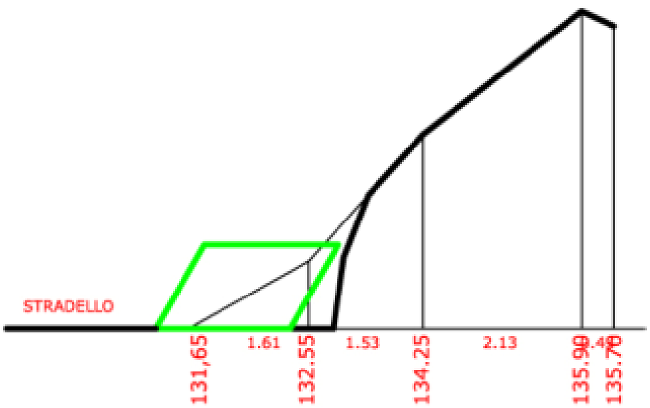


Sections of the intervention

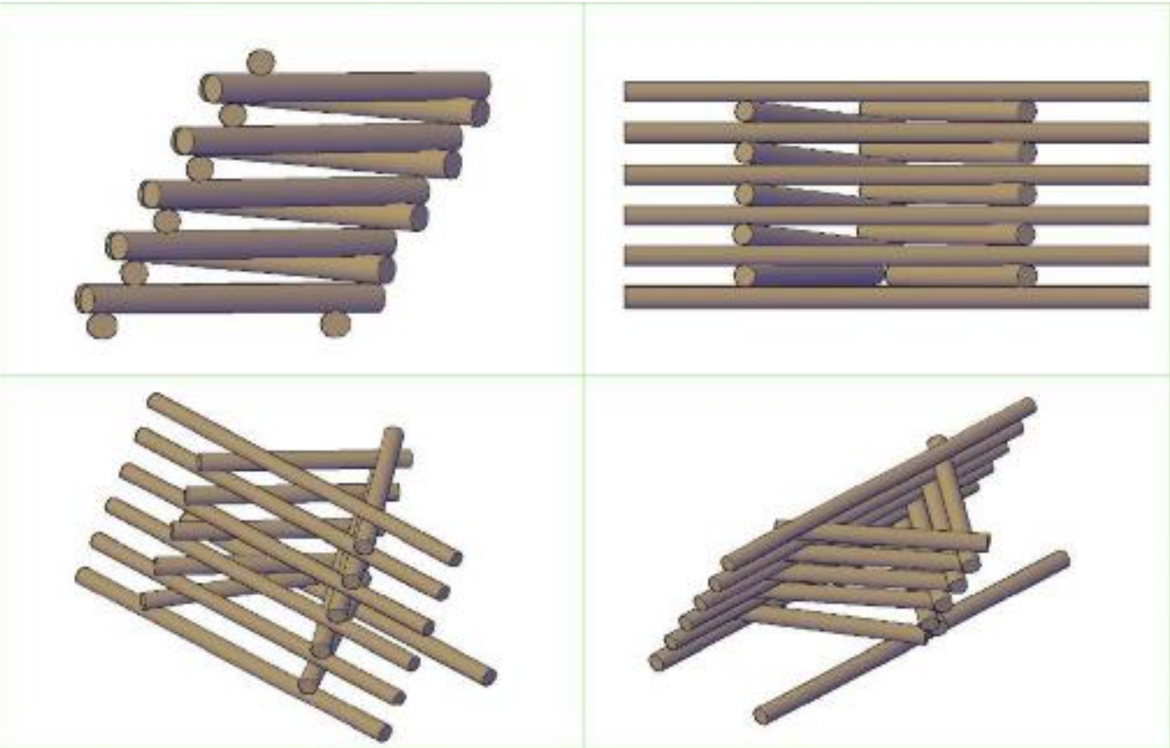
sezione 2



sezione 3



Three-dimensional views of the piling



List of materials and means used

The following is the list of materials used in the construction of the live piling.

Overall, they were necessary:

Materials

- 30 trunks of chestnut, not peeled, with a diameter of 16 cm. each with a length
- approximate 4 m.
- 8 iron bars (12mm.) 6 m long. used for nailing the piling
- 5 kw generator set

Tools

- small excavator to dig and fill the piling of earth
- 2 chainsaws

Safety devices

- 10 protection helmets
- 12 pairs of labor gloves
- 2 pairs of anti-noise headphones
- protective glasses

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Facility

- 2 electric extensions
- 3 tanks:
- a 20 liter tank of petrol.
- a 10 l mixture tank (3%).
- a 5 liter chain oil tank.
- 20 m metric wheel
- level
- wheelbarrow
- 2 bats 5 kg each
- 3 mallets 250 g each
- 2 picks
- 4 buckets
- 2200 watt flex
- different keys for flex
- drills:
- a professional 900 watt
- and another 750-watt
- different drill bits (12mm.) 40 cm long. for wood drilling
- 3 blades

The plants used on the construction site derive from the analysis of the structure, taking into account availability of the species present in the *Park of the Aurunci Mounts nursery*, from which they were procured, such as:

Piante	N°
Virburnum tinus	50
Ligustrum vulgare	50
Phillyrea angustifolia	25
Crataegus monogyna	25
Coronilla emerus	25
Rhamnus alaternus	25

Cost Analysis

Summary of costs (€/m3)

Pillar of double living support

Object	Unit of measure	Quantity	Elementary price	Amount
A) LABOR:				
skilled worker	hour	0,00	18,30	0,00
qualified worker	hour	0,70	17,23	12,06
laborer	hour	0,80	15,96	12,77
B) RENTAL:				
truck	hour	0,50	31,00	15,50
Excavator	hour	0,30	41,30	12,39
Chain saw	hour	0,30	3,20	0,96
Generator with drill	hour	0,10	4,30	0,43
C) MATERIALS:				
pieces of steel bars (50 cm)	n.	10,00	0,38	3,80
debarked wood	m3	0,50	114,60	57,30
shrubbery	n.	12,00	1,00	12,00
vegetable soil	m3	1,50	25,00	37,50
TOTAL COSTS				**164,71**
GENERAL EXPENSES 14 %			€/m3	23,06
FOR BUSINESS PROFITS 10 %			€/m3	2,31
SAFETY 6%			€/m3	9,88
APPLICATION PRICE FOR MEASUREMENT UNITS EQUAL TO 1 m3			€/m3	**199,96**

Photographic documentation

Topographic surveys

Pictures taken during the construction stage

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

Vegetation characterization

- Place : Monte Orlando (Gaeta)
- Altitude :130s.l.m.
- Exposure ; Nord –ovest

The vegetation characterization in the different bioengineering techniques is the following:

Latin Palificate

This work was completed **4 years ago**; it is characterized by a predominantly shrubby covering and its vegetative cover is 40%.

Present plants:

	d(mm)	h(cm)
• *Virburnum tinus*	7-9	80-120
• *Ligustrum vulgare*	4-6	100-120
• *Crataegus monogyna*	4-8	40-70
• *Phyllirea*	8 -10 mm	80-140

Simple palificate

This work was completed **4 years ago**; it is characterized by a predominantly shrubby covering and its vegetative cover is 40%.

Present plants :

	d(mm)	h(cm)
• *Virburnum tinus*	**6-7 mm**	**120**
• *Lonicera caprifolium*	**5 mm**	**50-100**

CASE STUDY - SLOPE

RIVER MELFA CONSTRUCTION SITE REPORT

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

River Melfa along Ponte S.S. n°6 Casilina comune of Roccasecca

UTM coordinates:

41°32′ 07″N 13°38′59″ E

Completion date of the design stage:

January 2008

Completion date of the construction stage:

January 2010

Client: (e.g. private or public person or industrial company):

Cooperative Agrifoglio

SUMMARY

It is a 40 Km river. The erosion risk was very high. It provoked a landslide of a slope along the river and a substantial risk for the overlying house. It needed an intervention to fix it.

ECOMED - *Ecoengineering in the Mediterranean Environment*

RIVER MELFA CASE STUDY REPORT

Authors: Jemmbuild

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title: River Melfa along Ponte S.S. n°6 Casilina comune of Roccasecca

Completion date of the design stage: January 2008

Completion date of the construction stage: January 2010

Client: cooperative Agrifoglio

Decision criteria for this type of construction: Securing of the site and erosion control

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

The principle key objective: was to put in safe the place along the river Melfa.

Historical aspects: The river Melfa starts from the mount Petroso and links the Comino valley to the Liri valley. It develops in a turning way. In the past, this territory belonged to the Sanniti and they fought against the Romans to defend this land until the final defeat in 293 b.C. By this date, Romans began to expand their territory without limits. So the river has an historical importance but it is also an aggregation point. In the last ten years, many initiative have been made to give value to this site. It has formed by a lot of rocks, stones, waterfalls and a final water jump of 6 meters. Kayak tours are organized along the river but it is possible only in some periods of the year because normally the river is dry.

Climatic aspects: Rainfalls are not so regular but the river becomes a danger in some periods. During the winter rainfalls could be abundant and they caused water flood. Reading the Regione Lazio information, in the year 2004/2005 the rain days were 113/114. By 2006 to 2008 the rains were very low. In the arid months the rainfalls has an average of about 72 mm, by October to February there is an average of about 116 mm.

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Soil physical aspects: It is a 40 Km river and the work was in the place Ponte S.S. n.6 Casilina. When there is a river flood, it is very dangerous for the road bridge which leads an important road such as via Casilina which arrived until Rome. The bridge has a Roman origin fundament but the rest of the bridge had been rebuilt after the Second World War. In winter Melfa river has very violent flooding.

Soil engineering aspects: The nature of the territory is constituted by sandstones and it had an high permeability. The rain permeates in the land and it caused the landslide and the danger in the high side and in the river bed.

Erosion risk: The erosion risk was very high. Analysing the development of river it has discovered a lot of stones and sands carried by the power of river and it was dangerous. These events provoked a landslide of a slope along the river and a substantial risk for the overlying house. The largeness of the landslide is about 25 mt and it has an high of about 13 mt from the river to the road. This situation is due to the erosion power of the river in several years and it is needed an intervention to fix it.

Risks to life and property: Water flood could cause the decline of stability of the structure of the house. The intervention was urgent. A risk should be represented by a possible sudden water flood because the workforce was working in the river channel and there would be a risk to life. The project has been done when the river was dry.

Native vegetation: There was not vegetation because the landslide destroyed all the vegetation. Originally willow trees grew here.

Cartography: The cartography used is:

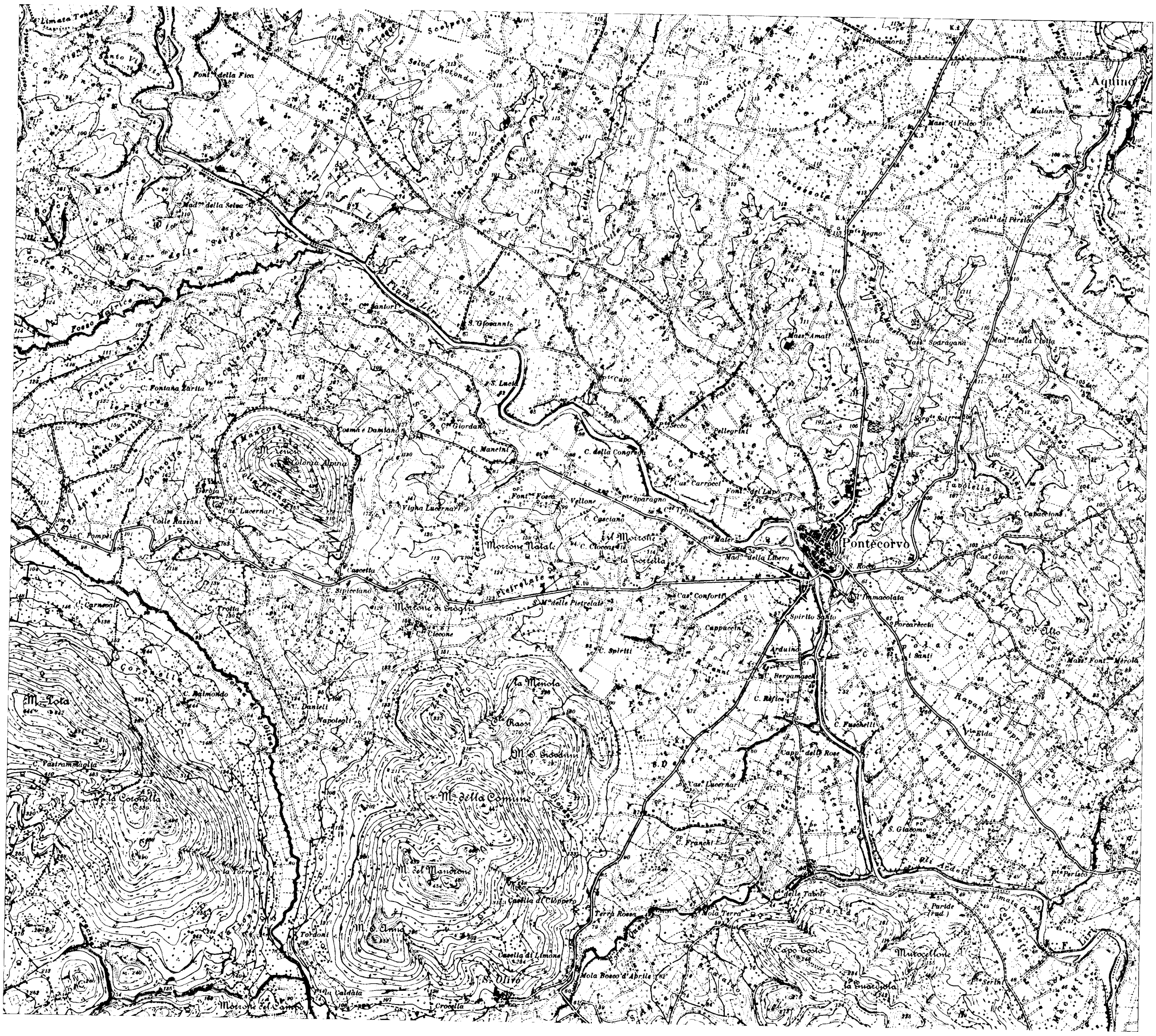
Carta Tecnica Regionale scala 1:10.000

Sections: 402040 – 402080 – 403010 - 403050

Carta IGM scala 1:25.000:

Quadrante: 402 I° - II°, 403 IV°

Photo taken by www.fiumemelfa.it . It represents a waterflood in 1992.



Topographic map

Starting situation

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

Species selection: The criteria for the plant species selection is to choose only autochtone plant species. Willow trees are used here.

Bioengineering techniques selection and improvements: The initial project previewed the use of gabions of 1x1 meter and reinforced earth with a 1/3 slope. In the construction stage they had been substituted by some metallic structures which had an anchorage and an higher resistance.

Function of vegetation: Soil reinforcement and enhancement of soil strength and surface protection against wind/water erosion.

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

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LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

Problems recorded during the construction stage: gabions have been substituted because they were destroyed by water floods

Detected flaws regarding the construction stage: increasing bed or river bank erosion in upstream or downstream areas adjacent to the work.

Plantation techniques: Plants are inserted in the metallic structures to cover all the surface and to help the stability of the slope. No changes are made in terms of plant species used in comparison with those included at the design stage. Plants are characteristic of the intervention area. No hormone treatment is used for improving plant rooting capacity and root system development.

Adverse climate conditions: The duration of works has been very long because there have been different water flood and several times the workforce stopped to work for danger in the river bed. During the design stage it was foreseen that works will have a duration of six months, but in the realty works had continued for a couple of years. The influence of whether was not foreseen.

Workforce: Nine units of workforce was used to complete this work. It was sufficient to reach the quality standard thought in the project stage.

Polluting matters or residues on inherent construction: The inert materials were used to refill the metallic structures and so there was not a transport of inert materials. To follow the guidelines of bioengineering, there was not impact of the environment because the structures have been partially refilled with autochthon land and covered with vegetation. At the beginning the slope was full of shrub vegetation. It had been replaced with cuttings of sallow. No polluting materials were used.

Proposed Improvements : In the construction stage the gabions and the reinforced earth have been substituted by metallic structures 3,60X3,10 meters. In the fundament of landslide the structures have been used with a structure opposed to the other in the way to build solid fundaments. They are refilled with autochthon earth but also with sandstones mixed to terrain.

Structures put in an opposite manner

Final result without vegetation

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Maintenance contract: It was not considered a maintenance contract. It didn't request maintenance during the works and it doesn't need it now in terms of performance and suitability.

Monitoring: Works finished at the end of 2011 but the company (Jemmbuild) continued to monitor the work situation. Every six months it is previewed a visit of the technique in the place to observe the resistance of the bioengineering work. After seven years the work is like the beginning.

Analysis of the gap between the planned work and the build work: In the designing stage the project previewed the use of gabions but the power of water should have destroyed these elements so the company decided to use some metallic structures which had the property to anchorate to the land and to resist to the power of river.

Conclusions of work:

- Very successful evolution of the work after ten years and after several water flood.
- Climate change couldn't affect the present situation
- If there will be a rain storm with a violent quantity of water it should be resistant but only the time could give the right answers.
- All the initial risks which were present in the intervention are none
- . The vegetation has partially covered the work because the cuttings are inserted only in the down side of the work.

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Vegetation put in the structures

Monitoring in 2018

A photo detail of the slope and the growing of cuttings

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Erasmus+ Programme
of the European Union

CASE STUDY - SLOPE

RIPE DI CASTELLALTO CONSTRUCTION SITE REPORT

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Specola in Ripe di Castellalto in Regione Abruzzo, Provincia di Teramo

UTM coordinates:
-

Completion date of the design stage:
30/05/2017

Completion date of the construction stage:
24/04/2017

Client: (e.g. private or public person or industrial company):
Ente Provincia di Teramo

SUMMARY

The landslide was caused by snowing, rainfalls and an earthquake in January 2017. The aim was to stabilize and create conditions for the establishing of the vegetation.

ECOMED

ECOMED - *Ecoengineering in the Mediterranean Environment*

RIPE DE CASTELLALTO CASE STUDY REPORT

Authors: Jemmbuild

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title : Urgent works in S.P. n.19 Specola in Ripe di Castellalto in Regione Abruzzo, Provincia di Teramo

Completion date of the design stage: 30/05/2017

Completion date of the construction stage: 24/04/2017 (The date of the design stage comes after the construction stage because they were defined urgent works)

Client: Ente Provincia di Teramo

Decision criteria for this type of construction: landslide to restore because of a slope caused by the bad weather conditions

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

Key Objectives: The aim was to stabilize and create conditions for the establishing of the vegetation.

Climatic aspects: There had not been climatic surveys because it was a urgent work and there was not time to do this. The slope was caused by snowing, rainfalls and an earthquake in January 2017. No apparent risks have been run because works began in April when the weather was going better.

Soil physical aspects: The stratigraphy of soil survey shows the presence of a level of vegetal terrain and, in the deep territory, there is a level of clayey silt and silty clay. There are also different surfaces of sand and in the very deep surface it shows lithoid characteristics. The territory had, in the past, several other phenomena of landslides and that continuously has caused the interruption of regular traffic on the road.

Native vegetation analysis: The landslide appeared with a little of native vegetation and overall there was shrub vegetation such as Hedysarumcoronarium and Arundo pliniana. It will be replaced in the construction stage.

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Erosion risk: It was essential to find an immediate solution to restore the landslide because it was necessary to put in safe the road along the slope. The traffic area was closed but the road needed to be opened the sooner as possible because it linked important strategic areas of territory. The purpose was to contrast the erosion phenomenon given by the bad atmospheric conditions and to reach the slope stability, keeping in safe the road just along the landslide.

Potential failure of vegetation: Vegetation should be inserted during the sunny season and it was possible that not all plants have a good result.

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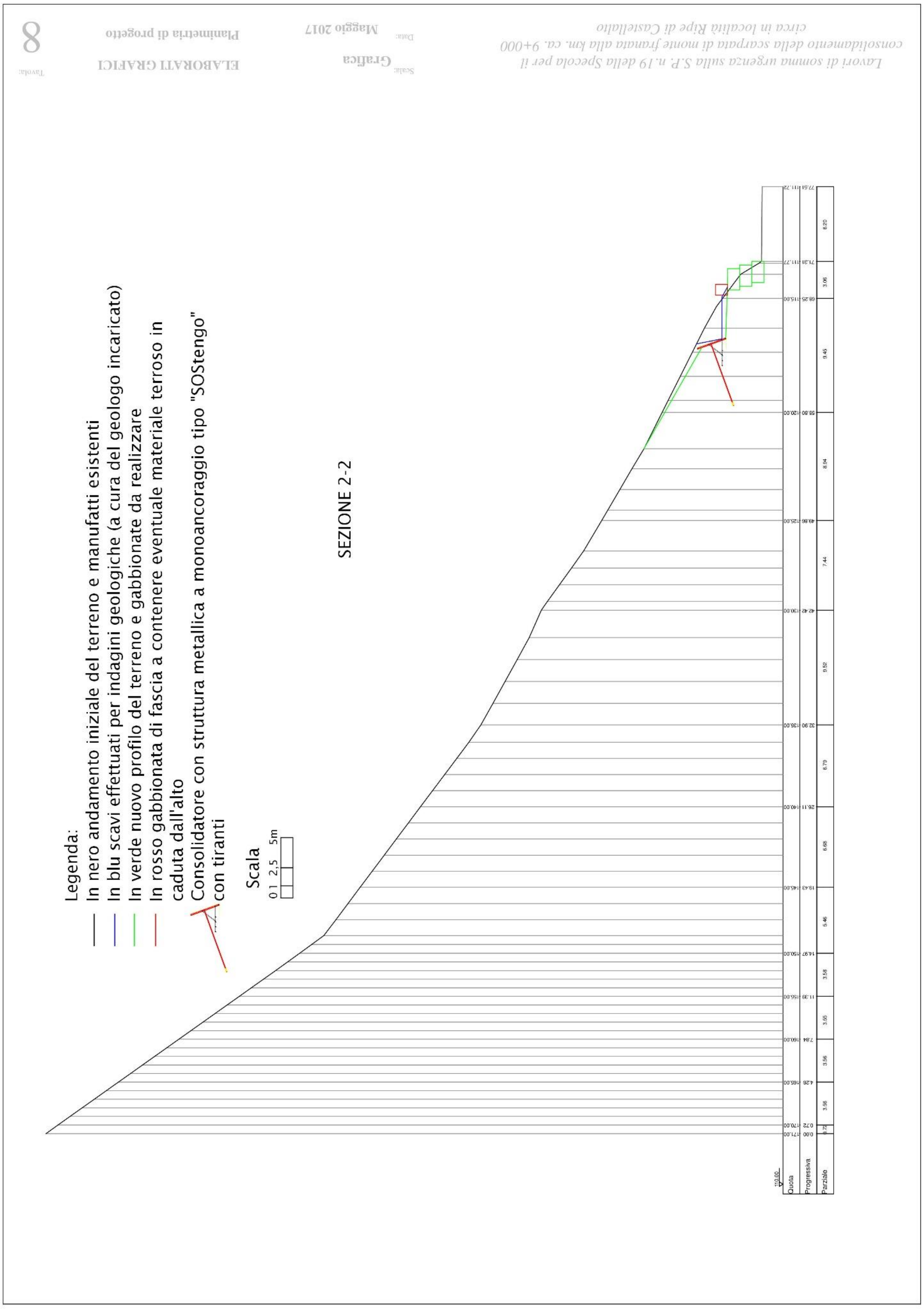
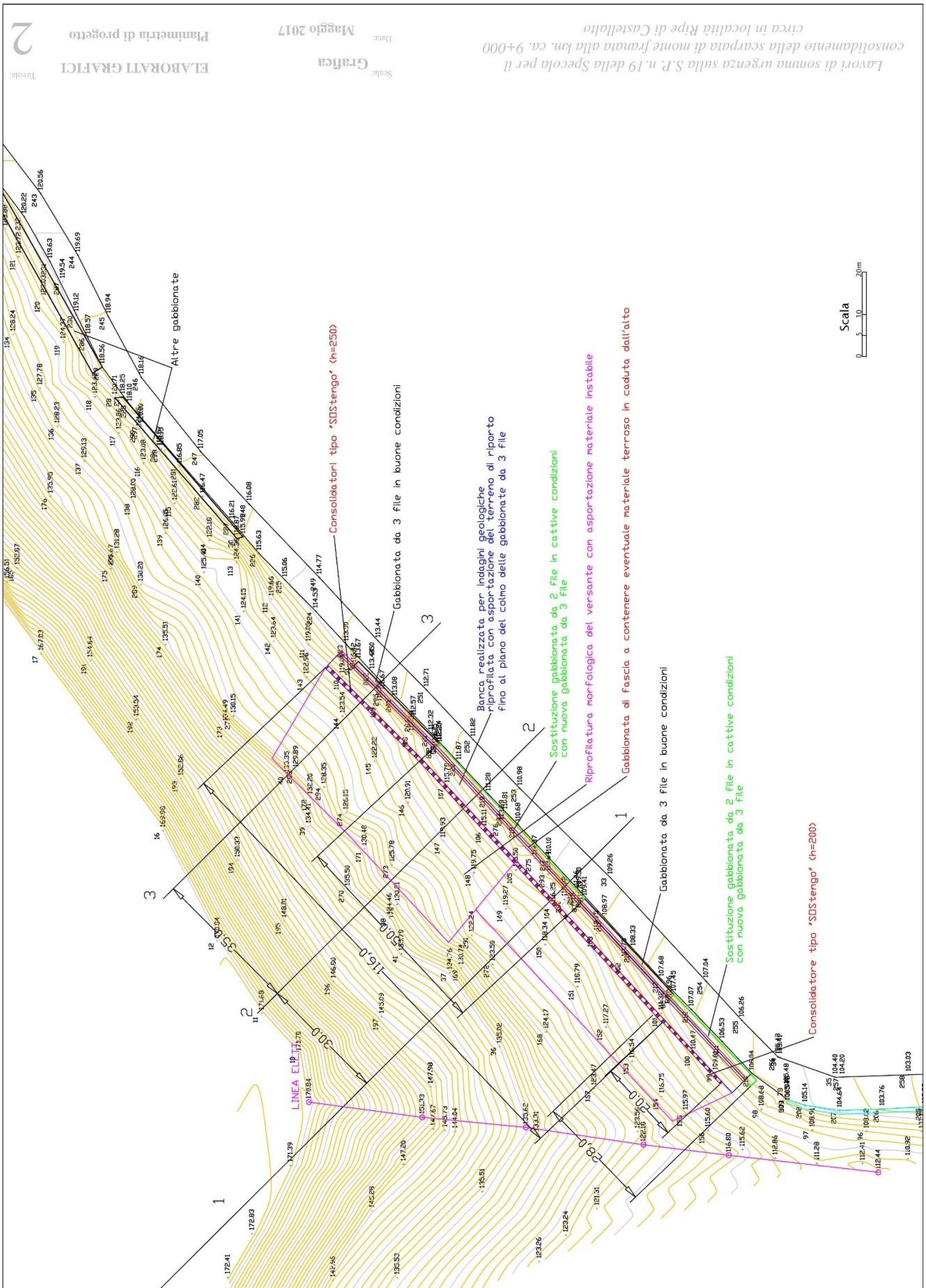
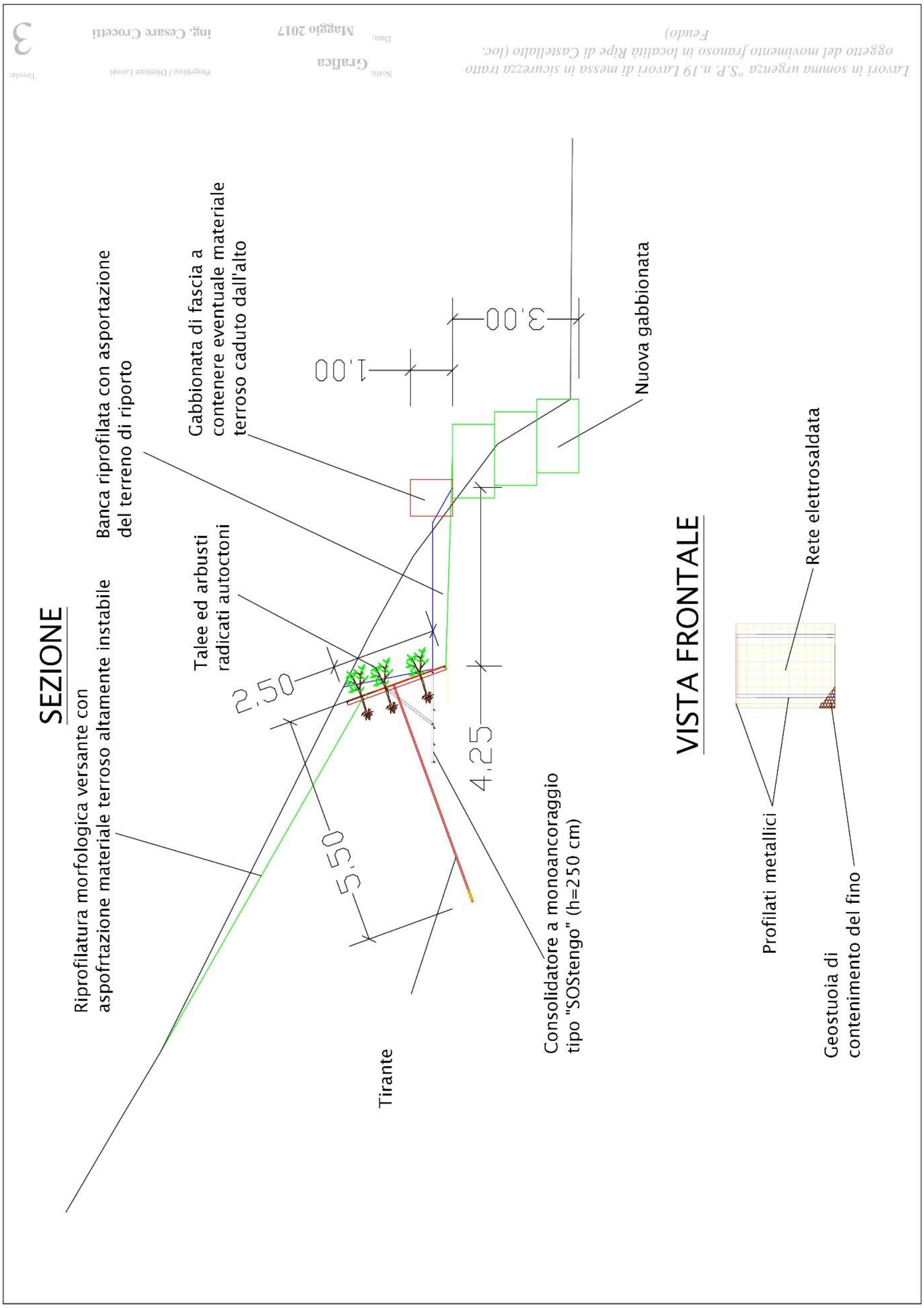


Legenda:
In nero andamento iniziale del terreno e manufatti esistenti
In blu scavi effettuati per indagini geologiche (a cura del geologo incaricato)
In verde nuovo profilo del terreno e gabbionate da realizzare
In rosso gabbionata di fascia a contenere eventuale materiale terroso in caduta dall'alto
Consolidatore con struttura metallica a monoancoraggio tipo "SOStengo" con tiranti
Scala
0 1 2,5 5m
SEZIONE 2-2
Quota
Progressiva
Parziale
Lavori di somma urgenza sulla S.P. n.19 della Specola per il consolidamento della scarpata di monte franata alla km. ca. 9+000 circa in località Ripe di Castellalto
Scala
Grafica
Data
Maggio 2017
ELABORATI GRAFICI
Planimetria di progetto
Tavola
8



Lavori di somma urgenza sulla S.P. n.19 della Specola per il consolidamento della scarpata di monte franata alla km. ca. 9+000 circa in località Ripe di Castellalto
Scala: Grafica
Data: Maggio 2017
Tavola: 2
ELABORATI GRAFICI
Planimetria di progetto
Altre gabbionate
Consolidatori tipo 'SOStengo' (h=250)
Gabbionata da 3 file in buone condizioni
Banca realizzata per indagini geologiche riprofilata con asportazione del terreno di riporto fino al piano del colmo delle gabbionate da 3 file
Sostituzione gabbionata da 2 file in cattive condizioni con nuova gabbionata da 3 file
Riprofilatura morfologica del versante con asportazione materiale instabile
Gabbionata di fascia a contenere eventuale materiale terroso in caduta dall'alto
Gabbionata da 3 file in buone condizioni
Sostituzione gabbionata da 2 file in cattive condizioni con nuova gabbionata da 3 file
Consolidatore tipo 'SOStengo' (h=200)
Scala


SEZIONE
Riprofilatura morfologica versante con aspofrtazione materiale terroso altamente instabile
Banca riprofilata con asportazione del terreno di riporto
Talee ed arbusti radicati autoctoni
Gabbionata di fascia a contenere eventuale materiale terroso caduto dall'alto
Nuova gabbionata
Consolidatore a monoancoraggio tipo "SOStengo" (h=250 cm)
Tirante
2,50
5,50
4,25
1,00
3,00
VISTA FRONTALE
Rete elettrosaldata
Profilati metallici
Geostuoia di contenimento del fino
Lavori in somma urgenza "S.P. n.19 Lavori di messa in sicurezza tratto oggetto del movimento franoso in località Ripe di Castellano (loc. Feudo)
Scala: Grafica
Data: Maggio 2017
Progettista / Direttore Lavori ing. Cesare Crocetti
Tavola: 3

WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

Bioengineering techniques selections: In the past years, some gabions were used to stabilize the slope but the frequent snowing has caused the fall down of some gabions and the falling of several quantity of mud terrain. Two rows of gabions had to be substituted by three new rows of reinforced metal structures.

Plant selection: The project involved the management of invasive species and the replacement by native species. Vegetation will guarantee the strength of intervention and it will reach the aesthetic goal hiding the metal structures. There will not be need of earthmoving because the goal is to use the falling terrain to refill the metal structures and to compact the landslide. About the analysis of risks, it was linked to the peculiarities of the territory.

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INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)


Disturbing/destabilizing elements present between the design stage and the construction stage: There were some changes in terms of the plant species used in comparison with those included at the design stage because of high temperature. Some plants died. It was important to value the economical resources of commitment and to make a significant change about vegetation.

Plantation techniques used to better attain and/or preserve soil humidity: The backfill soil of the metallic structures has been mixed with straw to ensure and preserve soil humidity and to get better the geotechnical construction site characterization.

Plants regionally distintive/characteristic of the intervention area: The species of plants have been chosen thanks to the surveys made in the field and finding out the native species which are present in the territory. It has been used the autochthon vegetal terrain to refill the metallic structures (around 50 cm) and to compact the land just over the protection elements. The presence of a lot of seeds, rhizomes of Hedysaurumcoronarium and Arundo pliniana helped the naissance of spontaneous revegetation of the slope. The vegetation has the function of soil reinforcement and enhancement of soil strength. Being urgent works to maintain the security, it has not been possible to plant in the best period for plants. Works continued along the summer 2017 characterised by high temperatures and a very low rate of rains.

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Plant density: It was used the Tamarix Africana because it was easy to find it and it has good property in consolidation and it can resist to hot weather conditions. A round 400 cuttings are put in by the month of June with a density of 1 cutting for m^2.

Adverse climate conditions: During the winter the weather has been very cold and it helped to provoke the landslide. During the summer the climate was characterized by hot temperatures and it has consequences on the plants insertion.

Workforce employed: The workforce employed is constituted by four people because the structures are light and fast to use.

Polluting matters or residues on inherent construction material: there are not inert materials to transport but it is used only the authochtone land. So there aren't any polluting matters or residues on inherent construction material. There is not landslide impact because the intervention is going to be covered with vegetation.

MAINTENANCE AND MONITORING STAGE ANALYSIS

Maintenance contract: There was not a maintenance step in the contract because it has not foreseen a budget but we are continuing to study the progress of work all the time we have the possibility to reach the place.

Bioengineering work monitoring tasks: The choice of vegetation material has strongly been influenced by meteorological conditions in the period from May to August. The principal plant which has been used is the Tamarix Africana in cuttings because it is common in the intervention zone and it is easy to find it in loco (so it is economical). The cuttings have been inserted in June but the percentage of establishment was very low because of the abnormal hot temperatures, not usual for Abruzzo Region. A first monitoring shows the difference between the cuttings planted in June and the others in the months later. The cuttings put in June had a percentage of growing about 10%; the other cuttings, planted in July, had a percentage of growing around 0% more or less. It is important to underline the fact that watering has been made for all the duration of the construction stage but water was not sufficient for plants. The conclusion is that the use of cuttings of Tamarix (tamarisk) is possible also in summer period but these strong Mediterranean cuttings have their limits and in extreme conditions of warm temperatures and drought they have not great results and it is better not to plant them. Using the authochtone land has permitted the growing of native plants of Hedysaurumcoronarium and Arundo pliniana and it has guaranteed a fast covered effect in some zones of intervention. It reached the result of a low impact work.

ANALYSIS OF THE WORK PERFORMANCE

Achieved functions: The site could be better with another intervention about plants: it could be complete if we plant other cuttings on the upper side of metallic structures. The landscape function and the functionality function was reached. The traffic was regularly established and the road was finally put in safety

Suitability of the plant species utilised in the work: After eight months, vegetation is not yet covering the work but some plants have grown up through the structures. It is essential to put other plants in favourable condition of weather. So very early the intervention should disappear with the help of bioengineering.

Climate: Now the climate change is not affecting the performance of the bioengineering intervention (see photo below), the structures mantain the stability of land and no landslides are happened during these eight months.

Very successful evolution of the work (all the main objectives were achieved) because now the stability is completely reached and climate conditions doesn't affect the security of the place.

CASE STUDIES. PORTUGAL

CASE STUDY - FLUVIAL

STREAMBANK STABILIZATION AND RIPARIAN RESTORATION USING SOIL BIOENGINEERING TECHNIQUES

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Rio de Couros, Portugal

UTM coordinates:
29T543430UTM4398192

Completion date of the design stage:
March 2007

Completion date of the construction stage:
April 2007

Client: (e.g. private or public person or industrial company):
Private company

SUMMARY

This project consisted in the use of soil bioengineering techniques in a low energy water course. The main goal was to stabilize the river bank, degraded by erosion, causing soil instability as well as to recover the riparian vegetation using live materials.

CASE STUDY - SLOPE

SLOPE STABILIZATION WITH VEGETATED REINFORCED EARTH WALL ON NATIONAL ROAD NO.16

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Albergaria-a-Velha, Portugal

UTM coordinates:
29T537920UTM4504043

Completion date of the design stage:
July 2011

Completion date of the construction stage:
November 2011

Client: (e.g. private or public person or industrial company):
Public (Municipality of Albergaria-a-Velha)

SUMMARY

A severe landslide ocurred on a roadside caused by the high inclination of the slope combined with an insufficient drainage.

The designed solution was a vegetated reinforced earth wall complemented with a hydroseeding.

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CASE STUDY - FLUVIAL

PARK OF THE TAGUS RIVER ESTUARY

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Alverca, Portugal

UTM coordinates:
29T496271UTM4303514

Completion date of the design stage:
November 2011

Completion date of the construction stage:
2013

Client: (e.g. private or public person or industrial company):
Public (Municipality of Vila Franca de Xira)

SUMMARY

Several bioengineering techniques were proposed in a waterfront requalification project. This case study aims at pointing out the negative implications of a poor construction work and the lack of oversight.

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CASE STUDY - FLUVIAL

REHABILITATION PROJECT OF REGATO DA CARVALHA (A41 HIGHWAY)

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Argoncilhe, Portugal

UTM coordinates:
29T539389UTM4539962

Completion date of the design stage:
2009

Completion date of the construction stage:
April 2011

Client: (e.g. private or public person or industrial company):
DLACE – Douro Litoral ACE (private company)

SUMMARY

The project was part of the compensatory measures resulting from the environmental impact assessment of the A41 Highway construction in Portugal

CASE STUDY - COASTAL

STABILIZATION AND REQUALIFICATION OF THE CRESMINA SAND DUNE

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Guincho Beach, Portugal

UTM coordinates:
29T459053UTM4287005

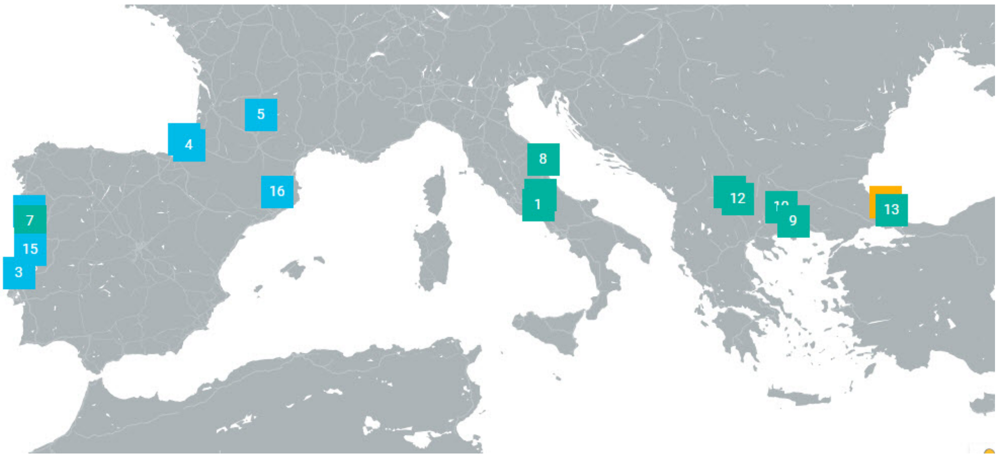
Completion date of the design stage:
May 2010

Completion date of the construction stage:
1st stage: November 2010, 2nd stage: January 2012

Client: (e.g. private or public person or industrial company):
Public (Cascais Natura – Environmental Agency of the Municipality of Cascais)

SUMMARY

The habitat management actions aimed at restoring and managing the impacts on the dunes, through the installation of biophysical structures, planting of characteristic species and the removal of non-native species.



ECOMED - ECOENGINEERING IN THE MEDITERRANEAN ENVIRONMENT

CASE STUDIES REPORT IN PORTUGAL

Authors: EcoSalix and University of Evora

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Case study #1 Streambank Stabilization and Riparian Restoration using Soil Bioengineering Techniques	
Work location	Rio de Couros
Country	Portugal
NUTS II	Centro
NUTS III	Médio Tejo
LAU1	Ourém
LAU2	União das Freguesias de Rio de Couros e Casal dos Bernardos
UTM coordinates	29T543430UTM4398192
Completion date of the design stage	
Completion date of the construction stage	April 30, 2007
Client	Private company
Decision criteria for this type of construction	Ecological restoration and slope stabilization
Area	200 **m²**
Project type	Fluvial
Bioengineering solution(s) implemented	Live slope grating and Live stakes of *Salix* sp. and *Nerium oleander*, plantations of *Sambucus nigra* and transplants of *Alnus glutinosa* and *Fraxinus angustifolia*
Project delivery method	Design-Build
Total project costs [cost/m²]	50 €/m²
Total costs of the bioengineering component [cost/m²]	35 €/m²

Case study #2 Slope Stabilization with Vegetated Reinforced Earth Wall on National Road n.º 16	
Work location	Albergaria-a-Velha
Country	Portugal

Co-funded by the Erasmus+ Programme of the European Union

NUTS II	Centro
NUTS III	Região de Aveiro
LAU1	Albergaria-a-Velha
LAU2	
UTM coordinates	29T537920UTM4504043
Completion date of the design stage	No data
Completion date of the construction stage	November, 2011
Client	Public (Municipality of Albergaria-a-Velha)
Decision criteria for this type of construction	Slope stabilization
Area	252 m^2
Project type	Slope
Bioengineering solution(s) implemented	Vegetated Reinforced Earth Wall and Hydroseeding
Project delivery method	Design-Bid-Build
Total project costs [cost/m^2]	149,40 €/m^2
Total costs of the bioengineering component [cost/m^2]	149,40 €/m^2

Case study #3 Park of the Tagus River Estuary	
Work location	Alverca
Country	Portugal
NUTS II	Área Metropolitana de Lisboa
NUTS III	Área Metropolitana de Lisboa
LAU1	Vila Franca de Xira
LAU2	Alverca do Ribatejo e Sobralinho
UTM coordinates	29T496271UTM4303514
Completion date of the design stage	No data
Completion date of the construction stage	November, 2011
Client	Public (Municipality of Vila Franca de Xira)
Decision criteria for this type of construction	Slope stabilization, erosion control
Area	5000 m^2
Project type	Fluvial
Bioengineering solution(s) implemented	Live slope grating; Living brush mattress; Bank pile wall; Cylindrical gabion; Live fascines; Hydroseeding; Turf Reinforcement Mat
Project delivery method	Design-Bid-Build
Total project costs [cost/m^2]	No data
Total costs of the bioengineering	No data

component [cost/m²]	

Case study #4 Rehabilitation Project of Regato da Carvalha (Douro Litoral Concession A41 - Picoto (IC2)/Ermida Road Junction (IC25), Section 1 - Argoncilhe/Road Junction A32/A41)	
Work location	Argoncilhe
Country	Portugal
NUTS II	Norte
NUTS III	Área Metropolitana do Porto
LAU1	Santa Maria da Feira
LAU2	São Martinho de Argoncilhe
UTM coordinates	29T539389UTM4539962
Completion date of the design stage	No data
Completion date of the construction stage	April, 2011
Client	Private company (Douro Litoral A.C.E.)
Decision criteria for this type of construction	Riverbank stabilization, ecological restoration
Area	646 m2
Project type	Fluvial
Bioengineering solution(s) implemented	Bank pile wall with live fascines
Project delivery method	No data
Total project costs [cost/m²]	115,13 €/m2
Total costs of the bioengineering component [cost/m²]	115,13 €/m2

Case study #5 Stabilization and Requalification of the Cresmina Sand Dune	
Work location	Praia do Guincho
Country	Portugal
NUTS II	Área Metropolitana de Lisboa
NUTS III	Área Metropolitana de Lisboa
LAU1	Cascais
LAU2	Alcabideche
UTM coordinates	29T459053UTM4287005
Completion date of the design stage	No data
Completion date of the construction stage	2011
Client	EMAC – Environmental Agency of the Municipality of Cascais
Decision criteria for this type of construction	Sand dune stabilization and requalification
Area	86000**m²**

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Project type	Coastal x Fluvial
Bioengineering solution(s) implemented	Dune regenerator in *Salix viminalis*
Project delivery method	Design-Build
Total project costs [cost/m²]	2,91 €/sqm Based on a total cost of 250.000,00 € (SWB Techniques and remaining works)
Total costs of the bioengineering component [cost/m²]	0,87 €/sqm Based on a total cost of 75.000,00 € (SWB Techniques)

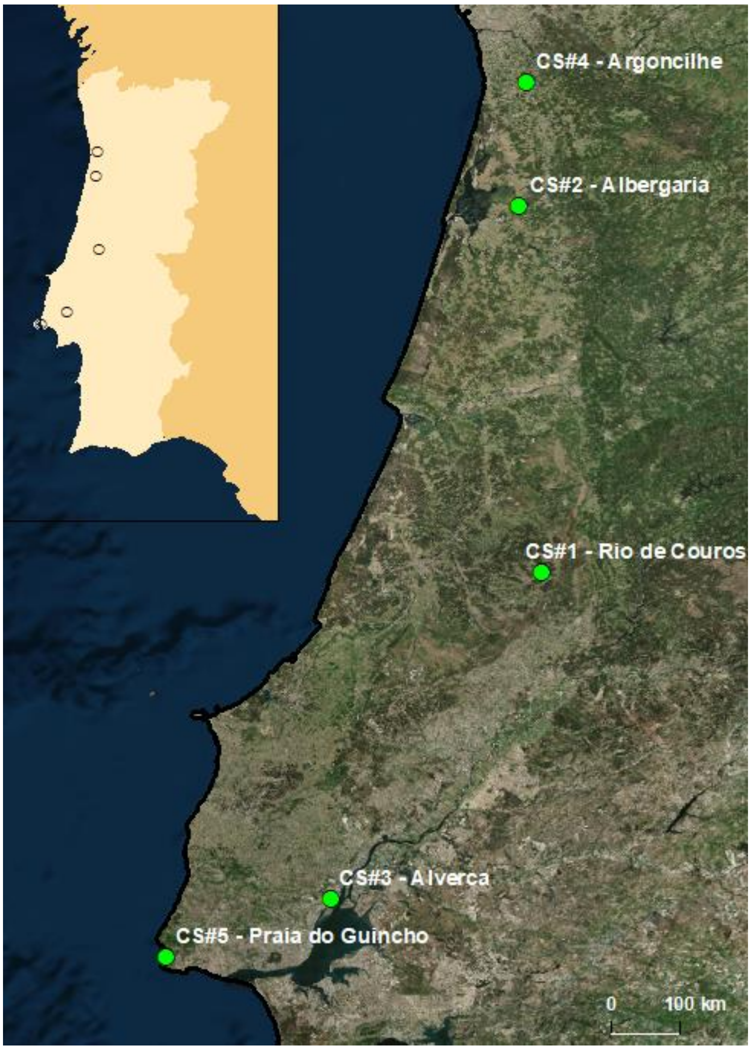

Figure 1. Study areas

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

Table 1.

Site appraisal:reconnaissance, desk/office studies, and inspections for biodiversity, dendrology,inspections for ecology

		CS#1	CS#2	CS#3	CS#4	CS#5
Climatic aspects[1)]		NA	NA	NA	NA	NA
Soil physics[2)]		NA	NA	NA	NA	NA
Soil chemistry[3)]		A	A	A	A	NA
Soil engineering aspects[4)]		A	A	A	A	NA
Visual soil/rock classification		NA	NA	NA	NA	NA
Geotechnical analysis		A[7)]	A[7)]	A[7)]	A	NA
Hydraulic/hydrographic analysis		NA	NA	NA	A	
Site topography and site surveying (geomatics)		NA	A	A	A	
Vegetation analysis		A	A	A	A	NA
Landscape features		A[8)]	A[10)]	A[10)]	A[11)]	
Problems, risks and hazards	Erosion risk	A	A	A	A	
	Geotechnical risks[5)]	A	A	A	A	
	Flooding risk[6)]	NA	NA	NA	A	
	Fire hazard	NA	NA	NA	NA	
	The extent and nature of potential failure of vegetation				A	
	Implications of the loss of function (temporarily or permanently) the vegetation is performing)	A	A	A	A	
	Costs of repair and making good any consequent damage	NA	NA	NA	NA	
	Risks to life, health or property	NA	A	NA	NA	
Other construction sites planned close to the site		N	N	N	Y	

A: Assessed; NA: Not assessed; ND: No data/Not applicable; N: No

1) For example, rainfall, temperature, potential evapotranspiration, exposure, aspect.

2) For example, grading, density, water regime.

3) For example, pH, conductivity, nutrients, organic matter, exchange capacity, acid toxicity.

4) For example, strength, permeability, aggregate stability

5) Include landslides, mass movement, liquefaction, seismicity

6) Including the characteristics of flood events that had affected the job site (data, flow rate, equivalent return period, speeds and shear boundary stress).

7) Only the assessment of slope stability was performed.

[8)]Flat landscape. Stream with one 1.5m-high artificial (concrete) bank, followed by a paved area. The other bank and adjacent terrain dominated by *Arundo donax*.
[10)]Steep slope only with herbaceous cover
[11)]The area of intervention for the construction of the A41 Highway platform is located in an area of medium urban density, where wooded areas (riverine forests, eucalyptus, pine and residual oak) are alternated with pasture and agricultural production zones

Table 2.

Data sources

	CS#1	CS#2	CS#3	CS#4	CS#5
Maps, photographs with the purpose of collecting historical information	X	X	X	X	X
Cadastral data, parcel ownership	X	X	X	X	X
Interviewing people for collecting historical information	X				
Collection of urban planning processes and information showing current or future impacts with the work/site			X	X	
Calculations and drawings related to this preliminary stage	X	X	X	X	X
Existing information in Regulatory Agencies (e.g. sustainability initiatives, resilience initiatives)					

Overview of Process:

Case study #1

After the client's contact, a technical visit to the site was carried out to evaluate possible technical solutions to be implemented for slope stabilization. In order to meet the technical requirements of safety, stability, cost and functionality without neglecting ecological and environmental aspects and resources, it was proposed to execute a live slope grating. Subsequently, the project was developed and after reaching an agreement with the customer, the construction phase took place.

Case study #2

After the client's contact, a technical visit to the site was carried out to evaluate possible technical solutions to be implemented for slope stabilization. In order to meet the technical requirements of safety, stability, cost and functionality without neglecting ecological and environmental aspects and resources, it was proposed to execute the vegetated reinforcement wall. Subsequently, the project was developed and after reaching an agreement with the customer, the construction phase took place.

Case study #3

All tasks performed by municipality without any control or assessment

Case study #5

All the tasks were performed by the Environmental Agency of the Municipality of Cascais, without the participation, supervision or advice from the project authors.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

Table 3.

Functional requirements of vegetation (select all that apply to the project)

	CS#1	CS#2	CS#3	CS#4	CS#5
Soil reinforcement and enhancement of soil strength		X	X	X	
Soil water removal		X			
Surface protection against traffic					X
Surface protection against wind/water erosion	X	X	X	X	X
Bank and channel reinforcement	X			X	
Shelter or screening	X			X	

Which **improvements** would you propose, at the design stage, regarding:

- Plant selection: There is no reference to pest and disease assessments in plants. In addition to site pre-assessment, monitoring should also include plant sanitation.
- Strategy implementation
- Bioengineering techniques selection
- Calculations
- etc.

Please indicate your main conclusions after the analysis of the bioegineering work at the design stage

- **Is there a clear criterion for the plant species selection? Which is the criteria follow for selecting the plant species included in the project? Do the plants that belong to the first successional stage of the intervention area well represented?**

  In all projects the criterion was to use native plants.C1: The criterion was the native riparian flora, however, the plants that belong to the first successional stage were not represented. Only the CS#2 herbaceous plants were used.

- **Was a phytosociological approach used in both the plant species selection process and the intervention strategy?**

  The phytosociological approach was not followed in any of the projects.

- **Are there clear criteria for the project strategy implementation?** Yes; Yes; Yes; The defined strategies follow clear criteria, based on the objectives of each intervention.

- **Are there clear criteria for the bioengineering techniques selections?**

  In general terms, CS#1, CS#2 and CS#3 had as main objective to reduce soil erosion by water flow and the probability of streambank ruptures, while CS#4 was developed with the objective of ecological restoration of the riverbanks and their riparian vegetation that suffered strong environmental impacts due to the construction of the highway. Safety criteria and slope stability were also met, as well as functionality, since the interventions increase the hydraulic roughness and consequently slow the flow of water. The use of torrential correction dams has been implemented with the aim of forming a new compensation profile, with less slope and that prevents erosion at the bottom of the riverbed. The interventions also present a relative degree of flexibility and adaptation to the morphological conditions of the riverbanks.

- **Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear?**

  Yes; Yes; Yes; CS#3 was badly designed because it didn’t considered the need of a protection against flow erosion in the Cribwall (no stones of

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fascines where implanted and the entire plantation was washed out allowing the infestation by *Arundo donax*.

Case study #1

Pre-Design/Planning Activities:

Measurement of the intervention area and the morphology of the riverbank;

Design Activities:

1. Structural design of the living slope grating;
2. Development of the Autocad drawings;
3. Elaboration of the project;
4. Budget development.

Case study #2

Design Activities:

1. Topographic survey of the area;
2. Structural design of the reinforced wall with an automatic calculation program developed by TENAX. The stability and definition of the type and size of the geogrids to be used in the construction of the wall and incorporated into the seismic action were verified by the equivalent static forces method. Minimum safety coefficient values of 1.5 were accepted for static and seismic actions;
3. Development of the Autocad drawings;
4. Elaboration of the project;

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

Table 4.

General issues, problems and defects

		CS#1	CS#2	CS#3	CS#4	CS#5
Problems during the construc	Increasing bed or river bank erosion in upstream or downstream areas adjacent to the work	n/d	n/a	n/a	N	

	Incorrect harvest method and transport conditions of the living material	n/d	n/a	?[3)]	N	
	Incorrect use and placement of the living material	n/d	n/a	N	N	
	Incorrect storage conditions of the living material	n/d	n/a	N	N	
	Incorrect machinery selection	n/d	N	N	N	
	Problems during the construction stage	N	N	N	N	
Problems between the design stage and the construction stage	Insufficient budget	N	N	N	N	
	Construction stage too short	N	n/d		N	
	Lack of a competent (effective) supervision during the construction stage	N	n/d	Y	N	
	Lack of and affective monitoring stage after the construction stage	N[1)]	N[2)]	N[2)]	N[5)]	
	Machinery utilised in the work	n/d	n/d			
Construction standards used in the work		No				
Type of insurance applied for designer/construction company		No	No	No	No	

N: No; Y: Yes; n/d: No data; n/s: Not applicable; No: None
[1)]A monitoring stage was defined
[2)]No monitoring activities were defined/planned
[3)]Live brush mattress with few live stakes/branches of *Salix*
[5)] A visual follow-up was carried out to verify the results of the work.

Table 5.

Issues related to construction features

	CS#1	CS#2	CS#3	CS#4	CS#5
Specific plantation techniques to conserve or enhance soil moisture	Y[1)]	Y[3)]	N		
Mycorrhizae	N	N	N	N	
Hormone treatments	n/d	n/d	N	N	
Changes in terms of the plant species between design and construction	N	N	N	N	
Distinctiveness of plants	Y	Y	Y	Y	
Quality control of materials	N[2)]	Y[4)]	N	N	

Quality control of inert materials	N[2)]	n/a	n/a	n/a	
Quality controls of living material	N	Y	N	N	
Plant density or seeding rate	n/d	n/d	n/a		
Bad connections/junctions between the logs	N	n/a	n/a	N	
Bad lateral connection of the work edges with the slope	N	N	N	N	
Insufficient or missing soil compaction	N	N	Y[5)]	N	
Adverse climate conditions	N	N	N	N	

N: No; Y: Yes; n/d: No data; n/s: Not applicable

1) Hydroseeding

2) Inert materials from adjacent sites, no quality control performed

3) In the 0,20 m next to the face of the walls, soil with higher concentration of organic matter was used to serve as base to the vegetation of the final slope

4) The seeds used were from qualified distributors and following the international xxxx standard

5) Yes, poor filling of the live slope grating

Table 6.

Miscellaneous

	CS#1	CS#2	CS#3	CS#4	CS#5
Qualification documents of the construction company in the field of soil- and water-bioengineering techniques	n/d	n/d	N	N	
Qualifications and sufficient number of the workforce employed	n/d	n/d	n/d	n/d	
Were there any adherent polluting matters or residues on inherent construction material?	N	N	N	N	
Groundwater appearance	N	N	N	N	
Sanitation failure	N	N	N	N	
Natural landslide impact	n/d	n/d	P	P	
Destruction by local residents (or vandalism)	N	N	N	N	

N: No; n/d: No data; P: Positive (theoretically good)

Conclusions at the construction stage analysis:

Additional remarks

C#1:

Construction Activities:

1. Cleaning and removal of invasive vegetation;
2. Reprofiling of riverbank by eliminating existing ravines;
3. Construction of the live slope grating;
4. Construction of the riprap at the base of the slope;
5. Filling of the live slope grating with local soil;
6. Plantations, transplants and hydroseeding.

C#2:

In the first phase, the activities related to the cleaning, excavation of the base and drainage installation were carried out at the base of the structure:

1. Excavation in semi-hard lands for the implantation of the walls;
2. Foot opening, in semi-rigid ground, for application of the base;
3. Drainage execution at the base of the wall composed of crushed stone with a thickness of 0.25 m enveloped in a Tenax GT330 separation geocomposite, combined with a geodrainage tube with a diameter of 160 mm;
4. Application of drainage geocomposite at the back of the wall.

In the second phase of the work the activities of the reinforced earth wall were carried out:

1. Topographic implantation of the lower alignment of the work with the placement iron panels anchored and spaced regularly to define the slope and alignment of the facing. The iron panels were then coated with organic coconut blanket;
2. Placement of the first geogrid (Tenax TT060) defined in the project fixed to the iron panels, with its largest dimension in the perpendicular direction to the front face of the wall;
3. Application, spreading and compaction of soil sub-layers with a 30 cm thickness;
4. The layers were compacted until reaching a relative compaction of 95% of the Proctor assay;
5. In the superior wall, the compaction was performed with light equipment (weight less than 1.0 ton). In the 0,20 m next to the face of the wall, soil

is higher concentration of organic matter was used to serve as base to the vegetation of the final slope;

6. Execution of successive layers with application of iron panels, reinforced geogrid and soil compacted until reaching the height of 5.40 m;

In the third phase of the work, the second earth reinforced wall was executed, as well as the drainage system and hydroseeding:

1. The construction procedure is the same as the one described in the preceding paragraphs, except for the placement of the iron panels. Tenax TT045 reinforcement geogrids were used;
2. Execution of the channel for drainage the water from the road;
3. Execution of the hydroseeding with native herbaceous plants.

Summary: The constructor followed all the steps exactly as defined on the design phase.

C#4:

1. In the first phase, preparatory works were done, like topographical location of the sections of intervention and alignment of the structures, cleaning and regularization of the riverbanks;
2. After that, it was done the construction of the bank pile wall in both sections 1 and 2:
3. In the third phase of the work, some activities were carried out at the slope in the upper part of the wall:
   - Landfill for slope formation;
   - Application and fixation of organic coconut fibre blanket;
   - Planting of native shrubs and trees species;
   - Execution of hydroseeding of native herbaceous plants.

All the works were carried out as planned.

Table 7.

Information regarding the bioengineering work monitoring and maintenance tasks carried out

	CS#1	CS#2	CS#3	CS#4	CS#5
Maintenance contract	Y	N	N	N	
Comparison between specification/design and ‘as built’ measure	n/d	ND	F[6)]	ND	
Information on any maintenance work during monitoring phase	Y[1)]	N[3)]	N	n/a	
available information regarding the bioengineering work monitoring tasks carried out	n/d	n/d	n/d	n/a	
monitoring	Y[2)]	N[3)]	n/d	N[3)]	
instrumentation left in situ for monitoring	N	N	N	N	
inspections carried out	n/d	Y[4)]	n/d	Y[8)]	
defects noted after the defect correction period	N	N	Y[7)]	N	
emergency works carried out	N	?[5)]	n/d	N	

Y: Yes; N: No; n/d: No data; n/a: Not applicable; ND: No differences were observed (Constructed following the design specifications); F: Failed

1) Maintenance activities included temporary irrigation, fertilization and pruning, fully adequate for the techniques applied and final goals.

2) The monitoring activities were scheduled to be carried out once per month on the first two years and then two times per year and performed as planned.

3) No monitoring activities were predicted. However, a follow-up was carried out to verify the results of the work.

4) A follow-up was carried out by the bioengineer responsible for the project to verify the results of the work.

5) The project was an emergency work.

6) Failed project. Several errors were done during the construction phase.

7) Several defects noted. Poor filling of the live slope grating, insufficient fixation of the turf reinforcement mat, live brush mattress with few live stakes/branches of *Salix* and a bank pile wall that is not supporting any soil as it its function.

8) Permanent inspections during construction phase by the Biophysical Engineer Rita Sousa.

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IN SITU FIELD WORK VARIABLES SELECTION

Table 8.

Characterization of cases studies

	CS#1	CS#2	CS#3	CS#4	CS#5
Soil type	Fluvisols	Fluvisols	Solonchaks	Cambisols	Arenosols
Elevation (m)	105	30	5	131	6
Slope angle (º)	4,06	3,44	1,91	2,13	2,64
Aspect (º)	183,37	123,69	180	333,44	5,19
P_{mean} (mm)	608,0	1317,6	687,2	1423,7	441,7
T_{mean}	15,2	14,2	16,9	15,3	14,8
$T_{mean/máx}$	19,3	18,8	21,8	21,2	17,2
$T_{mean/min}$	11,2	9,6	12,0	9,4	12,3
Insolation (h)	2457,2	2426,7	2788,0	2488,7	2430,9
Evaporation (mm)	844,8	751,8	1382,5	966,6	1149,1

Table 9.

Wooden elements

	CS#1	CS#2	CS#3	CS#4	CS#5
Tree species used for the timber utilized in the work	No data	No data	No data.	No data	
Diameters used	No data	No data	No data	No data	
Deterioration of the wooden elements	No significant deterioration	No significant deterioration	No significant deterioration	No significant deterioration	

Table 10.

Plants (in/out the bioengineering work)

	CS#1	CS#2	CS#3	CS#4	CS#5
Plant species	*Sambucus nigra* *Alnus glutinosa* *Fraxinus angustifólia* *Nerium oleander*		Salix sp		*Ammophila arenaria* ssp. *Australis* *Lotus creticus*
Heights and diameters	No data	No data	No data	No data	
Land cover rate					
Biodiversity index (nº of species)					
Evolution of plant composition: number and quantity of the different species					
Invasive allochthones plants affecting the area	N		*Arundo donax*		
Root depth					
Root tensile strength					
Root pull out strength					

Table 11.

Soil assessment

The selection of the chemical elements tested took into account its importance for the development of plants.

Phosphate (P) is a major plant nutrient. It is particularly beneficial in stimulating root growth.

Nitrate nitrogen (N) is an important plant nutrient which promotes foliar growth and increased yield.

Potassium, the third of the major nutrients, increases resistance to disease and hardens plant tissues.

Magnesium is an essential element for the growth of green plants. The ratio of calcium to magnesium is also an important factor in determining the availability of nutrients. If there is an excess of magnesium over the amount of calcium in the soil, plant growth can be seriously affected.

Aluminium is a commonly occurring element found in most inorganic soils. Soluble aluminium can be toxic to many plants. Solubility is promoted by acid conditions and liming is often used to prevent the take-up of aluminium.

Ammonia nitrogen is a rapidly available form of nitrogen and encourages green plant growth. Ammonia nitrogen forms the basis of some nitrogen fertilizers which are mainly used in horticultural soils and composts.

The amount of exchangeable calcium is an important factor in classifying soil and in making fertilizing recommendations. Calcium stimulates root development and influences the uptake of other nutrients. The ratio of calcium to magnesium is particularly important in determining nutrient availability.

Chlorides are the major components of soil salinity in most soils. Chloride levels are particularly high in coastal regions, or in areas which have been flooded with sea water. Soils with a chloride level above 1000 mg/l would be regarded as saline and sensitive crops would suffer. At increasingly high levels only salt tolerant crops can be grown.

Copper is an important trace element. Copper deficiency can cause stunting of growth and reduction in crop yield.

Iron is an important trace element and is essential to plant growth. Iron is thought to act as a catalyst to photosynthesis.

Manganese is an important trace element which promotes germination and functions in the metabolism of plant growth.

		Intervention	Control	Intervention	Control
C#1	Depth (cm)	< 35	< 30	> 45	> 30
	Ammonia (mg/l)	16	22,5	14	18
	Aluminium (mg/l)	-	-	-	0
	Calcium (mg/l)	1750	1250	1000	1250
	Iron (mg/l)	v.o.r.	v.o.r.	24	v.o.r.
	Magnesium (mg/l)	125	75	85	75
	Manganese (mg/l)	v.o.r.	v.o.r.	v.o.r.	25
	Nitrate (mg/l)	6,3	2,7	1,4	3,3
	Copper (mg/l)	16	2	0	0
	Potassium (mg/l)	190	155	80	120
	Chloride (mg/l)	625	625	500	500
	Phosphate (mg/l)	83	43	-	78
C#3	Depth (cm)	-			

	Ammonia (mg/l)	62			
	Aluminium (mg/l)	v.o.r.			
	Calcium (mg/l)	2000			
	Iron (mg/l)	v.o.r.			
	Magnesium (mg/l)	50			
	Manganese (mg/l)	7,25			
	Nitrate (mg/l)	v.o.r.			
	Copper (mg/l)	-			
	Potassium (mg/l)	350			
	Chloride (mg/l)	875			
	Phosphate (mg/l)	58			
C#4	Depth (cm)	< 20		20-50	
	Ammonia (mg/l)	2,2		20	
	Aluminium (mg/l)	0		-	
	Calcium (mg/l)	750		500	
	Iron (mg/l)	-		-	
	Magnesium (mg/l)	55		55	
	Manganese (mg/l)	15		9,25	
	Nitrate (mg/l)	4		0,9	
	Copper (mg/l)	0		0	
	Potassium (mg/l)	105		-	
	Chloride (mg/l)	1125		1000	
	Phosphate (mg/l)	-		-	

Table 12.

Soil pH

		Intervention	Control	Intervention	Control	Intervencion	Control
C#1	Depth (cm)	< 35	<10	> 35 - < 45	>10 - <30	> 45	> 30
	pH	7,12	6,93	7,07	6,95	6,61	6,30
	Temperature (ºC)	27	26,7	27	26,4	26,3	26,6
C#3	Depth (cm)						
	pH	7,19					
	Temperature (ºC)	26,4					
C#4	Depth (cm)	< 20	< 35	>20 -< 50	> 35	>50	

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pH	6,22	5,77	5,43	5,44	4,74	
Temperature (ºC)	26,5	27,5	27,2	26,8	27,2	

Table 13.

Organic Mater Content

		Intervention	Control	Intervention	Control	Intervencion	Control
C#1	Depth (cm)	< 35	<10	> 35 - < 45	>10 - <30	> 45	> 30
	Organic Mater Content (%)	9, 59	7,61	2,71	3,95	3,93	3,33
C#3	Depth (cm)						
	Organic Mater Content (%)	7,90					
C#4	Depth (cm)	< 20	< 35	>20 -< 50	> 35	>50	
	Organic Mater Content (%)	4,93	7,69	9,58	8,37	10,29	

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

Table 14.

Current state of working area

	CS#1	CS#2	CS#3	CS#4	CS#5
Stability	AE	AE	UP	AE	AE
Durability	AE	AE	UP	AE	AE
Ageing	AE	AE	UP	AE	AE
Deterioration	NSF	NSF	SF	NSF	NSF
State of “Flexible construction evolution”			NO	ODC	

AE: As expected; NSF: No signs of failure; UP: undesirable problem; SF: Signs of failure; NO: Not observed; ODC: Observed during completion

COMPARISON WITH REFERENCE SCENARIOS

PRE-RESTORED SCENARIO:

No data

TARGETED SCENARIO (END-POINT SCENARIO):

No data – it was not predefined

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LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

Table 15.

Information regarding the bioengineering work monitoring and maintenance tasks carried out

	CS#1	CS#2	CS#3	CS#4	CS#5
Are the plant species well adapted to the site conditions?	Y	Y	Y	Y	Y
Were the seeds used for the hydroseeding appropriately selected?	n/d	Y	n/d	Y	n/d
Problems related to the lack or abundance of water	N	N	N	N	n/d
Problems related to an excessive plant density	n/d	N	N	N	n/d
Problems related to soil fertility	N	N	N	N	n/d
Problems related to slope aspect/angle/topography	N	N	n/d	N	n/d
Problems with availability and adequacy of workforce with relevant qualifications	N	N	Y[2)]	N	n/d
Problems with access to the work site	N	N	N	N	n/d
Problems with health/safety (e.g. invasive species)	Y[1)]	N	N	N	n/d
Problems related to a maintenance contract failure	N	N	n/d	N	n/d
Problems related to a missing maintenance contract	N	N	n/d	N	n/d
Engineering/stability performance of the works	VG	VG	VB	VG	n/d
Sustainability performance of the works	VG	VG	VB	VG	n/d

Y: Yes; N: No; n/d: No data; VG: Very good; VB: Very bad

[1)] Dominance of *Arundo donax*

[2)] Problems related to the lack of knowledge of the contractor

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Table 16.

Qualitative evolution of intervention success

	CS#1	CS#2	CS#3	CS#4	CS#5
Very successful evolution of the work (all the main objectives were					

achieved) during 1 to 2 or 3 years after its completion					
The successful evolution of the work (all the main objectives were achieved) after more than 5 years after its completion					
Acceptable evolution and results (the main objectives were partially achieved) after more than 5 years after its completion					
Long-term failure (after more than 5 years after its completion): slope failure, erosion problems, etc.					
Short-term failure (within 2 or 3 years after its completion): slope failure, erosion problems, etc.					

C#1 Five years after its implementation, a post-opera evaluation shows us extremely positive results, which guarantee that the objectives initially proposed were achieved, since the river bank is stabilized and riparian gallery was restored. At an environmental level, the vegetal structure developed so far, allowed the diminution of the noise levels emitted by the factory existent on the opposite streambank.

C#2 The project was designed to meet the safety and stability of the slope, since the main objective was to stabilize the soil below the national road that has heavy traffic. Both aesthetic and environmental goals were simultaneously accomplished, since the chosen technique has a low environmental impact and easily integrates with nature. In addition, the work was economically viable compared to traditional engineering solutions, such as a concrete wall, gabions, etc. Functional criteria related to the surface flow and drainage of the water from the road were also used, as well as the infiltration of rainwater since the structure is permeable. To sum up, all objectives related to the technical criteria of safety, stability, costs, functionality, ecological and environmental have been achieved. The proposed solution worked exactly as expected.

C#3 Several errors were done during the conceptual and installation phase. Mainly, those problems were related to the inadequate solution adopted to the filling of the gaps between the Cribwall logs (it should have been done with organic mates, live fascines or rocks and cuttings) and lack of technical knowledge of the contractor. Besides that, there was a poor oversight of the construction works that was responsibility of the owner/design team.

Errors:

poor filling of the live slope grating, insufficient fixation of the turf reinforcement mat, live brush mattress with few live stakes/branches of salix and a bank pile wall that is not supporting any soil as it is his function.

C#4 All objectives related to the technical criteria of safety, stability, cost, functionality, ecological and environmental have been achieved. The implementation of techniques of Ecoengineering was fundamental for the adequate protection, stabilization and renaturalization of water courses. The main technical functions obtained with these interventions were the deep stabilization through the root system of the plants; soil surface protection (precipitation, surface water and ice); soil drainage; reduction of water velocity along the banks; increased superficial and deep soil cohesion.

The main ecological functions were the restoration of the riparian forest with increase of the floristic and faunistic biodiversity; protection against air pollution and noise reduction; shading and control of invasive plants; improvement of nutritional conditions and, consequently, soil fertility.

The implementation of these techniques also has aesthetic functions: landscape integration of natural structures caused by the construction of the highway; enrichment of the landscape through the creation of new elements, structures, shapes and colors of vegetation. As these techniques evolve over the years, they are expected to continue to benefit the riparian ecosystem.

C#5 No detailed evaluation could be made because site only assessed from distance because not accessible

Complementary information about the project descriptions:
Case study #1
B. PROJECT DESCRIPTION

1. Enter a short description of the project including the number and scope of bioengineering works, history and completion date, site conditions/context, and community. (max. 250 words; include a map/photo if possible):

This project consisted in the use of soil bioengineering techniques to achieve some key objectives in a low energy water course, and the main objective was to stabilize the river bank, which was quite degraded by erosion causing soil instability, as well to recover the riparian vegetation that was inexistent, using live materials. The first phase of the project consisted in removing and cleaning all the invasive vegetation that dominated the local, as well as the subsequent regularization of the embankment, eliminating the existing gullies. The technique of rip rap was applied to protect the base of the slope that was already being excavated by the erosive action of the water, and that compromised the stability of the entire river bank. Apart from the rip rap, a live slope grating was constructed, which allowed to ensure an effect of armature to the riverbank, guaranteeing in the initial phase the stability of the slope. In order to promote the establishment of the riparian gallery, some other soil bioengineering techniques were applied (live stakes, plantations, transplants and hydroseeding), which complemented the live slope grating.This project was constructed in April 2007 and took about 7 days to be completed.

2. Enter a description of the significant aspects of the project including a synopsis of project goals that address each of the following topics: accessibility, aesthetic, cost-effective, functionality, historic preservation, productive, restoration, secure/safe/stable, and sustainable.(max. 250 words; include a design drawing/detail/photo if possible by emailing it separately to aldo.freitas@ecosalix.pt):

The initial project consisted on the application of riprap to the full extent of the river bank. However, the developer, after learning about the Soil Bioengineering techniques, intended to change the prescribed solution. In aesthetic terms, the difference between the initial and the constructed solution is huge, with an added value to the work of Soil Bioengineering. Analyzing the total costs of intervention, the constructed work was also cheaper than initially planned. Regarding the ecological aspects, with the solution that was implemented, it was possible to reestablish the riparian gallery that was almost nonexistent, creating greater biodiversity.

Case study #2

B. PROJECT DESCRIPTION

1. Enter a short description of the project including the number and scope of bioengineering works, history and completion date, site conditions/context, and community.(max. 250 words; include a map/photo if possible):

This work is located on the National Road 16, where in the winter of 2010/2011 there was a landslide caused by the high inclination of the slope combined with an insufficient drainage at the crest of the slope. The excess of water caused the slide of a considerable volume of earth, putting in question the stability of the road located above it. The stabilization solution adopted consisted in a combination of two vegetated reinforced earth walls, complemented with a hydroseeding. On the first 5,40 meters, the reinforced geogrids were spaced 0.60 m with a slope of about 65 °. Above that, a second reinforced earth was constructed with the reinforced geogrids spaced 1m, having a 40° slope. After that, the front face of the reinforced wall was hydroseeded. This work started in September 2011 and ended in November 2011.

2. Enter a description of the significant aspects of the project including a synopsis of project goals that address each of the following topics: accessibility, aesthetic, cost-effective, functionality, historic preservation, productive, restoration, secure/safe/stable, and sustainable.(max. 250 words; include a design drawing/detail/photo if possible by emailing it separately to aldo.freitas@ecosalix.pt):

The project was designed to meet the safety and stability of the slope, since the main objective was to stabilize the soil below the national road that has heavy traffic. Both aesthetic and environmental goals were simultaneously accomplished, since the chosen technique has a low environmental impact and easily integrates with nature. In addition, the work is economically viable compared to traditional engineering solutions, such as a concrete wall, gabions, etc. Functional criteria related to the surface flow and drainage of the water from the road were also used, as well as the infiltration of rainwater since the structure is permeable.

Case study #5
B. PROJECT DESCRIPTION

1. Enter a short description of the project including the number and scope of bioengineering works, history and completion date, site conditions/context, and community. (max. 250 words; include a map/photo if possible):

The dunes of Cresmina-Guincho are a small part of the Guincho-Oitavos dune complex located in the Natural Park of Sintra-Cascais.

This dune system is very particular because the sand coming from the Guincho and Cresmina beaches returns to the sea more to the south (between the Oitavos and Guia) after migrating on the flat rocky platform of Cabo Raso. This system is called the Cresmina-Oitavos dune wind corridor.

This project took place through 2010 and 2011 and it was promoted by the Environmental Agency of the Municipality of Cascais.

For the recovery of the dune cord and establishment of the Habitat management actions, have been developed some measures, such as limiting access to the area of intervention through fencing, species eradication (e.g., *Acacia* spp., *Carpobrotus edulis*), biophysical structures built by dry rods of willow and installed in the embryonic and primary dunes in bands parallel to each other with a distance between 9-12 m lines perpendicular to the prevailing wind direction, planting of dune species (e.g., *Ammophila arenaria* ssp. *australis*, *Lotus creticus*) in front of the system and in the fixed dune. It was also created an elevated wooden walkway with access to the beach and connection to a nucleus of interpretation that allows to support to the visitors.

2. Enter a description of the significant aspects of the project including a synopsis of project goals that address each of the following topics: accessibility, aesthetic, cost-effective, functionality, historic preservation,

productive, restoration, secure/safe/stable, and sustainable.(max. 250 words; include a design drawing/detail/photo if possible by emailing it separately to aldo.freitas@ecosalix.pt):

The Cresmina-Guincho dune system, due to its natural values and biophysical and dynamic characteristics, requires specific protection and recovery measures. The management measures for the Cresmina - Guincho dune aim to control essentially the impacts on the system, namely by conditioning the access of people and vehicles to the site by limiting the visitor paths, either through the installation of a closed circuit of raised wooden walkways, or through fencing placed at the place of intervention.

Active site management is sought through concrete habitat management actions where the main objective is to stabilize the dune cord.

CASE STUDIES. SPAIN

CASE STUDY - FLUVIAL

RIVER BAZTAN CONSTRUCTION SITE REPORT

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Worklocation / projecttitle:

Fluvial restoration by means of bioengineering techniques in the Cantabrian basin within the European project InterregPoctefa H2O Gurea-Baztan framework

UTM coordinates:

UTM coordinates: 30T X: 616073, Y: 4777225

Completion date of thedesignstage:

August 2017

Completion date of theconstructionstage:

In progress (in oct 2018)

Client: (e.g. privateorpublic personor industrial company):

Gobierno de Navarra (Navarra Govern). The project is framed in the European project IterregPoctefa H20 Gurea-Ría baztán-Arraioz.

SUMMARY

The area is affected by both high discharge events and rapid draw-down scenarios.

Different water bioengineering techniques were implemented for both stabilising the riverbanks and controlling the riverflow erosion.

ECOMED - *Ecoengineering in the Mediterranean Environment*

RIVER BAZTAN CONSTRUCTION SITE REPORT

Authors: Paola Sangalli and Guillermo Tardio

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title: ***Fluvial restoration by means of bioengineering techniques in the Cantabrian basin within the European project InterregPoctefa H2O Gurea-Baztan framework***

UTM coordinates: 30T X: 616073, Y: 4777225

Completion date of the design stage: August 2017

Completion date of the construction stage: In progress

Client: (e.g. private or public person or industrial company): Gobierno de Navarra (Navarra Govern). The project is framed in the European project IterregPoctefa H20 Gurea-Ría baztán-Arraioz.

Decision criteria for this type of construction: (e.g. ecological restoration; prevention; erosion control; landslide to restore; etc.)

Erosion control, slope stabilization, fluvial restoration

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

The area is affected by both high discharge events and rapid draw-down scenarios.

The study area is affected by convective rain events during the summer season. In these events, high intensity rains take place in the intervention area.

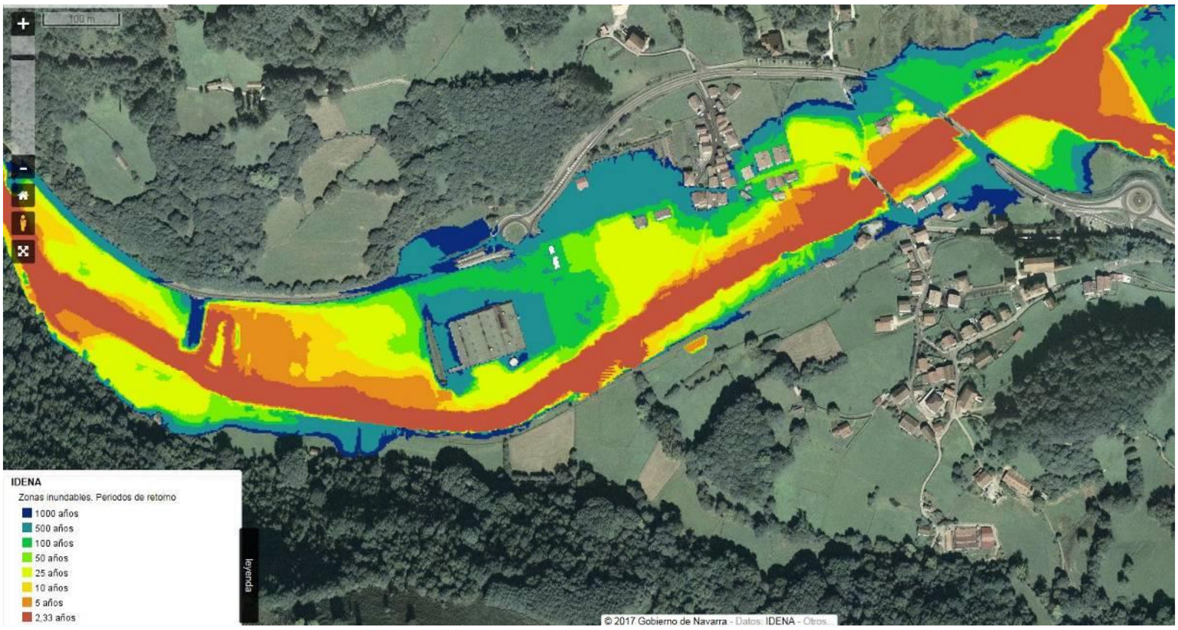
A hydrological preliminary analysis was carried out in order to detect the frequency of the flash-floods events within the intervention area.

By analyzing the historical discharge ad precipitation data series, the following features were detected:

- The high discharge events frequency is increasing
- The annual average discharge value has increased in the last 10 years

The concentration times of the river flows (the tributaries) connected to the intervention area are low. The combination of high rain fall events and low concentration values explains the occurrence of flash floods. This explains the high flood risk present in the intervention area.

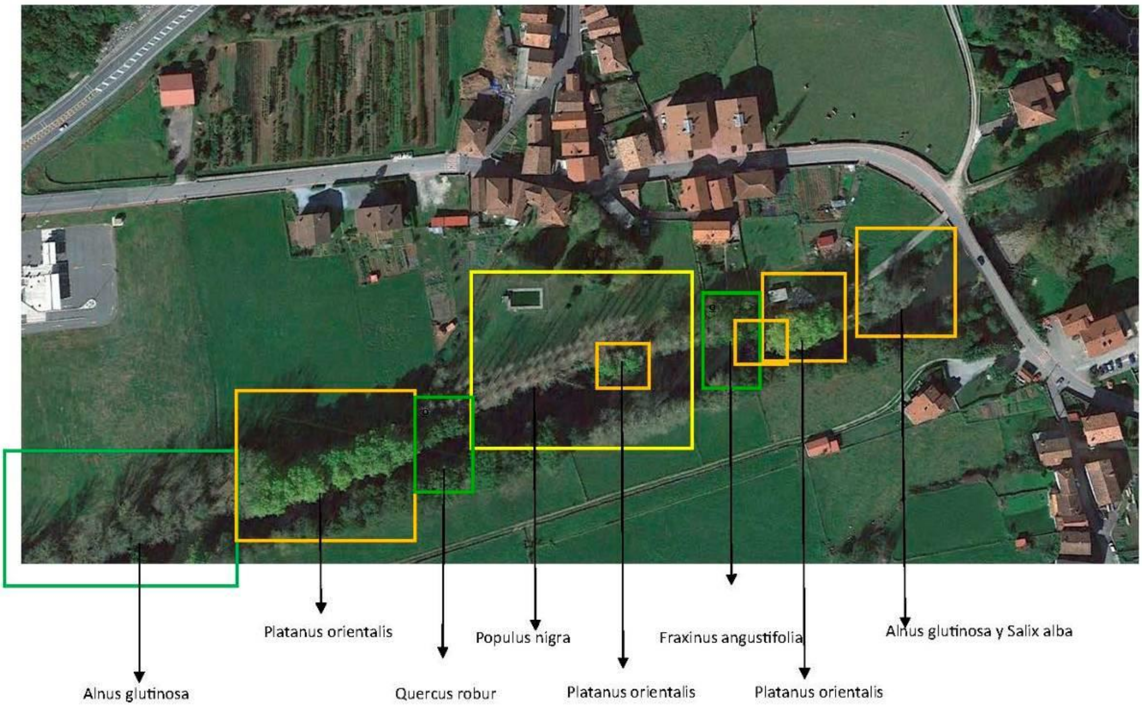
The flooded areas for different return periods are shown in the following figure:



Source: SCIA and Navarra Govern

The potential vegetation analysis was carried out for defining the plant species to be used within the project.

The existing vegetation was analyzed. This s shown in the following figure:



Source: SCIA and Navarra Govern

There are two environmental protection figures in the intervention area:

- LIC Belate (ES2200018)
- ZEC ES2200023 "RÍO BAZTAN Y REGATA ARTESIAGA"

The cadastral information of the study area was also attained.

The surrounding landscape was also analyzed.

The presence of many cross barriers (dams) is breaking the sediment transport equilibrium. The retention of sediments behind these structures increases the erosive capacity of the river flows.

The results of the analysis of the average daily discharge value hger than 90 m3/s is shown in a tabulated way:

Decade	Frequency of average daily discharge value higher than 90 m^3/s
1985-1995	5 times
1995-2005	1 time

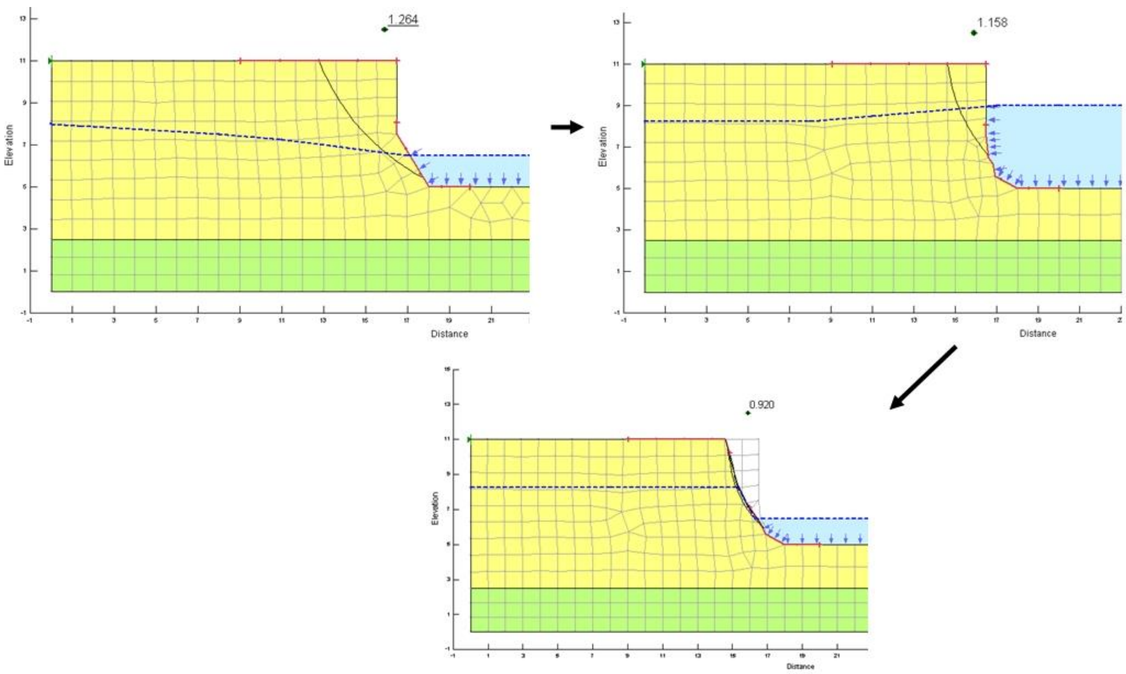
2005-2015	10 times

The variation of the annual average of the average daily discharge value is shown in the following table:

AVARAGE ANUAL VALUE OF THE AVARAGE DAILY DISCHARGE (m^3/s)	DECADE
5.42	1985-1995
4.92	1995-2005
5.69	2005-2015

It is concluded than high discharge scenarios are getting higher frequencies.

The combination of high intensity rains with short duration and long and soft rainfall scenarios generates critical situation in the study area. The latter saturates the soils while the former produces toe slope soil losses. The combination of the preceding two features triggers the massive slope failures existing in the intervention area.



Typical evolution of a fluvial slope during a rapid draw down

In the following images, the current state of the study area is shown:

Source: Paola Sangalli

The position of the vegetation clearly shows the original shoreline location.

The preceding photographs reflect the before mentioned phenomena.

Conclusions at this stage of analysis:

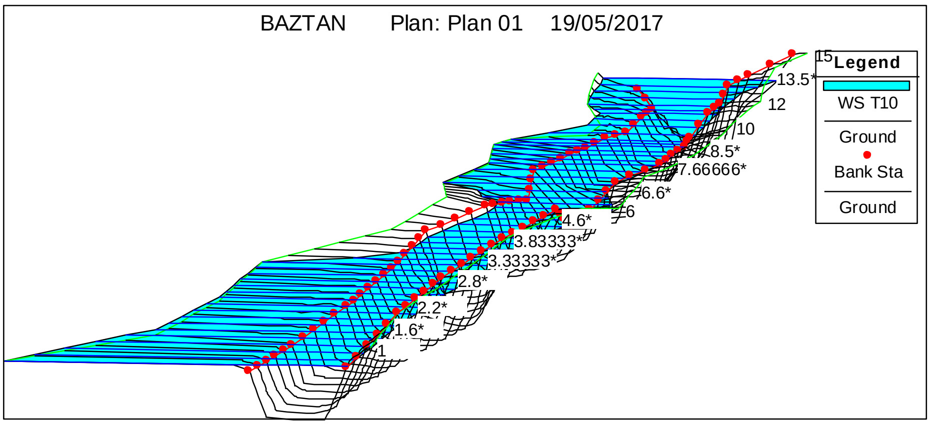
- There are frequent flash floods in the study area as a consequence of the combination of high intensity precipitations, with torrential characteristics, and low concentration times of the river flows.
- The high discharge scenarios in the study area are more frequent than in the past
- The combination of high intensity rains with short duration and long and soft rainfall scenarios generates critical situation in the study area.
- The erosive capacity of the river flow is high

- The hydraulic cross sectional area is not enough for conveying the flash flood discharge values.
- There is not a well developed riparian vegetation buffer
- The area is affected by a high rate riparian soil losses
- There are slope instability scenarios due to fluvial slope erosion phenomena

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

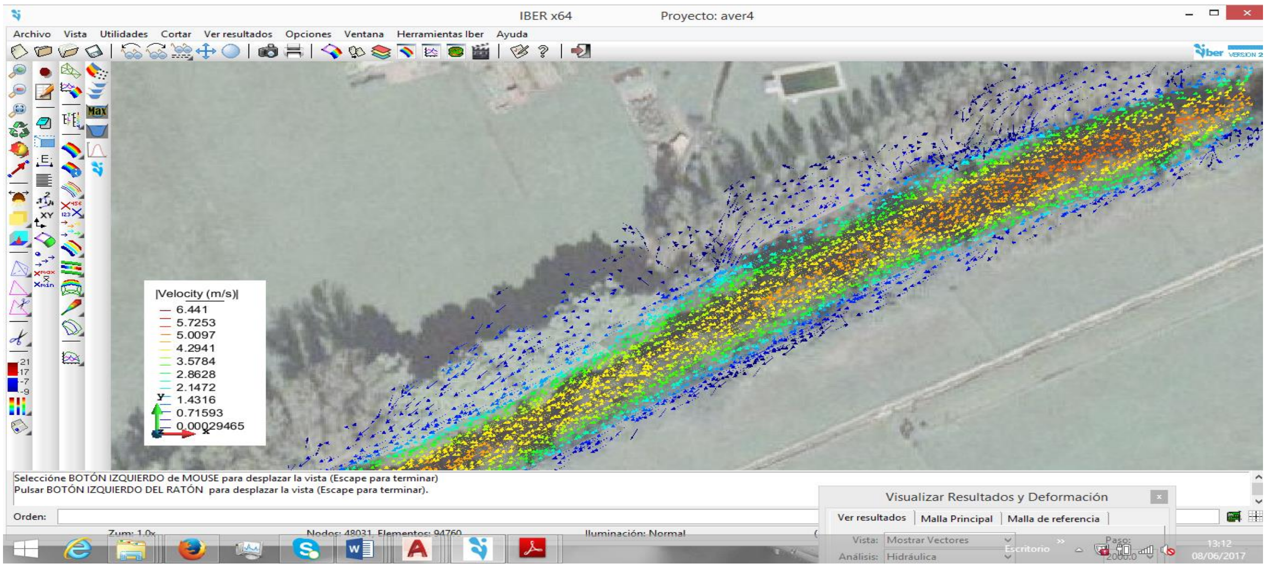
Both an unidimensional and a bidimensional hydraulic simulation were performed.

The results of the unidimensional simulation are shown in the following figure:



Source: SCIA and Navarra Govern

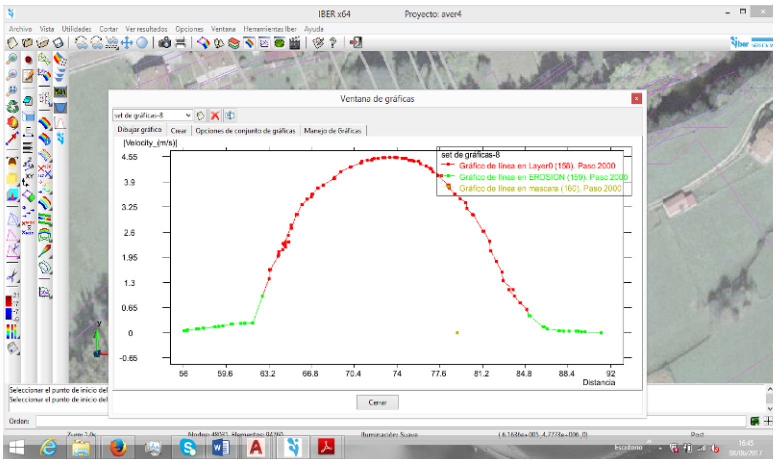
The results obtained from the bidimensional hydraulic simulation is shown in the following figure:



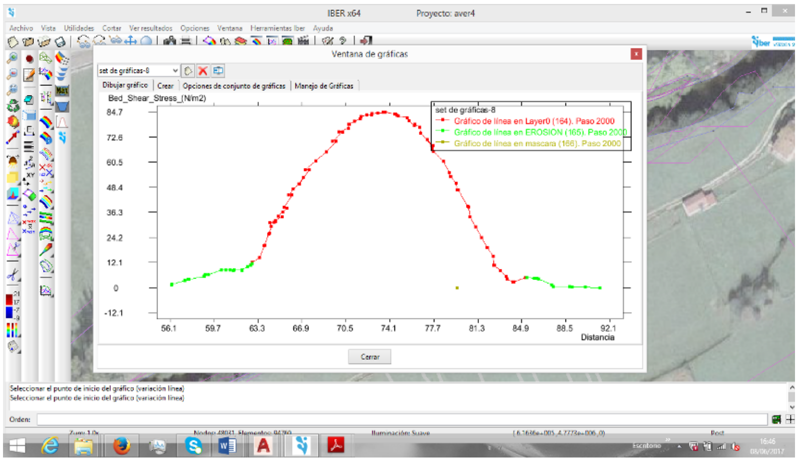
Source: SCIA and Navarra Govern

From the preceding simulations both the velocity and boundary shear stress values were obtained. By using these data, the critical areas were defined. The return period used for the intervention design was the 10 year return period.

Examples of plots showing the variation of velocity and bed shear stress along an axis perpendicular to the shoreline:



Velocity (m/s)



Bed shear stress (N/mm²)

The strategy followed within the project was the following:

- It is necessary to increase the riparian soil strength.
- It is necessary to protect the fluvial slope toes.
- It is necessary to support the riparian vegetation development. Recovery of the riparian vegetation functions.
- Substitution of the exotic species by local native plant species.
- Increase, where possible, the hydraulic cross sectional area.

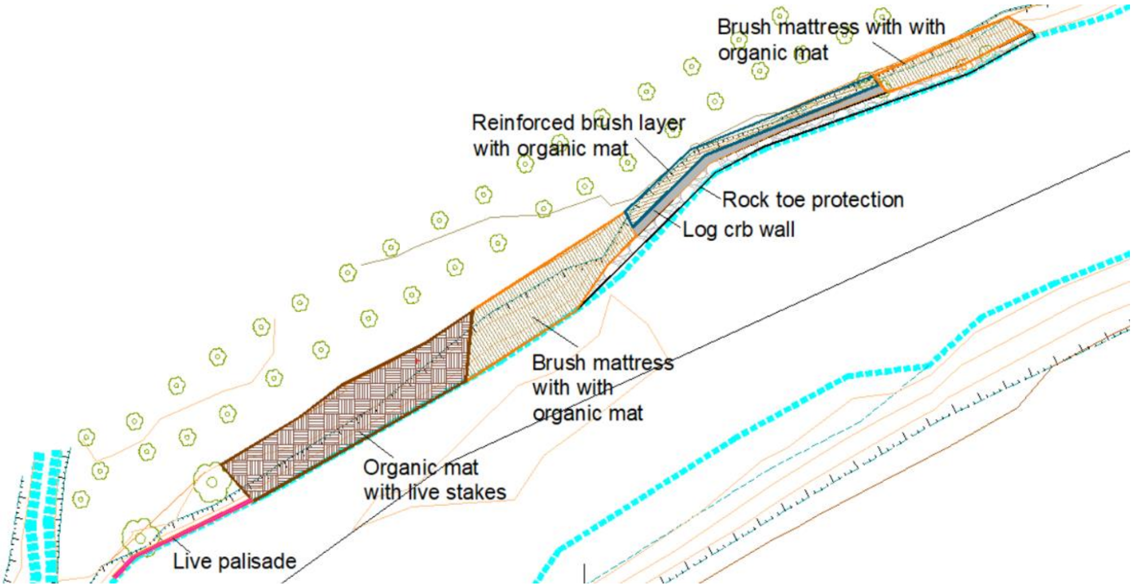
The soil and water bioengineering techniques selected for the intervention area were the following:

Vegetated log crib wall, brush mattress, live rock toe, live palisade, brush layers reinforced with organic mat, live stakes.

The following elements were designed:

- Rock size of the rock toe protection.
- Wooden elements diameters for both the crib walls and the palisades.
- Ramming depth of the vertical elements of the palisade.
- Distance between the headers of the log crib wall.
- Distance between the wooden vertical elements.
- Distance between the brush layer levels.

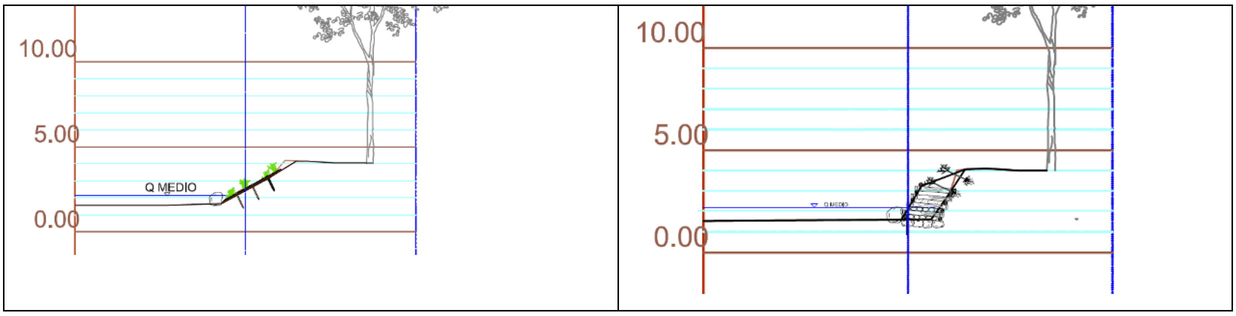
The localization of the different techniques is shown in the following figure:



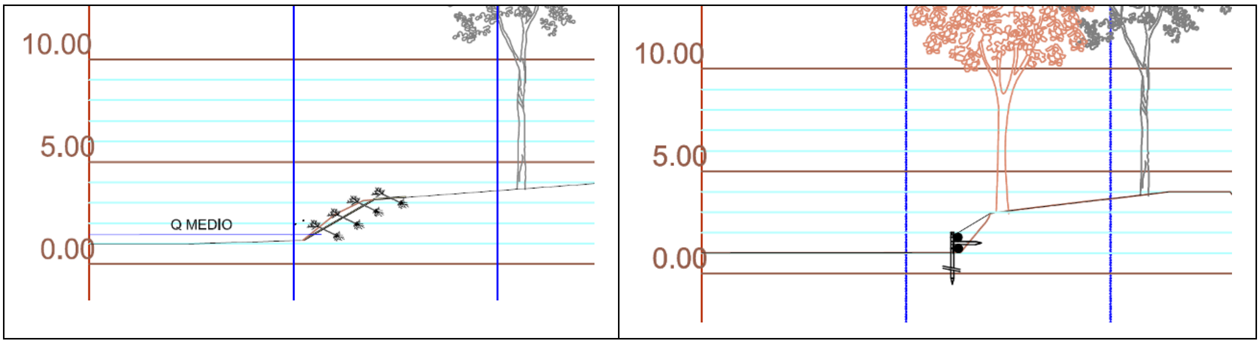
Source: SCIA and Navarra Govern

The different techniques were placed attending to the velocity and boundary shear stress values present in each location. The rigidity of each technique (its critical velocity and its critical bed shear stress value) was the criterion used for its selection.

In the following figures, some cross sectional views are presented:

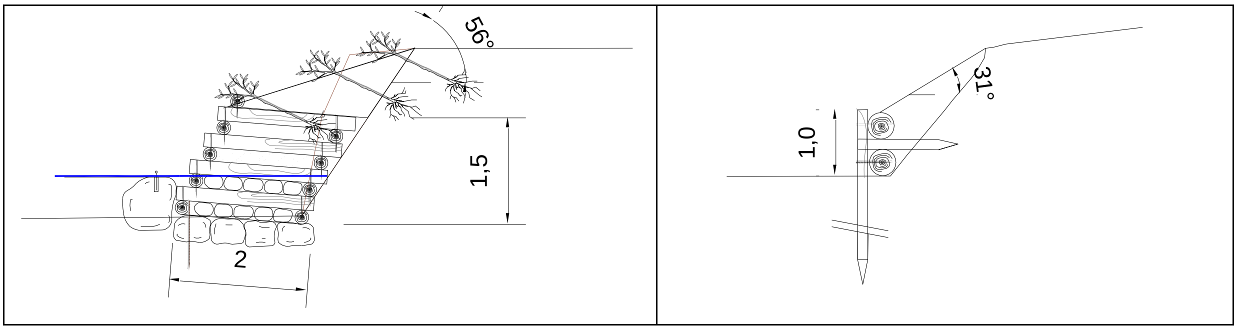


Source: SCIA and Navarra Govern



Source: SCIA and Navarra Govern

The log crib wall and the live palisade were calculated according to traditional timber structures design manuals.



Source: SCIA and Navarra Govern

The summary of the obtained results is shown in the following table:

The diameter of the rocks to be used for the rock slope toe protection is 0,5 m.

The distance between the different brush layer levels was taken according to the following table:

Slope (H:V)	Distance between the brush layers (m)
From 1,5:1 to 2:1	0,9 a 1,2
From 2:1 to 2,5:1	
From 2,5:1 to 3:1	1,2 a 1,5

Log crib wall

Height (m)	1,5 m
Base length (m)	2,0 m
Log diameter (m)	0,2 m

Palisade

Palisade heigh (m)	1,0 m
Diameter of the horizontal diameter (m)	0,1 m
Diameter of the vertical elements (m)	0,2 m
Distance between the vertical elements	0,5 m
Ramming depth (m)	1,7 m

Please indicate your main conclusions after the analysis of the bioengineering work at the design stage:

There is a good correlation between the proposed solutions and the diagnosis of the study area problems.

The preliminary analyses allowed and supported the detection of the problems present in the intervention area.

The localization of the proposed works is defined according to the minimum intervention principle.

The necessary initial rigidity is ensured. The development of the used living material will reinforce the bioengineered fluvial slopes as time progresses.

The natural evolution of native riparian plant species is fostered and supported by following the local phytosociological series of the study area.

Co-funded by the
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INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions of the bioengineering work performance analysis.

Co-funded by the Erasmus+ Programme of the European Union

LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

In the following pictures, the end of construction stage is showed:

Source: Paola Sangalli and Maria Elduayen

Brush mattress with organic mat and rock toe protection. Live log crib wall can be seen in the photograph background

Source: Paola Sangalli and Maria Elduayen

Organic mat and live poles

Source: Paola Sangalli and Maria Elduayen

Live palisade

General issues, problems and defects.

- Problems/defects/issues recorded during the construction stage (information retrieved from the construction company).

The elapsed time between the project stage and the beginning of the works was too long. Because of this, there were changes in the topography of the intervention area. New erosion processes changed the initial situation included in the project. This situation forced a re-adaptation of the initial solutions included in the project.

Issues related to construction features:

- Were there plantation techniques used to better attain and/or preserve soil humidity? (e.g. tree pit formation, mulching, etc.). No

- Was there any mycorrhizae used in the utilised plants? No
- Were there any changes in terms of the plant species used in comparison with those included at the design stage? No
- Were the utilised plants regionally distintive/characteristic of the intervention area? Yes, the potential vegetation analysis was used to define the plan species selection throughout the project.
- Were there any quality control for the materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed? Yes, National standards were used.
- Information regarding quality control for the inert materials (grey materials). Related normative (standard).
- Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard). National standards were used.
- Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard). No

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

Please, include here the main conclusions of your analysis at this stage.

Which improvements would you propose for the analysed bioengineering work at the construction stage?

Care should be taken regarding the elapsed time period between the design stage and the beginning of the construction stage. This is especially important in scenarios with high erosion rates.

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LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Given that the work is at its end of construction stage, maintenace actions have not been applied yet.

Both a maintenance plan and monitoring actions are being arranged.

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

Although the work is just at its end of construction stage, the work has already faced some intense rainfall events. The response of the work has been adequate.

So far, the achieved functions are: hydrologic and hydraulic functions, erosion control and, geotechnical functions. Over time, other functions such as the landscape and ecological functions will be achieved.

A monitoring plan is being prepared for assessing the evolution of the soil bioengineering work.

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Only preliminary and scarce results are available and therefore, no conclusions can be reached yet about the over soil bioengineering work performance.

Soil losses have been considerably reduced. Riverbanks stability are improved.

As it was detected in the hydrological analysis of the project, the frequency and peak discharge values is being increased. This trend could be partially explained by the effects of the Climate Change in the intervention area.

The project was done by a technical team with expertise in soil and water bioengineering. This was reflected not only in the techniques selection, design and localization but also throughout the construction supervision works.

Co-funded by the Erasmus+ Programme of the European Union

CASE STUDY - FLUVIAL

ARTIA CHANNEL CONSTRUCTION SITE REPORT

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Worklocation / Project title:
Artia cannel renaturalization woks

UTM coordinates:
Stage 1 of the project:

From X: 599120, Y: 4799150 to X: 599150, Y: 4799265

Stage 2 of the project:

From X: 599152, Y: 4799268 to X: 599174, Y: 4799111

Completion date of the design stage:
Project stage 1: October 2002; project stage 2: may 2003

Completion date of theconstruction stage:
Work stage 1: 2003; work stage 2: 2004

Client: (e.g. privateorpublicpersonor industrial company):
Govern of the Basque Country

SUMMARY

The Artia channel renaturalization project was one of the first soil and water bioengineering project done in the Basque Country and in Spain.

The Artia creek was channelized to prevent the frequent floods that were affecting the nearby neighborhoods.

ECOMED - ECOENGINEERING IN THE MEDITERRANEAN ENVIRONMENT

ARTIA CHANNEL CASE STUDY

Authors: Guillermo Tardio and Paola Sangalli

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Project title: The Artia channel renaturalization works

Work location: Irún, Spain

UTM coordinates:

Stage 1 of the project:

From X: 599120, Y: 4799150 to X: 599150, Y: 4799265

Stage 2 of the project:

From X: 599152, Y: 4799268 to X: 599174, Y: 4799111

Artia channel case study area

Completion date of the design stage: project stage 1: October 2002; project stage 2: may 2003.

Completion date of the construction stage: work stage 1: 2003; work stage 2: 2004

Client: Govern of the Basque Country.

The project was done and executed by the company Eulen and, external collaborators.

Co-funded by the Erasmus+ Programme of the European Union

Decision criteria for this type of construction: (e.g. ecological restoration; prevention; erosion control; landslide to restore; etc.): ecological restoration, floods control.

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

Introduction:

The Artia channel renaturalization project was one of the first soil and water bioengineering project done in the Basque Country and in Spain.

The pre-operational scenario is a channelized creek (the Artia creek) with a trapezoidal cross-sectional shape made of concrete. The river dimensions are not functional. There is no connection between the floodplains (no lateral connection) and there is no vertical connexion either (the riverbed made of concrete). The longitudinal dimension is also much altered. There are no natural transport dynamics and the hydrodynamic of the Artia creek is not functional.

The Artia creek was channelized to prevent the frequent floods that were affecting the nearby neighbourhoods. The work was done after the Spanish Civil War. As it can be seen in the following picture, in the pre-operational scenario, there was no vegetation and the ecological state of the intervention area is much degraded.

Pre-operational situation. The channel is formed by a trapezoidal cross section made of concrete

Taking advantage of the fact that a new urban development was being built on the site, the demolition of the old channel and the construction of a renaturalized creek using Soil and Water Bioengineering techniques were considered.

Climatic aspects (rainfall, temperature, potential evapotranspiration, exposure, aspect) the mean annual precipitation is 1800 mm, the mean annual temperature is 14.31º

- Soil physical aspects (grading, density, water regime): sands and limes
- Soil chemical aspects (pH, conductivity, nutrients, organic matter, exchange capacity, acid toxicity) no soil laboratory tests were carried out
- Soil engineering aspects (strength, permeability, aggregate stability): density: 1.7 t/m^3, angle of internal friction: 20º, cohesion: 0.8 t/m^2.

- **Native vegetation analysis**: no vegetation were present in the intervention area
- **Landscape features:** a straight channel is the main feature of the pre-operational landscape.
- **Problems**, risks and hazards that were addressed by the project: **flood risks**
- **Hydraulic/hydrographic analysis** including flooding risk assessment: hydraulic simulations of both the pre- and post-operational scenarios were carried out.

  The average slope is 0.54%

  Discharge of the 500 year return period = 76 m^3/s. The hydraulic simulations were also carried out using other discharge values (70, 60 and 50 m^3/s).
- **Cadastral data, parcel ownership**. The intervention area is owned by the State. Hydraulic public domain
- **Existing information in Regulatory Agencies** (e.g. sustainability initiatives, resilience initiatives). The topographical information was given by the Irun Council Topographical Services. The project followed both the Basque Country and Central State regulatory frameworks.

Description of the project:

The project consists of the demolition of the concrete channel and the construction of the new renaturalized creek using soil and water bioengineering techniques The right bank concrete wall could not be demolished because it is supporting a nearby sidewalk. For this reason, the channel was moved to the left, giving it greater width In this case, earth fills were performed in order to soften the riverbank geometry.

To allow the people of the new urban area to see and reach the river, in several parts mattress type gabions were used, that prevent the growth of the vegetation

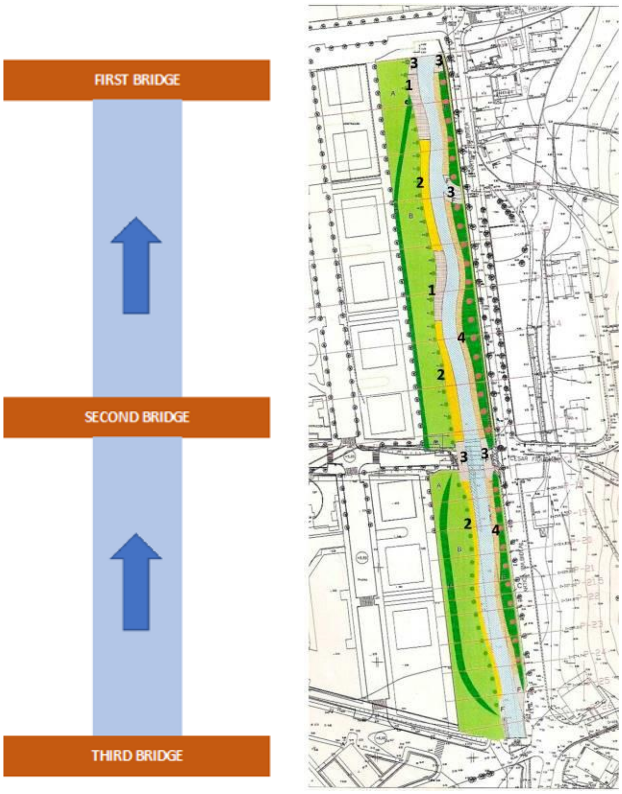
The project included the following actions:

- Elimination of the left hand side concrete wall.
- Demolition of the river bed concrete
- Construction of wider banks. Grading the slopes. Softening the creek fluvial slopes
- The utilization of soil and water bioengineering techniques to construct the banks. Right banks with double log crib walls (with live branches of *Salix atrocinerea* and *Salix alba*), vegetated rock walls (with *Tamarix gallica* and *Salix*

sp live branches). Left bank with brush mattresses (with *Tamarix gallica* live branches and *Salix* sp live stakes), and gabion mattress (with hydroseedling or *Phragmites* sp transplantation).

- Tree plantation along the river banks (*Fraxinus excelsior*, *Alnus glutinosa* and *Acer platanoides*).
- Plantation of shrubs (*Hedera helix*, *Coryllus avellana*, *Cornus sanguinea* and *Eounymus europaeus*).
- The living material used was: *Tamarix gallica* live stakes, *Salix* sp live branches,

The distribution of the soil and water bioengineering techniques is the following (see image below):



Between first and second bridge:

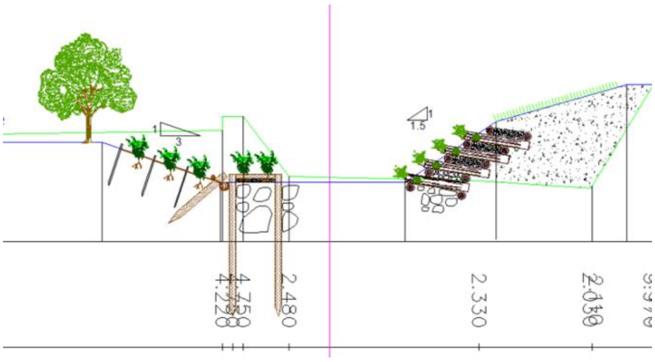
Left riverbank: 3-vegetated rock wall, 1 gabion mattress 2 brush mattress

Right riverbank: 3 vegetated rock wall, , 4 double log crib wall

Between the second and third bridges:

Left riverbank: 2 brush mattress, 3-vegetated rock wall

Right riverbank:4 double log crib wall,3 vegetated rock wall



Example of a project cross sectional view (a brush mattress on the left riverbank and a double crib wall on the right riverbank)

Between the first and the second bridges there is sea tidal influence. The potential vegetation in the upper half of this reach is dominated by marsh vegetation being the *Tamarix* sp the principal tree species withthin the transtition between the areas with and without sea tidal influence.

The diameter of the logs used in the log crib walls was 30 cm. The height of the double crib wall was 1.5 m. The first log row was buried into the ground. The log crib wall face has a 1.5H:1V slope.

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

At the design stage, the following variables were calculated:

The maximum shear boundary stress was lower than 100 N/m^2.

Rock size was calculated for both the fluvial slope and the riverbed positions. The methods used for each case are the following:

Rock size over the fluvial slope: Hallmarte method, Pilarczyk formula, Maynord formula.

Rock size at the riverbed: RIP-RAP software.

Both the grain size curve and the rock wall thickness were also calculated.

The following parameters were not calculated at the design stage:

The diameter of the soil and water bioengineering wooden elements were not calculated.

The ramming depths of the vertical elements were not calculated either.

- Was a phytosociological approach used in both the plant species selection process and the intervention strategy? The plant selection was done following the phytosociological approach. The potential vegetation of the is the *Alno-Padion, Alnion incanae, Salicion albae* (European Habitat 91R0)
- Are there clear criteria for the project strategy implementation? yes, the soil and water bioengineering approach is well reflected in the project.
- Are there clear criteria for the bioengineering techniques selections? Althouhg the localization of the bioengineering techniques is right, there are not explanations or justifications about it. The techniques choosen were oversized.
- Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear? There were neither structural nor geotechnical calculations included in the project. The only calculations are related to the rock wall size definition and the hydraulic parameters (velocities and shear stress)
- Functional requirements of vegetation (select all that apply to the project):
    - Soil reinforcement and enhancement of soil strength
    - Surface protection against wind/water erosion
    - Bank and channel reinforcement
    - Shelter or screening
- Which **improvements** would you propose, at the design stage, regarding:
    - Plant selection: *Tamarix* sp. was proposed to be used in all the log crib walls regardless sea tidal influence. The use of *Tamarix* sp. live branches is adequate for the stretch under the tidal influence. Outside that influence, the *Salix* sp live branches option is more adequate.
    - Strategy implementation: more explanations about the soil and water bioengineering approach would improve the project contents.
    - Bioengineering techniques selection. A justification of both the techniques selection and the techniques localization is lacking in the project.
    - Calculations: calculation of both the log diameters and the ramming depths are lacking.
    - Plantation schemes or drawings showing the distribution of the different plant species over the intervention area would have been very useful for the construction stage. Above all because of the limited experience the companies had in the Basque Country by that time.

Please indicate your main conclusions after the analysis of the bioengineering work at the design stage:

More calculations were needed to justify the size of the proposed bioengineering structures.

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The selection of the bioengineering techniques and their distribution over the riverbanks is correct, but it seems to be oversized

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions about the bioengineering work performance analysis.

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LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

- The question to answer here is: how was the work carried out by the contractor (Construction Company) during the construction stage?

  

Double crib wall, gabion mattress and bush mattress (source: P. Sangalli)

In the following picture, the post-operational stage is shown:

The renaturalized Artia creek-after one year and after 15 years (Source P. Sangalli)

In the preceding pictures, the following features can be seen:

- The left hand side riverbank has been softened by slope grading and earth fills.
- The right hand side riverbank has a higher inclination because for the space limitation in this side of the Artia creek.
- Tree plantations along the riverbanks
- Different soil and water bioengineering techniques can be seen.

The works were developed in two stages. In the following images the first and second construction stages are shown.

First construction stage (between th first and the second bridge)

Second construction stage (between the second and the third bridge)

General issues, problems and defects.

- Please give your opinion about disturbing/destabilizing elements present between the design stage and the construction stage:
  - Insufficient budget: not applicable
  - Construction stage too short: not applicable
  - Lack of a competent (effective) supervision during the construction stage: there was a good supervision throughout the construction stage.
  - Lack of and effective monitoring stage after the construction stage: Machinery utilized in the work: the machinery was adequate.
- Please, indicate the construction standards used in the work: National construction standards.

Issues related to construction features:

- Were there any plantation techniques used to better attain and/or preserve soil humidity? (e.g. tree pit formation, mulching, etc.). Not applicable
- Was there any mycorrhizae used in the utilised plants? No
- Were there any changes in terms of the plant species used in comparison with those included at the design stage? If so, how those changes were justified? There were some changes in the initial plantation planning
- Were the utilised plants regionally distinctive/characteristic of the intervention area? YES, potential vegetation plant species were utilised.
- Were there any quality control for the materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed? No
- Information regarding quality control for the inert materials (grey materials). Related normative (standard). Control as indicated in the project
- Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard). Both the NTJ standards (Spanish National recommendations) and Italian Technical Specifications were used.
- Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard).No. The herbaceous species seeding rate was of 50 g / m2
- Bad connections/junctions between the logs, No
- Bad lateral connection of the work edges with the slope, No
- Insufficient or missing soil compaction No
- Adverse climate conditions No
- Other (detail)…NO.

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

Please, include here the main conclusions of your analysis at this stage.

Which improvements would you propose for the analysed bioengineering work at the construction stage?

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The live stakes were not classified per plant species. This explains the inverse distribution of riparian plant species in some stretches of the Artia creek. For instance, one can find the *Fraxinus excelsior* right by the river and the *Salix* sp in a further position form the river.

The work force lack of experience in soil and water bioengineering works was another limitation of the construction stage.

Ensuring that the work force is well trained in the construction of soil and water bioengineering techniques is a crucial factor for an adequate development of the construction stage. By including a course before the beginning of the construction stage a minimum training level of the workforce would be ensured.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Please, provide information regarding the bioengineering work monitoring and maintenance tasks carried out.

- Was there a maintenance contract? *Yes, there were schedule maintenance tasks in two different time milestones: 5 years after the construction stage and 8 years after the construction stage.*
- Comparison between specification/design and 'as built' measure. *The construction company carried out the intervention according to the project.* Information on any maintenance work during monitoring phase. If applicable, conduct a characterisation of the maintenance tasks in terms of their performance and suitability. *The straight trunk of the Salix sp. trees clearly shows that there were maintenance tasks. There was a monitoring after the construction stage, it was visited in several times during the first 5 years and the vegetation was maintained by thinning.*

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

IN SITU FIELD WORK VARIABLES SELECTION

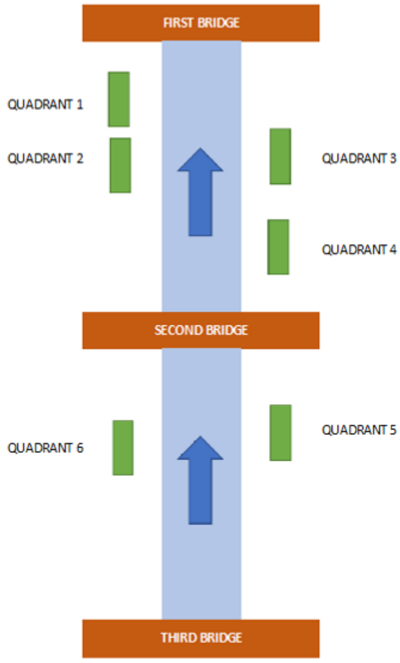
For the field work, a set of rectangular quadrants (plots) were defined. All the quadrants had 10 meters length and a width corresponding to the riparian buffer width.

For the definition and distribution of the quadrants over the study area, the following criteria were followed:

- The different soil and water bioengineering techniques used in the intervention area
- The presence or not of the sea tidal influence.
- The presence or absence of maintenance tasks on the adjacent meadows. The mowing mainly affects the left hand side riverbank of the intervention area.

By combining the preceding criteria, six quadrants were defined. Particularly:

- Quadrant 1: gabion wall with sea tidal influence
- Quadrant 2: brush mattress with sea tidal influence and affected by the surrounding meadows maintenance tasks (mainly mowing)
- Quadrant 3: log crib wall with sea tidal influence
- Quadrant 4: log crib wall without sea tidal influence
- Quadrant 5: log crib wall without sea tidal influence and belonging to the construction stage 2 (with one year less of service life)
- Quadrant 6: brush mattress belonging to the construction stage 2 and without the influence of the maintenance tasks (mainly mowing)



Quadrants localization

The selected field work variables are the following:

Characterization of the wooden elements (logs): measurements taken with a resistograph.

Characterization of the vegetation: plant species identification (tree, shrubs and herbs), breast height diameter, root collar diameter, height, vegetation cover of trees, shrubs and herbs.

Characterization of the fluvial quality index (FQI): it depends on the fragmentation level of the riparian buffer, the width of the riparian buffer, and the list of riparian plant species (climax riparian plant species of the intervention area).

Justification of the selected field work variables:

The characterization of the current state of the logs utilised in the bioengineering structures is necessary for checking the evolution of the soil and water bioengineering work. The logs offer an initial stabilization and erosion protection at the end of construction stage. As time progresses, the wooden elements deteriorate and the evolving vegetation progressively take over the stabilising role. Eventually, the logs will not fulfil any stabilising effect and they just play a slow release organic fertiliser function.

The vegetation characterization will depict the riparian buffer evolution within the past 16 years. The quality level of the riparian buffer is determined with the following information; plant species, densities, structure, land cover and, vegetation cover. The fragmentation level and the riparian buffer width are also essential variables to evaluate the riparian buffer health.

The measurements of both the breast height diameter ad the root collar diameter will allow the indirect estimation of the root distribution shape (Matheck et al., 1993; Preti et al., 2010; Tardio et al., 2016) and RAR (Root Area Ratio(index. With the preceding information it is possible to calculate the plan roots reinforcement effects.

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

WOODEN ELEMENTS CHARACTERIZATION:

After the use of the resistograph, the following results and conclusions were obtained:

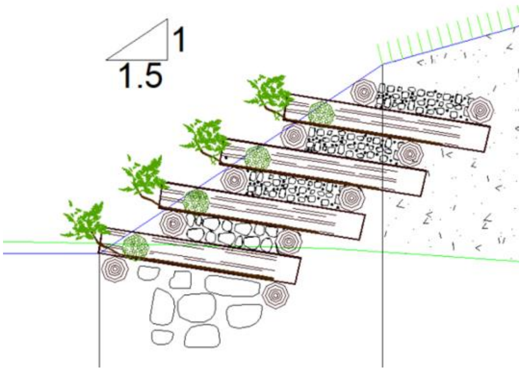
Logs in a direct contact with the water are much better preserved. The further from the water, the more deteriorated the logs are. This is because of the moisture change cycles the logs are subjected to. The part of the log in contact with the ground is much more deteriorated than the log upper part.

Measurements with the resistograph (source: Guillermo Tardio)

The part of the log with ground contact is more deteriorate than the log upper part (source: Guillermo Tardio)

Most of logs of the quadrant 5 are fully deteriorated without retaining any residual mechanical strength.

The logs under the sea tidal influence are better preserved (salt inhibits fungi attacks).

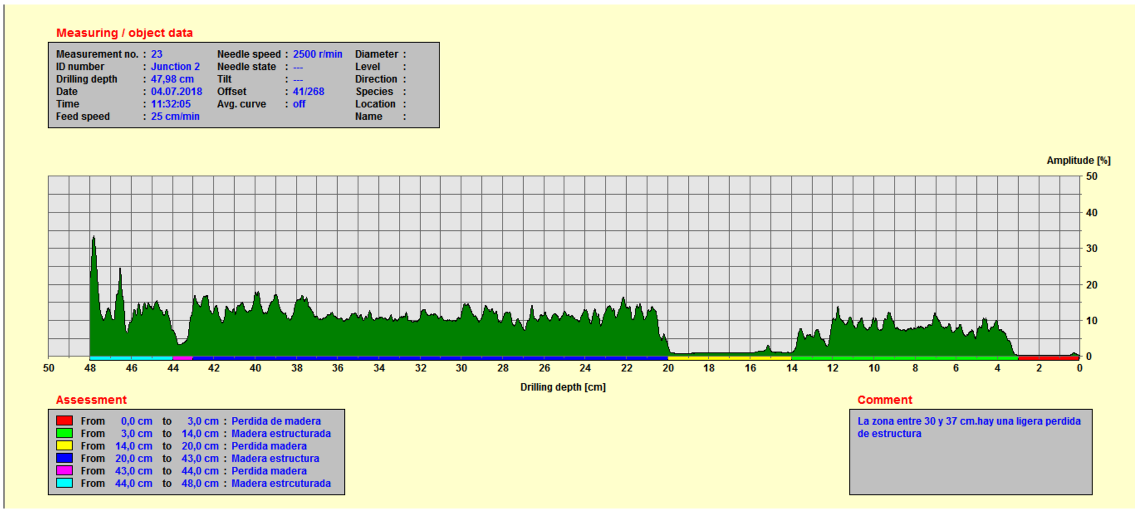


Double crib wall drawing detail (source: Artia project)

The trunks in ground contact are much deteriorated. The logs are no longer fulfilling any stabilising function. The remaining function is the fertilisation of the surrounding soil. Actually, nowadays the logs just work as a slow release organic fertilizer. The vegetation has already taken over the stabilization function. The volume occupied by the logs is now occupied by the roots and by the formed soil. The soil and water bioengineering approach and strategy has been successfully developed.

Roots occupying the soil volume initially occupied by the logs (source: Guillermo Tardío)

The wooden material utilised during the construction stage were green and barked logs. Because of this situation, the logs had a high water content level and the moisture loss process was very low. Hence, the logs were very vulnerable to the fungi attack from the very beginning of the bioengineering work service life. A minimum seasoning is recommendable to decrease the log water contents before their use in bioengineering works.



Resistograph plot corresponding to a test carried out in one of the crib wall junctions (connection between a header and a face log)

VEGETATION CHARACTERIZATION

The results obtained are shown in the following tables:

Tree species	Absolute frequancy					
	P1	P2	P3	P4	P5	P6
Acer platanoides	10	2	0	0	0	0
Fraxinus excelsior	2	0	8	0	1	1
Laurus nobilis	0	2	0	0	0	0
Salix atrocinerea	0	11	5	2	4	11
Coryllus avellana	0	0	11	11	6	0
Lygustrum japonicum	0	0	0	0	1	0
Alnus glutinosa	0	0	0	0	0	5
Total	12	15	24	13	12	17

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Especies	Relative frequency (%)					
	P1	P2	P3	P4	P5	P6
Acer platanoides	83.3	13.3	0.0	0.0	0.0	0.0
Fraxinus excelsior	16.7	0.0	33.3	0.0	8.3	5.9
Laurus nobilis	0	13.3	0.0	0.0	0.0	0.0
Salix atrocinerea	0	73.3	20.8	15.4	33.3	64.7
Coryllus avellana	0	0.0	45.8	84.6	50.0	0.0
Lygustrum japonicum	0	0.0	0.0	0.0	8.3	0.0
Alnus glutinosa	0	0.0	0.0	0.0	0.0	29.4
Total	100	100	100	100	100	100

The willows basal area (m^2) is shown in the following table:

	P2	**P3**	**P4**	**P5**	**P6**
Willow basal area (m2)	0.132	0.026	0.006	0.081	0.238

The willow relative basal area (%) is shown in the following table:

Quadrant	**P2**	**P3**	**P4**	**P5**	**P6**
Willow relative basal area (%)	45.21 €	5.26 €	6.67 €	47.65 €	81.79 €

The brush mattress technique can be found in quadrants 2 and 6.

The log crib wall technique can be found in quadrants 3, 4 y 5.

A one and two way ANOVA were carried out.

The results are the following:

ONE WAY ANOVA

Groups	*Count*	*Sum*	*Average*	*Variance*
Brush mattress	2	126.99	63.495	669.41405
Log crib wall	3	59.56	19.85333333	579.564133

TWO WAY ANOVA

Variations source	*Sum of squares*	*Degrees of freedom*	*Average of squares*	*F*	*Probabilty*	*F critical value*
Among groups	2285.514083	1	2285.514083	3.74973124	0.148230223	10.12796448
Inside the groups	1828.542317	3	609.5141056			
Total	4114.0564	4				

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Discussion about the ANOVA results:

The willow relative basal area is affected neither by the selected bioengineering technique nor by the sea tidal influence. The willow basal area is higher in the brush mattress technique case. The factor with a higher influence (although weak) is the sea tidal influence.

The main factors affecting the willow basal area is the mowing of the surrounding meadows and the riparian buffer width (which, in turn, is related to the presence of maintenance tasks of the meadows).

No matter the bioengineering technique used, the plots with higher riparian buffer width values and without meadow maintenance tasks have much higher willow basal area values compared to other scenarios. This situation is clearly reflected in the quadrant 6 where the buffer riparian width reaches its maximum value and where there are no meadow maintenance tasks either. Besides, in quadrant 6, a richer seedlings presence of riparian plant species was detected. Particularly, seedlings of *Equisetum* sp, *Rosa canina*, and *Mentha* sp were found in quadrant 6.

<u>Conclusions of the vegetation characterization analysis:</u>

The main factor preventing the development and evolution of the riparian buffer zone (in terms of composition and structure) is the meadow maintenance tasks. Those maintenance actions affect the very border of the existing riparian buffer zone.

The evolution of the riparian plant communities is being expressed. Alnus glutinosa is gaining presence by displacing Salix sp.

The maintenance actions over the adjacent meadows alter the herbaceous plant communities' composition and structure.

COMPARISONS WITH REFERENCE SCENARIOS

PRE-RESTORED SCENARIO:

The selected pre-restored scenario is the pre-operational situation of the intervention area.

As explained before, in the preoperational situation the Artia creek was turned into a concrete trapezoidal cross sectional channel. There was no riparian vegetation.

Another upstream stretch of the Artia channel was treated with a non vegetated rock wall. As it was checked out, after 16 years after the end of construction stage, no vegetation has been developed. Therefore, a simple rock wall technique (which, in turn, is a very common civil engineering technique in fluvial scenarios) does not trigger ecological processes. The scenario is very static and no ecosystem services are developed.

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Pre-operational scenario. Reach of the Artia creek that is still channelized (upstream from the intervention area)

TARGETED SCENARIO (END-POINT SCENARIO):

For this part of the analysis, comparisons between the bioengineering work current situation and the potential vegetation of the Artia creek were done. Hence, the endpoint scenario is defined by the European Habitat E91E0 which is the riparian forest of *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*).

The climax tree species of the preceding habitat are: *Alnus glutinosa*, *Fraxinus excelsior*, *Salix* sp. and, *Coryllus avellana*. These species are well represented within the intervention area. In some of the quadrants (e.g. quadrant 4), the *Coryllus avellana* is the dominant tree species. This situation could be fixed by enriching the composition of this riparian area by introducing other riparian species (e.g. *Alnus glutinosa* and *Fraxinus excelsior*). Indeed, in the areas not affected by the maintenance actions (e.g. quadrant 6), *Alnus glutinosa* is displacing *Salix* sp.

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

A completely new dynamic was generated after the implementation of the soil and water bioengineering approach and methodology. A riparian buffer area was developed. The stabilization role transfer between the initial inert element (the logs) and the evolving vegetation has been fully developed. The soil and water bioengineering strategy has been successfully accomplished.

The fluvial hydrodynamic processes have also been activated. Riffles and slow water areas are present now in the Artia creek.

Gravel accumulations within the Artia creek (source: Paola Sangalli)

This situation allows for the presence of a varied set of habitats for the fluvial fauna. The Artia creek dimensions were restored. Both the vertical and lateral dimensions are again functional.

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

The bioengineering work has fulfilled the pursued objectives. The Artia creek renaturalization process is fully developed. Compared to other reaches where the Artia creek is still channelized, the fluvial scenario is completely different. Many fluvial processes are present within this reach of the Artia creek. Ecosystem services are now offered to the citizenship of the surrounding areas.

The river dimensions have been restored (longitudinal, vertical, lateral and temporal).

The main limiting factors are the following:

- The width limitations of the right riverbank
- The mowing of the adjacent meadows is negatively affecting the development of the riparian zone in terms of its structure and plant composition.

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CASE STUDY - FLUVIAL

IMPROVEMENT PROJECT OF THE FLUVIAL AREA OF THE TENES RIVER IN SANTA EULÀLIA DE RONÇANA (Catalonia, Spain)

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / Project title:
Santa Eulàlia de Ronçana (Barcelona)

UTM coordinates:
Starting coordinates: 31T 436078 4612878

Ending coordinates: 31T 436998 4609376

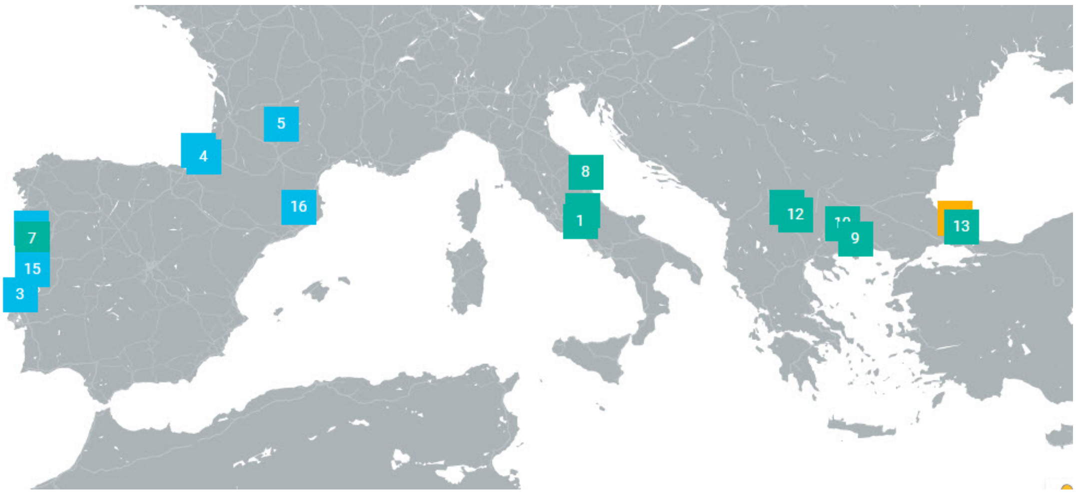
Completion date of the design stage:
October 2010

Completion date of the construction stage:
December 2011

Client: (e.g. private or public person or industrial company):
- Ajuntament de Santa Eulàlia de Ronçana (Council Town)
- Consorci per la Defensa de la Conca del Besós.
(Consortium for the Protection of the Besòs River Basin)
- FEDER funds for flooding risk areas

SUMMARY

In order to face problems of erosion, habitats and landscape degradation at the fluvial area of Tenes river in Catalonia, soil and water bioengineering techniques were used to recover the riparian ecosystem and renaturalize the environment.



ECOMED - *Ecoengineering in the Mediterranean Environment*

SANTA EULÀLIA DE RONÇANA CASE STUDY REPORT

Authors: Naturalea Conservaciò, SL

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title:

Improvement project of the fluvial area of the Tenes river in Santa Eulàlia de Ronçana

UTM coordinates:

Starting coordinates: 31T 436078 4612878

Ending coordinates: 31T 436998 4609376

Completion date of the design stage: 2010

Completion date of the construction stage: 2011

Client: Ajuntament de Santa Eulàlia de Ronçana (Council Town) / Consorci per la Defensa de la Conca del Besós. (Consortium for the Protection of the Besòs River Basin)/ FEDER funds for flooding risk areas

Decision criteria for this type of construction: Flooding protection and ecological restoration

Enterprises involved in the execution of the project:

Study area of the Tenes river in Santa Eulàlia de Ronçana

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OBJECTIVES

The main objectives of the actions that were planned to carry out have been:

- The **recovery of the autochthonous riparian vegetation** communities. Increasing the quality of riparian forest, faunal communities would also increase and other indirect enhancements would be developed like the physical protection of the river banks, the reduction of water temperatures by the shadow provided by the trees, the increase of the autodepuration capacity of the system, the increase of habitat diversity, the flood regulation, the improvement of the river as ecological corridor and also landscape an social use of the river area.
- The **river bank protection** in order to protect infraestructures already in the area,
- **Increase lateral connection** between the aquatic system and the riparian forest, with habitat creation resulting of this connection
- Monitoring the riparian vegetation in order to **reduce the blockage by vegetal debris** under the bridges or other structures due the *Arundo donax*
- **Increase of river longitudinal connection.** Taking out of the area the old dams and other hydraulic constructions no use
- **Recovery of drinking fountains** and other spaces traditionally associated to the river
- Establish **management criteria** with low maintenance requirements **to enhance ecological values**
- **Enforce of divulgation activities focused on fluvial ecosystem** to involve the society on the ecosystem conservation.

LEVEL 1. INFORMATION CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT

Previous field work:

New topographic survey of the project area
Geotechnical study

Inventory of native species of Interest
Inventory of invasive plants
Inventory of all the infrastructures present in the river
Waste inventory and discharges in the area
Meetings with the neighbours to evaluate their perception of the river and the associated problems

Technical work

Study of the previous projects of the area
Hydrology from the data provided by the ACA (Catalan Agency of water)
Urbanistic planning actual and future situation.
Hydraulic study

The riverbed of the river Tenes as it passes through Santa Eulàlia de Ronçana has had an important anthropic pressure due to the occupation of the land of its margins and the modification of the soil uses, which has modified the natural dynamics of the river. The presence of several factories that reduced the hydraulic capacity of the river and other infrastructures that broke the longitudinal connectivity of the river such as fords increase the flooding problems in the urban area.

The following images show how the changes in soil through the years as the village of Santa Eulàlia de Ronçana has increase.

Image of the area in 1945-46

Image of the area 2011

Images: ICGC

Previous projects of the area

The present working area has been targeted of previous projects and studies related with a better planning of the space, combining natural and urban aspects:

- Master Plan for the protection of avenues in the Besòs Basin (1999)

- Project for the environmental improvements of the River Tenes in Santa Eulàlia de Ronçana (Sector Pont Nou) (1999).

- Master plan for river areas in the Besòs river basin (Consortium for the Protection of the Besòs River Basin (CDCRB), 2001).

This document includes three previous studies:

- Hydrological study of the Besòs basin (1997).

- Biodiversity study in the Besòs basin (1997).

- Urban planning and infrastructure study in the Besòs basin (1998).

- Recommendations to municipal urban planning in order to incorporate the delimitation of flooding areas and the development of the Master plan for the River Basin master plan for the River Basin ACA (2004).

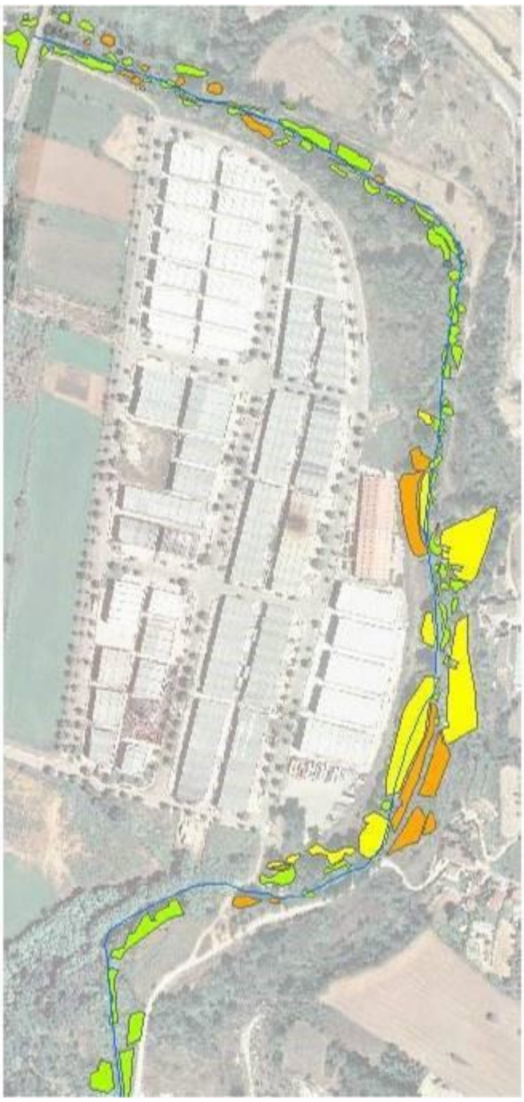
- Study of alternatives for the hydraulic and environmental conditioning of the river Tenes in Santa Eulàlia de Ronçana (ACA,Catalan Water Agency, 2008).

- Proposals for hydraulic and environmental improvement of the Tenes river (ACA, April 2010).

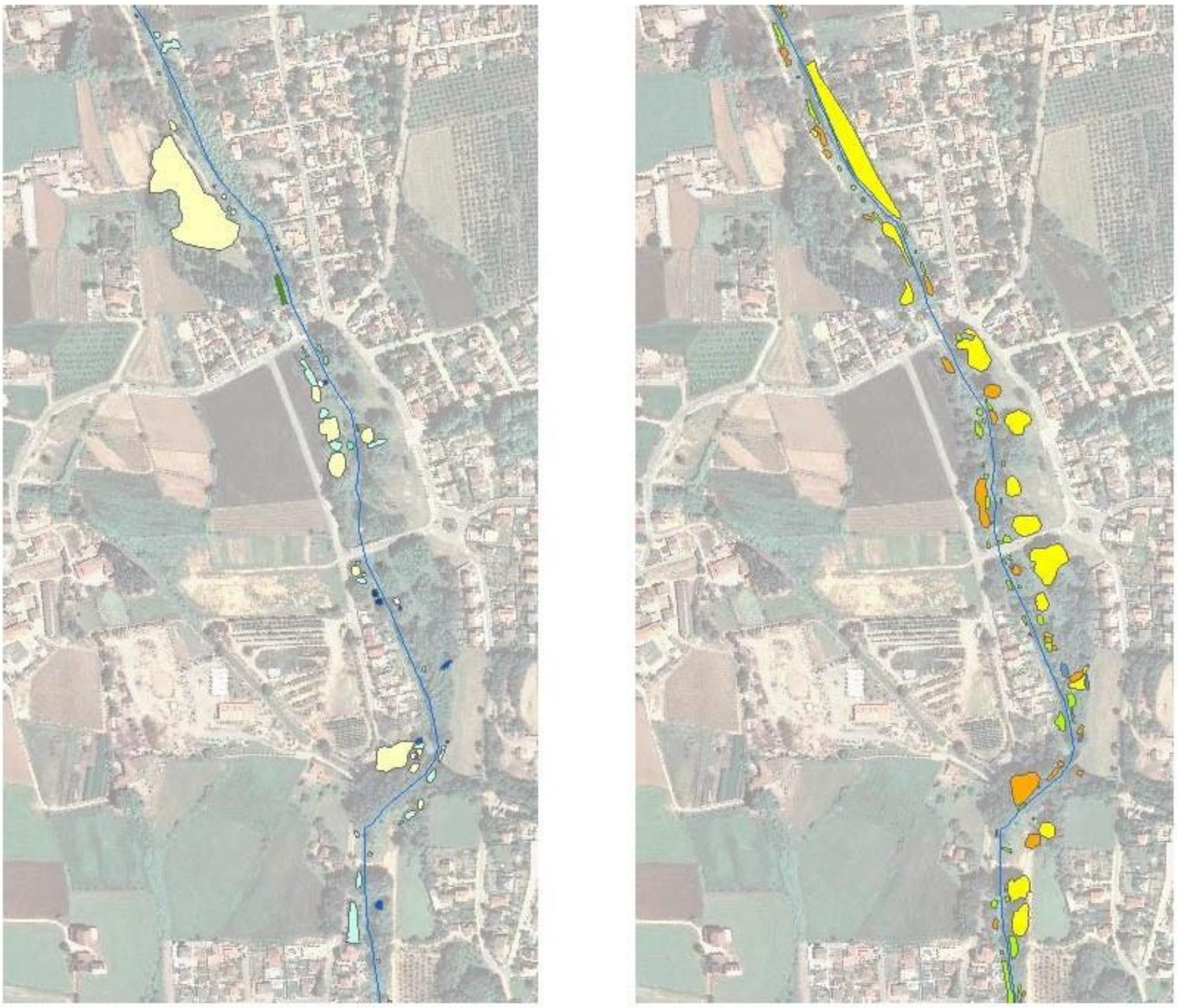
Besides all these plans, on April 2010, the Catalan Water Agency (ACA) wrote the "Study of alternatives for the hydraulic and environmental conditioning of the river Tenes in Santa Eulàlia de Ronçana" as the latest report focused on the hydrological correction of the river following technical and environmental guidelines.

The improvement project of the fluvial area of the Tenes river in Santa Eulàlia de Ronçana, has been promoted as an intention for an integrated river management. The main aim was to stablish the necessary actions to recover environmentally the habitats of the Tenes river for an enhancement of the landscape, environment and hydraulics (for reducing the risk of dragging and shutting down existing structures). In order to achieve these general goals, it was taken into account the landscape improvement through the replacement of invasive species basically of *Arundo donax*, and the restoration and stabilization of the riverbank.

General overview of the Tenes river with *Arundo donax* on both sides of the riverbank



Group of autochthonous (left image) and allochthonous (right) vegetation close to the area of Can Magre



Group of autochthonous (left image) and allochthonous (right) vegetation close to the area of Sant Isidre and Can Font

The flow of avenues associated to different periods of return of the river basin defined in the last study of the Planning Fluvial Space of the Besòs basin, are summarized in the following table:

Flow of avenues of the Tenes river in the work section (m³/s)				
Area	**$Q_{T=3}$**	**$Q_{T=10}$**	**$Q_{T=100}$**	**$Q_{T=500}$**
Pont de Ca l'Unyó	56,20	145,60	452,20	726,90
La Campinya	82,20	192,50	541,60	847,90
Sant Isidre	82,20	192,50	541,60	847,90
Sant Cristòfol	82,20	192,50	541,60	847,90
Can Sabater	82,20	192,50	541,60	847,90

The hydraulic modelling of the Tenes river its way through the village is based on the results of the study of the Planning Fluvial Space of the Besòs basin using the mathematical model of gradually varied or permanent HEC-RAS system, developed from the HEC-2, "Water surface profiles" based on the curves calculation known as the "standard step method."

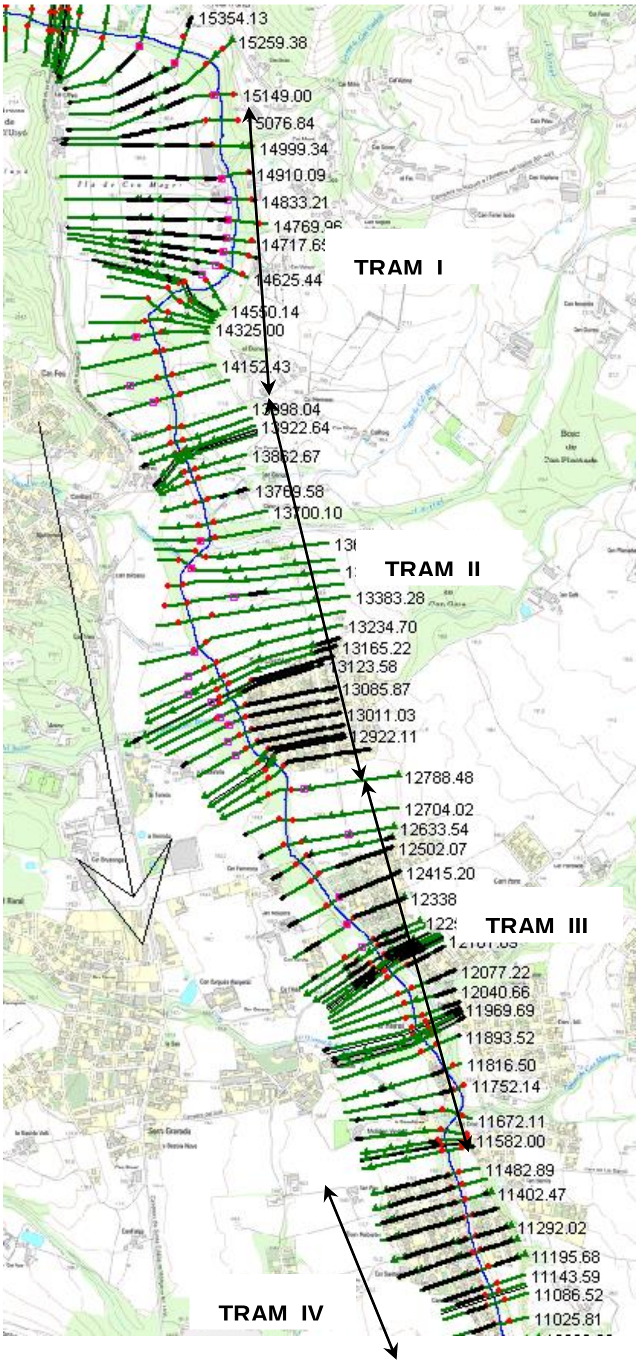


Image of different sections previous the works, as its initial state.

LEVEL 2. CONCEPTS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN

After a preliminary fieldwork, some actions were detected that helped to design a first draft of the actions that had to be proposed.

Impact removing: the project creates a new scenario after taking out of the area old infrastructures and all the invasive plants

As a general overview, industrial and general waste was detected in the riverbank all along the area due to its proximity to the industrial area and the village of Santa Eulàlia. Specifically the areas close to the walkway Campinya and Can Magre, soil piles and waste were detected permanently.

General waste (asbestos) and soil movements in the area of Can Magre

Soil and rune 6m^3 next to the industrial area

As a conclusion of the fieldwork, preliminary maintenance tasks along the riverbank were suggested. They were focused on waste cleaning and reed removal (*Arundo donax*) through mechanical treatment (grind the reed and dig out the surface layer of the terrain extracting rhizomes to avoid the re-sprout). Afterwards the areas were planted with autochthonous species of riparian forest with shrubbery and halophyte plants. Besides selective pruning and regeneration of existing riparian vegetation and plantation for the recovery of the autochthonous vegetation in different parts of the Tenes river was also suggested.

Designed works: focused in three main lines:

- Plantations with new plant production from *mother plants* of the area.

- Modify the slopes of the river margin with land movements to improve the hydraulic capacity

- Planning of the structures and techniques of soil and water bioengineering in different areas to protect the natural river margins and the occupied areas close to the river margins and slopes.

For these works it was stablished that 50-75% of the plants suggested for resprout would come from a mother plant close to the area which would have to be developed in a nursery carefully.

As a general rule, the helophytes would be planted at the nearest area of the river, the shrubs along the margins of the river bed while trees would be planted close to the river bed but a bit far from the water of the river.

The following species where planted in the Tenes river:

Specie	Height [cm]
Trees	
Alnus glutinosa	100-150 cm
Populus alba	100-150 cm
Fraxinus angustiflolia	100-150 cm
Ulmus minor	100-150 cm
Salix alba	100-150 cm
Shrubs	
Salix atrocinerea	60-80 cm
Salix eleagnos	60-80 cm
Sambucus nigra	60-80 cm
Corylus avellana	60-80 cm
Cornus sanguinea	60-80 cm
Crataegus monogyna	60-80 cm
Rhamnus alaternus	60-80 cm
Rubus ulmifolius	60-80 cm
Coriaria myrtifolia	60-80 cm
Lianas, herbs, helophytes	
Mentha rotundifolia	
Arum Italicum	
Scirpus holoschoenus	
Carex pendula	
Juncus inflexus	
Phragmites australis	
Typha rotundifolia	

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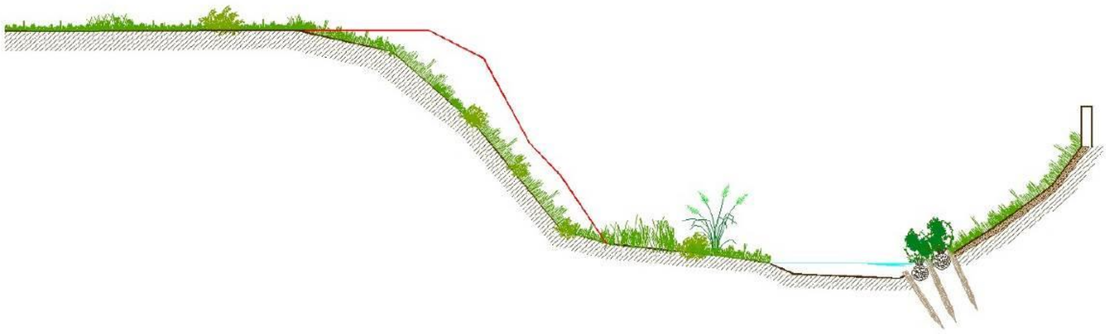
Hedera helix	
Clematis vitalba	
Iris pseudocorus	
Vinca diformis	

In some places it was also planned an improvement of the river margins through slope restoration to increase its river surface, and the ratio between the vegetation and water, besides the stabilization. Afterwards the slope restoration, the spread of a hydromat was suggested. It consisted of cotton material in order to implement vegetal surface and control the erosion of the slopes, made with specific straw (65%), cotton (25%), glues and polymers (10%).

The composition of the mixture was:

Specie	% of total
Agropyrum cristatum	30
Festuca rubra rubra	15
Agrostis nebulosa/ A.tenuis	10
Anthyllis vulneraria	10
Dactylis glomerata	10
Brachypodium phoenicoides	10
Cynodon dactylon	5
Lotus corniculatus	5
Trifolium repens	5

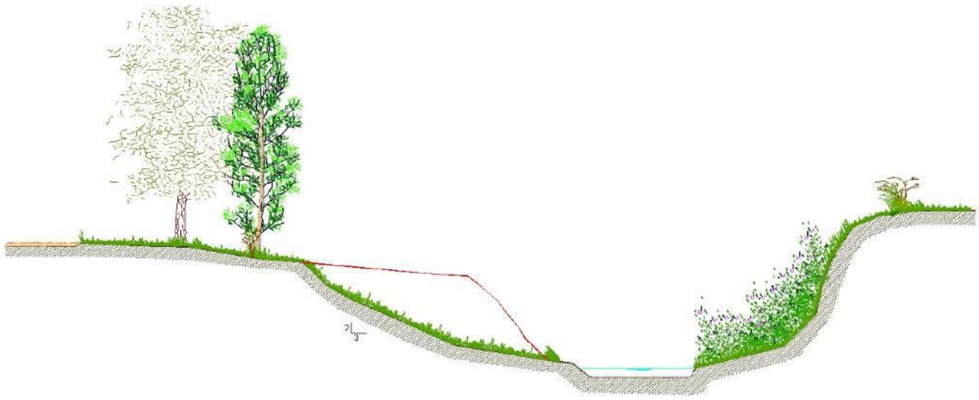
Based on the previous hydraulic study of the ACA (Catalonian Water Agency)) and with the aim to enhance the hydraulic capacity of the river, soil movements to the riverbed had to be done. In some places the soil of the riverbed was planned to be removed to achieve a softer slope and widen the area, as in the case of downstream of Sant Cristòfol’s ford. In this case, the left slope was suggested to be modified until a slope of 3H:2V with further plantation.



	Qtotal (m³/s)	Qcanal (m³/s)	Vel total (m/s)	Vel canal (m/s)	Tensió total (N/m²)	Tensió canal (N/m²)
secció núm.12						
$Q_{1,5}$	25	25	1.8	1.8	71.58	71.58
Q_3	82.2	82.2	2.73	2.73	138.05	138.05
Q_{10}	192.5	192.5	3.81	3.81	244.15	244.15
Q_{100}	541.6	376.8	2.46	3.64	86.78	190.53
Q_{500}	847.9	449.79	2.47	3.6	103.46	196.53

Profile of the Tenes river at Sant Cristòfol's ford afterward the soil movements and the proposed works and its hydraulic parameters. The red line represents the real situation of the area before the works.

Other sections were suggested to widen the riverbed in order to cut some allochthonous trees to be replaced with authoctonous plants and gain space to the natural riverbed, as in the section of the bridge of Can Font. Then, the stabilization of the right margin of the neighbourhood of Sant Cristòfol was planned to be done with a permanent reinforced mat and two coir Fiber rolls with plantation.



	Qtotal (m³/s)	Qcanal (m³/s)	Vel total (m/s)	Vel canal (m/s)	Tensió total (N/m²)	Tensió canal (N/m²)
secció núm.14						
$Q_{1,5}$	25	25	0.78	0.78	12.36	12.36
Q_3	82.2	82.2	1.22	1.22	25.61	25.61
Q_{10}	192.5	192.5	1.59	1.59	33.84	33.84
Q_{100}	541.6	451.68	1.52	1.97	29.97	58.42
Q_{500}	847.9	479.57	1.16	1.64	21.63	39.77

Profile of the Tenes river at the bridge of Can Font afterward the soil movements and the proposed works (on the right side of the image) and its hydraulic parameters. The red line represents the real situation of the area before the works.

All the structures designed had the common aim of protecting the river margins and widen it as possible to make that the river could flow all along its way. But also with the aim of protecting the margins where buildings, boundaries of plots and roads occupy spaces of the natural area of the river, leading to higher flooding level taking into account the hydrology of the area.

Margins of the Tenes river downstream the neighbourhood of Can Sabater.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS

Pre works

Plant production with local plants was carried out by the nursery Tres Turons two years before the execution of the project. They weren't contracted by Naturalea but the nursery followed the recommendations of Naturalea while caring the plants.

Besides, a crib wall of 100m was built in the area one year before the project started to show the potential of the actions purposed.

Moreover, information activities were carried out to explain the project to citizens and show the preliminary work.

First part of the work

The works were carried out though the company BarnaSfalt, S.A. while the clearance and reed removal were done by Jardi Pi.

Phase I. Remove and correct the impacts. Removal of anthropic elements in the river bank.

A. Removal of waste
B. Removal of runes/Sewer pipe
C. Removal or planning of gardens
D. Connecton of longitudinal elements
E. Anthropic sediments

Phase II. Removal of allocthonous species

A. Removal of *Arundo donax* present in the working area
B. Removal of *Ailanthus altissima*
C. Removal of *Ligustrum lucidum*
D. Removal of *Robinia pseudoacacia*

Phase III. Correction of the morphology

A. Unblocking of the ford
B. Enlargement of the river bed
C. Recovering of impacted spaces

Second part of the work

The execution of the soil and water bioengineering techniques was done by Naturalea Conservació, S.L, and all the plantations and forestall works were carried out by the company Jardi Pi.

For the execution of the techniques, the workers of Naturalea had vastly formation and thus, the working process was easy to manage as they knew how to implement the techniques and how to manage with the materials and plant properly for a success during their installation.

Phase IV. Restoration and consolidation of the natural heritage

A. Acceleration of the vegetation process of the river margins

B. Strengthening of the river bank in places where erosion is caused to transversal or longitudinal structures

C. Plantation of riparian forest

D. Creation of proper environments for the correct development of the vegetation

E. Progress in the forest structure

F. Creation of slow-water areas

G. Strengthening of areas suitable for the development of biofilms

H. Minimizing the effects of the waste in the river bank

I Stabilization of the slopes and river margins

Third part of the work

The works were carried out though company BarnaSfalt, S.A.

Phase V Restoration and consolidation of the archeologic and cultural heritage

C. Recovery and consolidation of public fountains

D. Recovery and consolidation of bridges and drainage systems with heritage interest

E. Other structures that belong to the heritage

Phase VI. Planning of the social use

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A. Maintenance of stone structures (walls, benches).

B. Creation of a new platform (opening of roads and improving existing ones)

C. Improvement of walkway areas

D. Areas of leisure

E. Paths management

F. Sign posts and markers

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

For these kind of big projects is better to do the different levels of execution in different years in order to do more intensive maintenance and see the adaptation of preliminary actions.

Weather conditions are very important in a river restoration project. In this case, part of the works was done in really bad conditions although this is not the common situation and as a general rule the works have to adapt to the weather.

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LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

The development of the Maintenance Plan is essential to achieve the intervention of the river recovery. The plan pretended to guarantee the viability of the actions that were carried out and ensure that they fulfill the functions for which they were planned and designed. It was carried out during the three years after the intervention.

In the case of the Tenes river, some maintenance recommendations were made in order to control the evolution of the techniques.

Recommendation	Remarks	Responsible	Term
Plantation irrigation	For works where shrubby species and autochthonous plants were planted for an adequate adaptation of the vegetation during their first stages of grow.	Barnasfalt Jardi Pi	-Abundance watering during plantation. - First year: once every 5 days (from Març to June) Once a week from July to September. - Second year: once every 45 days. Once every 15 days in summer.
Plant protection and stakes	Guarantee a proper growth of the trees and protection against predators	Barnasfalt Jardi Pi	Check if the protection are in good conditions once or twice a year. If not change them
Pruning	Selective pruning in areas with potential autochthonous vegetation to grant a good development of the riparian forest	Barnasfalt Jardi Pi	Once a year on March and October
Plants replacement	Check the conditions of the plants and replace the ones that are dead with the same species	Barnasfalt Jardi Pi	- All the year (better during winter months)
Clear shrubbery vegetation	Guarantee a good maintenance of open spaces and areas close to the fountain of Sant Cristòfol	Barnasfalt Jardi Pi	- Once or twice a year
Control of the expansion of the reed and rhizomes	Control and surveillance of the areas where *Arundo donax* or rhizomes are detected and remove them manually	Barnasfalt Jardi Pi	-Twice a year on March and September

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There were no instrumentation left in situ for monitoring, but instead a monitoring plan was stablished in order to assess the results obtained after the restoration of the area. The main parameters and index that were suggested for monitoring the state of the river after the intervention were:

- Cartography of the habitats and evolution between autochthonous and allochthonous vegetation

- Detection of impacts, interferences or disturbance that affect the river flow and ecology

- Causes and processes that cause the impacts

- Analysis of the water quality and the riparian forest

These monitoring reports were done by the Council of Santa Eulàlia and couldn’t be provided for this case study.

Besides monitoring reports, activities related with communication and dissemination of the works in the Tenes river were proposed. They were addressed to the citizens of Santa Eulàlia de Ronçana, environmental associations, industries, agricultural and enterprises of the area close to the influence area of the river so as to involve them in the improvement project from a more social aspect.

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

At the end of this document there is attached a summary of all soil and water Bioengineering techniques used (**Summary of the project executed**) with specific information on the location of each technique, their main aim in the area, the working details on how to execute the technique and some images of the area during their construction.

Below there is an explanation of some of the soil and water bioengineering techniques executed in the Tenes river.

SWB 1. Area of the bridge Cal Unyó and final ford of the Industrial area of Can Magre (left side of the river bank)

Aim

- Protection of the riverbank against erosion
- Introduction of riverside species of the area to increase the initial recovering and success of the plant
- Create a vegetated frontal to inhibit the growing of *Arundo donax* that can appear after floods.

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m^2]
Q50	2,42	205,63
Q100	2,66	236,26
Q500	2,70	192,55

Species used:

Salix atrocinerea

Salix alba

Seeds mixture

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Living fascines	None	Willow	102m (a) + 82m (b): diameter 25 cm
Cotton hydromat	HydraCX^2		

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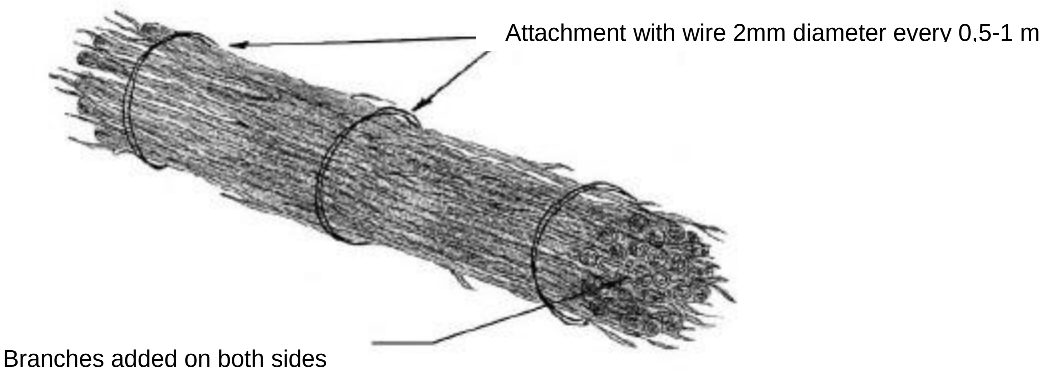
Location

Sketch of the technique



Images before


Images after

Outcome: objectives reached

SWB 2 Area of the final ford of the Industrial area of Can Magre and the walkway Campinya (left side of the river bank)

Aim

- Protection of the riverbank against erosion
- Introduction of riverside species of the area to increase the initial recovering and success of the plant
- Create a vegetated frontal to inhibit the growing of *Arundo donax* that can appear after floods

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m^2]
Q50	2,45	140,54
Q100	2,27	137,42
Q500	2,20	108,47

Species used:
Salix atrocinerea
Salix alba
Seeds mixture

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Living fascines	None	Willow	70m (b): diameter 25 cm
Cotton hydromat	HydraCX[2]		

Location

Images before

Images after

Outcome: objectives reached

SWB 3 Area of the walkway Campinya and the slope of Can Burgues

Aim

- Protection of the riverbank against erosion
- Introduction of riverside species of the area to increase the initial recovering and success of the plant
- Remove the invasive reed (*Arundo donax*) of the surrounding working area

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m^2]
Q50		
Q100	3,86	178,63
Q500	2,22	95,97

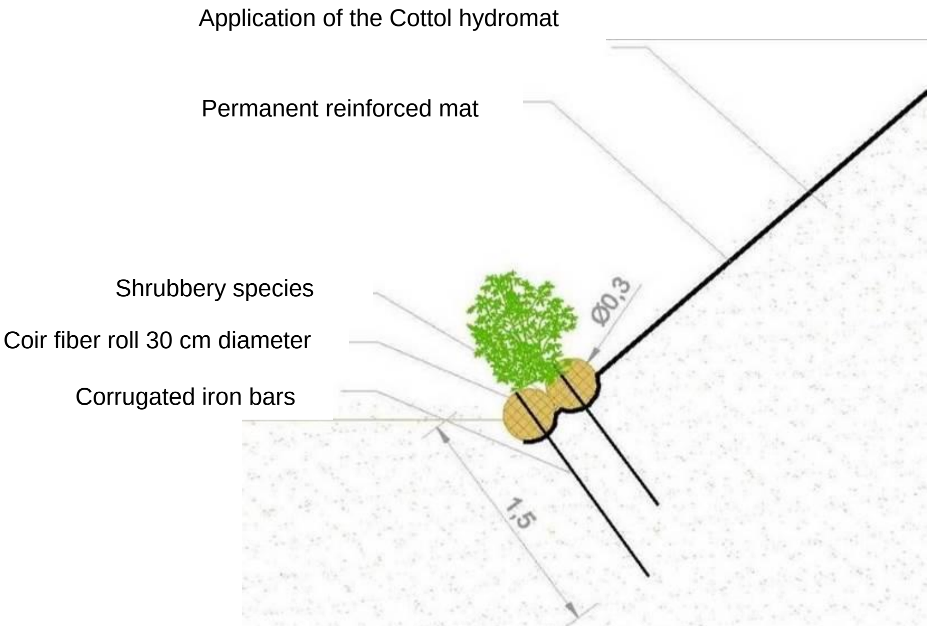
Species used:

Salix atrocinerea
Salix eleagnus
Salix purpurea
Cornus sanguínea
Sambucus nigra
Seeds mixture

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Cotton hydromat	HydraCX^2		2255 m^2
Permanent reinforced mat	C350 Vmax	-	115 m
Coir logs vegetated	Coir fiber roll	Willow	180 m

Location

Sketch of the technique



Images before

Images after

Outcome: permanent mat is working well but the willow presence is very low.

SWB 4 Installation of a Plant Carpet in the section of the river with common alder at Sant Isidre

Aim

- Introduction of helophite species of the area to increase the initial recovering and success of the plant

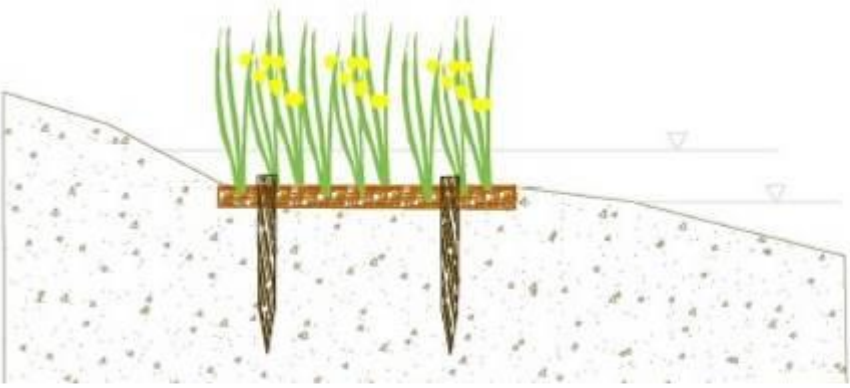
Species used:

Juncus inflexus
Scirpus holoschoenus
Carex vulpina
Iris pseudacorus

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Plurispecific helophyte brushes	Vegetated matts (Plant Carpet)	-	20 m^2 (2 Plant Carpet of 10 m^2 each)

Location

Sketch of the technique



Images before

Images after

Outcome: The technique was applied in a very active part of the river, hence, the river shape has changed and so did some plant species from their initial location. In spite of all, an excellent dispersion factor has been achieved.

SWB 5 Neighbourhood of Campinya and Can Font (left side of the river bank)

Aim

- Soil protection in areas affected by jobs against erosion
- Introduction of riverside species of the area to increase the initial recovering and success of the plant

Species used:
Agropyrum cristatum
Festuca rubra rubra
Agrostis nebulosa/ A.tenuis
Anthyllis vulneraria
Dactylis glomerata
Brachypodium phoenicoides
Cynodon dactylon
Lotus corniculatus
Trifolium repens

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Cotton hydromat	HydraCX[2]	Mix of seeds 0.34 kg/m^2	1400 m^2

Location

Images before

Images after

Outcome: objectives reached

SWB 6 Protection of the river bank erosion at Sant Isidre's ford

Aim

- Protection of the riverbank with a road against erosion
- Introduction of riverside species of the area to increase the initial recovering and success of the plant

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m^2]
Q50	-	-
Q100	*1,33*	*31,87*
Q500	*1,54*	*41,74*

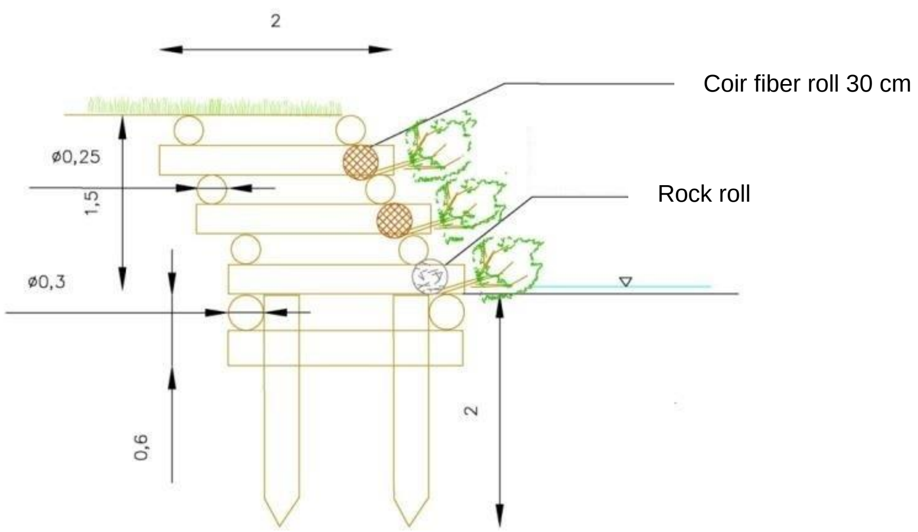
Species used and level

Specie	*Number of plants*	*Level*	
		1st	*2nd*
Salix atrocinerea	10	10	
Crataegus monogyna	30	10	20
Pistacea lentiscus	45	20	25
Viburnum tinus	30	10	20
Cornus sanguinea	35	20	15
Lingustrum vulgare	20	10	10
Corylus avellana	25	15	10
Sambucus nigra	45	25	20
Euonymus europaeus	10	5	5

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Krainer crib wall	Crib Wall with coir logs and rock rolls		50m length;1,50 m height
Cotton hydromat	HydraCX^2		1120 m^2

Location

Sketch of the technique



Images before

Images after

Outcome: objectives reached

SWB 7 Restoration of the slope before the fountain of Sant Cristòfol with slope grid and vegetated log crib wall foot

Aim

- Protection of the riverbank against erosion. Especial regressive erosion due de old bridge
- Introduction of riverside species of the area to increase the initial recovering and success of the plant

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m^2]
Q50	-	-
Q100	1,98	64,38
Q500	1,96	62,56

Species used and level

Specie	*Number of plants*	*Level*				
		1st	*2nd*	*3rd*	*4th*	*5th*
Salix atrocinerea	55	45	10			
Salix eleagnos	25	15	10			
Pistacea lentiscus	60			15	20	25
Viburnum tinus	20				10	10
Cornus sanguinea	45		15	10	10	10
Ligustrum vulgare	15			5	5	5
Corylus avellana	25		15	10		
Sambucus nigra	55		10	20	15	10

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Permanent reinforced mat	C350	-	24 m
Soil filling	-	-	148,8m^3
Slope grid		Chestnut wood	24 m
Crib wall	- Rock roll 40 cm diameter - vegetated coir log roll (fiber roll)	Chestnut wood	24 m

Location

Images before

Images after

Outcome: objectives reached

SWB 8 Restoration of the slope next to the fountain of Sant Cristòfol with fascines of death branches

Aim

- Elimination of an access to the river by the sheep
- Revegetation of the slope

Species used

Salix alba

Salix atrocinerea

Pistacea lentiscus

Cornus sanguinea

Corylus avellana

Sambucus nigra

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Fascines of death branches	- Fascines - Corrugated iron bars	Willow (from pruning material)	2.5-4 m (7 levels)
Plantation	-	Shrubbery species	60-80 cm

Location

Images before

Images after

Outcome: Objectives reached

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SWB 9 Slope stabilization on the right side of the river bank of Can Sabater

Aim

- Protection of the base to prevent erosion and recover the slope of the area
- Creation of a plant screen to prevent the dragged reed
- Remove the invasive reed (*Arundo donax*) of the surrounding working area

Species used and level

Specie	***Number of plants***	***Level***			
		1st	***2nd***	***3rd***	***4th***
Iris pseudacorus	-	X			
Scirpus holoschoenus	-	X			
Juncus inflexus	-	X			
Carex pendula	-	X			
Salix atrocinerea	450		450		
Salix elaeagnos	450		450		
Salix purpurea	225			225	
Crataegus monogyna	275				275
Cornus sanguinea	325				325
Corylus avellana	150				150
Sambucus nigra	375				375

Technique	**Specific product**	**Type of wood/seeds mix**	**Length/Surface**
Rollada viva riparial (Gradient vegetation rolls)	-Coir Fiber roll 30 cm diameter - Rock roll 40 cm diameter - Corrugated iron bars - Wooden sticks	Chestnut	357 m

Location

Images before



Images after



Outcome: With the years there have been different stages of vegetation development, depending on the site. Some areas had greater success than others, but in general terms the technique worked.

SWB 10 Living fascines with vegetated coir fiber roll on the right side of the river bank at the final part of the municipality

Aim

- Protection of the base to prevent erosion and recover the slope of the area
- Creation of a plant screen to prevent the dragged reed
- Remove the invasive reed (*Arundo donax*) of the surrounding working area

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m2]
Q50	2,48	69,65-
Q100	2,46	86,78
Q500	2,47	103,42

Species used

Iris pseudacorus
Scirpus holoschoenus
Carex vulpine
Juncus effuses
Lithrium salicaria

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Coir logs vegetated	Coir fiber roll 30 cm diameter	Willow	195 m

Location

Images before

Images after

Outcome: Objectives reached

SWB 11 Slope stabilization on the left side of the river bank of Can Sabater with a slope grid and protection of the base with vegetated coconut fiber roll

Aim

- Stabilization of the margin
- Creation of a plant screen to prevent the dragged reed
- Remove the invasive reed (*Arundo donax*) of the surrounding working area

Hydraulic requirements for 50, 100, 500 years

	Velocity [m/s]	Surface tension [N/m^2]
Q50	2,66	185,57
Q100	2,92	221,97
Q500	3,44	291,42

Species used

Iris pseudacorus
Scirpus holoschoenus
Juncus inflexus
Carex pendula

Technique	Specific product	Type of wood/seeds mix	Length/Surface
Permanent reinforced mat	C350	-	96 m length and 1.5 height
Coir logs vegetated	Fiber rollTM 30 cm diameter Wooden sticks	Chestnut wood	

Location

Images before

Images after

Outcome: Objectives reached

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

The designed works mainly affected areas of public water domain of the river in a length of 4,8 Km and didn't include protected green areas of the Natura 2000.
The budget took into account all the necessary works to clean the riverbed of any movements of soil or waste during the works afterwards they were completed.

There were neither problems related to a maintenance contract failure nor problems related to a missing maintenance contract because of the existence of the maintenance plan.
For the developing of the works, a safe and secure study was stablished according to the Spanish law of 31 / 1995 i del RD 1627 / 1997, in order to establish the technical bases to fix the parameters of the prevention of professional risks during the execution of the works of the project.

The existing services in the intervention area corresponded to low, medium and high electrical distribution networks, water supply and wastewater network and telephone network. The companies where previously informed about the works and areas planned to be affected so as them to corroborate that their services wouldn't be affected. There were no interruptions of the water and electric systems while the works were being executed.

In general terms there were no problems with the access to the work site.

According to the aims of the project and years after, it can be said that the suitability of the plants was the appropriate. As their selection was according to autochthonous plants, they have adapted to the conditions and have succeeded year after year with good results.

The technique of Rollada viva riparial was defined at a working meeting with Paolo Cornellini,, Paola Sangalli and Albert Sorolla during a visit of the AEIP-AIPIN for works in Switzerland and it was applied for the first time at this case, at the Tenes river in Santa Eulalia de Ronçana in 2011. Years later can be stated that the technique was a success as well as the kind of plants selected for the technique.

Detail of the Rollada viva riparial

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

In general terms, the whole work has been a **success** and the main objectives of the project were achieved after some years of its completion. There have been an ecological restoration of the river with an improving of the landscape and vegetation communities, as well as a great removal of the *reed*, with very few sprout of them, thanks to the maintenance plan stablished.

Besides the ecological and landscaping improvement, there has been a great social acceptance. All the expectations the stakeholders put in the works have been fulfilled since the works gave the targeted solutions and achieved the original goals. It is an area of leisure for the neighbours of Santa Eulàlia de Ronçana and surrounding areas and also for environmental education to schools.

Image of the Tenes riverbank where living fascines where installed. Picture: Naturalea.

CASE STUDIES.
TURKEY

CASE STUDY - SLOPE

KARTALTEPE METRO STATION SLOPE STABILIZATION PROJECT REPORT

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:
Kartaltepe (Kocatepe) metro station (Istanbul) slope stabilization works

UTM coordinates:
35T 659280 D 4545900

Completion date of the design stage:
1988

Completion date of the construction stage:
1988

Client: (e.g. private or public person or industrial company):
Public (Istanbul Metropolitan Municipality)

SUMMARY

The Kartaltepe metro station slope stabilization project is one of the good examples of soil-water bioengineering works.

The slopes of the hill, which was cut deeply (0-25 m) without taking any erosion control measures in the context of metro railway construction, was stabilized by improving soil conditions, seeding and planting.

ECOMED

ECOMED - *ECOENGINEERING IN THE MEDITERRANEAN ENVIRONMENT*

KARTALTEPE CASE STUDY REPORT

Authors: University of Istanbul

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title: KARTALTEPE (KOCATEPE) METRO STATION, ISTANBUL

UTM coordinates: 35T 659280 D 4545900

Completion date of the design stage: 1998

Completion date of the construction stage: 1998

Client: private company

Decision criteria for this type of construction: erosion control

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

- Project key objectives? They were erosion control and slope stability.
- Site appraisal: reconnaissance, desk/office studies, and inspections for ecology covering
    - Climatic aspects (mean annual rainfall was 691.4 mm, mean annual temperature was 13.7 ^{O}C, mean annual potential evapotranspiration was 704.5 mm, exposure is south and north.
    - Soil physical aspects: the site was completely sand and marn with low water holding capacity
    - Soil chemical aspects: No soil analyses was carried out in the design stage but we analysed soil samples collected from untreated site for pH, electrical conductivity, organic matter, loss on ignition and moisture content at field capacity (%) and compared with those from treated site
    - Soil engineering aspects were not examined in the design stage
- Native vegetation analysis: Due to excavation, there was no vegetation in the site before bioengineering works

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- Landscape features. The land was covered with sand cover and marn layer with poor drainage conditions
- Problems, risks and hazards that were addressed by the project including:
    - Erosion risk (rain erosivity, soil erodibility, overland flow)
    - Risks to metro station and railway
- Visual soil/rock classification. The area was completely covered with sand and marn material beneath the sand cover
- Hydraulic/hydrographic analysis including flooding risk assessment: Due to marn layer, the site had a poor drainage and permeability conditions
- Maps, photographs with the purpose of collecting historical information: Some photos were taken before the work (Fig. 1).

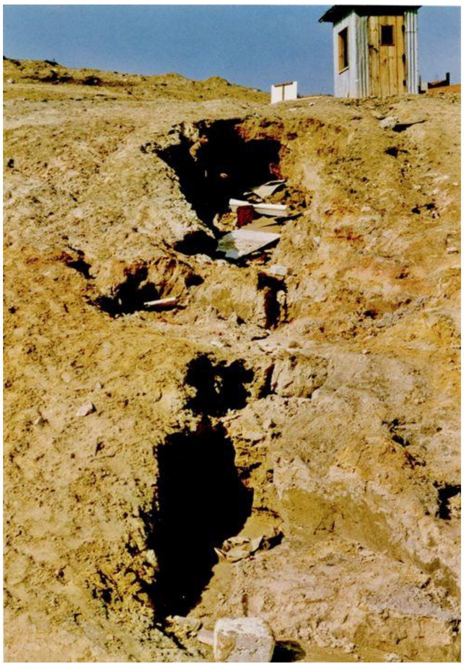

Fig. 1. Gully formation before rehabilitation

- Site topography and site surveying (geomatics): The site did not have a complex topography. It had a manmade smoot slope with a percentage of 25-35 %.
- Cadastral data, parcel ownership. The area is a state owned land and used for metro station
- Interviewing people for collecting historical information: Since the site did not a historical importance no interview was carried out during the design stage.
- Collection of urban planning processes and information showing current or future impacts with the work/site. The site used to be a hill but in the context of metro railway planning, this hill was cut deeply (0-25 m) without taking any

erosion control measures. Then, site experienced erosion and gully formation (Fig. 1).

- Other construction sites planned close to the site. There is no other sites planned close to the site
- Calculations and drawings related to this preliminary stage: During the design stage, how much sapling and seed material needed was calculated and planting plan was made (Fig. 2).

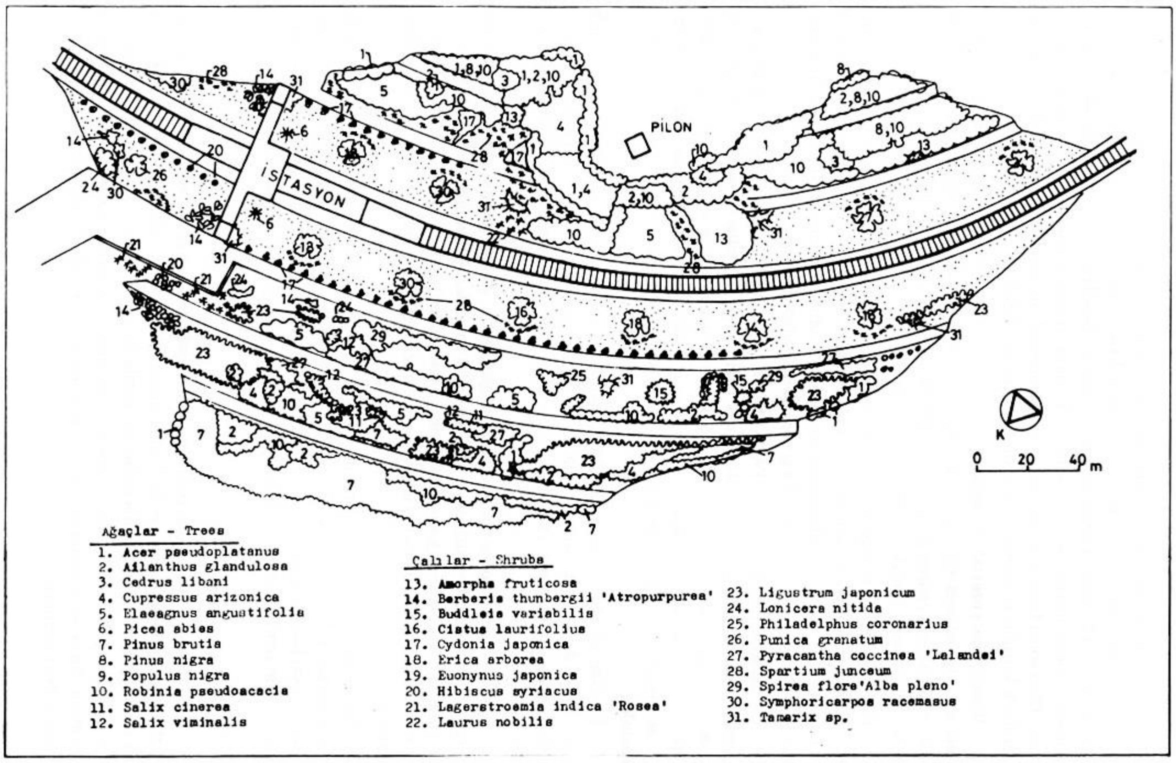

Fig. 2. Planting plan of Kartaltepe (Kocatepe) slope stabilization project (Çelik, 1994)[1]

- Existing information in Regulatory Agencies (e.g. sustainability initiatives, resilience initiatives): The site has been under the control of Istanbul Metropolitan Municipality before and after the project

LEVEL 2. WHAT WAS CALCULATED AND INCLUDED INTO THE PROJECT DESIGN?

- Is there a clear criterion for the plant species selection? Which is the criteria follow for selecting the plant species included in the project? Do the plants that belong to the first successional stage of the intervention area well represented?

[1] Çelik, H. E., 1994. The results of slope stabilization works at the Kartaltepe station of Istanbul light rapid transit system (LRTS) (Turkish with English summary), Review of the Faculty of Forestry, University of Istanbul, Series A, Volume 44, Number 1, İstanbul.

The plant species selection criteria were that plant species used must be suitable for climate conditions of the area, show good growth performance in poor soil conditions, be capable of protecting soil from erosion, provide a good scenery for environment due to being accessible for people, and commercially available.

Was a phytosociological approach used in both the plant species selection process and the intervention strategy?

No phytosociological approach was used in the plant selection.

- Are there clear criteria for the project strategy implementation?

  The criteria were first to stabilize the soil surface, prevent and rehabilitate the gully formation and then plant the entire area with woody and herbaceous plant species.

- Are there clear criteria for the bioengineering techniques selections?

  The criteria were to stop sheet erosion and gully formation with a combination of fence structures and vegetation establishment with using saplings of woody species and seeds of herbaceous vegetation.

- Is there a clear justification of the techniques design? Are the (structural and geotechnical) calculations clear?

  Yes, there was a clear justification of the techniques design for making wattle fences and prevent surface erosion. Calculations were clear about how many fence rows should be constructed with a distance between stakes and how may centimetres the stakes should be inserted into the soil.

- Functional requirements of vegetation (select all that apply to the project):
  - Soil reinforcement and enhancement of soil strength was achieved by burying /placing brunches of dead woody plant material during the rehabilitation of the gullies
  - Soil water removal: In order to improve permeability conditions, holes were made in the marn layer with using iron rods in some planting locations.
  - Surface protection against traffic. In order to prevent human traffic in the site, how much barbed wire and fence materials needed were calculated.
  - Surface protection against wind/water erosion. Amounts of tree sapling and seeds of herbaceous vegetation were estimated.
  - Bank and channel reinforcement. There was no channel or bank problem in the site
  - Shelter or screening. No shelter or screening was not applied in the site
- Which **improvements** would you propose, at the design stage, regarding:

  We would propose a riche plant selection and bioengineering techniques selection.

Please indicate your main conclusions after the analysis of the bioegineering work at the design stage:

We believe that construction company's preferences in the design stage were reasonable in the context of sustainability, labour and budget.

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

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LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

- The question to answer here is: how was the work carried out by the contractor (Construction Company) during the construction stage?

The construction stage corresponds to the construction of the client's project by a contractor (construction company) based on design documents approved by the client. Examples of the issues to be analyzed here are the following:

General issues, problems and defects.

- Problems/defects/issues recorded during the construction stage (information retrieved from the construction company). Poor soil conditions for plants growth and impermeable marn layer for water movement were the main problems.
- Detected flaws regarding the construction stage. E.g.

  Protection of the site from human traffic was the main flaw. In order to reach metro station people passed from the site for a short walking distance
- Please give your opinion about disturbing/destabilizing elements present between the design stage and the construction stage:

  Lack of an effective monitoring stage after the construction stage

  Due to human traffic, trampling affected seedling establishment and survival.
- Please, indicate the construction standards used in the work:

  Construction standards used in the work were taken from national and international literature.
- Please, indicate the kind/type of insurance applied for designer/construction company, write NONE when no insurance applied: NONE

Issues related to construction features:

- Were there any plantation techniques used to better attain and/or preserve soil humidity?

  Yes, additional fertile soil was added into plantation holes

- Were there any mycorrhizae used in the utilised plants? NO
- Were there any changes in terms of the plant species used in comparison with those included at the design stage? If so, how those changes were justified?

  No plant changes was done

-Were the utilised plants regionally distinctive/characteristic of the intervention area? The utilized plants species were naturally growing in the region

- Were there any quality control for the materials, plants (quality and origin) used in the work? If so, which normative (standard) was followed?

Saplings were inspected visually for viability in the nursery in order to make sure for transporting live plants to the site. But there was no a specific standard for plant selection.

- Information regarding quality control for the inert materials (grey materials). Related normative (standard).

Quality control of the materials were inspected visually according to scientific literature not to any standard. Eg. size and quality of the stacks

- Information regarding quality controls for the living material (vegetation, stakes, seeds, live branches, etc.). Related normative (standard).

Inspected just visually

- Were there any hormone treatment used for improving plant rooting capacity and root system development? Related normative (standard).

No hormones but fertile soils were used in the planting holes for a better growth performance

- Plant density. In case of herbaceous species: seeding rate. Plant density was 150 saplings per hectare for woody plants and 50 gr seeds per square meter for seeding with herbaceous plants species

- bad connections/junctions between the logs,

connections between stack were good

-bad lateral connection of the work edges with the slope,

Connections were good enough

- Insufficient or missing soil compaction: soil surface conditions were levelled before revegetation

-Adverse climate conditions NO

Miscellaneous:

- Information regarding the qualification documents of the construction company in the field of soil- and water-bioengineering techniques? Construction company had enough documents with good quality
- Qualifications and sufficient number of the workforce employed (in terms of workforce capacity to finish the work within the decided schedule and reaching the pursued quality standards)? Enough labour force was employed
- Were there any adherent polluting matters or residues on inherent construction material? NO
- Groundwater appearance? NO
- Sanitation failure? NO
- Natural landslide impact? NO, just gully formation
- Destruction by local residents (or vandalism) observed? Yes. Some people used the site for passing through to the nearby areas or for recreation purposes shortly after work completion. Because of this problem, 90% of plants disappeared in the following years after work was completed. However, intensive tree plantations and planting of grass cover in the area increased vegetation cover after late 1990's.

CONCLUSIONS AT THE CONSTRUCTION STAGE ANALYSIS:

Please, include here the main conclusions of your analysis at this stage.

Which improvements would you propose for the analysed bioengineering work at the construction stage?

Since fences were destroyed time to time, it affected success of the work especially, sapling survival rate. Some other effective ways could be sought to increase success of the construction stage like hiring more guards, especially for night shifts.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

Please, provide information regarding the bioengineering work monitoring and maintenance tasks carried out.

- Was there a maintenance contract? NO
- Comparison between specification/design and 'as built' measure Construction company carried out everything that was planned in the design stage

Information on any maintenance work during monitoring phase. If applicable, conduct a characterisation of the maintenance tasks in terms of their performance and suitability

There were some maintenance problems. Fence wires were destroyed time to time but fixed by municipality staff. Locations with poor sapling survival and seedling establishment were checked and revegetated. Intensive plantation applications carried out in the area after especially second half of the 1990's

- Analyse all the available information regarding the bioengineering work monitoring tasks carried out: Area was voluntarily monitored time to time for short periods by an expert from the construction Company.
- Was there any monitoring specified? If so, was it installed/performed as planned? If not, please note any reasons there was no monitoring specified in this case study:

  There was no monitoring programs specified in the contract because of problems associated with burocracy.
- Was there any instrumentation left in situ for monitoring? Detail? NO
- Were inspections carried out? How regularly? Who carried out the inspections (qualifications?).

  Inspections were carried out by the experts from the company during the whole construction stage but not in the monitoring stage.
- Were there any defects noted after the defect correction period? What was the nature of the defects? Who noted them? Who corrected them? Who paid for them? Value (as percentage of the total contract)?

  There were not any defects noted during the construction period.

- Were there any emergency works carried out? What was the nature of the works? Who carried them out? Who paid for them? Value (as percentage of the total contract)?

  There was no emergency work carried out in this case study

LEVEL 3. ANALYSIS OF THE CURRENT STATE OF THE BIOEGINEERING WORK

- This level is directly related to the field work protocol (protocol 3). In this level we will analyse the data related to the operation stage (or work service life stage) of the work. This is the stage in which the construction site field work takes place.

IN SITU FIELD WORK VARIABLES SELECTION

- Please, show the selected set of field work variables used for the bioengineering work field work analysis. **Please, recall that the selected set of field work variables should include those able to effectively reflect the bioengineering work evolution, performance, and beneficial effects.**
- Justify the set of field work variables you finally chose. Please, explain the criteria followed in this process. The field work variables can be classified according to the following categories:

WOODEN ELEMENTS

Tree species used for the timber utilised in the work: Wooden stakes with about 5-8 cm in diameter and 40-80 cm in length were also utilized. Live Salix and poplar branches were also used to interlace stakes. Bundles of dead plant branches were also used.

Diameters used: Stakes with 5-8 cm diameters
Mechanical properties measures result of both the deteriorated logs and green samples of the same tree species: Wooden stakes degraded and disappeared and nothing left from them on the site while some poplar trees developed from wattle fences.

Cross sectional loss: Result of comparison between the initial and current diameter values: No stakes left on the site to compare diameter lost.

PLANTS (IN/OUT THE BIOENGINEERING WORK).

Plant species (tree, shrub and herbaceous): 2/0 or older saplings of tree species were used for plantation. Tree species included Acer pseudoplatanus, Alianthus glandulosa, Amorpha fruticosa, Cedrus libani, Cupressus arizonica, Eleagnus angustifolia, Laurus nobilis, Picea alba, Pinus brutia, Pinus nigra, Populus nigra, and Robinia pseudoacacia, Salix viminalis, whereas shrub species were composed of Berberis thunbergii 'Atropurpurea', Buddleia variabilis, Cistus laurifolius, Cydonia japonica, Erica arborea, Euonymus japonica, Hibiscus syriacus, Ligustrum japonicum, Spartium junceum, and Tamarix sp.

Heights and diameters: trees 7-8 m in height, 25-30 cm in diameter

Land cover rate: canopy cover is less than 15-20%, turf grass cover is around 90+%

Biodiversity index (nº of species): not measured

Root depth: 60-100 cm

Root tensile strength: not measured

Root pull out strength: not measured

SOILS

Soil moisture observed: Available moisture content was determined

Soil pore pressure: not measured

Organic matter content: measured

Aggregate stability: not measured

Shear strength: not measured

Measured soil properties were presented in Table 1.

Table 1. Some selected soil properties at 0-40 cm soil depth in the bioengineering work area.

Soil parameters	Treated site (n=12)
Soil pH (1/2.5 H_2O)	7.8
Electrical conductivity (1/2.5 H_2O) (µS/cm)	205.1
Organic matter (Walkley-Black method) (%)	1.2
Lost on ignition (%)	3.57
Moisture content (%) at field capacity for 0-20 cm soil depth	14.2

WATER/TEMPERATURE/CLIMATE

Precipitation: mean annual precipitation is 691.4 mm

Snow period: about 2- 3 week

Temperature (air/soil): mean annual air temperature is 13.7 ^{O}C

Ground water appearance interacting or not: not

Air moisture content/humidity: 78%

Drainage (runoff, drains, etc): No runoff anymore

OTHER UTILISED GREY AND GREEN MATERIALS

A more detailed information can be found in Protocol 2 and 3.

Geotextiles biodegradable, mulch, geosynthetics, and rocks were not used

BIOENGINEERING WORK CURRENT STATE DESCRIPTION

Include in this section the field work variables description from a statistical point of view (number of samples, average, variance, variation coefficient, etc.).

Please indicate the field work procedures followed in your work.

Field work variables were presented in Table 1 and also soil properties measured in both treated and untreated site were statistically compared.

COMPARISONS WITH REFERENCE SCENARIOS

PRE-RESTORED SCENARIO:

A complementary analysis of an adjacent or nearby area without bioengineering intervention must also be accomplished (if possible) in order to assess the overall beneficial effects of the bioengineering intervention.

Location: Since there is no untreated site close/next to bioengineering work area due to site development, we were not able to take soil sample to compare with those of soils from the bioengineering work site

Please indicate the main differences found between the bioengineering work area and the pre-restored scenario: **We can only visually compare pre- and post-rehabilitation scenario for this case study. In this context, we can conclude that** there is significant difference between pre and post bioengineering work stages.

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There was surface and gully erosion before the works and now there is 15-20% canopy cover by trees and lawn cover nearly whole area (Fig. 3 and 4).

Fig. 3. General views just beginning of the the rehabilitation works (1998).

Fig. 4. General views after the rehabilitation and maintenance works (2018).

TARGETED SCENARIO (END-POINT SCENARIO):

The targeted scenario is a study area similar to the intervention area, but not in need of stabilisation. This site represents the study area if it were undisturbed or stable. Conditions at the reference site represent the conditions that are the goals of the intervention.

Location: there is no target area.

Field work variables measured: NO

Number of samples taken and field work variables average values: NO

The targeted scenario is to maintain current stage of the site; with a good herbaceous and woody vegetation cover without sheet or gully erosion

Currently, Bioengineering work provided a better landscape view and a nice place for recreation. All massy and dirty appearance disappeared from the site.

What is the effectiveness level of the intervention compared to the targeted situation? Which is the level of fulfilment of the restoration objectives? Is the work evolving at an adequate pace from a restoration performance point of view? **All goals were achieved after bioengineering work including stabilizing soil surface, preventing gully formation, bringing a good ornamental vegetation cover, and creating a nice place for recreation.**

Please indicate the presence of plants belonging to different successional stages in the intervention area, the pre-restored conditions and the targeted conditions (the end point scenario): Compared to case study site, untreated site was invaded by undesirable invasive plant species. In contrast, the site where bioengineering work carried out provides a good scene with different ornamental herbaceous and woody plants.

Is Climate Change affecting the achievement of the targeted conditions? In which variables this influence is more intense? Istanbul Metropolitan municipality is in charge of maintenance of the site and they irrigate the site when water is needed. Therefore, climate change is not detrimental in the site presently.

LEVEL 4. ANALYSIS OF THE WORK PERFORMANCE

In this section we should be able to do the following:

– Analysis of the gap between the planned (designed) work and the 'as built' work

Due to lack of maintenance and monitoring contract, vegetation structure was disturbed and Most of the tree species disappeared. but since 1990's tree species changed and interspaces was covered with turf grass by Municipality.

– Work performance and beneficial effect analysis: not done

– Which are the achieved functions or targets? For example, **Ecological functions**: such as biotope connectivity, habitat improvements (in number and in quality), plant community development, …., **hydrologic and hydraulic functions**, **geotechnical functions**, **landscape functions**, **socio-economic functions**, etc. Hydrologic and landscape functions were achieved in the site. Soil erosion was prevented, and poor drainage condition was improved and soil surface was covered with lawn.

Particularly, the assessment of the bioengineering work elements performance (inert elements, plants, other materials) will be done. Examples of this are the following:

- Suitability of the plant species utilised in the work: Are the plant species well adapted to the site conditions (soil, climate, aspect, etc.)?

  Plant species used for plantation were already selected in relation to their suitability to site condition requirements and their tolerance to poor soil conditions. Revegetation success in the poor sandy soil conditions indicate that there was a success in the selection of plant species
- Were the seeds used for the hydroseeding appropriately selected? Instead of hydroseeding, broadcast seeding was performed in the site.
- Problems related to the lack or abundance of water

  Water deficiency problem is solved with automatic irrigation system during second phase.

ECOMED

- Problems related to an excessive plant density

  There is no excessive plant density on the southern aspect whereas there is an excessive plant density on the northern aspect due to lack of maintenance works.

Problems related to soil fertility

  Sandy soil had a very low organic matter and it is still the same. So, fertile soil was added into plantation holes. Currently, Istanbul Metropolitan municipality fertilizes the site 2 times in a year.

- Problems related to slope aspect/angle/topography

  Topography was not a problem in the site. Before the stabilization work, there was 2 m deep gullies at the toe of the manmade slope and sheet erosion on the surface of two aspects.

- Problems with availability and adequacy of workforce with relevant qualifications

  Enough labour force used to hire but it is now questionable

- Problems with access to the work site

  There was no problem to access the site during construction because special cars used for transporting experts and labour.

- Problems with health/safety (e.g. invasive species) the northern exposure is under the threat of invasive plant species (Ailanthus glandulosa, Robinia pseudoacacia).

- Problems related to a maintenance contract failure There was no contract for maintenance.

- Problems related to a missing maintenance contract NO

- Engineering/Stability performance of the works Stability performance of work is satisfactory.

- Sustainability performance of the works Sustainability performance of the work is good. Site functions very well what it is expected to provide

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Please, show here your conclusions obtained after combining the different levels analysed (design, construction, /maintenance and monitoring).

Please, include in this section your opinion to describe the result of the work, in terms of the pursued objectives. You may use the following approach:

- Very successful evolution of the work (all the main objectives were achieved) during 1 to 2 or 3 years after its completion
- The successful evolution of the work (all the main objectives were achieved) after more than 5 years after its completion
- Acceptable evolution and results (the main objectives were partially achieved) after more than 5 years after its completion
- Long-term failure (after more than 5 years after its completion): slope failure, erosion problems, etc.
- Short-term failure (within 2 or 3 years after its completion): slope failure, erosion problems, etc.

With this bioengineering work all objectives were pursued at the beginning of the project. But due to lack of maintenance and monitoring contracts, human traffic caused disturbance in the site for both protection fences and vegetation. Therefore, some maintenance problems were appeared. For instance, fence wires were destroyed time to time but fixed by municipality staff. Locations with poor sapling survival and seedling establishment due to trampling were checked and revegetated. However, Intensive plantation applications carried out in the area after especially second half of the 1990's

Please, indicate how the initial risks that were present in the intervention area have decreased because of the bioengineering work benefitial effects. After tree species became mature and gaps between trees covered with turf grass by Municipality staff, risks for vegetation disturbance decreased.

Is the climate change affecting the performance of the bioengineering intervention? If so, please indicate how.

Since Istanbul Metropolitan Municipality is in charge of the site, they fertilize the site twice a year, irrigate the area, prune the trees, and mow the turf grass cover very often.

Finally, include in this section your opinion, in a justified manner, about why the work succeeded and/or failed in achieving its objectives. Include your proposals for improving the work performance and efficiency.

The final goal in this project was achieved. The site functions very well in terms of preventing soil erosion, creating a nice beautiful landscape for recreation, and presenting a nice scene with several ornamental plant species. It can be said that only lack of maintenance and monitoring contracts can be accepted as a failure in this case study because they affected vegetation structure of the site in the first phase.

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CASE STUDY - COASTAL

COASTAL SAND DUNE STABILIZATION, TERKOS LAKE PROJECT REPORT

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE:

Work location / project title:

Terkos sand dune area, Istanbul / Coastal sand dune stabilization to prevent sand movement into fresh water sources, Terkos Lake.

UTM coordinates:

35T 624016.78 E, 4584996.43 N - 637984.46 E, 4572430.11 N

Completion date of the design stage:

1961

Completion date of the construction stage:

1987

Client: (e.g. private or public person or industrial company):

Public - General Directorate of Forestry

SUMMARY

Main goal of the project was to prevent sand dune movement from Black Sea coast into adjacent fresh water source, Terkos Lake which provides potable water to Istanbul city.

Sand dune covered area was converted to a heavily dense vegetation cover consisting of woody, shrubby, and herbaceous plant species to stabilize sand dune movement permanently.

ECOMED - ECOENGINEERING IN THE MEDITERRANEAN ENVIRONMENT

TERKOS SAND DUNE CASE STUDY REPORT

Authors: University of Istanbul

GENERAL INFORMATION ABOUT THE PROJECT AND THE CONSTRUCTION SITE

Work location / project title:

Terkos sand dune area, Istanbul / Coastal sand dune stabilization to prevent sand movement into fresh water sources, Terkos Lake.

UTM coordinates:

35T 624016.78 E, 4584996.43 N - 637984.46 E, 4572430.11 N

Completion date of the design stage: 1961

Completion date of the construction stage: 1987

Client: (e.g. private or public person or industrial company):

Public-General Directorate of Forestry

INFORMATION RELATED TO THE ANALYSIS OF THE PROJECT

LEVEL 1. WHAT INFORMATION WAS CONSIDERED AND COLLECTED FOR DESIGNING THE PROJECT?

The main problem in the project site was the movement of wave- and windbornsands from Black Sea coast into the lake. In other words, sand dune movement into Terkos Lake had threatened fresh water sources storage capacity of Terkos Lake. There was no plant at the site to prevent sand dune movement into Terkos Lake. Therefore, it was aimed to stabilize the sand movement and revegetate the site by soil bioengineering works. However, soil conditions in the site were not appropriate for revegetation because of extremely poor and harshsand conditions.Also,there was a problem in terms of soil moisture since there was just pure sand in the site. In addition, water holding capacity of the sand was also low.

The wooden fences constructed to stabilize sand dune movement in 1961 (Archive of General Directorate of Forestry, 2012)

Since the land is a state owned area, General Directorate of Forestry (GDF) took an action to save Terkos Lake from sand dune movement. For this purpose, the main strategy was consisted of the followings:

1. Stabilization of sand dune movement
2. Construction of fences as combination wooden materials and dead reed wattlings close to the shoreline.
3. Establishing a grid system with dead shrub materialsbehind the fences.
4. Soil reinforcement.

Revegetation of the siteby planting with tree and shrub saplings and seeding with herbaceous plant species.

In the project site the soil bioengineering techniques were used for the following two processes:

1. The soil bioengineering techniques used for sand dune stabilization:

Fences were constructed on the sand dunes parallel to the shore line perpendicular prevailing wind direction as a combination of wooden and dead reed wattling materials.

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Wooden slabs with about 2 cm thickness and 10 cm wideness and poles 10x10cm were also utilized.

Additional fence rows established behind the wooden fence.

Then, a grid system was established perpendicular to the prevailing wind direction on the sand dune starting just behind the fences.

A view of wooden fences (on the left side) and the grid system (in the middle) and fences with dead plant materials rows (on the right side)which were constructed in the site in term of sand dune stabilization

2. The soil bioengineering techniques used for revegetation:

Following sand dune stabilization by using dead plant materials and wood, the soil reinforcement and enhancement of soil was achieved by putting fertile soils into planting holes for revegetation. In order to inoculate microorganisms to the duneforincreasing growth performance and survival rate of saplings, 2-2.5 kg fertile soils were added to the plantation holes.

In addition, drill seeding with some seeds of native herbaceous plants collected from surrounding area, then deep-hole plantation and patch sowing were the plantation techniques used.

In order to have enough saplings, seeds of tree and shrub species were provided by forest service and sown in pots in nursery. Seeds of herbaceous plant species were collected from surrounding area.

Plant species (trees and, shrubs): Tree species used included *Pinus maritima*, *Pinus pinea*, *Pinus brutia*, *Cupressus pyramidalis*, *Alnus glutinosa*, and *Robinia pseudoacacia* whereas shrub species were composed of *Tamarix sp*., *Spartium junceum*, *Hippophae rhamnoides*, and *Sarathammus scoporius*.

In addition to woody vegetation, native herbaceous vegetation species from surrounding area were also used such as *Ammophilla arenaria*, *Ammophilla brevilligulata*, *Isatis arenaria*, and *Allicum spp*.

Revegetation processes in the site by planting of saplings of some tree and shrub species

INFORMATION TO ANALYSE THE WORK THROUGHOUT ITS CONSTRUCTION AND SERVICE LIFE

- In this section the work will be analysed throughout its service life. We will have the following levels of analysis:

Level 1: Construction stage analysis

Level 2: Operation, maintenance and monitoring stage analysis

Level 3: Current state of the bioengineering work

Please note that, at level 3, comparisons with reference scenarios (pre-restored and end-point scenarios) will also be included.

Level 4: Analysis of the bioengineering work performance

Level 5: Conclusions from the bioengineering work performance analysis.

LEVEL 1. CONSTRUCTION STAGE ANALYSIS (CONSTRUCTION COMPANY'S WORK)

There were some flaws of construction stage which were about poor soil conditions, bad plant survival rates and short period of time. There was no soil at all at the site. There was only sand dune without soil formation so fertile soil from forest was used in the planting holes to increase the plant survival rates. However,plantation density varied between 2500-10000 saplings per hectare during the rehabilitation study while it presently decreased to 750 trees / ha. In order to help trees to show better growth performance, forest service has started maintenance works and been applying selective cutting method to thin the forest in the site.

Additionally, due to the lack of enough labor and/or money, construction stage of the work took long time.

LEVEL 2. MAINTENANCE AND MONITORING STAGE ANALYSIS

There was no maintenance problem. In terms of suitability, characterization of the maintenance tasks were achieved. After rehabilitation works were completed, the site was excluded from human activities and survival rate of tree saplings was monitored and analyzed. In case of plantation failure, locations with poor sapling survival and seedling establishment were checked and revegetated by forest service.

LEVEL 5. CONCLUSIONS OF THE BIOENGINEERING WORK PERFORMANCE

Sand dune movement was prevented and land surface was stabilized in the site.

Sand dune did not have organic matter. So, fertile soil was added into plantation holes. Also, there was a problem in terms of soil moisture because there was just pure sand in the site. So, water holding capacity was low and it is still low. That's why plant selection was made based on their tolerance to poor soil moisture conditions.

Plant species used for plantation were selected in relation to their site condition requirements and their tolerance to poor soil conditions. Revegetation success in the sand dune area indicated that there was a success in the selection of plant species.

As of 2018, tree species reached about 7-8 m height with a diameter of 25-30 cm at breast height.

Soil surface covered by woody and herbaceous vegetation with a percent varying between 71% and 100%. Organic matter content of the top soil and forest floor increased from 0% to 8% and none to 1 kg per square meter, respectively.

Overall project goal was to stabilize sand dune movement from Black Sea coast into Terkos Lake.The rehabilitation strategy to gain this goal worked very well and currently sand dune doesn't move forward to into fresh water sources and residents of Istanbul city utilize the fresh water from Terkos Lake. This bioengineering work has provided a green landscape on the sand dunes of Black Sea coast.

Wooden materials were degraded and some parts left on the site after completing their functions. And dimensions of the wooden materials were changed due to degradation as a result of environmental factors from climate conditions of the Black Sea cost. This situation and the time-consuming due to lack of enough labor and/or moneycan be accepted as the flaw of this project.

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PROPOSALS OF IMPROVEMENT FOR FUTURE SOIL AND WATER BIOENGINEERING WORKS

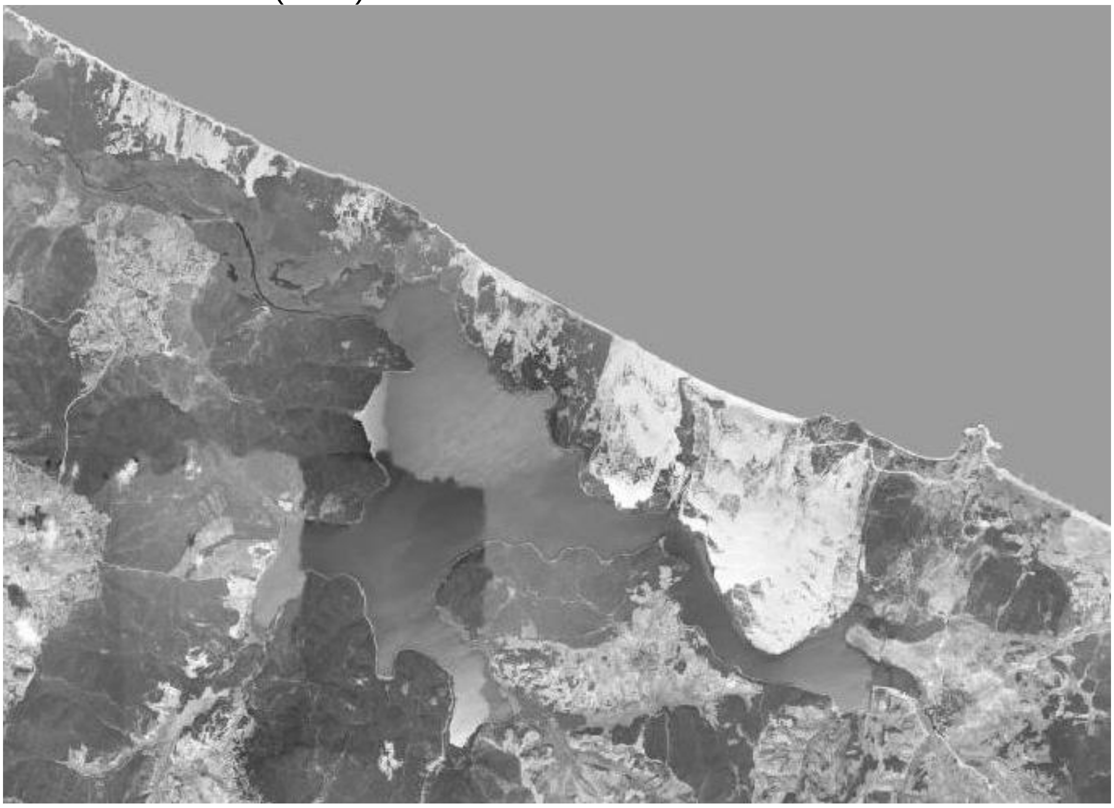
Construction stage can be improvable with an intensive work plan to gain time.

In the construction stage, there could be more alternative solutions to increase growth performance and survival rate of saplings. **For instance, fertile soil could be applied interspaces of the saplings in addition to planting holes. This strategy could increase organic content of the sand dune and promote seedling growth and survival of herbaceous plants.**

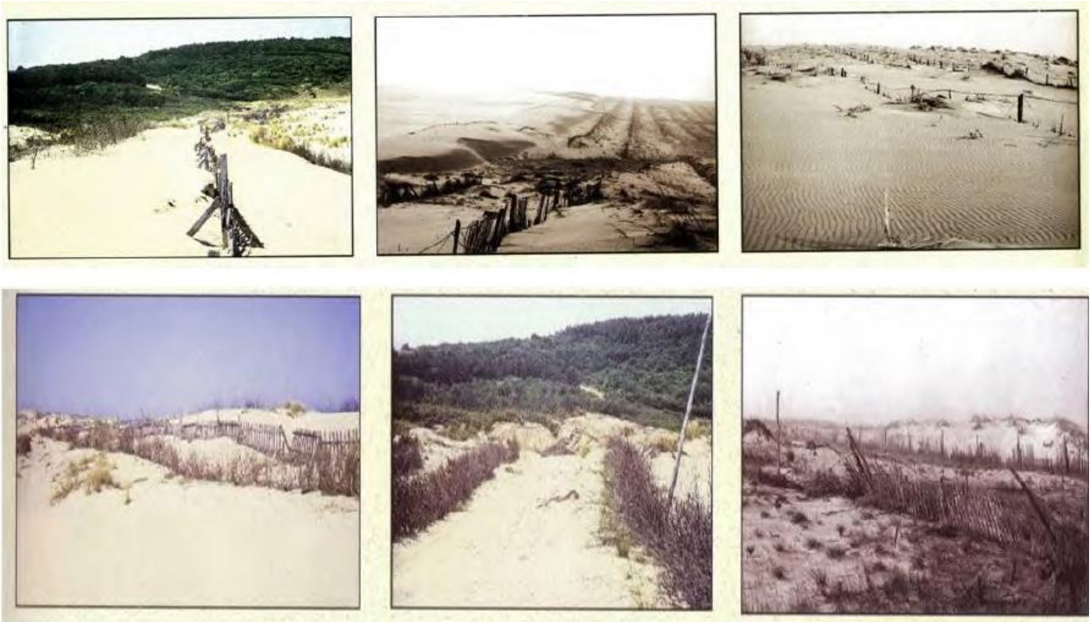
Also, in addition to conifer tree species, some broadleaf tree species could be selected for plantation. This preference could increase litter accumulation and turnover rate of the litter. Then, nutrient content of the sand could be improved a little bit quickly.

PICTURES

BEFORE WORKS (1970)



AT THE BEGINNING OF THE WORKS (1971)



AFTER WORKS (2018)


ÇATALCA ORMAN İŞLETME
MÜDÜRLÜĞÜ
ORMAN YÜKSEK MÜHENDİSİ
İBRAHİM AKSU
DURUSU (TERKOS) KUMUL AĞAÇLANDIRMA
HATIRA ORMANI