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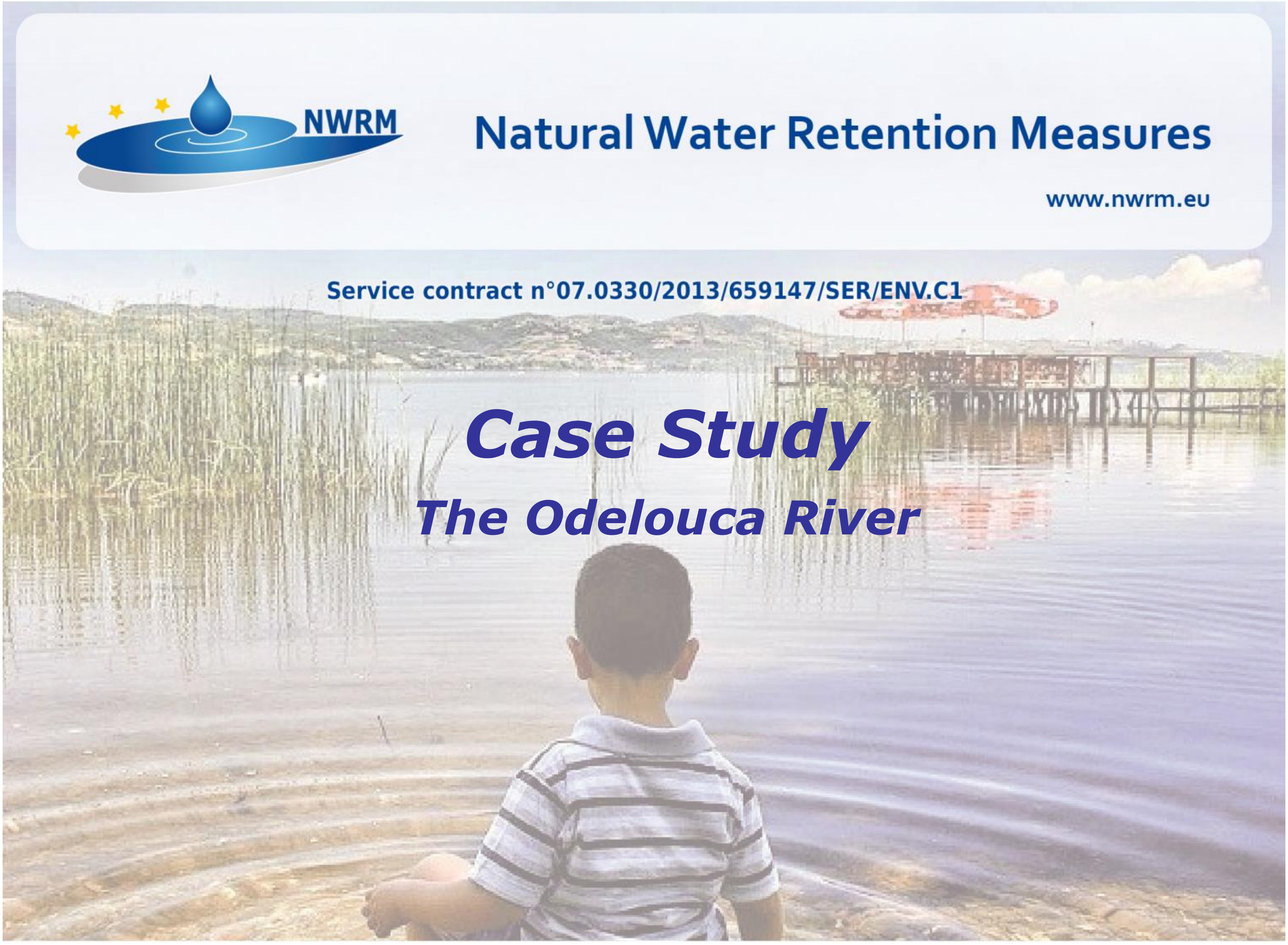

Natural Water Retention Measures

www.nwrm.eu

Service contract n°07.0330/2013/659147/SER/ENV.C1

Case Study

The Odelouca River

ACTeon environment research & consultancy

Office International de l'Eau

amec foster wheeler · BEF Latvia · enveco Environmental Economics Consultancy · I.A.CO Ltd Environmental & Water Consultants · IMDEA water · Regional Environmental Center · REKK · SLU · SRUC

Environment

This report was prepared by the NWRM project, led by Office International de l'Eau (OIEau), in consortium with Actéon Environment (France), AMEC Foster Wheeler (United Kingdom), BEF (Baltic States), ENVECO (Sweden), IACO (Cyprus/Greece), IMDEA Water (Spain), REC (Hungary/Central & Eastern Europe), REKK inc. (Hungary), SLU (Sweden) and SRUC (UK) under contract 07.0330/2013/659147/SER/ENV.C1 for the Directorate-General for Environment of the European Commission. The information and views set out in this report represent NWRM project's views on the subject matter and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this report. Neither the Commission nor any person acting on the Commission's behalf may be held Key words: Biophysical impact, runoff, water retention, effectiveness - Please consult the NWRM glossary for more information.

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I. Basic Information

Application ID	*Portugal_01*	
Application Name	**The Odelouca River: natural bank stabilization and riparian buffer galleries as part of mitigation and compensatory measures and through the use of bio-engineering techniques**	
Application Location	Country: Portugal	Country 2: *No*
	NUTS2 Code	PT15
	River Basin District Code	PTRH8
	WFD Water Body Code	
	Description	The Odelouca River, a sub-catchment of the Arade basin is a medium-sized, low-gradient, intermittent lowland stream. The typically Mediterranean climate exhibits a predictable seasonal pattern of rainfall (wet season from October to March, dry season from June to September), resulting in a relatively slow running river, subject to "flashy" spates in the winter, which is reduced to a dry riverbed with unconnected, temporary pools during the summer. Catchment topography varies from narrow steep sided valley walls to restricted meander valleys and small floodplains. The river was considered to have a remarkable value because of the former presence of intact and floristically diverse riparian galleries along the large stretches of the river corridor (then cleared and submersed following completion of the Odelouca Dam in 2010) and the presence of critically endangered species such as the endemic fish species and the Iberian Lynx. Agriculture (extensive citrus groves and low-level grazing) has replaced the natural Mediterranean cork-oak woodland vegetation, on the wider floodplain located downstream the dam. Urbanization is scant, restricted to two small villages and small agricultural hamlets. Some of its tributaries are affected by livestock activities and agricultural irrigation.
Application Site Coordinates	Latitude: *- ETRS89: 37,24407405 N to 37,26954422 N*	Longitude: *- ETRS89: 8,49881363 W to 8,49241368 W*
Target Sector(s)	Primary:	Hydromorphology
	Secondary:	Forest
Implemented NWRM(s)	Measure #1:	N10, Natural Bank Stabilization
	Measure #2:	F1, Riparian Buffers
Application short description	The measures implemented focus on the use of bio-engineering or natural techniques for rehabilitation of riparian buffer zones and river banks such as: i) resectioning of river banks and placement of geotextile to prevent erosion, retain soil moisture, prevent (re) growth of weeds and invasive plants and create favourable conditions for planted native plants (reed bed removal / placement of	

	geotextile; 100% coco fibre with 2 polypropylene nets); ii) construction of a crib wall and placement of stone filled gabions to stabilise river banks (vegetated rock armour, live cribwalls (i.e Krainer wall), and vegetated gabions); iii) planting of rehabilitated banks with native plant species, collected from cuttings and seeds in the area and grown on in local nurseries (e.g. Tamarix, Oleander, buckthorn and ash); iv) construction of artificial islands in the river channel; v) clearance of invasive riparian plant species (*Arundo donax* and *Acacia sp*).

II. Policy context and design targets

Brief description of the problem to be tackled	Main human impacts have been mostly related to changes in land use and alterations in water and channel management (Hooke, 2006; Aguiar and Ferreira, 2005). The construction of the Odelouca Dam (2010), to increase water supply for the Algarve Region (southern Portugal), implied a major morphological alteration in the middle course of the river Odelouca. Prior to the construction of the dam, upstream and downstream sections of the river had been already modified by human activities (due to agriculture of extensive citrus groves replacing riparian forest), causing disturbance in riverbanks and riparian vegetation. The lower course is the most degraded stretch, subject to re-sectioning and canalization in some areas. In many places invasive reed and giant reed beds have also replaced the riparian woody vegetation. The dam construction, and the flooded area, affected the section of the river that had been better ecologically preserved, which triggered the need of restoring the river functionality, the water retention capacity of the system and the ecosystem function.		
What were the primary & secondary targets when designing this application?	Primary target #1:	Biodiversity and gene-pool conservation in riparia	
	Secondary target #1:	Mass stabilisation and control of erosion rates	
	Secondary target #2:	Soil formation and maintenance	
	Remarks		
Which specific types of pressures did you aim at mitigating?	Pressure #1:	WFD indentified pressure	4.2.3 Dams, barriers and locks for drinking water
	Pressure #2:	WFD indentified pressure	4.2.4 Dams, barriers and locks for irrigation
	Pressure #3:	WFD indentified pressure	4.1.2 Physical alteration of channel/bed/riparian area/shore of water body for agriculture
	Pressure #4:	Other EU-Directive's identified pressure (specify)	The Habitats Directive (92/43/EEC)(5);
	Remarks	Regarding the Habitats Directive, specific pressures are: - A09: irrigation. - A10: Restructuring agricultural land holding (removal of hedges and copses or scrub (A10.01), stone walls and embankments (A10.02); including (temporary) transition from dry to mesic or wet conditions due to irrigation). - Diffuse pollution to surface waters due to agricultural and forestry activities (H01.05) and to household	

		sewage and waste waters (H01.08) - I01: invasive non-native species - J02.05.04: Modification of hydrographic functioning, general (reservoirs) - J02.06.01: Surface water abstractions for agriculture - J03.01: Reduction or loss of specific habitat features -J03.02: Anthropogenic reduction of habitat connectivity	
Which specific types of adverse impacts did you aim at mitigating?	Impact #1:	WFD indentified impact	Altered habitats due to morphological changes
	Impact #2:	WFD indentified impact	Diminution of quality of associated surface waters for chemical / quantitative reasons
	Impact #3:	Floods Directive indetified impact	Water body status
	Impact #4:	Floods Directive indetified impact	Protected areas
	Impact #5:	Floods Directive indetified impact	Other Environmental impacts
	Remarks	As has been pointed out before, the lower course was the most degraded stretch subject to re-sectioning and canalization in some areas. **Others from the WFD**: Organic pollution **Other from the Floods Directive**: Pollution sources (in both cases mainly due to diffuse pollution from irrigated agriculture)	
Which EU requirements and EU Directives were aimed at being addressed?	Requirement #1:	WFD-achievement of good ecological status	
	Requirement #2:	Floods Directive-establishing adequate PoM	
	Requirement #3:	Other EU-Directive requirements (Specify)	The Habitats Directive (92/43/EEC)(5);
	Requirement #4:	Other EU-Directive requirements (Specify)	The Birds Directive (79/409/EEC)(1);
	Requirement #5:	Other EU-Directive requirements (Specify)	An EU Strategy on adaptation to climate change (COM(2013) 216).
	Remarks Restoring riparian areas of surface waters via protected vegetated buffer zones goes beyond the concept of a buffer strip to provide a natural fully functional barrier to protect water bodies. This measure provides water purification services and improves river quality by reducing pollution caused by nutrients, pesticides, and suspended solids, flow (mass) regulation services by controlling erosion and sediment transport in addition to leading to runoff control. It contributes to the achievement of GES since it improves both the aquatic and the terrestrial ecosystems as it provides ecological corridors providing habitat services. In turn, natural bank stabilization also leads to multiple benefits, improving all aspects of GES including improvement/regulation of hydrological regime		

	(regulating river flows, improving the hydrological balance, increasing groundwater recharge and summer low-flow, increasing water exchange between the surface and the subsurface environment, and improving chemical and biological status). The improvement of GES also leads to increasing clean water availability and providing a water provisioning service. Implemented measures thus contribute to the WFD art. 4, FD art. 7, HD objectives 1 & 2, and BD art. 3.
Which national and/or regional policy challenges and/or requirements aimed to be addressed?	Monchique Site Natura 2000 (PTCON0037), ranked by Resolution of the Council of Ministers No. 142/97 of 28 August: preservation and conservation of existing habitats in the area, specifically those listed under the Habitats Directive transposed to national law by Decree-Law n.140/99 of 24 April. The Liga para a Protecçao da Naturaleza (LPN) presented a complaint to the EC for the violation of the Natura 2000 protected area with the construction of the Odelouca Dam. A ministerial order in 2005 confirmed the continuation of the works, including the conditions stipulated by the EC for its construction.

III. Site characteristics

Dominant Land Use type(s) *CORINE LU types and codes*	Dominant land use	324-Transitional woodland-shrub
	Secondary land use	323-Sclerophyllous vegetation
	Other important land use	243-Land principally occupied by agriculture, with significant areas of natural vegetation
	The previous categories represent 50% of the Land Use Cover (2006) in Algarve Region. In general forest and semi-natural areas represent 52% of the territory while agriculture is 40% of total uses. The other specific dominant uses in agriculture are: 241-Annual crops associated with permanent crops, 242-Complex cultivation patterns and 222-Fruit trees and berry plantations. Other important use is 311-Broad-leaved forest. Water bodies and wetlands are less than 4% of total land use.	
Climate zone	warm temperate dry	
Soil type	According to the European Soils Portal of JRC, in the area there are 3 predominant soil types: Luvisols, Cambisols, Regasols. Other sources include Lithosols as relevant in the study area.	
Average Slope	nearly level (0-1%) (The average slope of the basin is 26%)	
Mean Annual Rainfall	900 - 1200 mm (Annual average rainfall is 934 mm, however it varies depending on the pluviometric station location from 730 mm to 1086 mm. There are also high monthly variations: July and August are dry months with mean rainfall under 5mm, while December and January record the highest rainfall with values above 160 mm.	
Mean Annual Runoff	Select the Mean Annual Runoff value	
Average Runoff coefficient (or % imperviousness on site)	Select the Average Runoff Coefficient value	Select the % imperviousness on site
	Remarks	
Characterization of water quality status (prior to the implementation of the	Phosphorus and nitrogen loads disposed in the river are 20/t/year and 236/t/year, respectively. Livestock production (pig farming) is responsible for 39 ton/N/year of nitrogen loads to the basin and 6	

NWRMs)	ton/P/year of phosphorus loads. Diffuse sources of pollution (agriculture) are responsible for 35% of the loads of nitrogen and 18% of phosphorus loads. The highest load of phosphorous admissible in the Albufeira is 11,6 t/year High levels of Fecal Coliforms concentrations due to the lack of wastewater treatment plant for domestic sewage from São Marcos da Serra.
Comment on any specific site characteristic that influences the effectiveness of the applied NWRM(s) in a positive or negative way	*Positive way:*
	Negative way: High variability in rainfall patterns and risk of exposure to long drought periods may jeopardize the development of the riparian forest.

IV. Design & implementation parameters

Project scale	Medium (eg. public park, new development district)	Odelouca river, but more specifically, 7-km section of the river located downstream the dam.
Time frame	Date of installation/construction (MM.YYYY)	2011 (the programme started back in 2005, with preliminary studies)
	Expected average lifespan (life expectancy) of the application in years	*Note: Not applicable.*
Responsible authority and other stakeholders involved	*Name of responsible authority/ stakeholder*	*Role, responsibilities*
	1. Agência Portuguesa do Ambiente	Programme promoter
	2. Águas do Algarve	Monitoring and rehabilitation programme
	3. University of Trás-os-Montes e Alto Douro (UTAD) [CITAB and Fluvial Ecology Lab]	Studies and Monitoring (subcontracted by Águas do Algarve)
	4. RICOVER Project	Monitoring /studies
	5. Instituto Superior de Agronomia (ISA, University of Lisbon)	Studies and specification of the measures
	6. Landowners	Their agreement was needed in order to proceed with the works linked to their lands.
The application was initiated and financed by	The official body initially responsible for the Odelouca Programme was the *Instituto Nacional de Água* (INAG) (which now has been subsumed into the *Agência Portuguesa do Ambiente* (APA)).	
What were specific principles that were followed in the design of this application?	> To recover the functionality of the river > To improve the habitat of endangered species > To increase acceptability and participation of involved stakeholders (landowners) > The character of biological quality elements was assessed in relation to longitudinal changes in habitat quality, including riparian quality. > It was necessary to foresee a modification of the river channel, as downstream the dam the river flow varies (will be most likely reduced). The study area was divided into groups of physically similar units and then	

<table>
<tr><td></td><td colspan="3">the extent of given pressures within each unit was assessed; habitat and riparian integrity and types of impact were quantified in the study area allowing impact specific rehabilitation measures to be drawn up. This was done using the KT method.</td></tr>
<tr><td rowspan="2">Area (ha)</td><td colspan="2">Number of hectares treated by the NWRM(s).</td><td>N/A</td></tr>
<tr><td colspan="2">Text to specify</td><td>As the implementation of measures is recent and the monitoring process is still ongoing, there is not available information on what the actual area treated by the NWRM is.</td></tr>
<tr><td>Design capacity</td><td colspan="3">This information is not yet available.</td></tr>
<tr><td rowspan="8">Reference to existing engineering standards, guidelines and manuals that have been used during the design phase</td><td colspan="2">Reference</td><td>URL</td></tr>
<tr><td>1</td><td>General guidance on restoration:</td><td></td></tr>
<tr><td></td><td>González del Tánago, M., García de Jalón, D. 2001. Restauración de Ríos y Riberas. Escuela Técnica Superior de Ingenieros de Montes. Universidad Politécnica de Madrid. Fundación Conde del Valle de Salazar. Madrid. 319 pp.</td><td>Not available</td></tr>
<tr><td></td><td>Sacchi, L. 2003. Linee Guida Per Interventi Di Ingegneria Naturalistica Lungo I Corsi D'acqua. IRIS sas Strategie per L'ambiente. Direzione di progetto Pianificazione Territoriale – Servizio Pianificazione Paesistica Ambientale. Itália. 165pp.</td><td>http://www.guerini.it/index.php/linee-guida-per-interventi-di-ingegneria-naturalistica-lungo-i-corsi-d-acqua.html</td></tr>
<tr><td></td><td>Adam, P., Malavoi, J. R. & Debiais, N. 2007. Manuel de restauration hydromorphologique des cours d'eau. Agence de l'Eau Seine-Normandie. 60 pp.</td><td>http://www.eau-seine-normandie.fr/index.php?id=5313</td></tr>
<tr><td></td><td>Adam, P., Debiais, N., Gerber, F. & Lachat, B. 2008. Le génie végétal - Un Manuel technique au service de l'aménagement et de la restauration des milieux aquatiques. Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire. La Documentation Française. 290 pp.</td><td>http://www.unitheque.com/Livre/la_documentation_francaise/Le_genie_vegetal-19133.html#.U2CqToUpIfs</td></tr>
<tr><td></td><td>RRC–River Restoration Center. 2002. Manual of river restoration techniques. The River Restoration Center, Silsoe (UK), 122 pp.</td><td>http://www.therrc.co.uk/rrc_manual.php</td></tr>
<tr><td></td><td>Cortes, R. M. V. 2004. Requalificação de cursos de água. Instituto da Água.</td><td>Not available</td></tr>
</table>

		Lisboa. 135 pp.	
	2.	**River bank estabilization:**	
		Zenh, H. 2007. Manual Técnico de Engenharia Natural. Federação Europeia de Engenharia Natural. Zurich.	Not available
		Lachat, B. 1999. Guide de protection des berges de cours d'eau entechniques végétales. 2ª ed. Ministere de L'amenagement du Territoire et de L'environnement. 143 pp.	http://www.biotec.ch/down guide.html
		López-Jimeno, C. 1999. Manual de estabilización y revegetación de taludes. López Jimeno, C. (ed.). Madrid. 704 pp.	Not available
		WRC–Water and Rivers Commission. 2001. Stream Stabilisation. Water and Rivers Commission, River Restoration Report No. RR 10. 32 pp.	http://www.water.wa.gov.au/PublicationStore/first/11792.pdf
		Eubanks, C.E. & Meadows, D. 2002. A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization. U.S. Department of Agriculture Forest. San Dimas (USA). 187 pp.	http://www.fs.fed.us/publications/soil-bio-guide/
		González, C. M & Jimeno, C. L. 2007. Factores Ambientales: funciones y uso de la Vegetacion en la estabilizacion de Laderas, Jornadas Técnicas sobre Estabilidad de Laderas e Embalses, Zaragoza, Espanha. 75 pp.	http://oph.chebro.es/DOCUMENTACION/Congresos_Seminarios/Laderas2007/Ponencias/6%20Lopez%20Factores.pdf
	3.	**Fluvial and habitat restoration (focus in riparian vegetation):**	
		Jund, S., Paillard, C., Frossard, P. & Lachat, B. 2000. Guide de gestion de la végétation des bords de cours d'eau: Rapport général. Agence de l'eau Rhin-Meuse. 54 pp.	http://www.biotec.ch/205-2000-GuideRM.pdf
		Soulsby, C. 2002. Managing River Habitats for Fisheries: A guide to best practice. Scottish Environment Protection Agency (SEPA). Scotland. 36 pp.	http://www.sepa.org.uk/water/regulations/guidance/idoc.ashx?docid=36bca21f-9bdb-4914-92fb-84f91d606ea3&version=-1
		WDFW–Washington State Department of Fish and Wildlife. 2002. Integrated streambank protection guidelines. Washington State Aquatic Habitat Guidelines Program. Washington. USA. 98 pp.	http://wdfw.wa.gov/publications/00046/
		Arizpe, D., Mendes, A. & Rabaça, J. 2009. Sustainable riparian zones. A management guide. Generalitat	http://www.cma.gva.es/webdoc/documento.ashx?id=143055

	Valenciana. València. Spain. 286 pp.
Main factors and/or constraints that influenced the selection and design of the NWRM(s) in this application?	> Legal obligations: with the construction of the dam structure and the subsequent flooding of the basin, was mandatory (EC) to implement compensatory measures, which would improve the river functionality, and the habitats linked to it. > Agreement and permissions from landowners. > The reforestation of riparian areas was done with native plant species, collected from local sites and grown in local nurseries. The design of the measures had to take into account the availability of water, and should mimic when possible the natural distribution of plants.

V. Biophysical impacts

Impact category (short name) Select from the **drop-down menu** below:	**Impact description** (Text, approx. 200 words)	**Impact quantification** (specifying units)	
		Parameter value; units	% change in parameter value as compared to the state prior to the implementation of the NWRM(s)
Runoff attenuation / control (gross precipitation, leaf drip, stem flow and evaporation)	The restored cover of trees and bushes in the riparian gallery will intercept precipitation when it reaches a more mature structure, as currently, not enough time lapse has occurred to perceive these effects. Intercepted precipitation reduces direct runoff and delays the onset of peak flows, and it will become more efficient with a larger and more complex structure of the riparian gallery (i.e. width, different heights/layers of vegetation within the gallery). Some of the measures included the creation of artificial islands in the river channel, which may control the flow regime. Besides, the restoration of riverbanks and the elimination of invasive reed will reduce and diversify stream flow velocity.		
Peak flow rate reduction	See runoff attenuation above. However, the Odelouca is a regulated river now where the flow regime downstream is a managed environmental flow that is released from the Odelouca dam.		
Impact on groundwater	A developed riparian forest increases the density of roots in the soil and creates coarse substrates. During periods of high-energy flow, plant debris and sediments are conveyed and deposited downstream as the flow decreases, increasing habitat heterogeneity. A more heterogeneous structure of soils and riparian areas improve retention via infiltration of water from the river		

	itself during peaks in flow and from precipitation. Also a developed vegetation cover retains pollutants as plants “filter” water as it infiltrates to the aquifer, preventing its contamination.	
Impact on soil moisture and soil storage capacity	A well-developed riparian gallery provides organic matter to the soil through falling leaves and decomposition of senescent plants, which contributes to the creation of natural mulch. The result is an increase of organic content of the soil, which enhances its moisture content and fertility. Other side benefits of a developed riparian forest are the increase of shade areas, lowering local surface and air temperatures, thereby reducing rates of evapotranspiration.	
Restoring hydraulic connection	The restoration of riverbanks improves lateral connectivity of the river (interaction of the river with the valley) and vertical interaction with groundwater.	
Water quality Improvements	There is not measured evidence yet, but a well-developed riparian forest will also help retain pollutants (i.e excess nutrients from agriculture) by “filtering” water as it moves to the groundwater helping to prevent contamination of aquifers.	
WFD Ecological Status and objectives	In 2012, the sampling programme revealed that the overall ecological status of Odelouca river and its tributaries is “excellent” and “good”, despite some spots, which remain heavily organically polluted.	
Reducing flood risks (Floods Directive)	Bank storage of water has been enhanced with the implemented measures and thus its important role in reducing flood intensity and sustaining stream flow decreases. Measures have effect on the slope, rugosity, complexity and state of the riverbank, which are important factors in water storage capacity and retention.	
Mitigation of other biophysical impacts in relation to other EU Directives (e.g. Habitats, UWWT, etc.)	The Odelouca River is part of the Natura 2000 Network, as it is the habitat of two endemic fish species and the Iberian Lynx. By recovering the river functions, and retaining water, a proper functioning of ecosystems to support the habitat of these species is possible.	
Soil Quality Improvements	Increase in organic matter in soil and the development of roots enhances its structure and improves its functionality.	
Other	Erosion control: vegetated riverbanks help to reduce erosion and thus the amount of sediments in the river flow. Vegetation in riverbanks enhances drainage of soils close to the water level preventing them from collapse, supporting adjacent terrain weight. A study	

	(Beeson & Doyle, 1995) in 748-curve river stretches, 67% of non-vegetated areas suffered erosion during a storm event, while 14% of vegetated areas did under same conditions.

VI. Socio-Economic Information

What are the benefits and co-benefits of NWRMs in this application?	> Improvement of water retention capacity in the system > Reduction of flood vulnerability due to a better developed riparian forest > Improvement of water quality * The economic activity of the region is based on traditional activities, which occupied the riversides of the Odelouca with fruit trees (citrus) annual irrigation crops, vegetables gardens and livestock. Traditionally, landowners use as protection for flood risk ripraps and earth embankment, proving memory on past flood events (causing relevant damages). Despite the initial mistrust in the measures to be implemented, most landowners gave their permission to develop works within their property, which will have direct benefits on flood protection, improved soil composition, water availability, and landscape improvement.		
Financial costs	***Total:***	*5,698,300 €*	*This includes the total cost of the initial sub programme of measure (avifauna, fish fauna, riparian galleries and monitoring studies) (5,430,664 €) and the budget of the Project RICOVER for rehabilitation of riparian galleries (267,636 €).*
	Capital:	3.4 – 9.2 €/m^2 (median: 4.5 €/m^2)	Cost range for geotextile application in similar projects carried out in Spain (Mediterranean basins)
	Capital	20.7 €/m^2	Cost of the application of geotextile (coco fibre) plus willow stakes in Spain.
	Capital		Vegetated rock armour
	Capital	72.3 €/m^2	> Live cribwalls (Krainer wall): 5 wood logs [h=2m; □=20cm] plus 30 willow (alive) stakes.
	Capital		Vegetated gabions
	Capital	3,078 €/ha	Vegetation clearance (this is the average cost of 21 implemented projects in Spain). The range was 428 – 7019 €/ha
	Capital	25,203 €/ha	Re-vegetation (this is the average cost of 21 implemented projects in Spain). The range was 1614 - 80249 €/ha
	Land acquisition and value:		
	Operational:		
	Maintenance:		The average annual maintenance cost for bioengineering measures (using live material) is 5% of the investment cost. It is foreseen that maintenance should be 3 year long, thus the total maintenance cost could be estimated as the 15% of the investment cost
	Other:	*15,902 €*	*Monitoring*
Were financial	Was financial compensation required: No		

compensations required? What amount?	*Total amount of money paid (in €):*	
	Compensation schema:	
	Comments / Remarks: It is not specified in the literature of the case that the agreement with landowners required a compensation payment. Landowners had to give their consent to the implementation of the measures affecting their property/land.	
Economic costs	*Actual income loss:*	
	Additional costs:	
	Other opportunity costs:	
	Comments / Remarks:	
Which link can be made to the ecosystem services approach?	> Water retention in riverbanks and improvements in infiltration capacity will provide better water security (reliability of supply and resilience to drought). Water provision to deliver water services to the economy, in particular to irrigated agriculture > Flood security and protection (delay on flood peaks) > Amenities (associated to habitat protection): fish and plants, tourism, recreation, and others > Sediment retention > Carbon fixation > Wildlife habitats and ecological corridors > Streambanks stabilization > Providing shade, organic matter, food for streams and their biota > Filtration of chemicals and other pollutants	

VII. Monitoring & maintenance requirements

Monitoring requirements	Works to implement the above-described measures were done in 2011. Since then, monitoring of their effects has been carried out first as part of the RICOVER project (2011 and 2012) and then by UTAD under a contract with Águas do Algarve S.A. Only limited information has been obtained from these projects/contracts. However, some information is available. To assess the evolution of the riparian gallery, the programme covers botanical and faunal components (benthic macroinvertebrates, fish and avifauna – for riverine habitats). Regarding the recovery and rehabilitation of riparian galleries affected, the programme retrieved, re-qualified and valued the relevant stretches. We could assume that from the prior assessment that was carried out before the implementation of measures, some of the sampling methods might be used for monitoring and comparing results. Fauna (bird and fish population) is a good bioindicator for physical disturbance and key environmental variables (changes in land use/regulation/riparian forest changes). Macroinvertebrates are good indicator to flow regime variations. 25 sampling sites along the main course were established. River Habitat Survey was used to get data on substrate, slow type, natural features and modification of the margins and the river bed, land use, presence and complexity of riparian vegetation, and measurements of stream and bank dimensions. Features were recorded at a 10 spot checks situated at 50 m intervals and then assessed over a 500 m stretch.
Maintenance requirements	The responsible authority for monitoring is Águas do Algarve, S.A. There isn't information on specfic maintenance requirements. However: - no watering of planted native plants was applied despite the severity of the summer that followed their plantation. - Geotextile (coco fiber) is meant to decompost after 2 years of its implementation. - Gavions are difficult to replace and have a lifetime of 25 years (approx). Little to

	no maintenance required. - Wooden logs in Krainer walls tend to rot (depending on the wood type the lifetime can be up to 25 years). If the wall has been vegetated and the grown vegetation can end up as the stabilizing factor once the wooden logs lose their structural function.
What are the administrative costs?	Ecological Monitoring of the Odelouca River (carried out by UTAD under contract to Águas do Algarve, SA.): 15,902 €.

VIII. Performance metrics and assessment criteria

Which assessment methods and practices are used for assessing the biophysical impacts?	For the sampling programme of 2012, the WFD compliant protocols were used: Biological Quality Elements (BQE), and physicochemical and hydromorphological support elements. Additional protocols to assess the quality of riparian habitat (and habitat quality in general) were used along the 7km stretch. The findings were compared with defined control sites located upstream the reservoir, which were considered as spots with a "more natural" riverine condition.
Which methods are used to assess costs, benefits and cost-effectiveness of measures?	
How cost-effective are NWRM's compared to "traditional / structural" measures?	
How do (if applicable) specific basin characteristics influence the effectiveness of measures?	> When implementing NWRM in the Mediterranean region it should be taken into account the significant annual and interannual variation in precipitation levels as a result of different phases of the North Atlantic Oscillation (negative phases result in higher precipitation levels while positive phases result in higher temperatures and lower precipitation levels). In the case of the Odelouca river the variability in meteorological parameters may affect the success of the measure, i.e., the survival of the selected species for afforestation of riparian areas. Besides, socio-economic aspects are relevant, as the alteration of the ecosystem is closely related to the economic activities being developed in the basin; in this specific context, irrigated agriculture.
What is the standard time delay for measuring the effects of the measures?	Regarding river bank stabilization (N10), as most of the works carried out were related to bio-engineering, the effects of the measures were visible shortly after they were finished, regulating and reducing erosion in riverbanks. However, improvements in infiltration, water retention capacity or biodiversity are medium-term effects as they are linked to the development of the riparian forest (F1) which is not mature enough yet; to fully assess the effects and benefits it will provide further development of the green cover and the root system is needed.

IX. Main risks, implications, enabling factors and preconditions

What were the main implementation barriers?	> Physical constraints: Native species planted in the winter of 2011 were exposed to considerable water stress due to a exceptionally dry spring and summer, which presented a real threat to their survival during the first year. > Local farmers and landowners (and residents) initially met the implementation of the characterisation programme and subsequent rehabilitation programme along the riverbanks with much suspicion and some resistance. > Local farmers' general perception was that land subject to intervention was being taken away from them, that risk of flooding would be increased, that the native plants planted along the intervention zones were of no commercial value and should be replaced (i.e by fruit trees), that project personnel were "trespassing" [although, according to Decreto–Lei 54/2005 (República, 2005), the river banks and the channel are part of the public domain]. > However, access has never been refused
What were the main enabling and success factors?	> Cooperation between Águas do Algarve, the promoter company of the Odelouca dam, and the rest of stakeholders enables the implementation of the measures relevant for the restoration of damage sections of the river. > The initiative managed to get most of the needed permissions from landowners in order to start the works. 25 landowners accepted. Out of 32 identified private plots, 22 agreed to participate
Financing	> Main initial funding source was the *Instituto Nacional de Água (INAG),* currently *Ágencia Portuguesa do Ambiente (APA).* (5,430,664 €) > Additional funding: SUDOE Interreg IV4b (Programme of Territorial Cooperation, via EU ERDF) (267,636 €). > Águas do Algarve, SA. (15,902 €)
Flexibility & Adaptability	The initial report of the intervention (definition of the river sections affected by the programme, and the bio-engineering and traditional measures to be applied) was modified regarding: - The actual physical conditions of the sections - Suggestions and demands of landowners in order to accept the intervention - Alteration in the erosion processes, which were verified regarding the fragility of marginal habitats and the expansion of the reed.
Transferability	

X. Lessons learned

Key lessons	- Artificial water retention measures (i.e. dam) do induce significant hydromorphological pressures on streams, thus hindering, among other things, natural water retention capacity downstream. - Forested riparian zones deliver a number of ecosystem functions and services such as storing and fixing carbon; serving as wildlife habitats and ecological corridors; stabilizing riverbanks; providing shade, organic matter, and food for streams and their biota; retaining sediments and filtering chemicals (fertilizers and pesticides). Therefore, further to their effect on water yield, they contribute to a wide range of benefits for society. - Riparian afforestation is by no means just about planting trees but also about introducing other vegetation types such as scrub, mostly through laterally recovering space for the river. Afforestation is compatible (and

	there are synergies indeed) with riparian clearing (in this case of invasive species). - Although there is still no evidence available for the Odelouca sub-catchment, it all suggests that nitrogen levels can be reduced in rivers (by plants or microbial denitrification) through forcing water to circulate through afforested riparian buffers. - The Odelouca case study is a good example about the characterization and assessment of intermittent Mediterranean river systems for restoration and requalification measures, including bioengineering techniques, closely related to green infrastructures. - Monitoring is critical. River Habitat Survey (RHS) is a good way of assessing habitat quality including riparian complexity, diversity of hydromorphological features and artificialisation of aquatic habitats (features that may affect facets of the local water cycle). - Riparian vegetation is central to the physical, chemical, and trophic health of streams. However, riparian restoration is still its formative stage and can be a complex process. - Further efforts on the ex-post assessment of the impacts of vegetation changes on seasonal water yield and flow regime would be required.

XI. References

Key People		*Name / affiliation*	*Contact details*
	1.	*Samantha J. Hughes*	*shughes@utad.pt*
	2.	*Prof Rui Cortes*	*rcortes@utad.pt*

Source Type	Journal
Source Author(s)	Boavida I., Santos J.M., Cortes R., Pinheiro A.N. & Ferreira M.T
Source Title	Benchmarking river habitat improvement.
Year of publication	2011
Editor/Publisher	River Research and Applications, 28, 1768-1779
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Boavida I., Santos J.M., Cortes R., Pinheiro A.N. & Ferreira M.T
Source Title	Assessment of instream structures for habitat improvement for two critically endangered fish species
Year of publication	2011
Editor/Publisher	Aquatic Ecology, 45, 113-124.
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Cortes R., Oliveira S., Cabral D., Santos S. & Ferreira M.T
Source Title	Different scales of analysis in classifying streams: from a multimetric towards an integrated system approach
Year of publication	2002
Editor/Publisher	Archives fur Hydrobiology, 13, 209-224.

Source Weblink	Weblink

Source Type	Project Report
Source Author(s)	Cortes, R, Jesus, J., Boavida, I., Hughes, S., Varandas, S.,
Source Title	Programa de recalificación del río Odelouca (cuenca del Arade, Portugal)
Year of publication	2012
Editor/Publisher	In Campodron, J. Ferreira, T., Ordeix, M., 2012, Restauración y Gestión Ecológica Fluvial, Un manual de buenas prácticas de gestión de ríos y riberas. Ricover Project.
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Doble R., Brunner P., Mccallum J. & Cook P
Source Title	An analysis of the effect of river bank slope and unsaturated flow in the bank storage process
Year of publication	2012
Editor/Publisher	Ground Water, 50, 77-86.
Source Weblink	Weblink

Source Type	Other (specify) (European Directive)
Source Author(s)	European Commission.
Source Title	EC (92/43/EEC) Council Directive on the conservation of natural habitats and of wild fauna and flora
Year of publication	
Editor/Publisher	Official Journal of the European Communities OJ L206. pp. 7-50.
Source Weblink	Weblink

Source Type	Other (specify) (European Directive)
Source Author(s)	European Commission.
Source Title	Directive 2000/60/EC of the European Parliament: establishing a framework for Community action in the field of water policy
Year of publication	2000
Editor/Publisher	Official Journal of the European Communities, L327, 1-72.
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Fernandes M., Ferreira M., Hughes S., Cortes R., Santos J. & Pinheiro J.
Source Title	Preclassification of Ecological Quality in the Odelouca catchment area and its use in restoration guidelines
Year of publication	2007
Editor/Publisher	Recursos Hídricos (APRH), 28, 15-24
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Hughes S., Cabecinha E., Andrade Dos Santos J., Mendes Andrade C., Lopes D., Trindade H., Cabral J., Santos M., Lourenço J., Aranha J., Sanches Fernandes L., Morais M., Mendonça Leite M., Coutinho De Oliveira P. & Cortes R.
Source Title	A predictive modelling tool for assessing climate, land use and hydrological change on reservoir physicochemical and biological properties.
Year of publication	2012
Editor/Publisher	Area, 44, 432-442.
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Hughes S., Santos J., Ferreira M., R C. & Mendes A.
Source Title	Ecological assessment of an intermittent Mediterranean river using community structure and function: evaluating the role of different organism groups.
Year of publication	2009
Editor/Publisher	Freshwater Biology, 54, 2383-2400.
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Hughes S.J., Ferreira M.T. & Cortes R.M.V.
Source Title	Hierarchical spatial patterns and drivers of change in benthic macro invertebrate communities in an intermittent Mediterranean river.
Year of publication	2008
Editor/Publisher	Aquatic Conservation: Marine and Freshwater Ecosystems, 18, 742-760
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Hughes S.J., Santos J.M., Ferreira T. & Mendes A
Source Title	Evaluating the Response of Biological Assemblages as Potential Indicators for Restoration Measures in an Intermittent Mediterranean River.
Year of publication	2010
Editor/Publisher	Environmental Management, 46, 285-301.
Source Weblink	Weblink

Source Type	Journal
Source Author(s)	Munné A, Prat N., Solà C., Bonada N. & Rieradeval M.
Source Title	A simple field method for assessing the ecological quality of riparian habitat in rivers and streams: QBR index.
Year of publication	2003
Editor/Publisher	Aquatic Conservation: Marine and Freshwater Ecosystems, 13, 147-163

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Source Type	Journal
Source Author(s)	Raven P., Holmes N., Pádua J., Ferreira J., Hughes S., Baker L., Taylor L. & Seager K.
Source Title	River Habitat Survey in Southern Portugal: Results from 2009
Year of publication	2009
Editor/Publisher	I.D.Á.I.P. Environment Agency, Instituto Superior De Agronomia), p. 29.
Source Weblink	Weblink

Source Type	Project Report
Source Author(s)	Viriato, M., Berjano, M., Duarte, M., Caixinhas, R., Cortes, r., Ferreira, MT.,
Source Title	Recalificación de galerías de ribera en el área de la presa del Odelouca: de la concesión a la intervención
Year of publication	2012
Editor/Publisher	In Campodron, J. Ferreira, T., Ordeix, M., 2012, Restauración y Gestión Ecológica Fluvial, Un manual de buenas prácticas de gestión de ríos y riberas. Ricover Project.
Source Weblink	Weblink

Source Type	Project Report
Source Author(s)	Xiao G., Mcpherson E., Simpson J. & Ustin S.
Source Title	Rainfall interception by Sacramento's Urban Forest.
Year of publication	1998
Editor/Publisher	Journal of Arboriculture, 24, 235-244.
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Source Type	Book
Source Author(s)	García, a., Catalinas, M., Alonso, ME., Gallego, P.,
Source Title	Guía técnica para la caracterización de las actuaciones a considerer en planes hidrológicos y estudios de viabilidad
Year of publication	2012
Editor/Publisher	CEDEX
Source Weblink	

XII. Photos Gallery

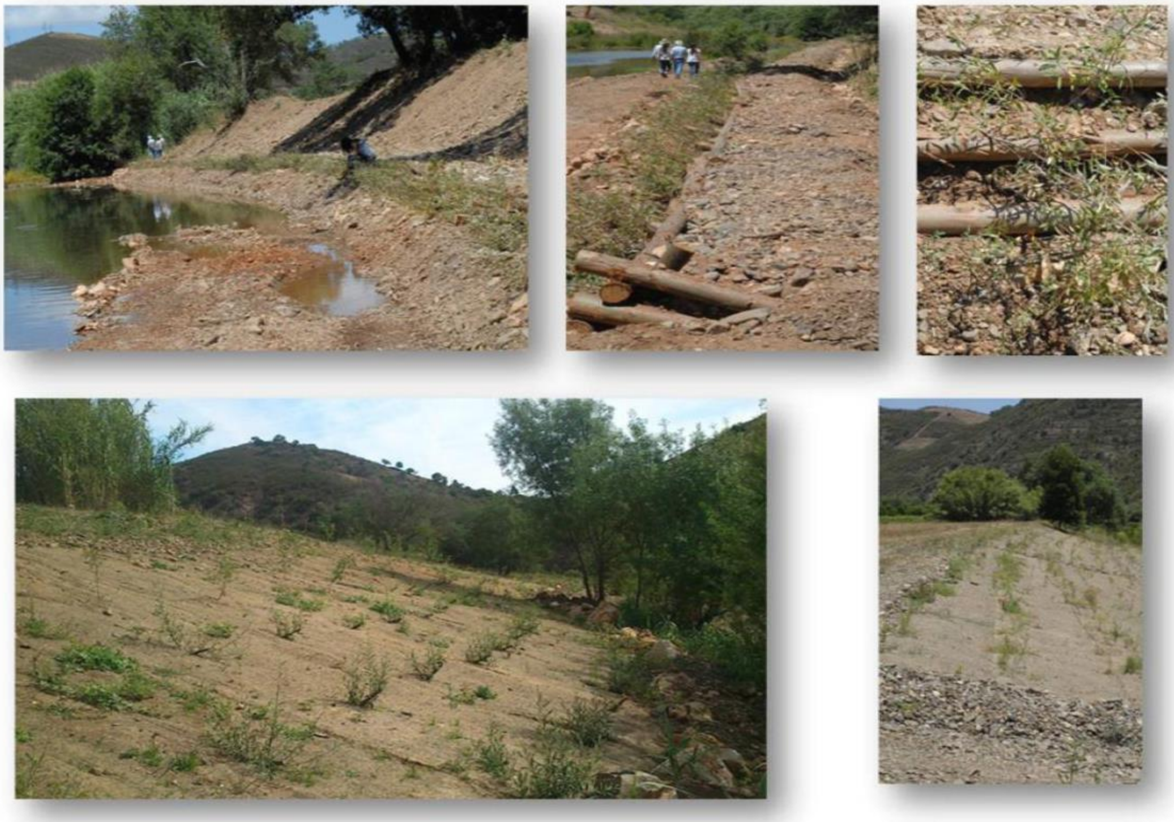

Figure 1 Examples of bank stabilisation techniques used at the Odelouca rehabilitation sites. The top photographs show the bank corrected by construction of a crib wall. The lower photographs show a bank that has been resectioned to give a more natural profile, covered with geotextile and planted with a selection of native species.

Source: Samantha J. Hughes (Universidade de Trás-os-Montes e Alto Douro (UTAD), Portugal) and Rui Cortes (Universidade de Trás-os-Montes e Alto Douro (UTAD), Portugal)

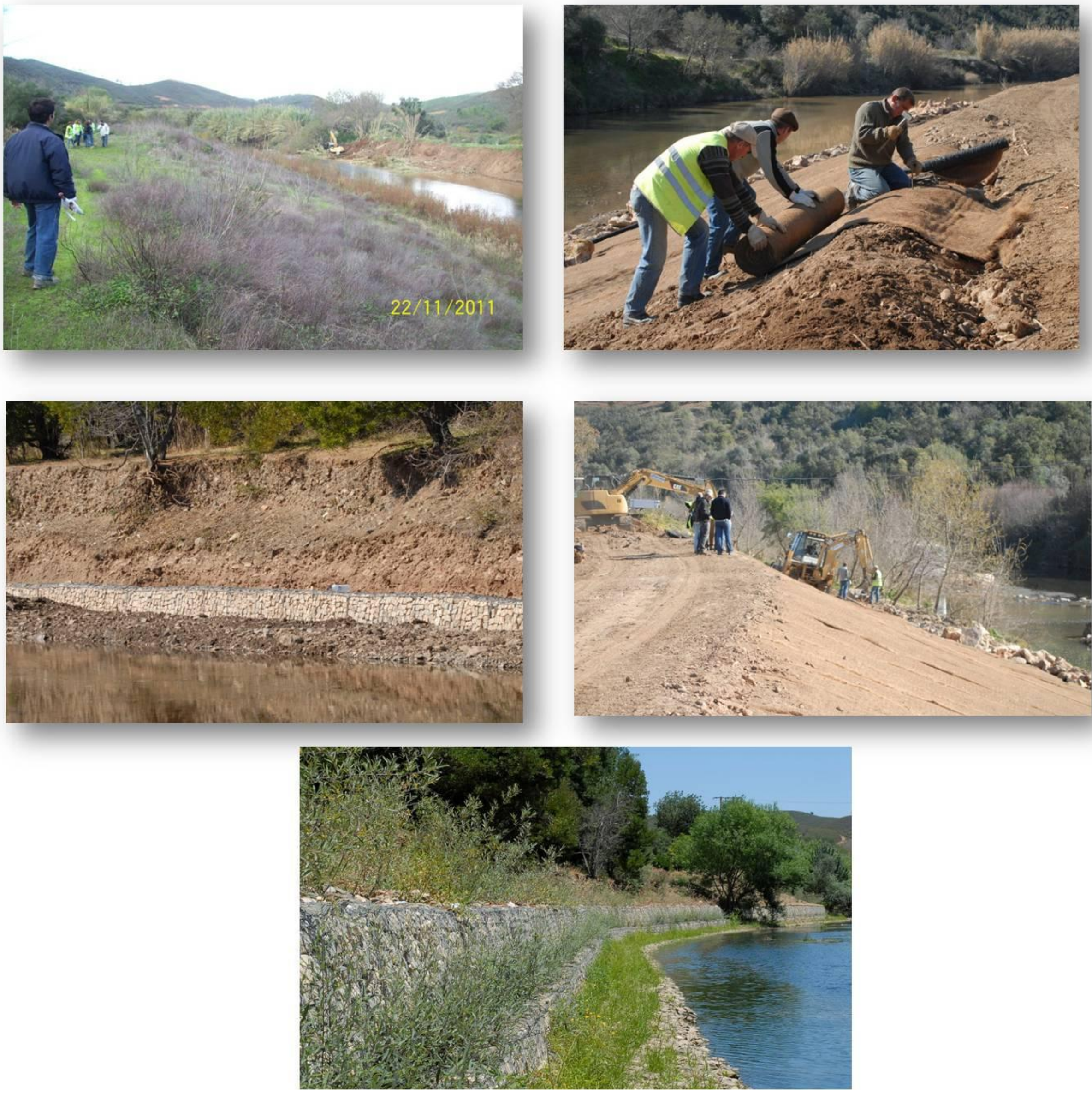

Figure 2 Pictures taken at the outset of the bioengineering works at the selected sites on the Odelouca – winter 2011 – 2012. Gabions (not a NWRM but a means to the implementation of one of them) had to be placed along the right banks at site M where (i) erosion was so intense and (ii) heavy machinery aggravated the situation that the bank was in danger of collapsing.

Source: Samantha J. Hughes (Universidade de Trás-os-Montes e Alto Douro (UTAD), Portugal) and Rui Cortes (Universidade de Trás-os-Montes e Alto Douro (UTAD), Portugal)