ON GROUNDWATER INNOVATIVE METHODOLOGIES, DIAGNOSIS, OBJECTIVES AND MEASURES FOR PORTUGAL'S NEW RIVER BASIN MANAGEMENT PLANS

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ABSTRACT

The European Union Water Framework Directive (WFD) aims to protect inland surface waters, transitional waters, coastal waters and groundwater. It also aims to achieve certain environmental objectives through the implementation of programs of measures specified in River Basin Management Plans (RBMP). Information systems have been identified as a prority tool for managing water resources effectively and efficiently, contributing to the goals to be established by RBMP. In this context, the Portuguese regional water authorities (ARHs) Norte (North), Centro (Centre) and Tejo (Tagus) selected LNEC to conduct studies for the design and development of geographic information to support planning and management of water resources. Besides, ARH Tejo also selected LNEC to develop groundwater components of Tagus River and Ribeiras do Oeste Basin Management Plans (Tagus RBMP/Oeste RBMP). This included the characterization and modeling of quantitative and qualitative aspects of groundwater bodies.

Aiming to dessiminate EU Member-states water resources scientific knowledge in PR China, this paper addresses some of the innovative issues developed in Portugal for RBMP, exemplified for the Tagus RBMP and the Oeste RBMP, *e.g.* climate change scenarios modeling and the results of major changes expected for groundwater recharge by 2071-2101. This evaluation was based on expected values of temperature increase and decrease in precipitation for the aquifer system of Torres Vedras (Oeste RBMP). Regarding groundwater depending ecosystems results of a methodology to classify regional surface water bodies expected to be in hydraulic connection with the underlying body of groundwater is presented. Tagus RBMP and Oeste RBMP groundwater outcome was published by the Consortium that developed the Groundwater Component (Lote 2) of Tagus RBMP and Oeste RBMP, formed by Hidroprojecto, LNEC and ICCE, in Lobo-Ferreira *et al.* (2011a and b).

Keywords: *River basin management plans, Groundwater, data models, climate change, GIS*

INTRODUCTION

Legislative Framework

The European Parliament and the Council Directive of 23 October 2000 (2000/60/EC), better known as the Water Framework Directive (WFD) came into force in Portugal on 22 December 2000, having been transposed in Portugal by Law No. 58/2005 of December 29 – the Water Act. The Portuguese Water Act and the WFD aim to protect inland surface waters, transitional waters, coastal waters and groundwater, affecting certain environmental objectives through the implementation of programs of measures specified in management plans for River Basin or Hydrographic Regions.

The Portuguese Water Act defined in art. 1 its overall objectives, and especially in art. 47 those with relevance to groundwater. Plans will set out the objectives to be achieved by 2015. These should be established considering, among other things, the assessment of chemical status and quantitative status of groundwater bodies.

The programs include basic measures, projects and actions needed to achieve the environmental objectives laid down in legislation, as is stated in paragraph 3 of Article 30. of the Portuguese Water Act, and paragraph 1 of Article 5. Decree-Law No. 77/2006 of 30 March (paragraph 34, Part 6, Volume I, Ordinance No. 1284 / 2009).

The additional measures aimed at ensuring greater protection or improvement of additional water whenever necessary, particularly for compliance with international agreements and include the measures, projects and actions set out in paragraph 6 of Article 30 of the Portuguese Water Act, and paragraph 2 of Article 5. Decree-Law No. 77/2006 of 30 March (see paragraph 35, Part 6, Vol I, Order No. 1284/2009).

Organizational Structure

To develop the process of preparing the Tagus river basin management plan (Tagus RBMP) the regional water authority (ARH Tejo) established an organizational structure based on thematic areas which are summarized in Figure 1.

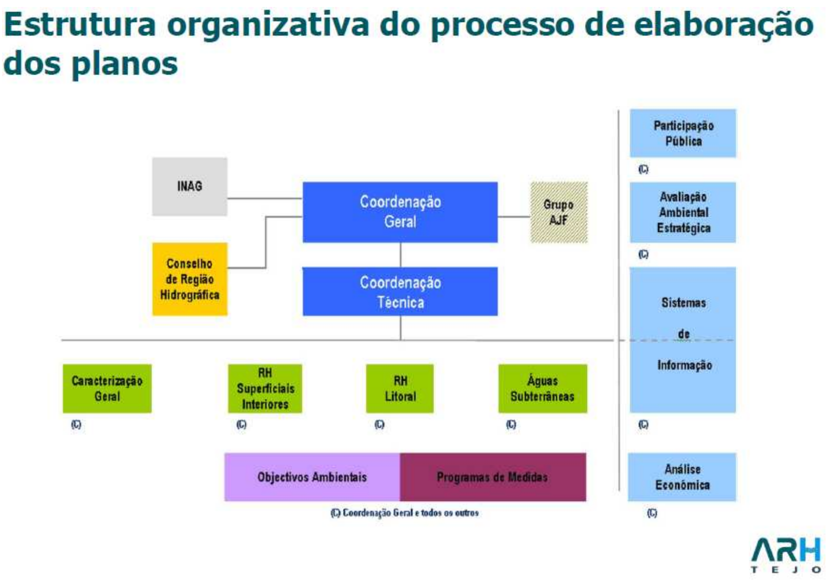

Figure 1 - Organisational structure to support preparation of RBMPs (Source: Simone Pio: Technical Session "Challenges of Water Management." Santarém, 2009)

The Tagus RBMP was developed in accordance with the provisions in the EU Technical Guideline nº 18 which states that the structure of the RBMP report comprises Parts 1 to 7 and the complementary parts A and B, as follows:

- Part 1 - Background and Overview
- Part 2 - Characterization of the Hydrographic Region
- Part 3 - Summary of the Characterization and Diagnosis of Hydrographic Region
- Part 4 - Prospective Scenarios
- Part 5 - Objectives
- Part 6 - Programme of Measures and Investment
- Part 7 - Promotion System, Monitoring, and Evaluation
- Complementary Part A - Strategic Environmental Assessment
- Complementary Part B - Public Participation

Part 1 defines the legal and institutional framework of the planning process. This part also identifies and characterizes the objectives of the Plan and the principles of planning and management of water resources.

Part 2 elaborates the characterization of the river basin, which is a dynamic and organized technical content, allowing for a diagnosis of current situation.

Part 3 synthesises and characterises the basins according to seven thematic areas:

- Thematic area 1 - Water Quality
- Thematic area 2 - Water Quantity
- Thematic area 3 - Risk Management and Enhancement of Water Domain
- Thematic area 4 - Institutional and Regulatory Framework
- Thematic area 5 - Economic and Financial Framework
- Thematic area 6 - Monitoring, Research and Knowledge
- Thematic area 7 - Communication and Governance

Part 4 includes future scenarios that support identification and analysis of socio-economic trends that influence the pressures and impacts generated by the uses of water.

Part 5 sets out the strategic objectives for the environment and other river basin and water bodies, identifying those at risk of not achieving the goals, and analyzes the cases exemptions and extensions of time.

Part 6 presents the program of measures (basic additional and supplementary) to achieve the objectives, establishes priorities for implementation, and defines financial programming.

Finally, Part 7 defines the promotion system monitoring, control and evaluation, involving a coordination and monitoring and an organizational system that ensures the implementation, coherence and consistency of the implementation of measures as well as their coordinated implementation with other sectoral plans and programs.

The groundwater outcome was published by the Consortium that developed the Groundwater Component (Lote 2) of Tagus RBMP and Oeste RBMP, formed by Hidroprojecto, LNEC and ICCE, in Lobo-Ferreira *et al.* (2011a and b).

DRIVERS FOR DEVELOPING EU RIVER BASIN MANAGEMENT PLANS

Highlighting the development on GIS

The Tagus River Basin Management Plan was developed from its beginning in a GIS environment.

The characteristics of the GIS spatial information makes this subsystem as a cross-sectional component of the Plan, covering the existing information available at ARH Tejo, and all the new assessed contents that allow geo-referencing.

The transverse dimension of GIS, which comes from the common representation of the territory (digital cartography), the need for harmonization of forms of representation and coding of mapped entities, was a guarantor of coherence and consistency of information used and produced, and a powerful tool for the analysis and presentation of the Plan.

In parallel, to the Centro Region Water Authority (ARH Centro), an analysis of the aquifer systems covered by the geographical areas of the basins of the rivers Mondego, Vouga and Lis was developed by Charneca *et al.* (2011).

Information systems have been identified as a tool for managing water resources effectively and efficiently, contributing to the goals to be established in EU RBMPs. In this context, ARH Centro invited LNEC to conduct a study for the design of geographic information systems to support planning and management of water resources, the development of flood hazard maps for rivers and estuaries and the characterization and modeling of quantitative and qualitative aspects of groundwater bodies under the jurisdiction of ARH Centro. The objective of the groundwater component is the quantitative and the qualitative groundwater mathematical modeling of Leirosa-Monte Real aquifer and the Aveiro Quaternary Alluvium aquifer, besides the hydrogeological characterization of all aquifers in the area under jurisdiction of ARH Centro, groundwater recharge assessment (Martins *et al.* 2011a), characterization of the vulnerability to pollution (Martins and Henriques 2011), characterization of the vulnerability to seawater intrusion (Martins *et al.*, 2011b), as well as modeling protection zones for groundwater pumping wells.

Highlighting Groundwater Dependent Ecosystems (GDE)

Monteiro *et al.* (2011) presented three methodologies for the identification of Groundwater Dependent Ecosystems (GDE) of Portugal´s Hydrographic Regions 6 (Sado and Mira River Basins) and 7 (Guadiana River Basin): (1) establishment of a mapping criterion to get a picture of the regional surface water bodies expected to be in hydraulic connection with the underlying groundwater body, (2) a case by case analysis of the conceptual models of groundwater flow systems with upward seepage areas associated with aquatic ecosystems (ponds and streams) or dependent terrestrial ecosystems (riparian areas and areas of diffuse discharge) and (3) temporary ponds whose existence is due to local hydrogeological conditions that support ecosystems with specific characteristics. Monteiro *et al.* (2011) intended to provide a starting point for the discussion of criteria for identification of GDE, at regional scale.

Figure 2 illustrates the identification of GDEs associated with groundwater body Viana - Alvito.

The EU Habitats Directive (92/43/EEC) classifies Mediterranean temporary ponds as priority habitats. Salvador *et al.* (2011) identified the importance of Mediterranean temporary ponds in Portugal.

The overlay of geographical distribution of these ponds with the hydrogeological properties of the environments in which they occur shows that these ecosystems are dependent on groundwater as their hydroperiod is generally higher than the simple accumulation of rainwater in depressions of permeable land. Thus, it is considered that temporary ponds are included in the category of protected areas identified in Annex IV of the WFD. About 400 ponds were identified, from which it was possible to conduct a preliminary analysis of hydrogeological context that is presented and discussed using some examples below.

GDEs identified in the Tagus RBMP region are surface water bodies associated with groundwater, associated with terrestrial ecosystems (riparian areas), and terrestrial ecosystems dependent on groundwater.

Terrestrial GDEs are the wetlands resulting from diffuse upward percolation of ground water (Mediterranean temporary ponds). The GDE identified in the Tagus RBMP are represented in Figure 3 (*cf.* Lobo-Ferreira *et al.*, 2011a).

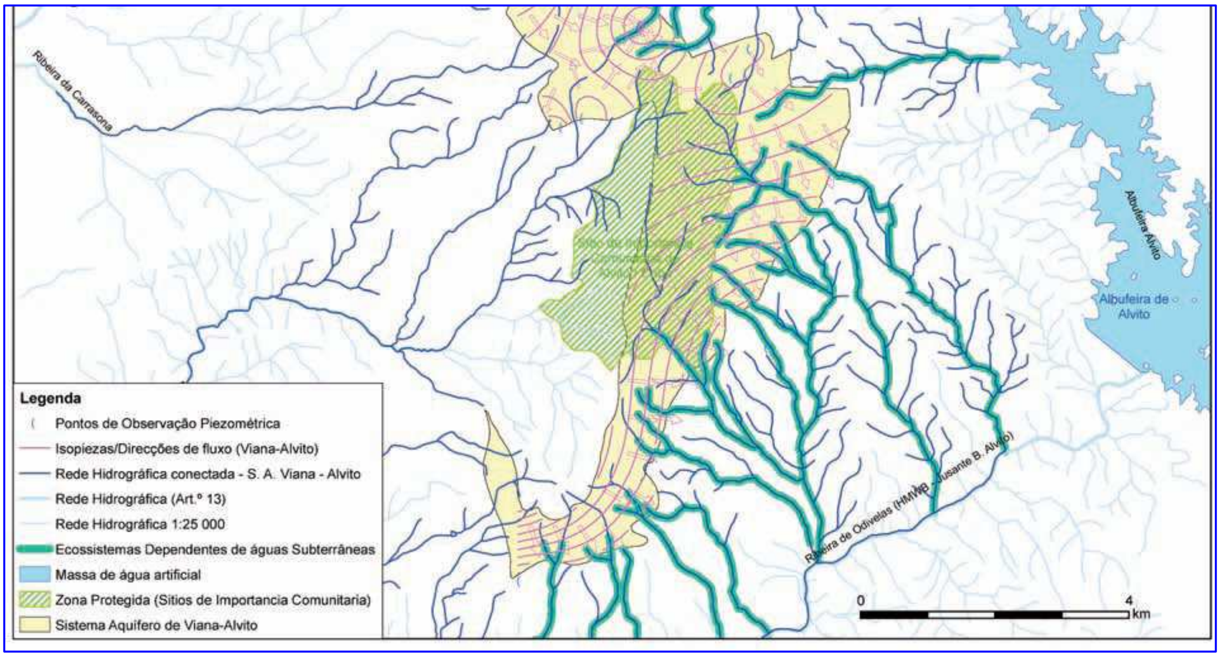

Figure 2 - Identification of groundwater dependent ecosystems associated with groundwater body Viana - Alvito (Source: Monteiro *et al.*, 2011)

Emphasis on monitoring campaigns for the collections of new water samples

With regard to monitoring, and in accordance with the provisions of the ARH Tejo Working Programme for the Tagus RBMP, two monitoring campaign have been held for collecting water samples including those for chemical and biological analysis. The first campaign, consisting of 270 network points and 34 basis points of the SP network (hazardous substances), began the sampling collection in June 2010 and ended in August 2010 (dry season). A second campaign was held in February 2011 (wet season).

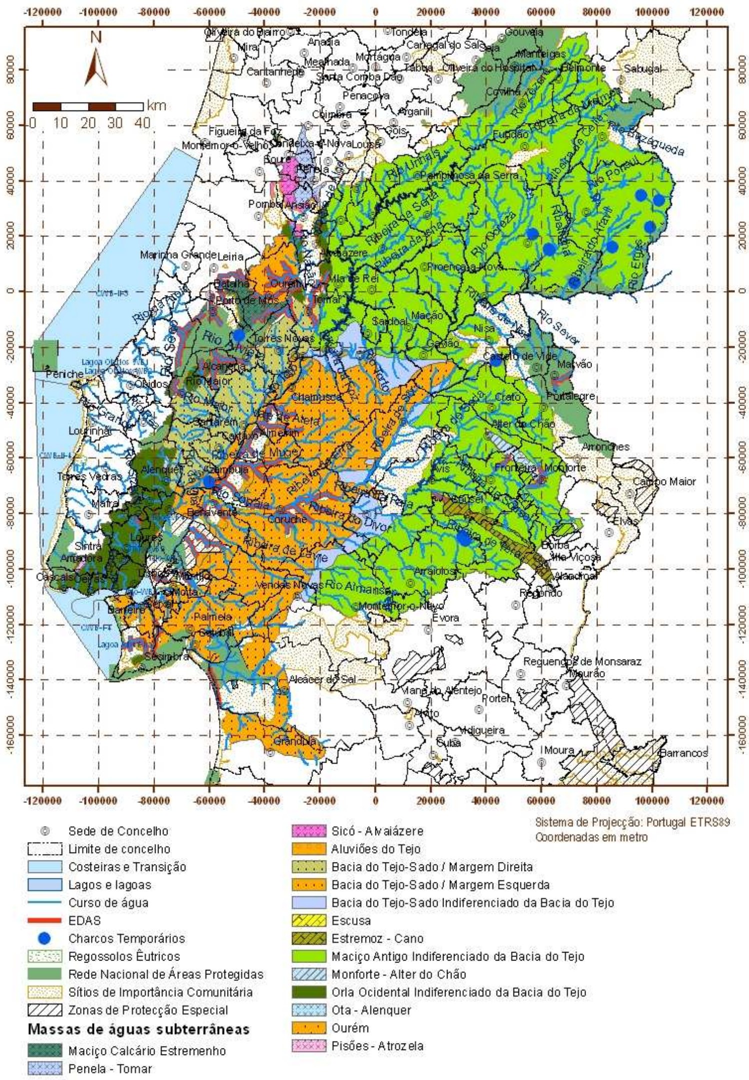

Figure 3 - Groundwater dependent ecosystems represented in the cartographic coverage used for the preparation of Tagus RBMP (Source: Lobo-Ferreira *et al.*, 2011a)

Characterization of groundwater bodies in RBMPs

The Tagus RBMP area covers three hydrogeological units, which coincide with mainland Portugal´s three basic geological structures: Old Massif, Ceno-Mesozoic Western Rim, and the Tagus-Sado Terciary Basin. All together fifteen water bodies have been considered by Lobo-Ferreira *et al.* (2011a) (Figure 4).

Of the fifteen listed water bodies (Figure 4), twelve had been identified as aquifers by Almeida *et al*. (2000). The three bodies of water which were not identified as aquifer systems were "Old Massive Undifferentiated Tagus Basin," "West Rim Undifferentiated Tagus Basin," and "River Tagus-Sado Undifferentiated Tagus Basin." These three bodies of water comprise all the geological formations that were not considered as aquifer systems in the hydrogeologic units, respectively in the Old Massif, in the Ceno-Mesozoic Western Rim and the Terciary Tagus-Sado Basin.

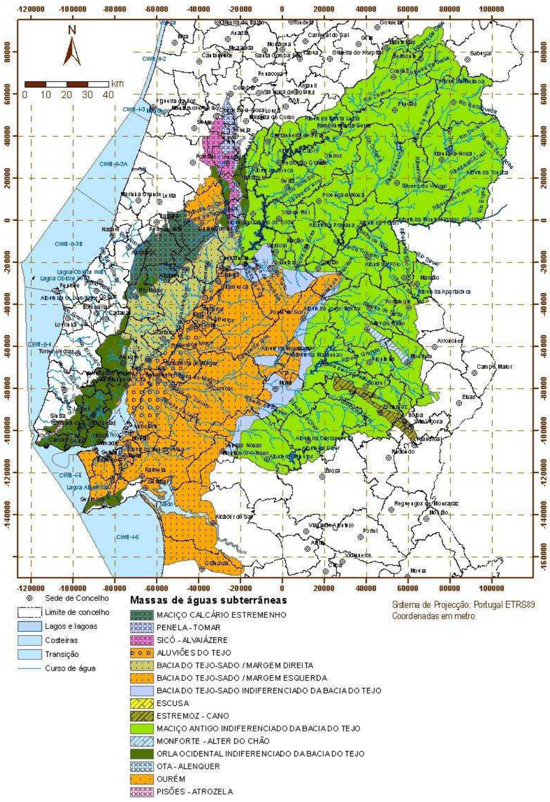

Figure 4 - Groundwater Water Bodies in the Tagus Basin Region (Source: Lobo-Ferreira *et al.*, 2011a)

SPECIFIC METHODS

Groundwater recharge assessment

Groundwater recharge was assessed using the mathematical model BALSEQ_MOD (Oliveira, 2004, 2006). The model has as background BALSEQ model developed by Lobo Ferreira (1981, 1982) to estimate the recharge of groundwater on the island of Porto Santo, located in the archipelago of Madeira, Portugal. BALSEQ_MOD uses sequential daily precipitation, soil infiltration, increased storage in the soil, direct runoff, evapotranspiration, soil water and deep infiltration (water that infiltrates below the base of the soil when the soil moisture content is higher than the value of its field capacity and the water drains by gravity). The deep infiltration of water is used as an estimation of the refilling of the saturated zone closest to the surface.

30 years time series of daily precipitation for each water body have been used, bridging data gaps through statistical methods. Evapotranspiration series were calculated based on temperature, wind speed and minimum relative humidity for the same period of time.

The soil types in each aquifer were deduced from the outcropping geological formations, based on geological mapping at various scales. Each soil type was assigned characteristic parameters such as hydraulic conductivity, field capacity, porosity, etc. This information was superimposed on land use.

Land use, was based on EU CORINE mapping of mainland Portugal, and included the analysis of aerial photography.

The data output resulting from running the model included the average annual precipitation, real evapotranspiration, direct runoff and groundwater recharge.

This methodology was used for groundwater recharge assessment studies of Tagus RBMP and also for the RBMP of Oeste region (Figure 5).

Based on the analysis of possible climate change for Portugal, BALSEQ_MOD model have been runned for the expected variation in precipitation and temperature (rise) for the period 2071-2101. This analysis was also made for 2050 scenario. Figures 6, 7 and 8 illustrate the methodology referred to the aquifer system of Torres Vedras, which was modeled for the Oeste RBMP. We have assessed the variation of the average rainfall by considering two different scenarios: a corrective factor that applies to all data of a current series of 30 years (1979 to 2009, *cf.* Figure 6), and another that takes the same amount of precipitation only from the smallest events of rainfall in the series, according to the methodology described by Oliveira and Lobo-Ferreira (2007). The potential reduction expected for aquifer recharge, as can be seen in Figure 7 and Figure 8, is greater than 50%.

Infiltration Facility Index

The Infiltration Facility Index (IFI), developed by Oliveira and Lobo Ferreira (2002) requires the characterization of four factors:

1. Geology. The first factor can take the IFIs to its maximum value (if an area is very fractured or a karst area). If this is not the case then three other factors have to be assessed:
2. Soil type.
3. Topographic slope (<2%, 2-6%, 6-12%, 12-18%,> 18%).
4. Maximum amount of storable water in the soil which can be used for evapotranspiration - AGUT (ten classes of 50 mm ranging from <50 mm to > 450 mm).

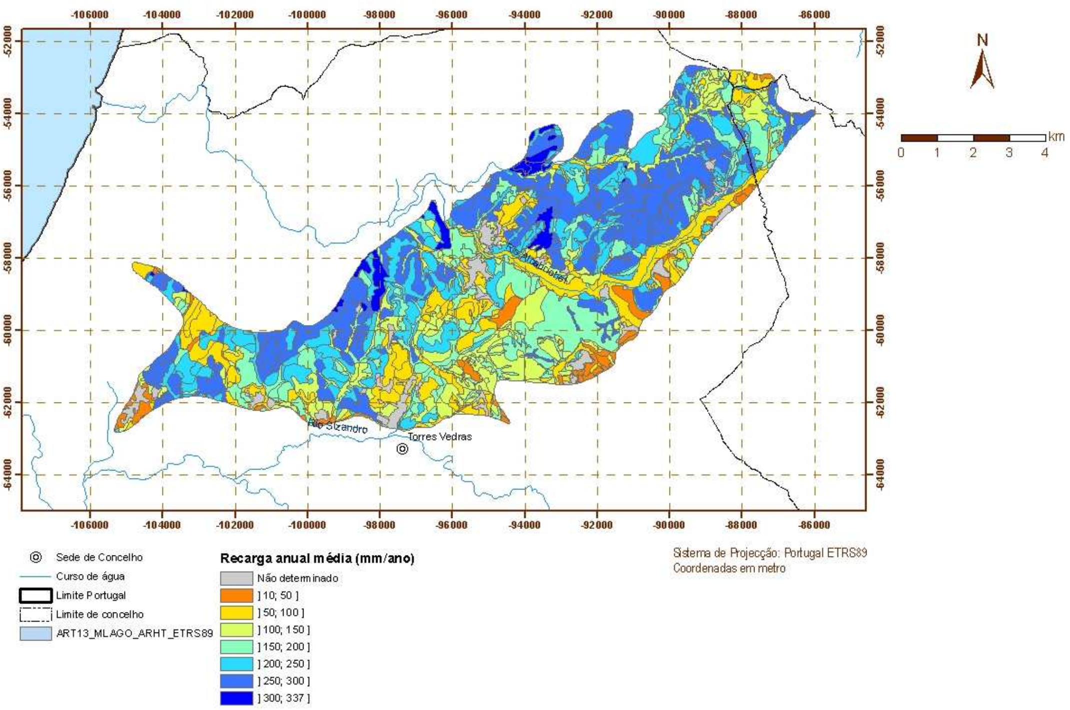

Figure 5 – Average annual recharge of the Torres Vedras aquifer system (in 2009)

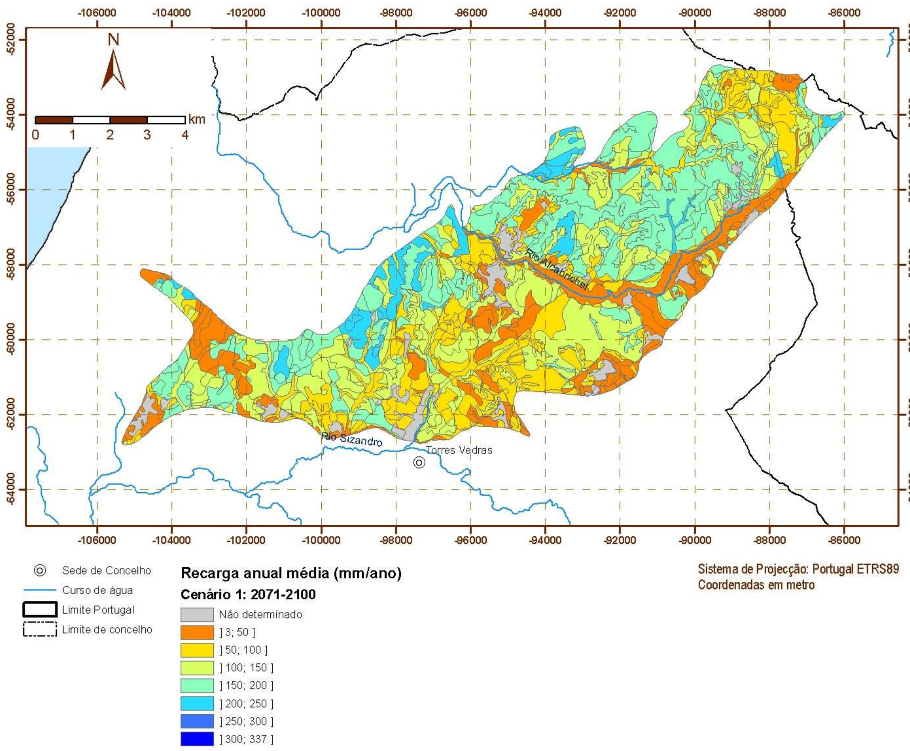

Figure 6 - Expected average annual recharge for Torres Vedras aquifer system for Scenario 1 in 2071-2101

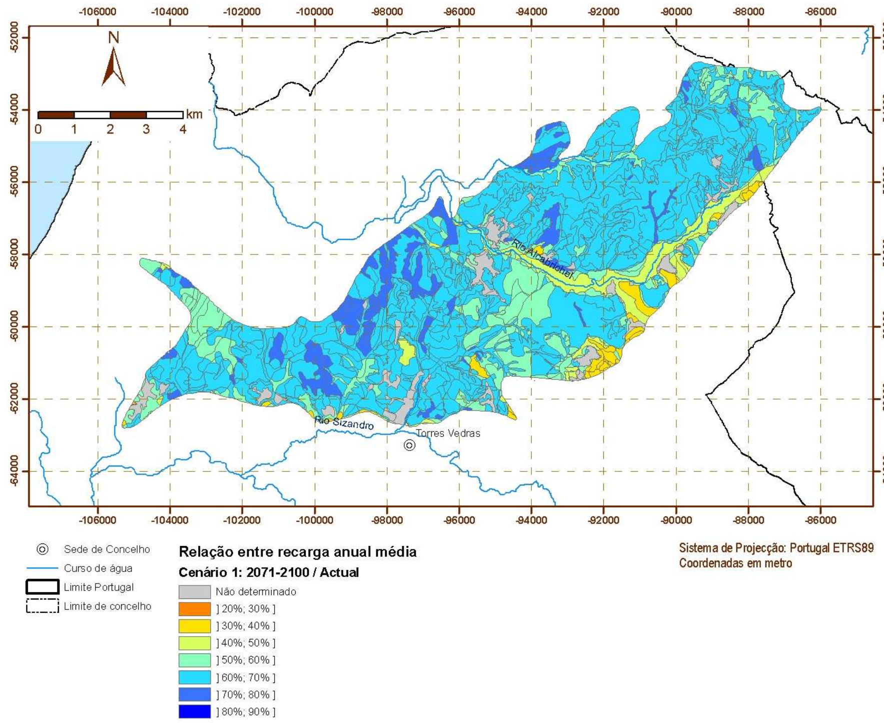

Figure 7 - Relationship between current (1979-2009) and average annual recharge expected for Torres Vedras aquifer system for Scenario 1 in 2071-2101

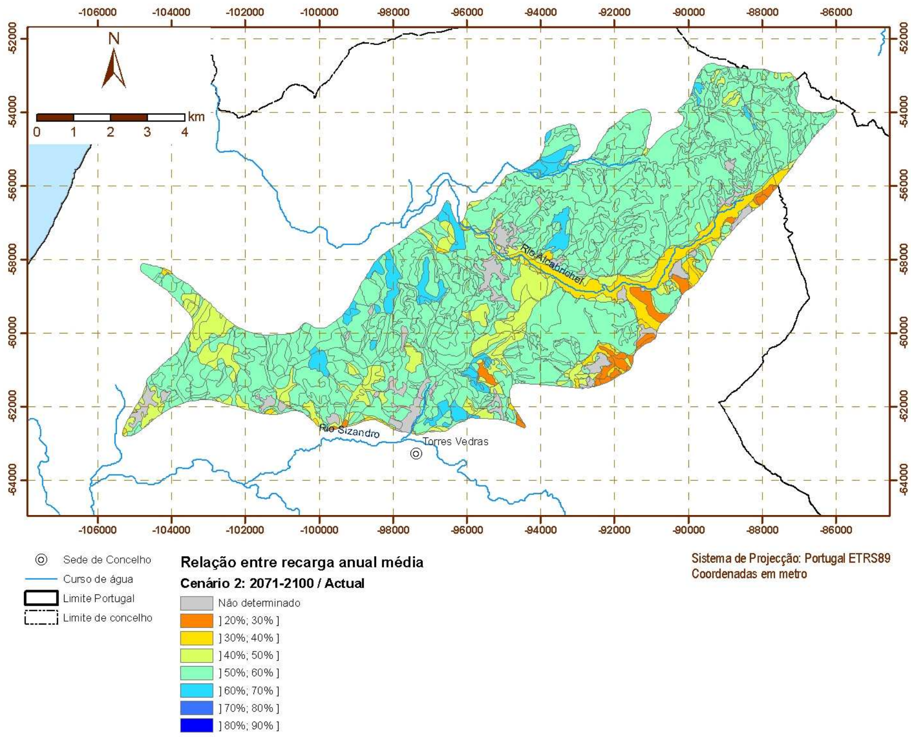

Figure 8 - Relationship between current (1979-2009) and average annual recharge expected for Torres Vedras aquifer system Scenario 2 in 2071-2101

Each class is assigned an index between 1 and 10, which eventually combine to produce the IFIs. The maximum index (IFI = 30) means the most favorable conditions for the infiltration and is obtained for a type A soil, terrain slope <2% and AGUT <50mm. Identified areas with high IFI (more conductive to infiltration), these should be validated with field observations and information from residents on the behavior of these areas during the occurrence of rain.

In order to define special protection areas for groundwater recharge in Tagus RBMP and in RBMP of Oeste, IFI index was applied to all groundwater bodies that have, or potentially may have, pumping wells for human consumption. Areas that drain into groundwater bodies could possibly be considered as special protection areas, when measures allowing greater infiltration could possibly be implement, such as land use change to areas that allow greater recharge.

Characterization of maximum infiltration areas include:

- their identification and description;
- the quantitative status of groundwater bodies affected;
- the conditions to be considered for licensing of the use or occupation;
- measures that are provided and their status:
  - programmed;
  - under implementation;
  - already implemented.

For conditioning the use of areas which are areas of infiltration the following was considered:

- delimitation of special protection areas for groundwater recharge;
- definition and implementation of rules and limitations to the use of special

protection areas for groundwater recharge, and respective licensing conditions;

- defining land use constratints for special protection areas regarding groundwater recharge;
- programming interventions in areas of high infiltration.

Figure 9 shows IFI index calculated for the area of the Tagus RBMP.

Risk of accidental pollution associated with roads

For the purposes of analyzing the risk of accidental pollution associated with roads, we simplified the method published by Leitão *et al.* (2005). We divided the scale of the IFI index, previously presented, in four risk classes, respectively:

- 3-15 – Low risk
- 16 to 20 – Medium risk
- 21 to 25 – High risk
- 26 to 30 - Very high risk

Figure 10 shows the IFI analysis overlapping the roads network map, protected areas of pumping wells, springs and a 1 km area adjacent to the road axis, allowing classification of the risk of accidental pollution from road to groundwater, according to the four above mentionned risk classes from low to very high.

DATA MODELS

As mentionned before, the Water Framework Directive aims to protect inland surface waters, transitional waters, coastal waters and groundwater. It also aims to achieve certain environmental objectives through the implementation of programs of measures specified in River Basin Management Plans (RBMP). As an exemple, information systems have been identified by ARH Centro as a tool for managing water resources effectively and efficiently, contributing to the goals to be established by these ARH Centro RBMPs. As previously noted in this context, ARHs Norte, Centro and Tagus selected LNEC to conduct studies for the design and development of geographic information systems to support planning and management of water resources. This included the characterization and modeling of quantitative and qualitative aspects of groundwater bodies applicable to the river basin under study. The aim is the definition and implementation of data models for geographic databases and geographic referenced thematic characterization of the river system of water bodies and groundwater, and their protected areas.

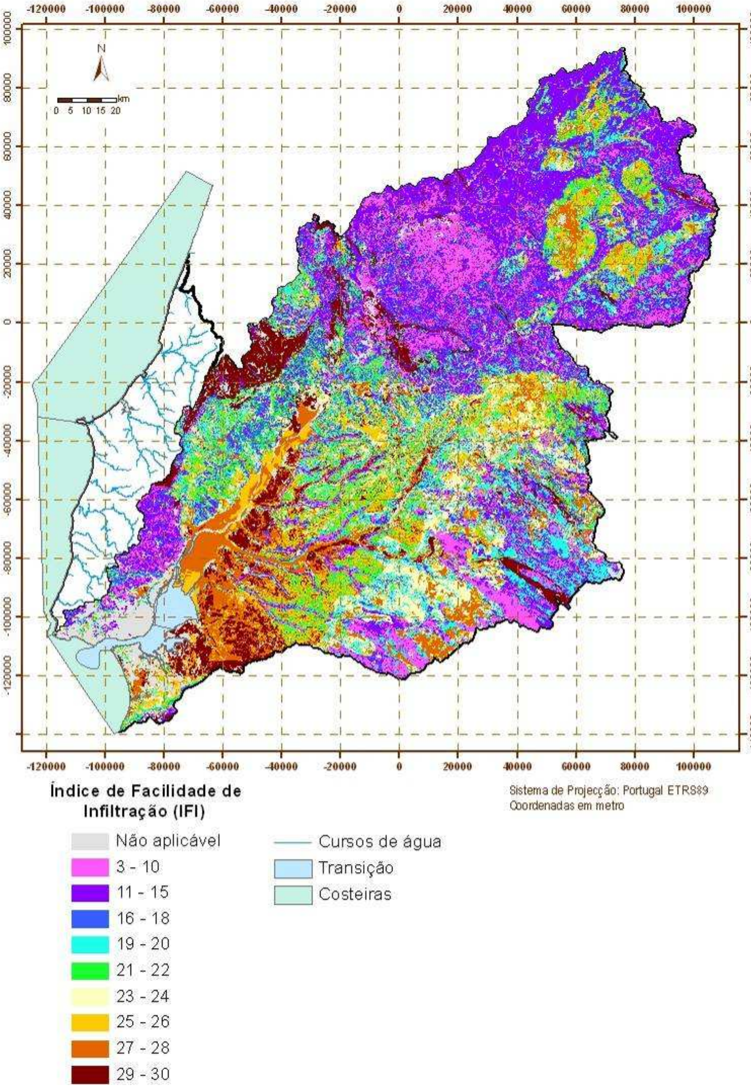

Figure 9 - Tagus RBMP Facility Infiltration Index mapping (Source: Lobo-Ferreira *et al.*, 2011a)

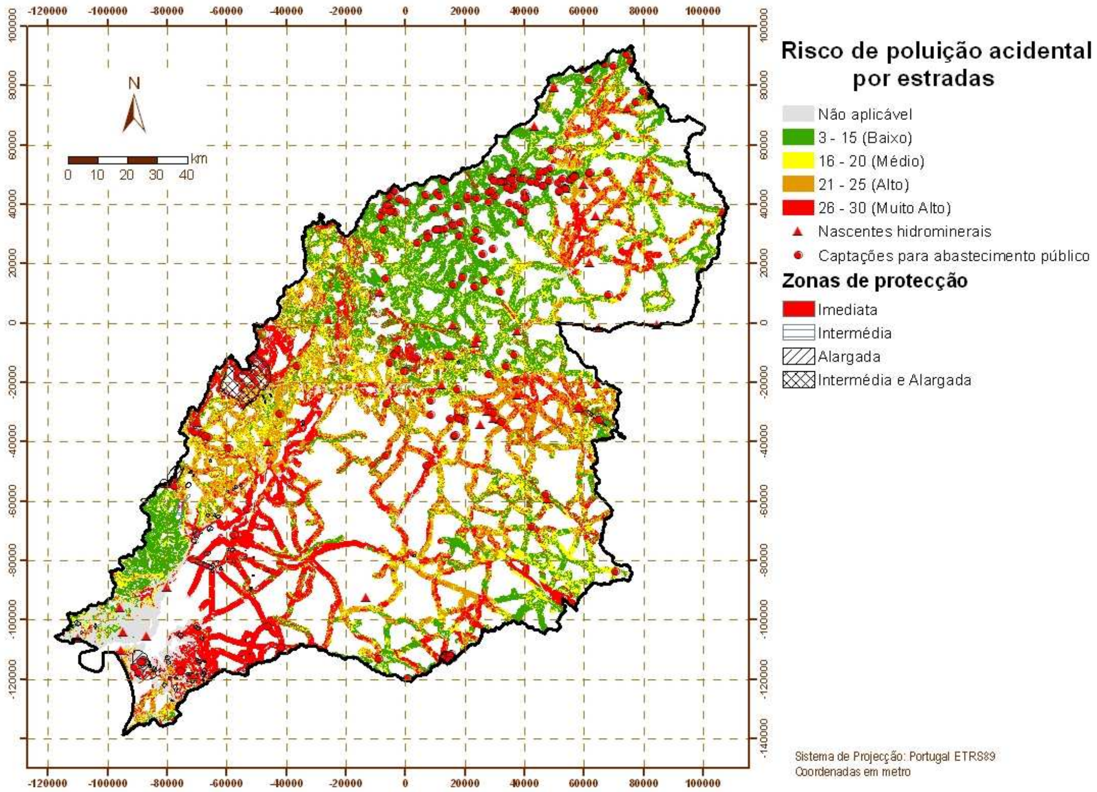

Figure 10 - Map of the risk of accidental pollution associated with roads of Tagus RBMP area (Source: Lobo-Ferreira *et al.*, 2011a)

This component was divided into the following tasks:

Task 1.1. - Requirement analysis of models of spatial data;

Task 1.2. - Specification of geographic information through data models;

Task 1.3. - Implementation and validation of the data model;

Task 1.4. - Support for the trial of the system and to define strategies for its maintenance.

The MDG supports the development of products relating to the components of qualitative and quantitative modeling in aquifers, which includes the hydrogeological characterization of the area of jurisdiction of ARH Centro, the characterization of the vulnerability to pollution and seawater intrusion, as well as groundwater protection and zoning for the abstraction of groundwater.

Figure 11 illustrates a class diagram, in this case referring to the associations between the class and their pumping wells ("PontosAguaSubterranea", in Portuguese in the figure) groundwater abstraction protection zoning.

CONCEPTUAL AND MATHEMATICAL MODELS

For the developement of the conceptual model of Tagus RBMP and Oeste RBMP groundwater bodies a survey was completed with HydrogeoAnalyst including over 1500 logs of pumping wells.

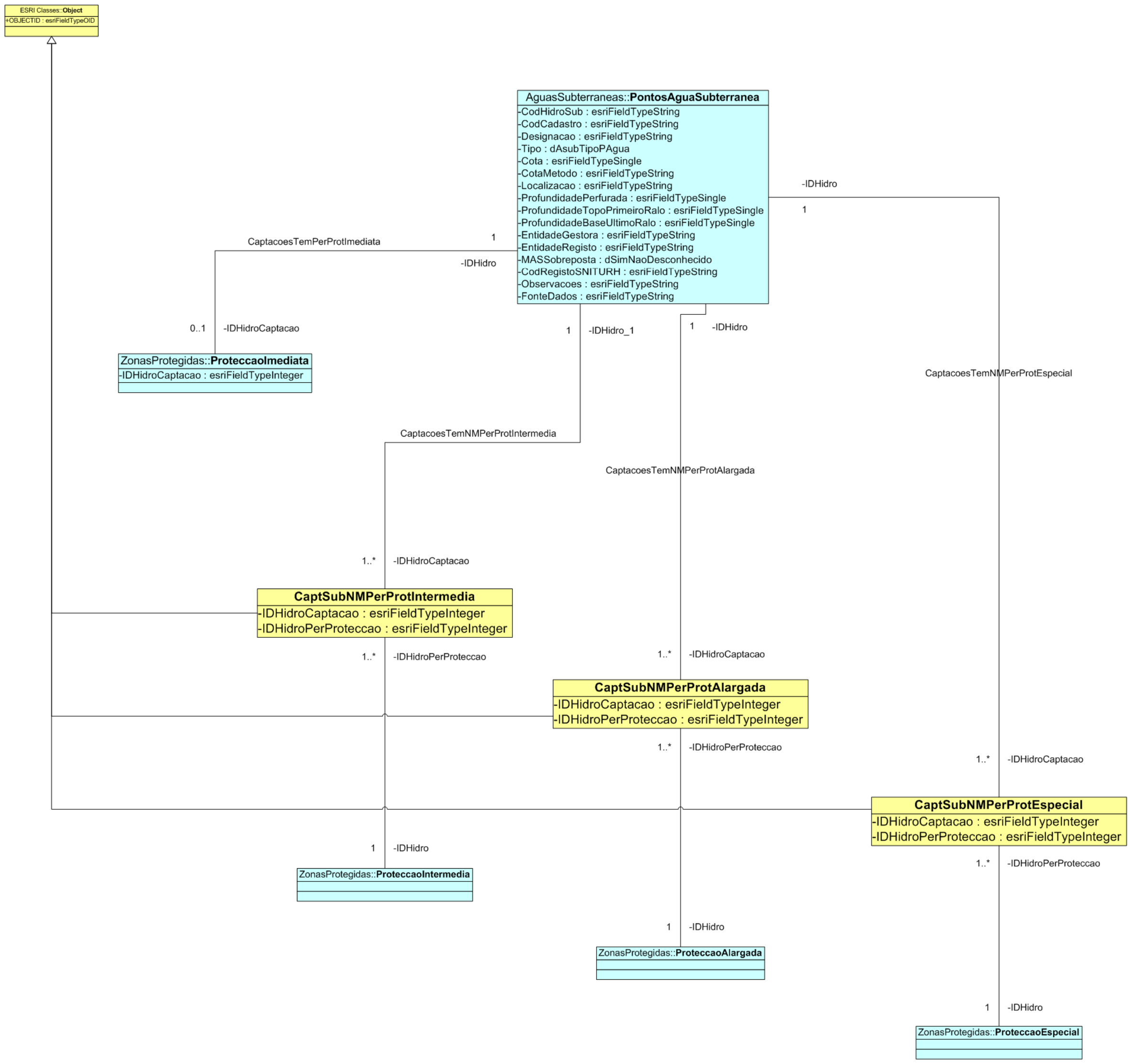

Figure 11 - Class diagram related to the associations between the class and their pumping wells (PontosAguaSubterranea) groundwater abstraction protection zoning. (Source: Charneca *et al.*, 2011)

Figure 12 presents an example of those logs for the aquifer system of Torres Vedras (Oeste RBMP). The combination of information from the logs allows the visualization of the conceptual model. In the example of the aquifer system of Torres Vedras, surveys shows an aquifer system consisting of alternation of sand and clay, as shown in W-E and NNE-SSW sections in Figure 13. The sandstone units are separated from the surface by a clay unit, and the unit of sandstone and clay alternations are separated from the surface by at least two units of clay, the second significant thickness in the central zone of the aquifer system. In the unit of alternating sandstone and clay (unit 5) the central and eastern sector of the aquifer system (*cf.* NNE-SSW section in Figure 13) has a strong clay component that defines various sandstone sub-units. Sector South seems dominated by an absence of significant levels of thick clays (*cf.* WE section), assuming more predominantly sandy layers. Figure 14 shows the directions of flow in the aquifer system of Torres Vedras, calculated by Vieira da Silva (2010) for 1970 and 2010 situations.

DIAGNOSIS ASSESSMENT REQUIREMENTS

Water Quality Thematic Area

The results of the analysis of pressures and their impacts on groundwater quality in the region of the Tagus RBMP as presented by Lobo-Ferreira *et al.* (2011a) is characterized by a set of five of the 15 groundwater bodies at risk of not complying the water quality objectives as defined in the WFD.

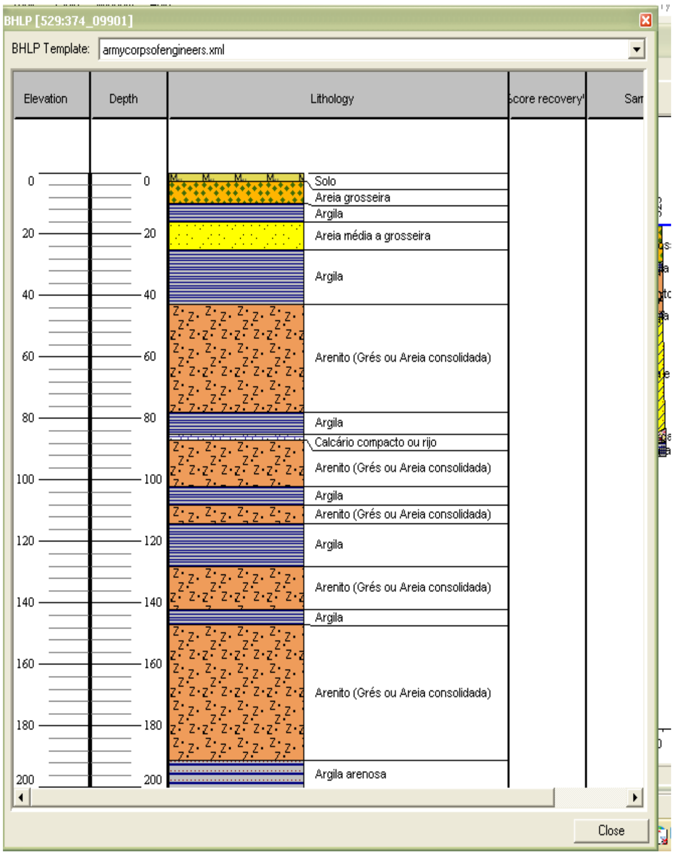

Figure 12 - Log of pumping well n. 529_374 of the Torres Vedras aquifer system

These are the masses that are in one or more of three situations: (1) bad chemical status, (2) with statistically significant upward trend in any parameter with a value exceeding 75% of regulatory limits and (3) subject to high pressures with high mass impact on vulnerability.

The chemical status was evaluated by applying all the tests required by the WFD. Figure 15 presents the general chemical synthesis, significant and constant trends in the Tagus RBMP groundwaters.

Water Quantity Thematic Area

Exemplifying the trend analysis developed (on the evolution of groundwater levels) we present in Figure 16 the time series of observations in piezometers 318/2, located in Estremadura Limestone Massif. According to LNEC criterion of trend analysis that considers critical value the downward trend of 100 mm / year (= 0.274 mm / day) for the maximum annual piezometric levels, there are no critical downward trends in this aquifer.

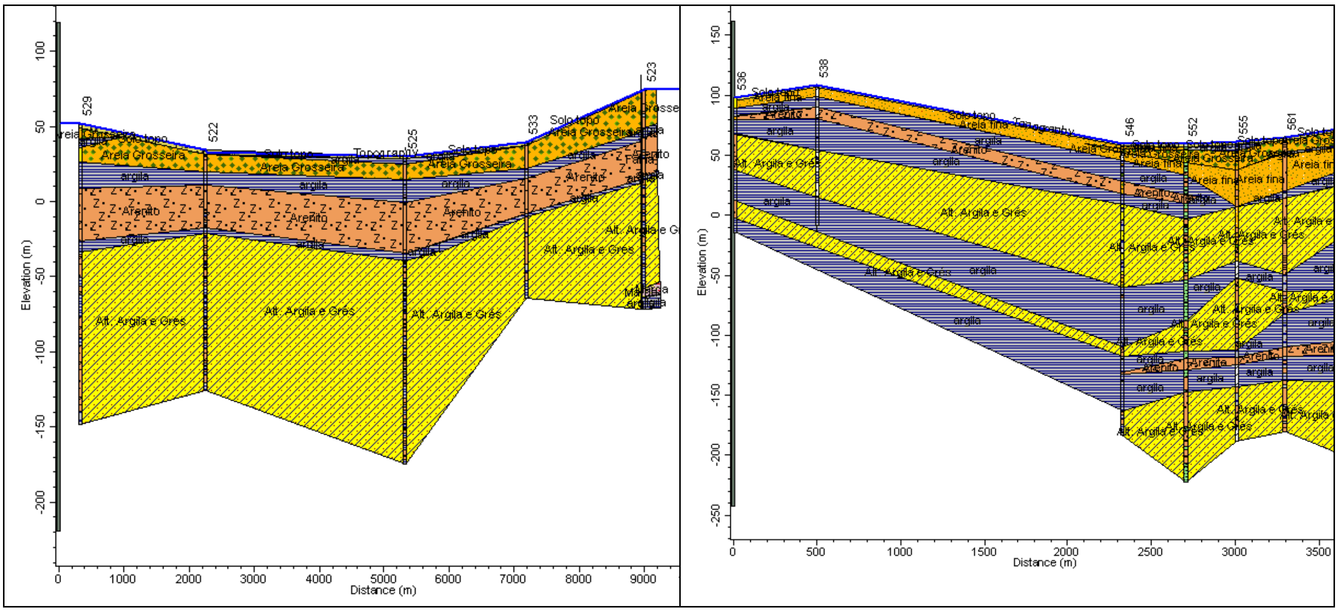

Figure 13 - W-E and NNE-SSW sections in the Torres Vedras aquifer system

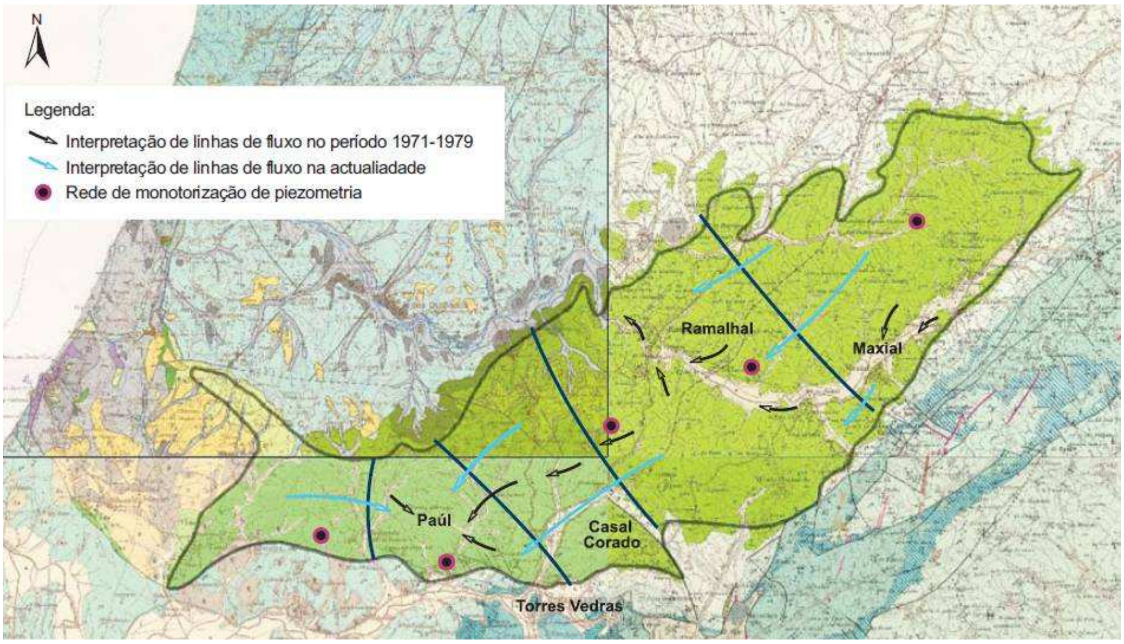

Figure 14 - Flow directions in the Torres Vedras aquifer system in 1970s and today. (Source: Vieira da Silva, 2010).

However in other aquifer systems of Tagus RBMP, the overall assessment of trends in piezometric levels over time showed some situations with piezometric levels lowering in the following groundwater bodies: O15 - Ourém, T1 - Right Bank of Tagus-Sado, T3 - Left Bank of Tagus-Sado, and also in the northern part of the water body T7 - Tagus alluvium. Figure 17 represents the assessment of trends in annual maximum piezometric levels, considering the downward trend as cases where the annual fall is greater than 100 mm/year.

According to the results of mass balance of groundwater developed by Lobo-Ferreira *et al.* (2011a), exploitation rates calculated for the groundwater bodies of Tagus RBMP vary between 1.5% and 77%.

According to this assessment, we classified the quantitative status of all bodies of groundwater in the Tagus RBMP as "good."

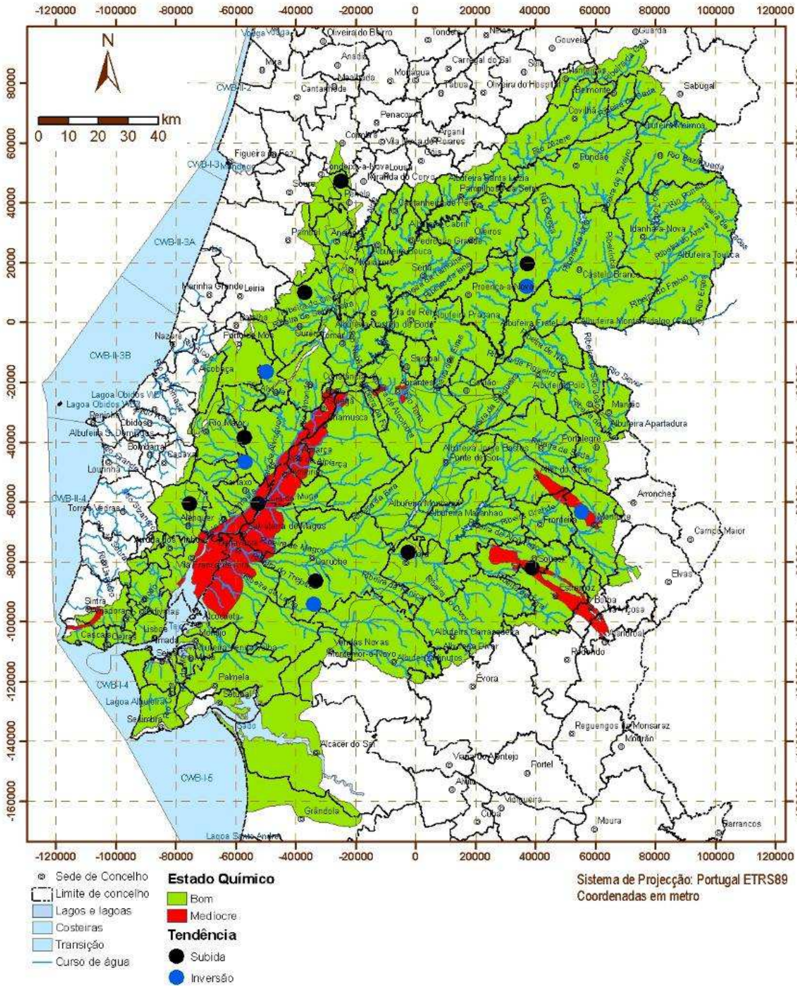

Figure 15 - Summary of the General Chemical Status and the significant and constant groundwater trends in Tagus RBMP (black ball: growing trend; blue ball: trend reversal) (Source: Lobo-Ferreira *et al.*, 2011a)

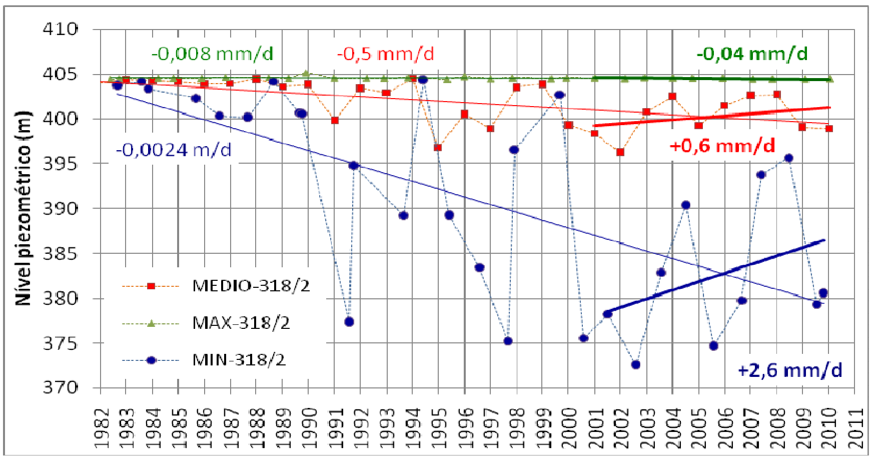

Figure 16 - Piezometric Levels: annual maximum, minimum and average in piezometers 318/2 (Estremadura Limestone Massif) per year hydrological and trends of evolution (Source: Lobo-Ferreira *et al.*, 2011a)

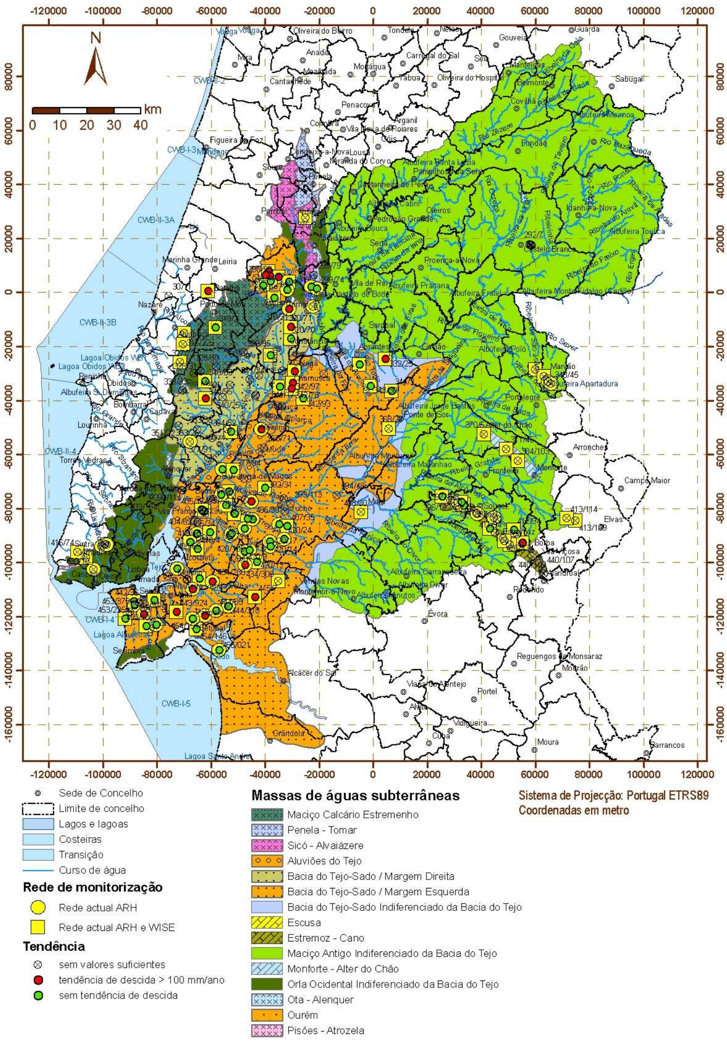

Figure 17 - Evolution of piezometric levels in Tagus RBMP monitoring wells (Source: Lobo-Ferreira *et al.*, 2011a)

OBJECTIVES

Water Quality Thematic Area

The main objective in this thematic area is to achieve good status of groundwater, through the protection, improvement and recovery of all bodies of groundwater and reversing any significant and sustained trend of increasing concentration of pollutants resulting from human activity, in order to gradually reduce their pollution levels.

According to Lobo-Ferreira *et al.* (2011a) the bodies of groundwater which currently do not meet the desired quality objectives in the area of the Tagus RBMP are: Monforte - Alter do Chão; Estremoz - Cano; Pisões - Atrozela and the Tagus alluvium. The Left Bank of Tagus-Sado also has a statistically significant upward trend of nitrate and ammonium nitrogen. The proposed targets will ensure the progressive reduction of pollution of groundwater and prevent the worsening of pollution. The proposed timeframe for achieving environmental objectives for Estremoz-Cano is 2021, and for the Tagus alluvium is 2027.

For the remaining groundwater bodies (Undifferentiated Old Massif of the Tagus Basin, Escusa, Undifferentiated West Rim of Tagus Basin, Penela-Tomar, Sicó-Alvaiázere, Ourém, Estremadura Limestone Massif, Ota-Alenquer, Undifferentiated Basin of Tejo-Sado and the Right river bank of Tagus-Sado), the objectives are to avoid further deterioration, protect and improve the status of aquatic and terrestrial ecosystems and wetlands directly depending on aquatic ecosystems in relation to their water needs.

Water Quantity Thematic Area

In Tagus RBMP, the main objective in this thematic area is to maintain the good status of groundwater, by ensuring a balance between extraction and recharge of water bodies.

Apparent downward trends were recorded in some piezometers, namely those relating to the following groundwater bodies: (1) Ourém, (2) Right Bank of Tagus-Sado, (3) Left Bank of Tagus-Sado, and (4) Area north of Tagus alluvium.

Given that there are some uncertainties in the available data series, either because of their limited length or because of discontinuity, and since there are no water bodies where the relationship extraction / recharge approach a value considered critical (90%) for the maintenance of good quantitative status of bodies of groundwater, we proposed none of these groundwater bodies to be considered in a bad status.

Thus, for these water bodies objectives are to promote sustainable water use, based on long-term protection of available water resources.

CONCLUSIONS

To facilitate the dissemination of the results achieved in the River Basin Management Plans (RBMP) of mainland Portugal, all concluded during 2011, we addressed in this paper some aspects related to groundwater. The characterization of the 8 Hydrographic Regions of mainland Portugal was made by river basins, integrating groundwater bodies. We presented the drivers for preparing Portuguese RBMP, *e.g.* for Tagus and Oeste RBMPs, highlighting the development of GIS, the data model, the groundwater dependent ecosystems (GDE), conceptual models based on well logs and monitoring campaigns for sampling new groundwater data. We presented methodologies developed in Portugal, that assess recharge of aquifers (model BALSEQ_MOD), the Facility Infiltration Index (IFI) and the risk of accidental pollution associated with roads, based also on the IFI index.

Regarding measures Lobo-Ferreira *et al.* (2011a) proposed for the Tagus RBMP, approximately 60 basic measures and 30 additional measures, which aim, respectively, for the achievement of environmental laws and for ensuring greater protection and a further improvement of the water quality, where it is necessary. Under the additional measures a priori considered sites for intervention, due to the proven presence of contamination, are the following: (1) some areas in Seixal, the former Siderurgia Nacional (National Steel) and others in the area of SPEL old sandpits, (2) old Barreiro's industrial zone, and (3) the industrial area of Alcanena.

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