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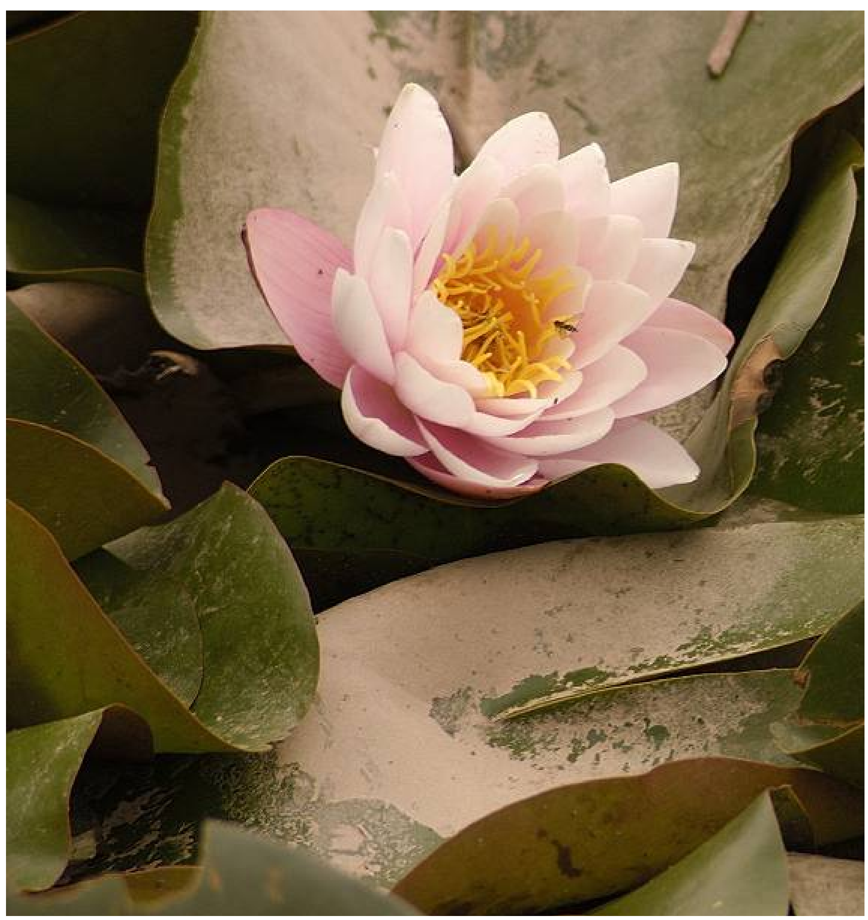
Final Report

Technical assessment of the Portuguese National Programme for Dams with High Hydropower Potential (PNBEPH) Phase I and II

EC/DG environment
Framework contract No 07.0307/2008/ENV.A2/FRA/0020 –Lot 2

Project – 11/004766| 07/07/2009



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Technical assessment of the Portuguese National Programme for Dams with High Hydropower Potential (PNBEPH)

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EXECUTIVE SUMMARY

1 Description of the case

The Portuguese National Programme for Dams with High Hydropower Potential (PNBEPH) foresees the construction of 10 new hydropower installations in several river basins. Among other relevant impacts that fall out of the scope of this study, hydropower projects can have an important impact on water quality - mainly on hydro-morphological conditions for aquatic life to sustain.

According to the Water Framework Directive (WFD), the deadline for achieving a good status of surface waters is 2015. In the meantime, Member States should avoid taking action that could jeopardize the achievement of the objectives of the directive, notably the general objective of good status of water bodies. Derogations for building new infrastructure projects (notably dams) are possible under Article 4.7, if certain strict conditions are met and an assessment is done according to these conditions. These conditions include amongst others that there are no significantly better environmental options, the benefits of the new infrastructure outweigh the benefits of achieving the WFD environmental objectives and all practicable mitigation measures are taken to address the adverse impact of the status of the water body. In addition, the justification for those modifications should be included in the river basin management plans due to be adopted in December 2009 after public consultation.

2 Complaint and objective of the study

The information made available thus far by the Portuguese authorities focused mainly on possible impacts on nature and biodiversity. The potential impacts of the dams on the status of the affected water bodies needs to be thoroughly assessed. The Portuguese authorities listed general mitigation measures, but have not specified any measures related to the selected dams or specific Portuguese situation. The Portuguese authorities indicated in general terms the benefits of the new set of dams but have failed to perform a proper comparison with the benefits of attaining the WFD environmental objectives. There is no assessment as to whether there are other means to achieve the objectives served by the dams.

The general objective of the study is to perform an independent assessment of the Portuguese National Programme of Dams with High Hydroelectric Potential with a focus on the fulfillment of EU water legislation. All the 10 dams that are foreseen are subject to this assessment. Special effort should be put into the analysis of the projects affecting the Douro River Basin, given the predictable cumulative impacts of 6 such projects in this same river basin.

The specific objectives are the assessment of:

- the benefits of the PNBEPH;
- the impacts of PNBEPH;
- the alternative options.

3 Task 1: Assessment of benefits of the PNBEPH

The PNBEPH evaluates its benefits on the basis of certain assumptions that do not take into account some environmental restrictions and climate change forecasts.

Following items are investigated.

3.1 What is the estimated effect on predicted energy production of considering minimum flows to maintain good ecological status below dams?

In the PNBEPH plan, it is unclear how the minimum flow is taken into account. Additional information (received in May 2009) mentioned a discharge (minimum) flow of 3 % of the average annual flow. The energy production for the different hydropower installations is therefore calculated with a minimum flow of 3 %. To maintain good ecological status below the dams, the impact of higher minimum flows on the energy production needs to be assessed.

Based on a literature review, the Tennant Method adapted to Portugal was chosen to calculate minimum flows. This method provides a good estimate of the resources needed to maintain a minimum flow, while taking into account intra-annual variability of water resources. However, for the months where the actual flow was lower than the minimum flows, data on the actual flow were used.

To determine the impact of the minimum flow a tool was developed to calculate the energy production. The energy production was calculated with an electrical efficiency factor of 90 %, assuming a maximum net head and with a minimum flow of 3 %. A deviation of 3% was found between the energy production calculated with this tool and the energy production according to the PNBEPH report.

The energy production would be reduced by about 20% in case of a minimum flow representing the quality fair and 35 % for the flow quality good.

It can be concluded that the energy production given in the PNBEPH is overestimated when a good ecological status below the dams must be realized. A detailed study to determine the minimum flow, as also stated in the PNBEPH, must still be performed, e.g. during the EIA.

The Tennant Method adapted to Portugal is easy to use in a planning stage and for policy purposes. It is recommend to define appropriate minimum flows on a case by case basis, taking into account the local information which is available to evaluate the different impacts.

3.2 What is the estimated effect in predicted energy production of considering the future reductions of resource availability due to climate change?

Not only the future reductions of resource availability due to climate change are assessed but also the reductions already taken place in the years since 1991 are taken into account.

Therefore 2 scenarios are studied: an actual runoff scenario and a climate change scenario. In these scenarios only the impact of changing runoff data on the energy production is evaluated. For the evaporation the same data as those in the PNBEPH plan are used. But it should be mentioned that climate change will also have an impact on the evaporation data as evaporation will increase.

In the first scenario the reduction in energy production is evaluated when using data series characteristic for the 25 most recent years. When comparing the recent runoff data with those used in the PNBEPH a decrease in average annual runoff is observed varying from -14 % for the Douro basin to -28 % for the Mondego-Vouga basin. For the Tejo basin represented by Almourol alone no difference in average yearly runoff is observed (as only one site is studied, this is not really representative). For each of the studied stations the decrease in runoff occurs mainly at the end of the winter (from January on) and in spring. In some stations an increase in runoff is observed from late autumn to the beginning of the winter.

From this evaluation it could be derived that there is already a substantial difference in runoff which will have his impact on the energy production as given in the PNBEPH plan. This reduction in energy production varies between 15 % (minimum flow 3 %) to 43 % (flow quality good) in function of the minimum flow situation considered.

When taking into account future climate change, a worst case situation of a decrease in water resources of -20 % by 2050 is calculated. The reduction in energy production increases from 33 % (minimum flow 3 %) to 55 % (flow quality good). This reduction in runoff is calculated using the runoff data characteristic for the most recent data series of the last 25 years.

As studies mention that the reduction in water resources by 2050 will be smaller in the Douro basin than in the central basins, the difference in impact is also evaluated. The effect on the scenario 2050 is rather limited as the reduction in energy production varies between 28 % to 52 % (in stead of 33 % to 55 %).

3.3 What is the influence of the reduction on the estimated energy production on the economic efficiency of the projects?

The impact of the minimum flow scenarios on the internal rate of return is also investigated. This is done for the data series used in the PNBEPH (period 1941-91). The results show that only a few projects still show an economic efficiency. For a minimum flow representing a flow quality good the hydropower installations Foz Tua, Fridao and Gouvaes can be considered to be viable. For the flow quality fair, this is also the case for the installations Padroselos, Alto Tamega and Almourol.

When considering the climate change predictions the impact on the economic efficiency of these projects will be even greater.

It should be noted that economic efficiency is not the only criterion which must be considered in the evaluation and the selection of the most suitable projects.

4 Task 2: Assessment of impacts of the PNBEPH

The impacts of dams in water environment are well known[1]. Despite the PNBEPH provides considerable detail about the definition of individual projects, the assessment of

[1] See WFD Common Implementation Strategy Policy Paper "WFD and Hydro-morphological pressures. Focus on hydropower, navigation and flood defence activities.

the impacts of each dam in the water environment is very poor. Also the accumulated effects in particular river basins are not considered or investigated. In the current legislative framework, the impacts on water environment should be assessed against the WFD ecological status classification scheme.

Following questions are discussed in detail.

4.1 What are the main effects of hydropower dams in the water environment from the perspective of the WFD ecological status (upstream and downstream)?

Based on the overall literature review of hydropower impacts and the published literature available about hydropower impacts in Portuguese river basins, the major impacts to be looked for evaluating PNBEPH impacts in Portuguese river basins are:

- Changed sediment patterns;
- Changed flow and habitat conditions;
- Barrrier function;
- Changes in nutrient (and organic) conditions.

The actual impact will depend on the sensitivity of the river basin, which is mainly depending on its natural characteristics and the range and magnitude of existing pressures. This will be taken into account when performing the ecological impact analysis.

The following mitigation measures seem to be the most effective with regard to mitigation of hydropeaking:

- Fish passes;
- Natural flow variations;
- Minimum flow;
- Attenuation of hydropeaking.

However, when looking at the cost-effectiveness of the approach, especially the attenuation of hydropeaking seems to be difficult to realize.

4.2 What is the likely effect of each dam in the PNBEPH in the water environment from the perspective of the WFD ecological status (upstream and downstream)?

The assessment of the impacts in the water environment is performed for 3 scenarios:

- Scenario 1: without consideration of minimum flows;
- Scenario 2: taking into account minimum flow as mitigation measure;
- Scenario 3: considering minimum flow and fish passes as mitigation measures.

Recommendations for better policy integration" (November 2006) and accompanying documents available at http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/thematic_documents/hydromorphology

4.2.1 Scenario 1: No mitigation measures

The impacts of planned hydropower stations on connectivity, habitat quality and biological elements, and protected areas are investigated. When comparing the magnitude of the impact, the extent of effect and the cumulative impacts caused, the following conclusions can be made:

- Five of the planned dams in the Douro River Basin (Padroselos, Alto Tâmega-Vidago, Daivões, Fridão and Gouvães) cause the Tâmega river basin to be affected as whole and as such have the largest cumulative impact. They will cause significant deterioration of the middle section of this river basin, which is currently in relative good status. Also the planned Tua dam will cause deterioration of one of the last unaffected rivers in the Douro River Basin. The planned dams in the Douro River Basin have therefore the largest cumulative impacts, which add to those already caused by other existing 60 dams in this basin.
- With regard to the impact caused on natural river systems, it is expected Almourol (in the Tejo river basin) and Pinhosão (in the Vouga river basin) will have the greatest impact, considering the unaffected state of these river stretches at the moment, the lack of migration barriers, and the important habitat area for migrating fish.
- When looking at the impact on natural protected areas, the Tejo estuary as well as the Gouvães area should be considered. The specific impacts caused by the Almourol dam, which is predicted to have an effect up to the coastal area, as well as the Gouvães dam, which has 3 diversions and has significant effects on a protected area where it is included, are discussed in detail in Task 2c.
- For the length of effect, those dams that have a significant effect due to the length of the flooded area (=the reservoir) upstream are in order of length impacted: Almourol, Pinhosão, Foz Tua and Fridão. However, the length of the reservoir corresponds to the maximum area that will be flooded so the actual impact could be lower. With regard to downstream effects Almourol, Alto Tâmega-Vidago, Pinhosão and Gouvães can be considered as the most important ones. As regards the total length of effect, certainly Almourol and Alto-Tâmega-Vidago are the most extensive.

As a conclusion, when taking all criteria into account for defining the impacts caused by each of the dams on its upstream and downstream area, the cascade of dams in the Tâmega sub-basin (and if looked at individually the Alto Tâmega-Vidago and the Gouvães in particular), the enormous effect of the Almourol dam on the Tejo river and its estuary, as well as the significant impact caused by the Pinhosão dam on the almost unaffected Vouga river (especially towards migrating fish) can be included in the list of dams of the PNBEPH project that are likely to impact the aquatic ecosystem in the most extensive and significant way.

4.2.2 Scenario 2: Minimum Flow

The design of adequate ecological flows is essential to maintain a good ecological status and preserve the biological elements that are present in the river. Often, fish species are used as indicators for estimating adequate ecological flows in a river stretch. The best methodology for defining minimum flows is based on a detailed model that requires determining habitat preferences (in terms of depth, velocity etc) for Iberian fish and a huge amount of location-specific information (as it has been discussed in the chapter on minimum flows under Task 1). This kind of methods allow for the maintenance of suitable conditions for fish species and are considered appropriate to preserve the biological communities that occur in the river. Some experiences based on the application of these methods have been developed in Portugal and are presented in Annex 16. However, because of the lack of information and the modelling being out of the scope of the study, a scenario analysing the effects and potential benefits of minimum flows is as such considered as not feasible. Nevertheless, it must be stressed that *including minimum flows in the operation of the dams planned under the PNBEPH is certainly needed in order to mitigate their effects on the fish communities that have been identified along the river stretches located downstream of the dams.* Further on, it is necessary to implement minimum flows to allow proper functioning of the fish pass (included as an essential mitigation measure as well).

4.2.3 Scenario 3: Minimum flow and fish passes

Fish passes are a mitigation measure of the negative impacts on fish populations. Despite the existing legislation they are still not being implemented in the majority of dams and weirs and a large percentage of the implemented fish pass are not effective. Fish passes also do require appropriate minimum flow. Based on the fish monitoring data and the information available on fish passing efficiency and fish habitat requirements, the following conclusions were made:

The **Tâmega sub-basin,** especially in its middle section, is one of the last "almost unregulated" affluent of Douro River and can be seen at a last refuge for migrating species. The Torrão and Crestuma dam are already acting as a migration barrier and there is also a problem with eutrophication and migration. Fish passes are a necessary mitigation measure but it is not guaranteed that, taking into account the cascade of dams and the current eutrophication pressure that migrating fish will be able to get up to the upper reaches of the Tâmega sub-basin.

For the **Foz Tua,** more information is available because of the EIA process (EIA Foz Tua, 2008). One of the conclusions of this EIA is that because of the absence of migrating species together with the cost of installing a fish pass, it is not part of the plan. However, fish pass improvement at dams in the Douro river basin downstream of the Tua confluence is certainly priority because of the long-term objective of improving continuity in the Douro River Basin, and the evidence that resident species such as *Pseudrochondrostoma sp.* and *Barbus sp.* are using fish passes to migrate to the upper courses of the Tua River.

For the **Vouga river basin**, because 4 migrating species are still present in this area, the instalment of a fish pass at the **Pinhasão dam** would be an absolute requirement to guarantee free migration of these species, especially considering the high habitat quality of the river Vouga. The Vouga river basin is also one off the few river basins that still host *Peteromyzon marinus*. At the **Mondego river basin**, there were no migrating species monitored and there are 2 dams and one weir downstream of the planned location for the Girabolhos dam. However, resident species also use fish passes and are affected by migration barriers, thuis it is still essential to implement fish passes as a mitigation measure.

For **Almourol,** there is currently no fish migration barrier in this area (until Belver dam), so a fish pass would be an absolute requirement as the area up to the next dam is hosts *Petromyzon marinus.*

For **Alvito,** the current bottleneck is the Belver dam and also possibly Pacrana dam (no fish pass efficiency report available). The area is currently of importance for resident fish and fish pass efficiency improvement in downstream dams would be a priority here.

4.3 What are the likely (cumulative) impacts of each dam or group of dams on nature values protected by the European Nature Directives?

It is evident that the PNBEPH will cause significant impacts on species protected under the Natura directives. It will also have a considerable direct impact on a Natura 2000 site (Alvão-Marão), which has not been properly assessed, and some indirect impacts on other four Natura 2000 sites (Rio Vouga, Carregal do Sal, Ria de Aveiro and Estuário do Tejo), which have not been considered at all in the SEA. The opinion expressed by the ICNB (national authority on biodiversity conservation) considered that the Couvaes dam would have a significant adverse effect on the Alvão-Marão Natura 2000 site, but the SEA did not take this opinion into account. Therefore, at least in this case, the effects on the site integrity (criterion C1.2) could have not been properly assessed.

The SEA included the impact on species included in the Portuguese Red List (those classified at leas as “vulnerable” were considered under criterion 2) but only considered the presence of those species in the areas affected by the dams and did not consider the critical areas or the areas important for the conservation of those species.

The presence of threatened species in areas that currently have a low fragmentation and a high level of naturalness, assessed under criterion C4 (linked to WFM) is not given sufficient consideration in the SEA, and this criterion has a low relative weight in the assessment.

Furthermore, cumulative impacts have not been evaluated, as acknowledged in the SEA, while it is also evident that the five dams planned in the Tâmega sub-basin (four of them in the river Tâmega) will have significant cumulative impacts in a section of this sub-basin, which currently has relative good conditions and a low level of fragmentation. It should be taken into account that despite the existence of organic pollution/eutrophication problems, the river areas that will be affected by the construction of new dams have currently a good habitat quality. Data from a preliminary ecological assessment carried out in Portugal showed high scores for biological indexes based on macro-invertebrates, macrophytes and fish data in the Tâmega river, which suggests the existence of well structured fish communities and good habitat conditions for this group.

The criteria used in the evaluation of effects on biodiversity in the SEA and the values assigned to these criteria seem not sufficient to detect these potential significant impacts. Also adequate mitigation measures have not been sufficiently described. The SEA mentions that mitigation measures should be defined in detail in the EIA of each dam and only some general guidelines are provided in relation to 1) River continuum (although it is considered that there is limited knowledge about the possible mitigation measures for fish species of Mediterranean ecosystems and therefore admits that in some cases these measures might be not viable), 2) Ecological flows (they should be designed in the EIA of each project, according to best practice available for Mediterranean ecosystems) and 3) Other mitigation measures shall be considered taking into account particular natural values. Compensation measures shall also be defined for unavoidable impacts in accordance with detailed studies to be carried out in the EIA for each dam.

5 Task 3: Assessment of alternative options

The starting point of the PNBEPH is the need to increase renewable energy production in line with Community objectives.

The PNBEPH does not look at possibilities to upgrade existing hydropower installations.

The Strategic Environmental Assessment (SEA) elaborated for the PNBEPH considers four options. Those are largely driven by energy production considerations and reduction of greenhouse gas emissions. There is very little consideration to water impacts. It is not clear what the degree of affection is to the water environment of each of the options. From a preliminary assessment it appears that, due to the selection of factors considered in the SEA, the analysis carried out does not react to the impacts on the water environment.

5.1 What is the estimated increase in capacity that can be achieved through upgrading existing hydropower installations?

Through upgrading, there is a potential to increase capacity but it is difficult to exactly quantify this potential increase.

In the evaluation a number of issues were not considered, such as

- the potential use of existing dams for energy production (more than 50 dams have now other uses);
- adaptations of existing installations to pumped storage hydropower installations;
- the potential of new technologies;
- the impact of climate change (and especially water resources);
- possible upgrading and refurbishment of the existing installations;
- the assumption that the selection of the projects under construction and in study are the ones which were best suitable to be adapted or upgraded;
- lack of information regarding former refurbishments and upgrading.

By turbine and generator upgrading a capacity increase between 173 and 553 MW_e should be possible to realize.

At least it should be noted that detailed analysis and study of all the other hydropower installations, especially those operating more than 30 years, could result in a substantial increase of hydropower capacity.

5.2 To what extent the definition of factors to be considered in the SEA and the options chosen influence the outcome of the SEA? To what extent the outcome of the SEA is at all influenced by the assessment of the impacts on the water environment?

With regard to the definition of factors considered in the SEA and the options chosen, the following can be concluded:

- The outcome of the SEA is mainly influenced by the critical factor biodiversity, including for approx. 29 % impacts on water (mainly focusing on overlap with habitat areas of threatened species dependent on the lotic system). The critical factor water resources, including impacts on water for approx. 12.5 % (mainly focussing on interference with existing infrastructure for water use and groundwater) is less reflected in the outcome. Explicit impact of WFD objectives is limited to 8 % in the critical factor biodiversity and 10 % in the critical factor water resources. However, the parameters used to assess the WFD objectives are considered as being not compliant.

- The definition of the strategic options has determined a list of selected hydropower projects representative for each strategic option and has a strong influence on the final outcome of the SEA. However, in the definition of the options, specific impacts on water environment were not taken into account. The difference in the representative list of option C (environmental constraints) and option D (Energetic, socio-economic and environmental balance) is limited to 1 project.

Regarding the assessment of impacts on the water environment and its compliance with the WFD, the following conclusions can be made:

- The main shortcomings in the SEA are related to (1) the incompleteness of the considered impacts (changes in sediment patterns, flow and habitat quality and the barrier function of the hydropower station are not looked at); (2) the incompleteness of the data to assess the impacts of hydropower stations and the (3) non-compliance of the data and rules applied following the criteria of the Water Framework Directive.
- An ecological assessment following the requirements as set by the WFD has been performed in Task 2b in this study. Comparing the impacts assessed, the indicators used and the scale of the assessment, one could conclude that the SEA of the PNBEPH has serious gaps and can be considered as being non-compliant with the Water Framework Directive’s requirements. Impacts in relation to the water environment based on the WFD requirements should have been included in a prominent and transparent way. From the conclusions obtained in Task 2b, one could see it is certainly possible to estimate the magnitude and scale of impact (ecological and hydro-morphological) on the water environment at the planning stage, and this has not been done in the SEA of the PNBEPH.

INTRODUCTION

1 Description of the case

The Portuguese National Programme for Dams with High Hydropower Potential (PNBEPH) foresees the construction of 10 new hydropower installations in several river basins (**Annex 1**). Among other relevant impacts that fall out of the scope of this study, hydropower projects can have an important impact on water quality - mainly on hydro-morphological conditions for aquatic life to sustain.

According to the Water Framework Directive (WFD), the deadline for achieving a good status of surface waters is 2015. In the meantime, Member States should avoid taking action that could jeopardize the achievement of the objectives of the directive, notably the general objective of good status of water bodies. Derogations for building new infrastructure projects (notably dams) are possible under Article 4.7, if certain strict conditions are met and an assessment is done according to these conditions. These conditions include amongst others that there are no significantly better environmental options, the benefits of the new infrastructure outweigh the benefits of achieving the WFD environmental objectives and all practicable mitigation measures are taken to address the adverse impact of the status of the water body. In addition, the justification for those modifications should be included in the river basin management plans due to be adopted in December 2009 after public consultation.

2 Complaint and objective of the study

The information made available thus far by the Portuguese authorities focused mainly on possible impacts on nature and biodiversity. The potential impacts of the dams on the status of the affected water bodies needs to be thoroughly assessed. The Portuguese authorities listed general mitigation measures, but have not specified any measures related to the selected dams or specific Portuguese situation. The Portuguese authorities indicated in general terms the benefits of the new set of dams but have failed to perform a proper comparison with the benefits of attaining the WFD environmental objectives. There is no assessment as to whether there are other means to achieve the objectives served by the dams.

The general objective of the study is to perform an independent assessment of the Portuguese National Programme of Dams with High Hydroelectric Potential with a focus on the fulfilment of EU water legislation. All the 10 dams that are foreseen are subject to this assessment. Special effort should be put into the analysis of the projects affecting the Douro River Basin, given the predictable cumulative impacts of 6 such projects in this same river basin.

The specific objectives will be the following:

Objective 1: Assessment of benefits of the PNBEPH

The PNBEPH evaluates its benefits on the basis of certain assumptions that do not take into account some environmental restrictions and climate change forecasts.

- In estimating energy production the PNBEPH does not consider that *minimum flows* should be maintained in the rivers downstream of the dams to maintain WFD good ecological status. This may have an impact on overestimating the benefits of the PNBEPH in terms of energy production. This issue is also linked to the installation of fish passes to allow the migration of fish. What is the estimated effect in predicted energy production of considering minimum flows to maintain good ecological status below dams?
- In estimating energy production the PNBEPH does not take into account the predictions of *reduction of precipitation due to climate change*. The Iberian Peninsula will be one of the areas in Europe that will be worst hit by climate change. What is the estimated effect in predicted energy production of considering the future reductions of resource availability due to climate change?

The influence of the reduction on the estimated energy production on the economic efficiency of the projects should be investigated.

Objective 2: Assessment of impacts of the PNBEPH

The impacts of dams in water environment are well known[2]. Despite the PNBEPH provides considerable detail about the definition of individual projects, the assessment of the impacts of each dam in the water environment is very poor. Also the accumulated effects in particular river basins are not considered or investigated. In the current legislative framework, the impacts on water environment should be assessed against the WFD ecological status classification scheme.

- What are the main effects of hydropower dams in the water environment from the perspective of the WFD ecological status (upstream and downstream)?
- What is the likely effect of each dam in the PNBEPH in the water environment from the perspective of the WFD ecological status (upstream and downstream)?
- What are the (cumulative) effects of each dam or group of dams in water environment and uses in the river basins they are located, taken into account their current situation? Potential cumulative impacts on nature values protected under Directives 92/43/CEE and 79/409/CEE should equally be assessed against provisions of these Directives.

Objective 3: Assessment of alternative options

The starting point of the PNBEPH is the need to increase renewable energy production in line with Community objectives.

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[2] See WFD Common Implementation Strategy Policy Paper "WFD and Hydro-morphological pressures. Focus on hydropower, navigation and flood defence activities. Recommendations for better policy integration" (November 2006) and accompanying documents available at http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/thematic_documents/hydromorphology

The PNBEPH does not look at possibilities to upgrade existing hydropower installations. What is the estimated increase in capacity that can be achieved through upgrading existing installations?

The Strategic Environmental Assessment (SEA) elaborated for the PNBEPH considers four options. Those are largely driven by energy production considerations and reduction of greenhouse gas emissions. There is very little consideration to water impacts. It is not clear what the degree of affection is to the water environment of each of the options. From a preliminary assessment it appears that, due to the selection of factors considered in the SEA, the analysis carried out does not react to the impacts on the water environment. To what extent the definition of the factors to be considered in the SEA and the options chosen influence the outcome of the SEA and to what extent this outcome is at all influenced by the assessment of the impacts on water environment?

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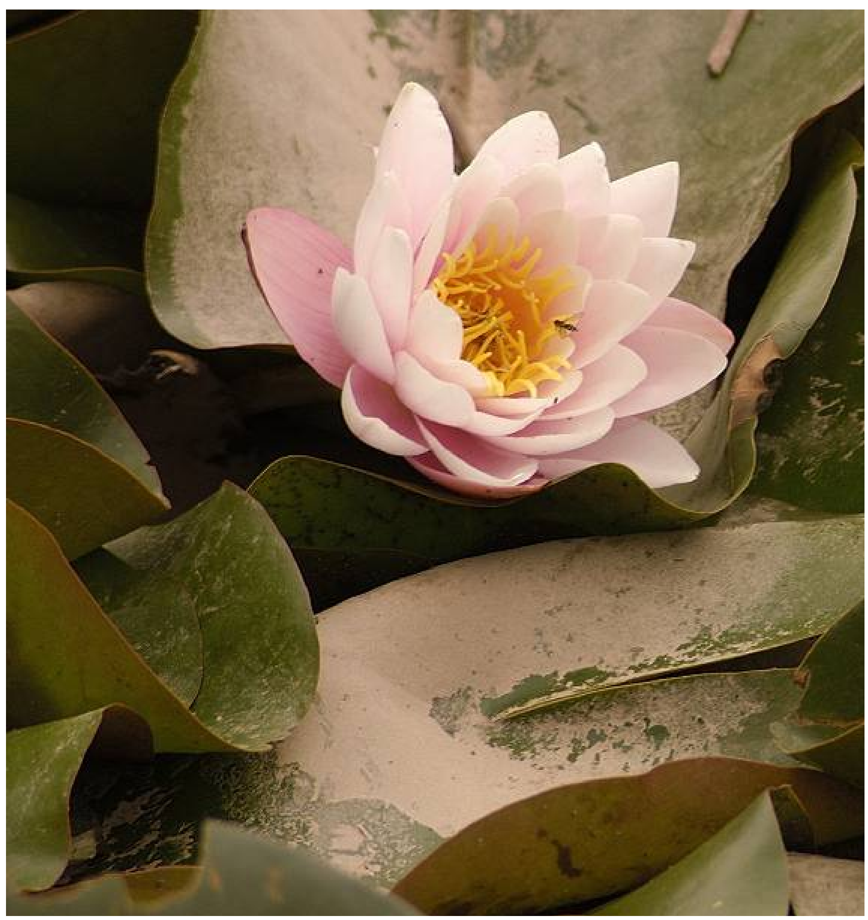

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1.1 Introduction

The structure and function of riverine systems are based on five components: hydrology, biology, geomorphology, water quality, and connectivity. A proposal for an instream standard should try to mimic a natural flow regime in order to protect aquatic life functions dependent on the natural flow regime.

Research has found that the natural biota is dependent upon basic hydrology: longitudinal (headwater to mouth), lateral (channel to floodplain), vertical (channel bed with groundwater), and chronological. Significant disruptions in any of these hydrologic features will be detrimental to the natural biota. For example, changes in the timings of releases in the spring will affect natural spawning cues of anadromous fish. Removal of flooding flows will affect wetlands on the floodplain and cause changes in riparian zones, siltation of gravel beds and removal of spawning habitat.

The alteration of natural flow conditions, in volume and timing, often occurs downstream from projects for hydroelectric generation where large volumes of water are either stored or diverted. Consequently, a limit for the minimum flow and an occasional maximum or flushing flow may be required to maintain aquatic habitats in the stream.

Several desktop standard-setting methods are available[3] . These methods often provide results that approximate those provided by more detailed, site-specific methods, but they lack the ability to quantitatively and incrementally assess the relationship between habitat availability and flow.

Some basic criteria are used in several countries to estimate minimum flows, which usually consider some percentage of average annual flow (**Table 1:**).

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[3] These include, for instance, the US Fish and Wildlife Service Aquatic Base Flow Method (USFWS ABF), and the Tennant Method, which are described in this document.

Table 1: Criteria used in different countries to estimate minimum flow

COUNTRY	MOST FREQUENT CRITERIA
Spain	10-20 % of annual average flow.
France	10 % of annual average flow but for modules over 80 m^3/s, 5 % of the module is admissible.
Italy (depending upon region)	10 % of the annual module in some regions and in others a specific flow rate of 2 $l/s.km^2$
Ireland	1-10 % of annual average flow.
Great Britain (England and Scotland)	Q_{347} (flow equal or greater 90 % of the time throughout the year).
Switzerland (La Vaudoise Canton Law)	The maintenance flow is deduced from an algorithm based on the Q_{347} known as the "Mathey formula".
Austria	Q_{300} (flow equal or greater for 300 days of the year).
Germany	30-60 % of annual average flow.
United States	New England Flow Method (USFWS, 1981). Also known as the ABF (Aquatic Base Flow).
Canada (East coast)	25 % of annual average flow.
Republic of South Africa	Building Block Methodology (King *et al.*, 2000).

1.2 Overview of methods for determining minimum flows

Instream flows are valuable for maintaining fish and wildlife habitat. This concern has led to the provision of instream flows specifically for environmental purposes, also sometimes called environmental flows. These are designed to enhance or maintain the habitat for riparian or aquatic life. For indigenous species, the best model is one which mimics nature, since the biota have evolved in accordance with the historical patterns of high, low and zero flows. The minimum flow is normally specified as an instantaneous flow rather than a daily average, meaning that the flow should never drop below the minimum at any time. Instream flow recommendations may also include artificial floods or flushing flow, which are e.g. designed to remove fine material from the stream-bed. In establishing instream flow requirements the difficulty lies in deciding how much modification of the natural flow regime is acceptable and a great deal of scientific uncertainty persists.

One of the main difficulties in determining an instream flow requirement is lack of quantitative data. This becomes especially critical, when the preservation of aquatic habitat conflicts with other water uses. To assist in the development of instream flow recommendations, a number of numerical techniques have been developed over the past few decades. Most of the efforts have been focused on the preservation of trout or salmon habitat in cold-water streams. Over time, increasingly sophisticated techniques have been derived which consider the changes in stream hydraulics at varying flow levels and the habitat requirements of species at different life stages and seasons.

This chapter wants to give an introduction to several methods existent, which are summarily described below.

1.2.1 Methods based on historical flow data

E.g. Tennant/Montana; Aquatic Base Flow, Flow Duration Curve Method; 7Q10, Arkansas; Texas; Base Flow.

Application: river wide planning purposes, watershed management at regional or national scale, hydraulic or hydrological projects in a preliminary phase.

Tennant method

The Tennant method is one of the most widely used methods. It was created using data from the Montana region (Tennant 1976), and was developed through field observations and measurements. Data were collected on 58 cross sections on 11 different streams within Montana, Nebraska, and Wyoming. Tennant collected detailed cross section data that characterized different aspects of fish habitat. These included width, depth, velocity, temperature, substrate and side channels, bars and islands, cover, migration, invertebrates, fishing and floating, and esthetics and natural beauty. Tennant looked at both warm water fisheries and cold water fisheries. These metrics were related to a qualitative fish habitat quality. This allowed for a determination of discharge to fish habitat through the correlation of physical geometric and biological parameters to discharge. Tennant then related percent of the average flows to fish habitat qualities and split his flow recommendations into two different segments of the year, October to March and April to September (**Table 2**).

So through a somewhat complex methodology Tennant produced an easy to apply standard that can be used with very little data. The technique utilizes only the average annual flow for the stream. It then states that certain flows relate to the qualitative fish habitat ratings, which is used to define the flow needed to protect fish habitat that is of the quality desired. This allows professional staff working in a regulatory environment to set the required flow by using the percent of the average annual flow (AAF) without further onsite data collection.

The obvious benefit of this method is that regulators or land managers are able to set flow requirements without expensive field data collection, or processing. The Tennant method is considered a standard setting method, meaning that it uses a single, fixed rule as a minimum base flow. This means that it is easy to apply to any situation without collecting lots of data or being expensive. But it also means that it treats all situations the same and uses a single criterion in all circumstances, because Tennant did not provide criteria that a stream must meet for this method to be applicable. The method has also been adapted to other regions with different conditions by altering the seasonal distribution of the percentages to define the minimum flows. However, it is generally acknowledged that this method should be restricted to reconnaissance level planning (Mosley 1983).

Table 2: Base flow regimes recommended by Tennant method (percentage of the average annual flow)

Description of flows	October- March	April-September	
Flushing or maximum			200 %
Optimum range			60 - 100%
Outstanding	40 %	60 %	
Excellent	30 %	50 %	
Good	20 %	40 %	
Fair or degrading	10 %	30 %	
Poor or minimum	10 %	10 %	

Description of flows	October- March	April-September	
Severe degradation			0 - 10%

Flows are defined as a percentage fraction of the average annual flow. When the natural flows in the period considered, allows for the maintenance of the estimated percentage; otherwise, the average flows in that period should be used as minimum flow.

Aquatic Base Flow Method (ABF), USFWS 1981

The US Fish and Wildlife Service developed this method in New England. The method's ecological underpinnings are that the natural ecological hydrological system serves as a baseline or reference condition from which stream flow conditions suitable for the protection of aquatic life could be identified.

The USFWS used historical flow records for New England and evaluated gage data from 48 unregulated rivers with drainage areas greater than 50 square miles and with a 25 year gage record. The ABF method assumes that the most critical flows to be maintained are in August when the metabolic stress to aquatic organisms is at its highest due to high water temperatures, diminished living space, low dissolved oxygen, and low or diminished food supply. It was determined that the historical (unaltered) median flows will protect critical reproductive functions. Where adequate records (25 years of unaltered, free-flowing, 50 mi.2 or greater USGS gaging measurements) exist the USFWS recommends that using the median of the monthly means of August flows will be adequate throughout the year unless additional flow releases are necessary for fish spawning and incubation. If spawning and incubation are an issue, the USFWS recommends flow releases equivalent to the historical median of monthly means stream flow throughout the applicable spawning and incubation period. Where inadequate records exist or for rivers regulated by dams or upstream diversions, the USFWS recommends using 0.5 cfsm[4] unless spawning and incubation are a concern where the recommendation is 1.0 cfsm in the fall/winter and 4.0 cfsm in the spring.

This method has been modified and adapted to other areas in the US (e.g. Rode Island, see annex). Main changes introduced concern:

- the use of the August median flow rather than the median of the monthly August mean flows;
- the use of monthly criteria rather than 3 seasonal values.

1.2.2 Methods based on flow and hydraulic parameters relations

E.g. Colorado/U.S.F.W.S. Wetted Perimeter.

Application: To stream level in order to keep the hydrological features of the stream subjected to hydraulic projects. These methods are more accurate than those previously mentioned, but are not appropriate for streams with highly variable flows, such as streams located in the south of Portugal.

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[4] CFSM Cubic Feet per Second per Square Mile (rate of discharge of water)

Wetted Perimeter Method

Tennant's method worked by keeping water in the channel. The wetted perimeter method was proposed as a further elaboration of Tennant's observations. In this method the amount of water perimeter at several stages in sample channel cross-sections is plotted against the corresponding discharge rates to determine if the wetted perimeter increases abruptly with stage. If it does, it is taken as a minimum flow stage and discharge. The conditions of timing and critical periods must again be applied.

1.2.3 Methods based on flow and habitat relations

E.g. Instream Flow Incremental Methodology-IFIM/Physical HaBitat Simulation System - PHABSIM)).

Application: To stream level. This methodology involves transect analysis and is based on the evaluation of suitable habitat availability for particular aquatic species, mainly fish, as a function of the stream flow. These methods are the most accurate, but require detailed analysis of the hydromorphological and biological features of the river.

Instream Flow Incremental Methodology (IFIM) / Physical HaBitat Simulation System (PHABSIM)

The IFIM methodology, developed by the US Fish and Wildlife Service, is made up of a collection of analytical procedures and computer models and allows the development of different approaches adapting to the ecosystem in focus. The IFIM has been described using the sequence of seven steps as follows:

1. Description of status quo of the ecosystem using key variables (e.g. water quality, channel form or flow regime).
2. Development of functions or mathematical expressions describing the habitat preferences of evaluation species.
3. Development of functions or mathematical expressions integrating the macro and micro-habitat availability of the present system.
4. Incrementally change one or more variables to reflect a particular management option, determining habitat availability based on relationships developed in 2 and 3.
5. Determination of potential alternatives of remedial actions to correct adverse impacts found in previous step (4).
6. Repetition of 3 and 4 in order to evaluate impacts of a range of management alternatives.
7. Evaluation of alternatives under the strategic management objectives and preparation of recommendations for the project.

Curves are developed by combining population-habitat data with the availability of habitat type and subsequently normalized to obtain suitability index from 0 to 1. Ideally, criteria should be developed at different times of the year.

PHABSIM forms a major component of IFIM following the assumption that aquatic species will react to changes in the hydraulic environment. Programs are available for modelling changes in water surface and velocity patterns with discharge and combining these with habitat-suitability curves to produce habitat-discharge relationships. Results obtained display the change in a composite factor, the weighted usable area (WUA) in relation to discharge. WUA is an indicator of the net suitability of use of a given reach by a certain life stage of a certain species. WUAs are determined as functions of depth, velocity, cover and substrate for specific discharges, so that the physical habitat is redefined at each discharge to obtain a functional relationship.

1.2.4 Other methods

E.g. Holistic method, Building Block Methodology, Downstream Response to Imposed Flow. Application: These methods use a fluvial ecosystem approach and require complex and detailed information.

Other models that require physical habitat assessment and use a habitat modelling approach, like the HARPHA (Austria), FISU (Finland), 5M7 (France), Rhyahabsim (New Zealand), HEP (Holland), River-2D (Canada) are also available but have not been considered in this project.

1.2.5 Discussion

Several models have been developed to determine instream flow requirements. Their fundamentals differ in complexity and aim. Data availability limits the applicability and the output. The input requirements for their functionality can be illustrated as seen in **Table 3**. The data availability for our project allows for the application of the purely hydrological-based models (Tennant and ABF). Other models require data input that is not available at this stage, but they could be applied in later stages, i.e. in the design and preparation of each hydroelectric project of the PNBEPH.

Table 3: Overview of model requirements

Model	Q	T	d	v	Fish	Macroinvertebrate
Tennant	X					
Hydraulic methods	X		X	X	optional	
Aquatic Base Flow	X					
IFIM/PHABSIM	X	optional	X	X	X (either)	(or) X

All methods require discharge input (Q). The physical habitat model PHABSIM also requires depth (d) and velocity input (v). Habitat curves are being defined in relation to fish and/or macro-invertebrate habitat curves. Optionally a temperature input dependency can be defined (T).

1.3 Minimum flow methods used in Spain

1.3.1 Background information

In Spain there is a legal requirement for ecological flows implementation but its definition, in quantity and temporal pattern, has not been accurately fixed (Manteiga and Olmeda, 1992). During the last decade 'Confederaciones Hidrográficas' (water authorities) were forced by law (Ley de Aguas, 1986) to include in their Water Planning quantitative evaluations of ‘Ecological Flows’ considered as minimum instream flows. Due to their lack of personnel with limnological knowledge, most of the ‘ecological flow’ determinations have been based on historical flow records (10% mean annual flow, or flow frequency distribution) with no serious limnological considerations.

Table 3. Criteria established in the different Hydrological Basin Plans and in certain Autonomous Communities, together with the denomination given to the environmental flows in each case. *Criterios establecidos en los distintos Planes Hidrológicos de Cuenca y en algunas Comunidades Autónomas, junto con la denominación que en cada caso reciben los caudales ambientales.*

WATER AUTHORITY	CRITERIA
Norte I, II y III. *Minimum flow*	10 % of annual average flow, with 50 l/s as minimum.
Duero	Without specifications.
Tajo. *Environmental demand*	The volume corresponding to 50 % of natural summer average flow.
Guadiana I y II. *Minimum volume*	1 % of natural incoming for each reservoir.
Guadalquivir y Guadalete-Barbate *Environmental demand*	50 l/s as maximum in addition to the admitted uses of water.
Sur. *Ecological flow*	10 % of annual average flow.
Ebro. *Minimum flow*	10 % of annual average flow.
Júcar. *Maximum stock*	1 % of total water resources.
Segura. *Minimum flow*	10 % of annual average flow.
Cuencas Internas de Cataluña. *Maintenance flow*	QBM method (Palau & Alcázar, 1996).
Galicia-Costa. *Minimum flow*	10 % of annual average flow.
AUTONOMOUS COMMUNITY	**CRITERIA**
Galicia. *Ecological flow*	Any well verified method.
Asturias. *Minimum ecological flow*	20 % of the annual average flow.
Navarra. *Minimum flow*	10 % of the annual average flow for “cyprinid rivers” and Q_{330} for “salmonid rivers”.
Aragón. *Ecological flow*	Without specifications.
Cataluña. *Maintenance flow*	QBM method.
Castilla y León. *Ecological flow*	20 % of the annual average flow.
Castilla-La Mancha. *Minimum ecological flow*	10 % of the annual average flow.
Extremadura. *Minimum flow*	Without specifications.

Nevertheless, a few water managers have realized the importance of developing a methodology to determine minimum ecological flows based on biological data. Their efforts were the first attempts to apply Instream Flow Incremental Methodology (IFIM) to determine ecological flows on Spanish rivers (García de Jalón, 1990; Cubillo et al., 1990), and even the development of other new methodologies (Palau, 1994; Docampo and de Bikuña, 1995).

Palau and Alcazar (1996) proposed a method based on the application of the simple moving average forecasting model from historical daily flow records. They found in Catalonian rivers a characteristic minimum flow, called Basic Flow, using natural stream flow time series. These minimum flows were computed applying moving averages to increasing intervals of consecutive daily flow records, up to a maximum of 100 days per year. For each day interval a mean annual minimum moving average (MAMMA) is determined; and among these MAMMA values, the one that produces a greater relative increase between day intervals was selected as the Basic Flow.

In the Basque country, Docampo and de Bikuña (1995) developed a peculiar method, adapted to Basque country streams, based on the hypothesis that macroinvertebrate communities change along the river continuum. For each watershed they elaborated empirical relationships between the number of benthic species, the channel wetted perimeter and the instream flow (expressed in terms of geometrical mean), and it is assumed that the minimum acceptable flow is the one able to maintain at least 15 different species.

As IFIM became popular around the world, Spanish water authorities and natural conservation institutions have promoted studies on minimum instream flows based on this methodology. More than 100 stream reaches have been studied in Spain (Garcia de Jalón, 2003), analysing bed topography, hydraulic, substrate and refuge conditions, natural flow regime and aquatic communities composition, phenology and habitat requirements. Relationships between instream flows and potential useful habitat were established using 1 and 2–D hydraulic models, together with the habitat requirements of key indigenous fish species and macrobenthic diversity.

Minimum flows were determined by selecting those flows that produced the greatest rate of habitat change. The evaluation of the potential habitat produced by natural flow regimes was used to understand the life strategy of autochthonous fishes and their flow requirements. Variability of the natural flow regime was found to be the main factor structuring stream types. In torrential Mediterranean streams, basic flows were ecologically nonsense because the stream channel is too large relative to the wetted channel produced by modal flows. Here, fisheries life strategy is migration and, therefore, minimum flows must be calculated at a scale larger than that of stream reach. Minimum flows, natural flow regime and the habitat requirement of native fish species at different scale, are the components used to the proposal of an 'ecological flow regime' for each river reach.

1.3.2 The use of Instream Flow Incremental Methodology (IFIM) to determine ecological flows on Spanish rivers (Garcia de Jalón 2003)

The habitat requirement of the aquatic community is defined by an 'indicator species' whose habitat needs represent or envelop those of the whole community. Generally a large native fish species of the stream reach that is at the top of the trophic pyramid (trout, barbell, salmon, nase) is selected as indicator. In the physical habitat two main components are distinguished: the channel structure, (types of bottom substratum and quality of refugee), that for a range of low flows is relatively independent of instream flows and the hydraulic conditions (depth and velocity), which are flow dependent.

As IFIM–based methodology is used to evaluate ecological flows, and not to predict fish densities or biomass, only the physical habitat (that is controlled by instream flows) is considered. The density of an aquatic population in a stream reach is determined by both physical and biological factors. While flows can change almost instantaneously, changes in a population have an inertial delay due to the time of biological processes (reproduction, recruitment, growth, mortality). Thus, the 'weighted useful area' (WUA) is considered as a value of the potential stream habitat independently occupied or not. Using one– and two–dimensional hydraulic simulation models and habitat requirements of the main indigenous fish species, and also macrobenthic species, relationships between instream flows and potential useful habitat (or weighted useful area) were established.

For some Iberian endemic species, barbell (Barbus bocagei), Iberian nase (Chondrostoma polylepis) and Iberian chub (Squalius pyrenaicus), preference curves were developed (Martínez–Capel and Garcia de Jalón, 2002). For a given species different life stages have different habitat requirements (represented by different preference or suitability curves). Thus different WUA–Instream Flow relations for each development stage were obtained. The stage with the highest requirements was used to determine the instream flow. Generally, adult requirements are those of greater habitat demand. In few cases spawning habitat demands are the critical ones, and their flow requirements should be incorporated during the spawning months (December to March in salmonids, and March to July in cyprinids). In small streams inhabited by fish with migratory behaviour, adult demands are considered critical only during reproduction periods, while juvenile or fry demands are considered critical for the rest of the year.

Minimum Flows Determination

Criteria for minimum flows were determined by selecting in the habitat–flow curves, those flows where the greatest rate of habitat change occurs for the more exigent stage development (García de Jalón 1990). Analyzing the curves that represent these relationships between potential habitat and instream flows, a typical shape is frequently found. The potential habitat value increases with flow very rapidly, until the stage where the slope smoothes and the curve eventually reaches its maximum value. Two flow values, with ecological meaning, can be defined in these curves:

- Basic Flow: is the minimum flow needed for the conservation of the communities. At lower flows than basic flow, the potential habitat decreases sharply, while for greater values the habitat increases only slightly. Different development stages with particular habitat requirements may lead to basic flow variations through the year.
- Optimum Flow: is the instream flow that produces a maximum value of potential habitat. Obviously, it is the reference flow for ecological enhancement.

Channel maintenance flows

Because of flow regulation high frequency floods below the dams are usually of less importance than in natural conditions and the channel size is reduced and invaded by riparian vegetation. This implies important modifications of the physical habitat provided by the river. In order to maintain or to restore the channel dynamic processes, the ecological flow regime should include flood events that correspond to the bankfull discharges.

Bankfull discharge flows were determined from natural daily flow records, analyzing annual maximum flows. For streams in the north, centre and west of Spain, bankfull discharges have a recurrence of 1.5 to 2 years. For temporal or more torrential rivers in arid watersheds, bankfull discharges are found at larger return period (5 to 8 years). If the stream is slightly regulated, or is regulated recently, bankfull discharge can be estimated from cross–sections and hydraulic model application.

Ecological regimes

Habitat and instream flow requirements vary with seasons. For example spawning and embryo development periods require a certain level of flows without floods. During summer with critical high water temperatures, salmonids require swift water currents (and thus higher flows) in order to compensate lower dissolved oxygen. The annual and seasonal variability of the natural flow regime was found to be the main factor structuring stream communities, especially controlling the biotic answer to minimum flow conditions.

Thus, it is necessary to define an ecological regime of flow. This regime may be established in two ways:

a) taking into account the needs of the selected indicator species, assuming different flow requirements of their development stages;
b) taking into account the needs of the indicator species only for annual critical conditions in the dry season and giving a flow fluctuation proportionally to natural flow regime for the remaining seasons.

This instream flow strategy of imitating nature is because of the selection for native species, and also for the maintenance of geomorphological processes and the conservation of biological integrity. The procedure consists of using the mean monthly flows of the natural regime as the pattern of flow fluctuation, fixing the value of the basic flow to the minimum monthly flow. The flows for the remaining months in the ecological regime are adjusted by proportional reduction of the natural regime.

Flow regimes in Mediterranean streams

Mediterranean streams have natural regimes with an important torrential component that is reflected in strong seasonal and interannual fluctuations. This last fact shall also be considered on the proposal of ecological regimes, as native species have evolved under these torrential conditions, and are adapted to them. Under regulated conditions Mediterranean stream species cannot compete successfully with many introduced (generalist and limnethic) species (García de Jalón et al., 1992; Morillo et al., 2002). In order to favour native species, the ecological flow regime of the streams was adapted to the characteristics of the hydrological year.

During dry years the ecological regime is built using 'low basic flow' as preference for the driest month, while during humid years it is determined using the 'high basic flow'. Both regimes fluctuate in a similar manner to the natural regime. Dry years in these streams were defined as those with a mean annual flow less than half of the average for whole series. On stream reaches below dams, the consideration of dry years may be done by the evaluation of the reservoir–stored water quantity.

The natural flow regime in the Mediterranean streams is characterised by low flows during summer, and frequently the channel is completely dry during a certain period. In these streams monthly average flows during summer are lower than basic flows. This is possible because the channel size is a consequence of bankfull discharge, while basic flows are calculated through the channel morphology and the amount of habitat represented. As bankfull discharge is relatively huge compared to the normal or modal flows, the stream channel is too large to be wetted by modal flows. Thus fish living in these rivers have a life strategy based on temporal migration and, therefore, minimum flows must be determined from a scale larger than the stream reach. In Mediterranean streams the ecological regime has been defined leaving the natural flows for the months in which values are lower than the basic flow. For the remaining months the ecological regime imitates natural fluctuation but the monthly mean values are reduced by the coefficient obtained from the ratio of basic flow to mean annual natural flow (Garcia de Jalón 2003).

1.3.3 Some recommendations for determining minimum flows in Spain

The design of ecological flow regimes allows the implementation of environmental water planning. Spanish water authorities are planning to establish these ecological flow regimes downstream of the main dams, according to the methodology presented above. Due to the fact that it is not possible to apply this methodology to every stream reach, an extrapolation tool was developed. Baeza and García de Jalón (1997, 1999) have classified stream reaches of the Spanish Tajo basin according to their hydrological, geological, climatic and topographic characteristic. For each stream type class, models for predicting minimum ecological or basic flows were developed.

However, today in Spain there are many reaches without enough instream flows, and it is not possible to implement ecological flows there because the water rights have been given. These water concessions are often excessive and their capacity is long term (duration time is more than 60 years). Therefore, these water rights are incompatible with any ecological flow regime, and only through public expropriation an ecological regime can be applied. Only in unregulated streams, under new planned reservoirs and water abstractions works it would be possible to apply these ecological flow regimes. In fact, at present no ecological flow regime has been applied in Spanish river or stream reaches.

When exploitation schemes produce flows that are higher than minimum ecological flow regime (in certain stream reaches below dams), the real flow conditions (observed regime) present great differences with natural flows. The effect of high summer flows in rivers with natural dry or very low natural flows have completely changed fluvial communities, favouring introduced species that have especially impacted native fish species. Therefore, it is not only a question of minimum instream flows that must be maintained following the ecological regime, but also a question of maximum instream flows that should not be reached, especially during the natural dry season.

Richter et al. (1997) proposed different quantitative parameters that can be used to characterize a natural flow regime from their biological significance. These parameters can be used to quantify the deviation of the regulated stream flow regime from its natural one.

Finally, it must be considered that the resilience of fluvial systems (the capacity to recover from disturbance) diminishes as their flow regulation intensity increases. And, thus, the ecological flows that must be maintained below a reservoir or on diverted reaches should be increased if new reservoirs and water transfers are built in the basin.

1.4 Minimum flow prescriptions and methods applied in Portugal

1.4.1 Legislation prescribing the establishment of minimum flow

Minimum flows are considered in several Portuguese legislative documents and regulations, as mentioned below. However, the methodologies to estimate minimum flows are not described.

- Lei de Bases do Ambiente (Basic Environment law) (nº 11/87 de 7 de Abril);
- Decreto - Lei nº46/94 de 22 de Fevereiro (Use of water resources);
- Article 33º: water use for hydropower. b) Ecological flow is necessary to safeguard public and third parties interests;
- Decreto-Lei nº 69/2000 de 3 de Maio modified by Decreto-Lei nº 197/2005 de 8 de Novembro (Environmental Impact Assessment). EIA of new dams shall consider the ecological flow needed downstream;
- Lei nº 58/2005 de 29 de Dezembro (Lei da Água/Water Law (Transposition of the WFD 2000/60/CE);
- Article 54º. Monitoring of surface and ground water status and protected areas;

- 3rd paragraph: “For surface waters, the national monitoring programme shall include water volume or level and the flow when considered relevant for defining the ecological and chemical status and the ecological potential”;
- Lei nº7/2008 de 15 de Fevereiro lei das pescas nas águas interiores (Fishing on inland waters);
- Artigo 12.º Caudal ecológico (ecological flow):
  1. Owners or users of hydraulic infrastructure shall maintain the ecological flow, which shall be adequate and adapted to suitable variations in order to maintain the aquatic species life cycle and the integrity of the aquatic ecosystem.
  2. The evaluation of the ecological flow must be ensured by the owners and users, allowing its adaptation in order to guarantee its efficiency.

1.4.2 Minimum flows in the National Water Plan (Plano Nacional da Água)

In 2002, Portugal approved a National Water Plan (Plano Nacional da Água, PNA) defining the national framework for an integrative management of water (Decreto-Lei nº 112/2002, de 17 de Abril). This Plan is based on an assessment of the situation of water courses and it defines measures to reach the objectives fixed.

In volume 1, there is a section on ecological flows (section 2.7.3) where is stated that hydrological installations generally alter the hydrological pattern of water bodies downstream, where reduction on mean flows, seasonal variability and extreme episodes (floods and droughts) occur. These alterations on natural flows affect the aquatic habitats and species.

This section also highlights that 15.8 % of water bodies on Continental Portugal are modified. If only the 11 biggest river basins (with areas larger than 1000 km²) are considered, the percentage of modified water bodies exceeds 90 %. Besides large dams, there are also a great number of small installations, mainly on the Alentejo region (south), for irrigation. On the other hand, in the North there are old and small weirs used for hydro-power. So in view of this information, the Plan asserts that the number of modified water bodies is underestimated.

Concerning national legislation on ecological flows, the PNA states that since 1989 there is a legal basis to consider the obligation of maintaining a minimum flow downstream a reservoir when delivering permits for new hydraulic installations, in order to reduce the negative impacts on aquatic ecosystems. Moreover, in view of the current legislation (described in the plan and updated on the previous section of this document), the PNA indicates that the conservation of aquatic ecosystems is considered by Portuguese legislation at planning, management and utilization stages for water resources. Therefore, it is crucial to maintain a regime of ecological flows which are implicitly, and sometimes explicitly, covered by the national legislation. In contrast, *the legislation does not establish values or methods to define these ecological flows, except for international rivers for which a provisional regime of flows is established* in the ‘Protocolo Adicional’ of the ‘Convençao para a Protecçao e o Aproveitamento Sustentável das aguas das bacias Luso-Espanholas’ (**Table 4**).

Concerning the definition of ecological flows in Continental Portugal, the PNA indicates that it is generally based on the natural hydrological regimes, assuming that a given percentage of the average annual flow can guarantee a certain level of ecological integrity. These methods are based on the use of flow records. However, more recently and for large hydraulic installations like Alqueva, Enxoé or Alto Lindoso and Touvedo, and for boundaries stretches of international rivers, other approaches have also been adopted taking into account the hydrological regime of rivers and their ecosystems characteristics as well.

In summary, since 1989 the ecological flows in Portugal have been usually established according to the following practices:

- For mini-hydrics and other installations North of Tagus river: flow not lower than 2.5% to 5% of the modular flow were maintained during the whole year, in cases *where the instantaneous flow of the natural regime allows for it***.**
- Hydro-agricultural installations South of Tagus river: flow equal or higher than 5% of the modular flow, for medium years, in cases where this percentage is lower or equal to the mean monthly flow. When this is not the case, the mean monthly flow for the month should be maintained, with the possibility of a zero flow for summer months.
- For the large hydraulic installations of Alqueva, Enxoé and Alto Lindoso e Touvedo other methodologies where applied. These are briefly described in **Table 5**.
- River Basin Management Plans of International Rivers includes ecological flows for the rivers concerned based on flow records and specified on the Protocolo Adicional of the 'Convençao sobre Cooperaçao para a Protecçao e o Aproveitamento Sustentável das águas das bacias Luso Espanholas' (**Table 5**).

Table 4: Ecological flows proposed for the international sections of the Rivers Minho, Lima, Douro, Tejo and Guadiana in the Synthesis of the Management Plans of the Portuguese-Spanish River Basins

		Out	Nov	Dez	Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set	Ano
Minho	Caudal (m3/s)	5,6	19,3	42,2	55,6	324,5	243,4	178,2	124,7	12,7	6	3,7	3,1	83,3
	Afluência (hm3)	15,0	50,0	113,0	149,0	785,0	652,0	462,0	334.0	33,0	16,0	10,0	8,0	2627
Lima	Caudal (m3/s)	3,0	4,0	8,0	10,0	45,0	44,0	32,0	25,0	15,0	3,0	3,0	3,0	16
	Afluência (hm3)	8,0	10,4	21,4	26,8	108,9	117,8	82,9	67,0	38,9	8,0	8,0	7,8	506
Douro	Caudal (m3/s)	23,9	52,5	84,4	103	298,4	244,9	185,6	133,7	35,1	14,2	5,2	7,3	97,7
	Afluência (hm3)	64,0	136,0	226,0	276,0	722,0	656,0	481,0	358,0	91,0	38,0	14,0	19,0	3081
Tejo	Caudal (m3/s)	11,6	27,4	41,8	50,8	324,5	261,4	232,6	146,7	63,3	5,2	3,7	5	96,1
	Afluência (hm3)	31,0	71,0	112,0	136,0	785,0	700,0	603,0	393,0	164,0	14,0	10,0	13,0	3032
Guadiana	Caudal (m3/s)	10,1	23,1	104,2	104,2	104,2	104,2	104,2	66,8	15,8	16,1	10,1	10	56
	Afluência (hm3)	10,1	60,0	279,0	279,0	252,0	279,0	270,0	179,0	41,0	43,0	27,0	26,0	1766

However, even if there is a legal obligation for hydrological installations to maintain an ecological flow, the PNA points out a lack of control of this regulation which should be undertaken by regional environmental authorities (Direçoes Regionais de Ambiente e Odenamento to Territorio). This situation leads to a general ignorance about the current fulfilment of the legislation when delivering authorisations for hydrological installations.

Taking into account this situation, the PNA recommends:

- The new national legal framework concerning ecological flows should consider the four current situations:
  a) Hydrological installations built before 1989-1990,
  b) Hydrological installation permits conceded after 1989-1990 for which ecological flow where defined but which are considered to be provisional,

c) Hydrological installations permits delivered after this Plan and
d) Ecological flows for the international rivers (Lima, Minho, Douro, Tejo and Guadiana).

- The methodologies applied for the Alqueva and Alto Lindoso e Touvedo installations can be considered as pilot projects to assign ecological flows.
- Considering the need to apply ecological flows in already built installations, feasible technical solutions should be developed.

1.4.3 Minimum flow in River Basin Management Plans

As regards the River Basin Management Plans, the corresponding regulations[5] usually indicate that the minimum flow could be determined by the "*Aquatic Base Flow modified*" method.

When no other estimate of the minimum flow is available, for the *Douro, Vouga and Mondego* river basins it is stated that minimum flow should be at least *25% of the average annual natural flow*.

1.4.4 Methods for defining minimum flows in Portugal

Table 5 presents the use of some methods described in the previous chapters for the definition of minimum flows in several existing dams in Portugal.

Table 5: Application of several methods to calculate minimum flows in Portugal

Project	Basin	River	Methods	References
Torga small dam (North)	Douro	Tuela	IFIM; Wetted Perimeter; Tennant	Alves, 1993 in Alves & Bernardo, 2003
Alqueva Dam (South)	Guadiana	Guadiana	Tennant modified; Texas Wetted Perimeter IFIM (monitoring program is recommended).	Alves & Bernardo, 2003 Alves, 1996
Enxoé Dam (South)	Guadiana	Enxoé	A Modified Flow and habitat relation-based method was applied. The process involved: • characterization of fish assemblages along the river in order to identify the most important reaches, • analysis of aerial photo-graphy to identify interannual variation of summer water availability for the river in general and especially for the more relevant reaches, • development of a precipita-	Bernardo & Alves, 1999

[5] E.g. Normas Regulamentares do Plano de Bacia Douro, Tejo, Guadiana (INAG)

Project	Basin	River	Methods	References
			tion–runoff model to relate river runoff to the persistence of the summer pools (e.g. Temez model).	
Touvedo Dam (North)	Lima	Lima	Base Flow; Wetted Perimeter and IFIM. Monitoring	Lopes *et al.* 2002; 2003
Belver Dam (Centre)	Tejo	Tejo	The method used was based on the Wetted perimeter–discharge relations	Oliveira *et al.* 2004
Portuguese–Spanish Water Treaty	Minho Douro Tejo Guadiana		Aquatic Base Flow (modified)	Alves & Bernardo, 2003

A publication of INAG (Alves & Bernardo, 2003: Caudais Ecológicos em Portugal) provides a comprehensive review of methods for the definition of minimum flows in Portugal. Some of the methods considered for the design of minimum flows in Portugal, are described below.

Tennant Method adapted to Portugal

A modification of the Tennant's methods has been suggested for the Douro, Tejo and Guadiana international rivers basins in Portugal (European Commission, 1996 in Alves e Bernardo, 2003) The Tennant's method is adapted considering the hydrological and ecological characteristic of the rivers in the Iberian Peninsula (**Table 6**).

Table 6: Base flow regime recommended for the Douro, Tejo and Guardiana international rivers basins (based on adapted Tennant method)

Description of flows	June-September (dry season)	April, May, October, November	December-March (humid season)
Excellent	40%	50%	60%
Good	30%	40%	50%
Fair or degrading	10%	20%	30%
Poor or minimum	10%	10%	10%
Severe degradation		0-10%	

Flows are defined as a percentage of the average annual flow

The method has been adapted to the hydrological pattern in Portuguese rivers, to which the aquatic wildlife is adapted, where June-September corresponds to the dry season, December-March represents the humid season and April, May, October and November are considered in an intermediate situation, neither dry nor wet. In a hydrological normal year first rains occur in October and November and the first droughts appear in April and May.

Aquatic Base Flow modified with redistribution

As above described, the Aquatic Base Flow uses the median of the August mean flow as the minimum flow. However, this approach is only applicable when data series larger than 25 years are available and the stream has a not modified regime. In the remaining cases the minimum flow is a percentage of the flow defined for the basin area (**Table 7**). In the spawning season the flow median is determined from the flow observed during the spawning period.

Table 7: Minimum flow recommended according to the Aquatic Base Flow Base (Russel, 1998)

Season	Available data	
	<25 years ($m^3s^{-1}km^2$)	>25 years[(a)]
April-1st half June	0.29	100 % August median
2nd half June-September	0.04	100 % August median
October-March[(b)]	0.07	100 % August median

a) natural river (unregulated), river basin> 130 km^2, precision equal or higher than 10 %
b) spawning and incubation period
c) when the flow upstream the dam is lower than the August median, the flow to be maintained is that recorded in the site.

Alves & Bernardo have proposed some modifications to this method:

- the median flow is calculated not only for August but for the period July-September (dry season);
- The intra-annual variability is introduced by using the following redistribution factor: mean monthly flow is divided by annual mean flow.

This method is recommended in the River Basin Management Plans and has been applied to some Portuguese sections of international river basins (e.g. see table below, from Tejo RBMP, 2000). However, according to some experts consulted during this evaluation, this method is generally not considered very appropriate for the definition of minimum flows.

Regime Transitório de Caudais Ecológicos na Secção de Cedillo

Mês	Escoamento médio mensal		Redução do escoamento médio mensal, segundo o Método do Caudal Básico Modificado (com redistribuição)	Regime de caudal ecológico							
				Ano médio		Ano muito seco (5%)		Ano seco (20%)		Ano muito húmido (95%)	
	(hm^3)	(m^3/s)		(hm^3)	(m^3/s)	(hm^3)	(m^3/s)	(hm^3)	(m^3/s)	(hm^3)	(m^3/s)
Outubro	376	140	0,08	31,0	11,6	5,8	2,2	8,3	3,1	132,9	49,6
Novembro	994	383	0,07	71,0	27,4	6,5	2,5	12,6	4,9	220,7	85,2
Dezembro	1 602	598	0,07	112,0	41,8	12,2	4,6	30,6	11,4	285,9	106,7
Janeiro	1 951	728	0,07	136,0	50,8	13,9	5,2	44,1	16,5	320,2	119,6
Fevereiro	2 150	889	0,37	785,0	324,5	113,9	47,1	247,9	102,5	1 972,0	815,1
Março	1 899	709	0,37	700,0	261,4	127,5	47,6	184,7	69,0	1 779,3	664,3
Abril	1 477	570	0,41	603,0	232,6	141,3	54,5	297,6	114,8	1 386,5	534,9
Maio	921	344	0,43	393,0	146,7	115,6	43,2	168,1	62,8	876,5	327,2
Junho	393	152	0,42	164,0	63,3	54,7	21,1	85,1	32,8	335,5	129,4
Julho	172	64	0,08	14,0	5,2	6,5	2,4	9,1	3,4	22,4	8,4
Agosto	123	46	0,08	10,0	3,7	5,5	2,1	7,1	2,6	15,0	5,6
Setembro	134	52	0,10	13,0	5,0	6,4	2,5	9,0	3,5	21,8	8,4
Ano	**12 192**	**387**	**0,25**	**3 032,0**	**96,1**	**999,5**	**31,7**	**1 788,6**	**56,7**	**5 848,4**	**185,5**

Basic Flow Method (Palau & Alcazar 1996)

This method is based on the analysis of historical daily flow records. The minimum flow is calculated applying moving averages to increasing intervals of consecutive daily flow records, up to a maximum of 100 days per year. For each interval a mean annual minimum moving average is determined; and among these values, the one that produces a greater relative increase between intervals is selected as the Basic Flow. This method was developed for Catalonian rivers.

Method developed by Alves & Bernardo (INAG) for Portuguese Rivers

This method is applicable to project planning phase. The method takes into account ecological aspects and is considered appropriate to define minimum flows that are adequate to maintain fish communities and riparian vegetation.

This method is based on the definition of homogenous hydrological regions at national scale, based on analysis of flow patterns from a number of variables obtained from daily flow records (e.g. daily median flow, daily mean flow, mean annual flow, flow seasonal variation, characterization of high flows and flood patterns, mean annual values of mean flows with the duration of 1,3,7,30,90,120 and 183 days, flood frequency, intra-annual median time between floods (in days), inter-annual median time between floods -in days, mean duration of floods (in days); flood predictability index; Median of hydrological days with floods...).

Table 8: Minimum flow calculation for the three regions identified in the method proposed by Alves & Bernardo (2003)

Regions	Ecological flow regime											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
North of Tejo (exc. Terra Quente)	q75	q75	q75	q75	q90	q90	q90	q90	q90	q75	q75	q75
South of Tejo	qmed	q25	$\frac{q50+q25}{2}$	q50	q50	q50	q50	q50	q50	qmed	qmed	qmed
Terra Quente Subregion	q50	q50	q75	q75	q75	q75	q90	q90	q75	q50	qmed	qmed

- qmed is the mean flow in the month indicated.
- q75 is the flow which is reached or exceeded on 75% of days in the month (on the basis of a series of mean daily flow).

This method allows determining minimum flows also when local flow data series are incomplete or not available. In this case, minimum flow can be determined using multiple regression equations that have been developed for this method and information about parameters such as local precipitation, temperature and land use data are needed.

Hydrological-hydraulic Method proposed by Portela (2005) for Southern Portugal

This author has developed a method for Portuguese Rivers which is applicable to semi-arid regions of the southern of Portugal. The method considers the intra-and inter-annual flow variations, flow height and velocity.

The minimum flow is defined on a monthly basis using the following formula:

$$Qi = Qeco \frac{Qmes\ i}{Q mod}$$

Where:

- Qi=minimum flow in the month I;
- Qmes i= mean daily flow in the month I;
- Qeco= minimum flow when considering mean monthly flows;
- Qmod= modular flow.

Marmelo (2007) tried to adapt it to the rivers of Northern Portugal and proposed that the highest mean daily flows were not considered in the calculation of minimum flow.

1.5 Proposal of methods to determine minimum flow for the PNBEPH hydropower installations

1.5.1 Preliminary considerations

Some general considerations should be taken into account when selecting a method for the definition of minimum/ecological flows.

- An instream flow standard should mimic the natural flow regime as closely as possible in order to adequately represent the five riverine components (hydrology, biology, geomorphology, water quality and connectivity). The natural flow regime of virtually all rivers is inherently variable (**Illustration 1**), and this variability is critical to ecosystem function and native biodiversity. For this reason, providing a single flow value (minimum, optimal, or otherwise) cannot meet the life cycle requirements for all riverine species. Movement from a seasonal standard to a monthly standard more closely approximates the natural flow regime.

Illustration 1: Average monthly flows considered for definition of minimum flows regime (Source: Alcazar, 2007)

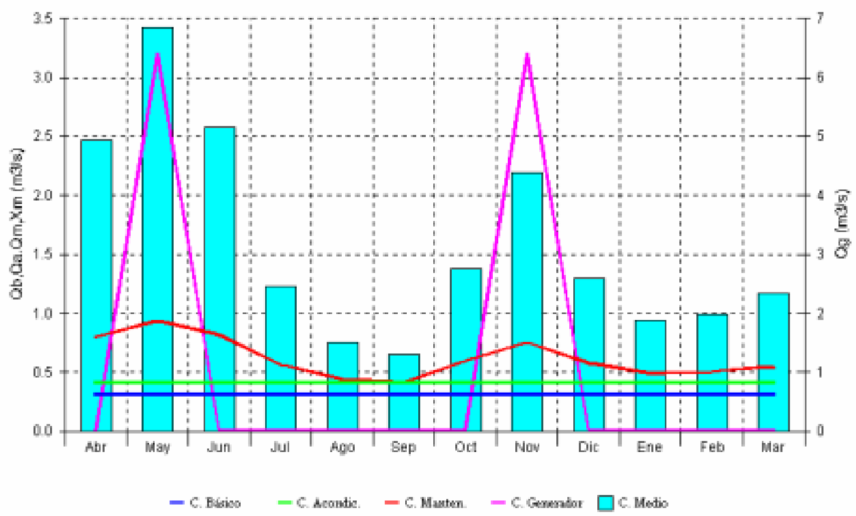


Figura 2.2. Ejemplo de aplicación del Régimen de Caudales de Mantenimiento.

- A sufficiently representative and recent time series of flow records should be considered when planning for water management. Bearing in mind the recent changes in climate and water resources availability, some authors (e.g. Aguilar & Del Moral, 2008) have suggested that the most recent series of flow records available (e.g. last 25 years) should be considered. This aspect should also be taken into account for estimating minimum/ecological flows (Sánchez & Martínez 2008). There are evidences of the reduction of water provision to reservoirs in different basins of the Iberian Peninsula. A reduction of about 20 % has been observed when comparing complete old series of data with more recent series, e.g. from 1981 to 2006. A reduction of about 12 % is also observed in precipitation. The reduction in the water flow regimes in the Portuguese rivers is also acknowledged in the National Water Plan (PNA, 2002).
- A methodology for the assessment of the minimum flow requirements in Portuguese streams should consider some particular issues that are briefly presented below:
  - The high variability of flow regime in Portuguese rivers (periods of prolonged low flows and droughts). This phenomenon is more actuated in southern streams than in the northern streams.
  - The importance of floods to promote post-summer recolonization and spawning migrations (diadromous and resident fish) upstream in river systems.

- The function of seasonal high flow events to maintain channel morphology and substrate conditions.
- The need of endemic fish conservation and the habitat requirements of endemic fish species.
- The importance of riparian vegetation, which has a high ecological and landscape value in many sectors, even in first-order streams, where fish assemblages may not exist or are very simple and with no conservation value;
- The effects of flow regulation on sedimentary dynamics in estuarine zones and on estuarine communities (however there is a lack of information on this subject).

- Finally, the methodology to be used for estimating minimum/ecological flows for the dams included in the PNBEPH should be as simple as possible and adapted to available data, but it should also be suitable to evaluate the requirements at this planning stage. Further on, a precise definition of ecological flow is envisaged in the design and preparation of each hydroelectric project included in the PNBEPH. The estimation of minimum flows at this stage should also serve the purpose of assessing the possible effects of considering minimum flows on the calculation of energy production in these projects.

1.5.2 Method proposed: Tennant Method adapted to Portugal

For this particular case, the following issues must be taken into account:

- projects are in the planning phase;
- in general, monthly and annual flow data are available (from SNIRH);
- methods developed and/or adapted to Portuguese rivers are required;
- simple and time-efficient methods are required.

Taking into account that the proposed method will be used to estimate the water volume required for maintaining an appropriate minimum flow downstream from each dam of the PNBEPH, we consider the *Tennant method adapted to Portuguese rivers* a good choice for this purpose. This method may provide a good estimate of the resource needed to provide minimum flows, taking into account intra-annual variability of water resources, and it is a rather simple method that can be applied to practically all projects included in the PNBEPH with the available data.

The Tennant (or Montana) Method is a desk-top approach that is relatively inexpensive, quick, and easy to apply. Its development required considerable research and input from experts. The results compare relatively well with those from data-intensive techniques. The approach is based on the relationship among river condition, the amount of flow in the river, and the resultant fish habitat. These are used to recommend environmental flows for the maintenance of fish, wildlife, recreation, and related resources. The method is claimed to be applicable to a wide range of river types and sizes, and the general approach, at least, may be applicable in many parts of the world (Davis and Hirji, 2003). Once the initial relationship between river condition and flow has been established for a region, the data requirements of the method are moderate, requiring measured or easily simulated monthly hydrological data.

In cases where time and resources are a major constraint, a specially tailored Tennant approach, based on the knowledge of the habitat responses of the biota of interest in the region or country considered, can provide a good medium-resolution technique for determining environmental flows. The outcome of such a “Tailored Tennant” approach would be a table similar to that in **Table 2:**, but based on empirical observations that are relevant to the country where it will be applied (Davis and Hirji 2003).

The Tennant method adapted to Portugal could therefore be applied to estimate the ecological flow for each dam in the PNBEPH, using flow data series obtained from hydrometric stations located as close as possible to the dams, which may provide recent data (e.g. last 25 years).

The estimated minimum flows should then be compared to the average monthly flows in the corresponding stations and they should be adjusted by leaving the natural flows for the months in which these are lower than the estimated minimum flow, in order to allow for the maintenance of the natural regime to which the biological communities are adapted (Garcia de Jalón, 2003).

2 Impact on energy production due to climate change

2.1 Introduction

Over the past 150 years, mean temperature has increased by almost 0.8 ºC globally and by about 1.0 ºC in Europe. Eleven of the last twelve years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850).

The temperature increase is widespread over the globe and is greater at higher northern latitudes. At continental, regional and ocean basin scales, numerous long term changes in other aspects of climate have also been observed. For example, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia whereas precipitation declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia (IPCC 2007).

In line with this global climate trend, climate in Europe has been changing. During the 21st century, temperature in Europe is projected to rise by 2.0 to 6.3°C. Temperature and other changes in the climate system are likely to induce profound changes in the functioning and services of European's natural and human systems.

The impacts of climate change are already being observed and are projected to become more pronounced. Extreme weather events, including heat waves, droughts and floods, are expected to become more frequent and intense. In Europe the largest temperature increases are in southern Europe and the Arctic region. Precipitation decreases in southern Europe and increases in the north/north-west. This leads to impacts on natural ecosystems, human health and water resources (EEA 2009).

Water is essential to life and is an indispensable resource for nearly all human activity. It is intricately linked with climate through a large number of connections and feedback cycles, so that any alteration in the climate system will induce changes in the hydrological cycle. According to the European Environment Agency (EEA), for the coming decades, global warming is projected to further intensify the hydrological cycle. Climate change is projected to lead to major changes in yearly and seasonal water availability across Europe (EEA 2008b).

In this scenario of climate change, the present document reviews different publications in order to assess the effects of possible future temperature and precipitation variability as well as changes on water resource availability on hydro-power production in Portugal.

2.2 Climate scenarios

The IPCC, in its Special Report on Emissions Scenarios (SRES), describes four climate scenarios that are generally used to make future predictions. These scenarios are based on four storylines considering a range of plausible changes in population and economic activity over the 21st century. These storylines are summarized in **Table 9**:

- Storylines A1 and B1: assume a world economy dominated by global trade and alliances; global population is expected to increase from today's 6.6 billion and peak at 8.7 billion in 2050.
- Storylines A2 and B2: scenarios with less globalisation and more co-operation; global population is expected to increase until 2100, reaching 10.4 billion (B2) and 15 billion (A2) by the end of the century.

In general, all SRES scenarios depict a society that is richer than today, with world gross domestic product (GDP) rising to 10 - 26 times today's levels by 2100. A narrowing of income differences between world regions is assumed in all SRES scenarios – with technology representing a driving force as important as demographic change and economic development.

Table 9: Summary of the four storylines (source: Bates et al. 2008)

Economic emphasis

Global integration	**A1 storyline**	**A2 storyline**	Regional emphasis
	World: market-oriented Economy: fastest per capita growth Population: 2050 peak, then decline Governance: strong regional interactions; income convergence Technology: three scenario groups: • **A1FI**: fossil-intensive • **A1T**: non-fossil energy sources • **A1B**: balanced across all sources	World: differentiated Economy: regionally oriented; lowest per capita growth Population: continuously increasing Governance: self-reliance with preservation of local identities Technology: slowest and most fragmented development	
	B1 storyline	**B2 storyline**	
	World: convergent Economy: service and information-based; lower growth than A1 Population: same as A1 Governance: global solutions to economic, social and environmental sustainability Technology: clean and resource-efficient	World: local solutions Economy: intermediate growth Population: continuously increasing at lower rate than A2 Governance: local and regional solutions to environmental protection and social equity Technology: more rapid than A2; less rapid, more diverse than A1/B1	

Environmental emphasis

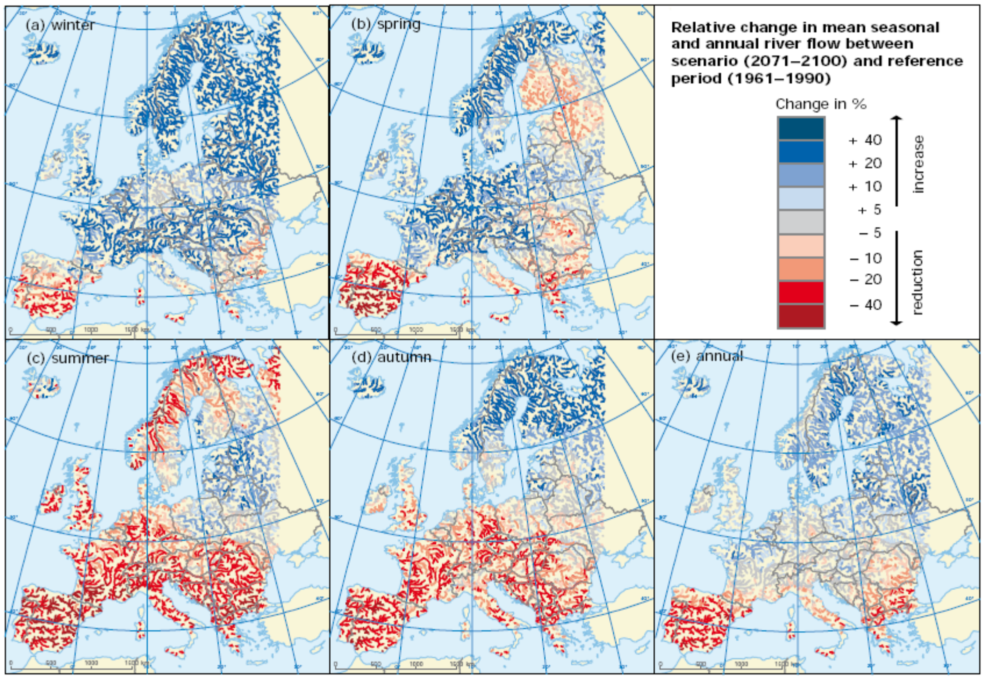
2.3 Projections for Southern Europe

Several studies indicate that in South-Eastern Europe, annual rainfall and river discharge have already begun to decrease in the past few decades. On the last IPCC report on Climate Change and Water (2008), for all scenarios, mean annual precipitation is projected to increase in northern Europe and to decrease further south. However, the change in precipitation varies substantially from season to season and across regions. Summer precipitation would decrease substantially (in some areas up to 70 % in the SRES A2 scenario) in southern and central Europe, and to a smaller degree up to central Scandinavia. Moreover, a substantial and widespread decrease of precipitation (up to 30 – 45 %) over the Mediterranean Basin as well as over western and central Europe is predicted. Other studies on climate change suggest that there could be a decrease in precipitation of more than 25 % in parts of the Iberian Peninsula (EEA 2005).

These and other effects of climate change will have a range of impacts on water resources. For example, annual runoff increases are projected in Atlantic and Northern Europe, and decreases in Central, Mediterranean and Eastern Europe. According to the A2 and B2 scenarios, annual average runoff is projected to increase in Northern Europe by approximately 5 – 15 % up to the 2020s and by 9 – 22 % up to the 2070s. Meanwhile, in Southern Europe, runoff is projected to decrease by 0 – 23 % up to the 2020s and by 6 – 36 % up to the 2070s (for the same set of assumptions) (**Illustration 2**).

Another effect of a warmer climate on water resources is an increase in evapotrans-piration, which would produce a decrease in water supply (Bates et al. 2008).

Illustration 2: Projected change in mean seasonal and annual river flow between 2071 - 2100 and the reference period 1961-1990 (Source EEA 2008a)



Climate change may also modify the timing and magnitude of both floods and droughts. In relation to the first, the EEA has estimated that the occurrence of greatest flood risk could move from spring to winter and be enhanced by the expansion of impermeable surfaces due to urbanization (EEA 2005). Concerning droughts, Southern Europe, which already suffer most form water stress, will be particularly exposed to reductions in water resources and will see an increase in the frequency and intensity of droughts.

2.4 Projections for Portugal

In Portugal, the "**Scenarios, Impacts and Adaptation Measures - SIAM project**", represents one of the more important initiatives concerning climate change at a national scale. The project, supported by public and private founds, focused on a core set of socioeconomic and biophysical impacts, and was based upon scenarios of future climate change produced by climate models.

The SIAM project analysed and tested 6 climate models, and concluded that the Hadley Centre models HadCM3 and HadRM2 provided the most accurate results. They were therefore selected to estimate future climate changes integrating the SRES A2C and B2A[6] scenarios for the HadCM3 model and a unique scenario for HadRM2.

Nevertheless, the presentation of the results of this study is somewhat confusing. Different publications based on this study (e.g. Santos et al 2002, Veiga da Cunha, 2002, 2004, Cleto 2008) provide different, and sometimes contradictory, results. Also, the main report prepared from the SIAM projects provides some unclear conclusions. This is shown in some of the results presented below.

[6] A2C – priority for economic interests. B2A – increase of community values and environmental concern.

2.4.1 Temperature and precipitation

The SIAM project results indicate an *increase of mean annual temperature of about 2.5ºC by 2050, and between 3.9ºC and 5.9ºC by 2100*. As regards the *precipitation*, results showed, in general, a *decrease up to 10 % in the northern region, which could go as far as 30 % in the southern region***.** Nevertheless, some results indicate an increase in precipitation for some regions.

Table 10, **Table 11**, **Table 12** and **Illustration 3** present different results from SIAM project for changes predicted in average annual temperature and precipitation.

Table 10: Changes in average temperature and precipitation (from the reference period 1960-1994) predicted by six climate models tested in the SIAM project; the HadCM3 and HadRM2 models provided the most accurate results. (Source: Veiga da Cunha, 2002)

Tabela 2 - Alterações dos valores médios anuais de T e P relativos a 1960-1994

	Temperatura (ºC)		Precipitação (%)	
Região Norte	**2050**	**2100**	**2050**	**2100**
HadCM2	+ 2,3	+ 3,9	- 4,2	- 5,3
HadCM3	+ 2,5	+ 3,9	- 5,7	- 9,4
HadRM2		+ 5,8		- 6,6
ECHAM4	+ 2,5	+ 3,7	- 19,7	- 21,7
CGCM1	+ 2,6	+ 4,7	- 10,2	- 16,6
PROMES	+ 3,2		+ 11,8	
Região Centro				
HadCM2	+ 2,6	+ 4,4	- 1,4	- 1,0
HadCM3	+ 2,9	+ 4,3	- 8,4	- 13,7
HadRM2		+ 5,9		- 8,2
ECHAM4	+ 3,1	+ 4,7	- 23,6	- 31,4
CGCM1	+ 3,1	+ 5,5	- 19,9	- 35,6
PROMES	+ 3,3		+ 7,4	
Região Sul				
HadCM2	+ 2,7	+ 4,4	- 3,4	- 0,7
HadCM3	+ 2,7	+ 4,0	- 16,8	- 25,8
HadRM2		+ 5,9		- 12,2
ECHAM4	+ 2,7	+ 3,9	- 29,1	- 26,9
CGCM1	+ 2,5	+ 4,6	- 23,2	- 33,9
PROMES	+ 3,3		+ 12,1	

Table 11: Source: Santos et al. 2002 (chapter 5: Water Resources)

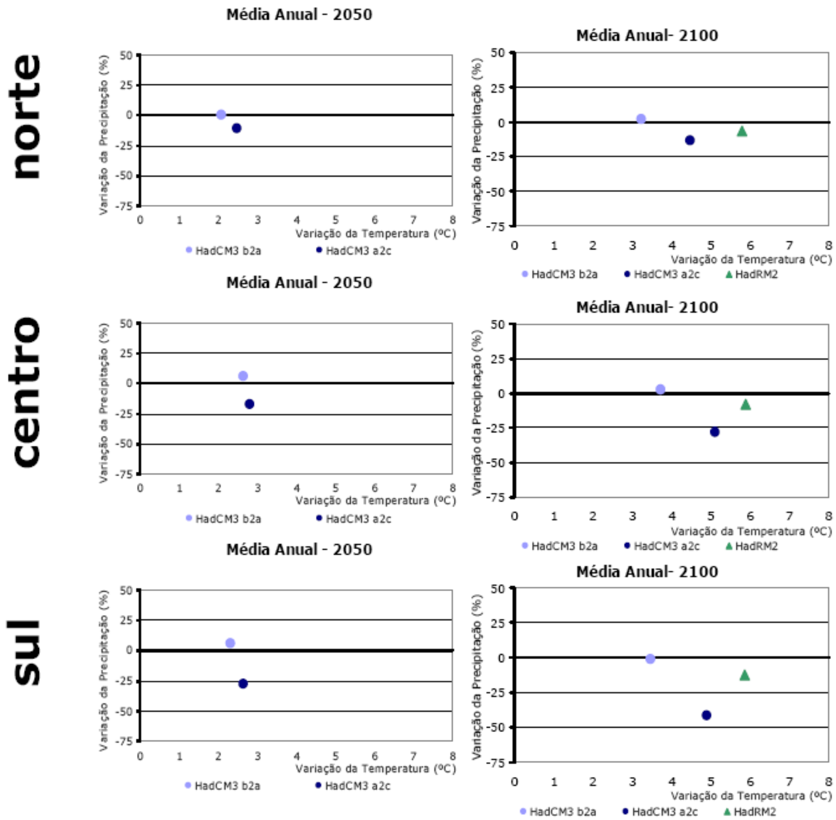
Table 5.11 – Annual average precipitation and temperature changes from 1960-1994 predicted by HadCM3 and HadRM2

Scenario	North		Centre		South	
	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.
HadCM3 2050	- 6%	+ 2.5°C	- 8%	+ 2.9°C	- 17%	+ 2.7°C
HadCM3 2100	- 9%	+ 3.9°C	- 14%	+ 4.3°C	- 26%	+ 4.0°C
HadRM2 2100	+ 7%	+ 5.8°C	- 2%	+ 5.9°C	- 11%	+ 5.9°C

Table 12: Source: Veiga da Cunha et al. 2004

Modelo / Ano	Norte		Centro		Sul	
	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.
HadCM3 B2a 2050	0%	+2.1ºC	+6%	+2.7ºC	+6%	+2.3ºC
HadCM3 A2c 2050	11%	+2.5ºC	-18%	+2.8ºC	-28%	+2.6ºC
HadCM3 B2a 2100	+1.6%	+3.2ºC	+2%	+3.7ºC	-1%	+3.5ºC
HadCM3 A2c 2100	-13.6%	+4.5ºC	-28%	+5.1ºC	-42%	+4.9ºC
HadRM2 2100	-7%	+5.8ºC	-8%	+5.9ºC	-12%	+5.9ºC

Illustration 3: Average annual temperature (x) and precipitation (y) variation in Portugal by 2050 and 2100 per region and season (as predicted by HadCM3B2a, HadCM3A2c and HadRM2 - models:scenarios)



At a seasonal scale, the temperature increase would be higher in summer (+3º-5ºC by 2050) than in winter (+ 2ºC). By 2100, predictions suggest an increase in temperature of 5º to 7ºC in summer (Veiga da Cunha et al. 2002).

SIAM-project models predict a strong change in the seasonal distribution of precipitation. By 2050, an *increase in winter precipitation up to 10 % in the northern region* is expected, *along with a general decrease for the remaining seasons that could reach 20 % to 30 % in summer and autumn* (results were not consistent for the south).

Veiga da Cunha et al. (2002) agree with this conclusion about seasonal variability in precipitation. They also suggest that trends for precipitation are not so definitive. For winter, conclusions about the magnitude and direction of variability could not be made, but all the models analysed indicate a reduced average monthly precipitation for summer and autumn that could go up to 50 %.

By 2100, spring precipitation is expected to decrease between 0 and 20 % in the north, and between 10 % and 50 % in the south. In summer, a reduction of precipitation between 30 % and 50 % is expected for all regions. Finally, autumn precipitation may decrease between 0 % and 25 % in the north, and between 0 % and 50 % in the south.

Illustration 4: Temperature (X) and precipitation (Y) variation (% in Portugal by 2050 per region and season (as predicted by HadCM3B2a, HadCM3A2c models/scenarios)

Regions: Norte: North, Centro: Central, Sul: South

Seasons: Inverno: Winter, Primavera: Spring, Verão: Summer, Autono: Autumn.

Source: Veiga da Cunha et al. 2004

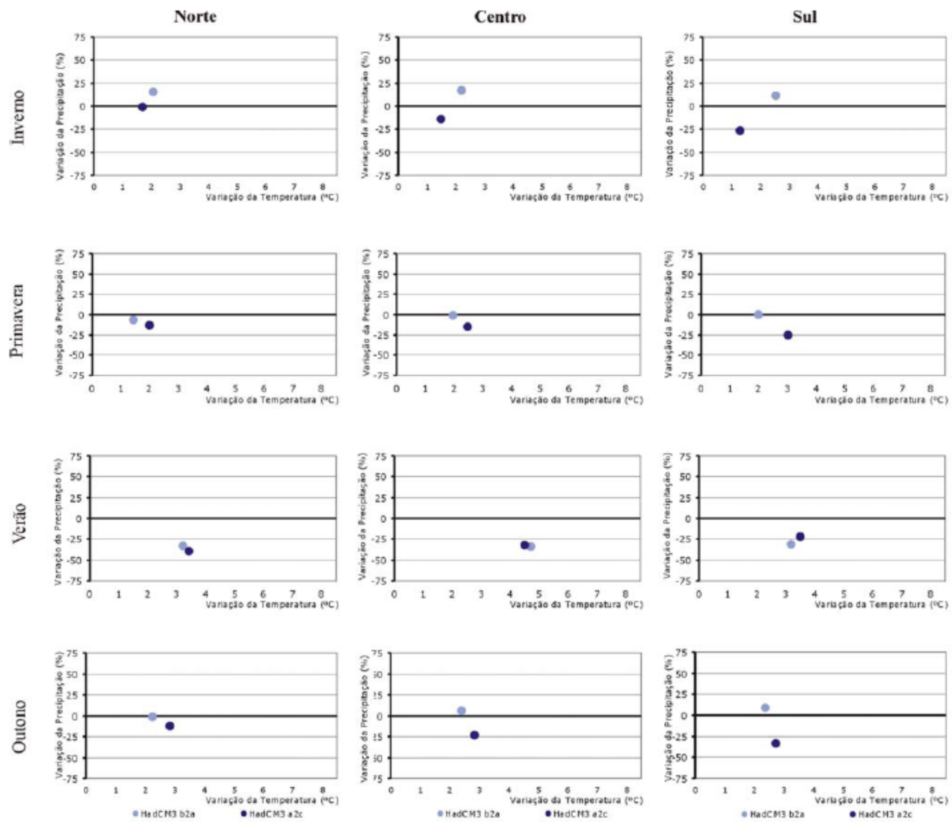
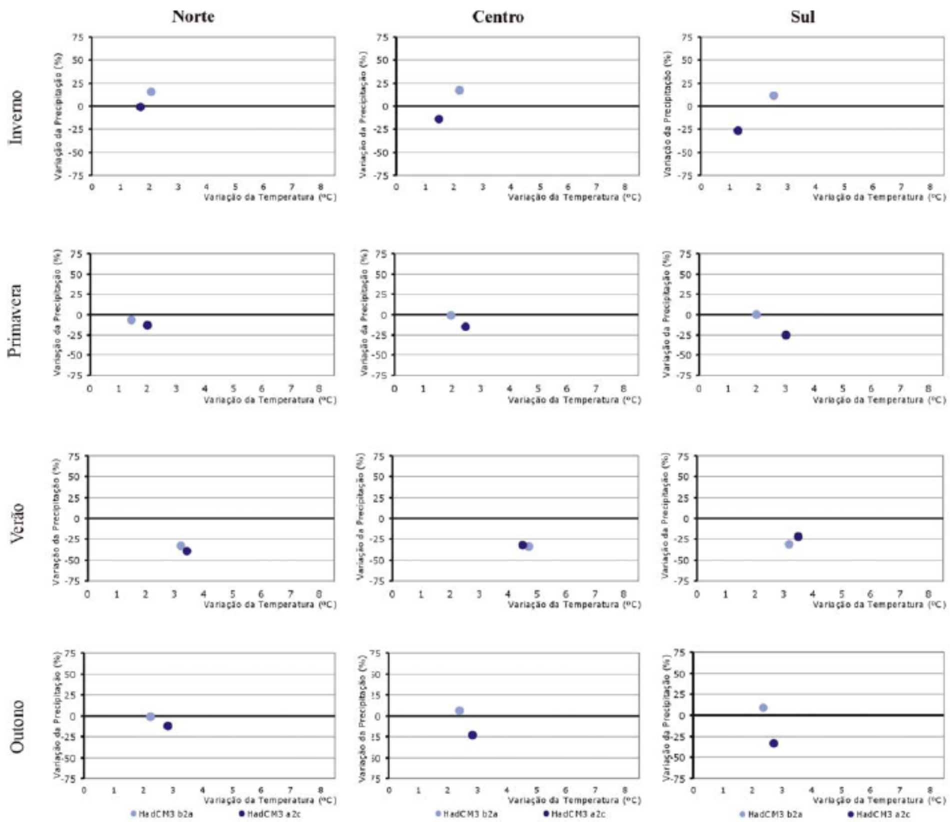


Illustration 5: Temperature (X) and precipitation (Y) variation in Portugal by 2100 per region and season (as predicted by HadCM3B2a, HadCM3A2c and HadRM2 models/scenarios

Regions: Norte: North, Centro: Central, Sul: South

Seasons: Inverno: Winter, Primavera: Spring, Verão: Summer, Autono: Autumn

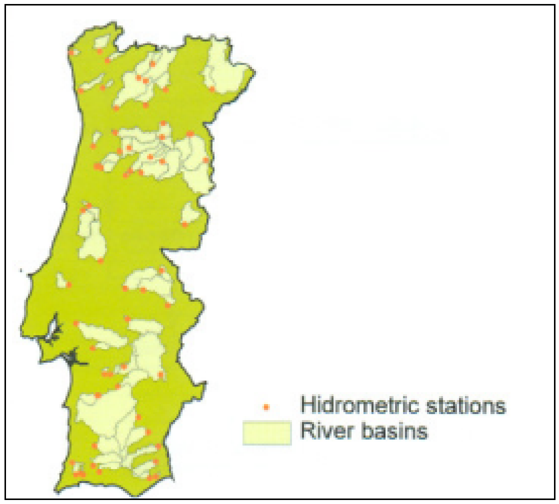
Source: Veiga da Cunha et al. 2004



2.4.2 Water resources

With reduced precipitation and potential increased warming-induced evapotranspiration, water availability is likely to decrease.

Illustration 6: Hydrometric stations considered in the SIAM study



'Within the SIAM project, the climate change impacts on water availability were evaluated by comparing the results of a hydrological model (the Temez model), which was run under different climatic scenarios.

In total, river runoffs in 2050 and 2100 for 62 river basins in Portugal (**Illustration 6**) were simulated under the two climate models. Both models (HadCM3 and HadRM2) predict an increase in the runoff spatial and seasonal asymmetry (SIAM 2002). **Table 13** and **Table 14** summarize the main results of this project per major river basin and season by 2050 and 2100 respectively.

Table 13: Summary of predicted changes on average seasonal and annual runoff per large River basin regions and season by 2050

River Basin	*Scenario*	*Average runoff change (%) by 2050*				
		Winter	*Spring*	*Summer*	*Autumn*	*ANNUAL*
North and Douro	HadCM3 2050	*	−15 -20	−20 -40	−0 -20	−10
Vouga and Mondego	HadCM3 2050	*	*	*	−30 -60	−15 -20
Tejo	HadCM3 2050	*	*	*	−30 -60	−15 -20
Sado, Mira, Guadiana	HadCM3 2050	−0 -40	−30 -60	*	*	−20 -50
Algarve	HadCM3 2050	−0 -40	−30 -60	*	*	−20 -50

* No value given in the document

Source: Elaborated summarizing results from SIAM report (Santos et al. 2002)

As indicated in **Table 13**, by 2050 the model *HadCM3 predicts a reduction in the average annual runoff going from -10 % for northern river basins to -50 % for southern river basins.* This runoff reduction is more pronounced in autumn for northern (North and Douro) and central (Vouga-Mondego, Tejo) river basins, while for the southern river basins (Sado-Mira-Guadiana, Algarve) the reduction would be more accentuated in spring.

In contrast with precedent predictions for 2050, estimates of water runoff changes by 2100 in the SIAM project are not as clear. Indeed, despite indicating similar general trends, SIAM results by 2100 from the two climate models used are contradictory. Both models predict a decrease in runoff for spring, summer and autumn. But for winter, HadCM3 predicts a runoff decrease whereas HadRM2 predicts an increase. Veiga da Cunha et al. (2002) have attributed these contradictory results to the differences in the resolution of the models applied. They argue that the regional model (HadRM2), which has a higher resolution, presents higher results variability when they are aggregated in large hydrological units.

The increase in winter runoff predicted by HadRM2 model is related to a predicted increase in winter precipitation, which seems to be more significant when applying the HadRM2 scenario on the Tejo, Sado, Mira and Guadiana river basins (**Table 14**). At this point, it can be highlighted that these values do not agree with overall projections made by the IPCC and the EEA for the Iberian region.

Table 14: Summary of predicted changes on average seasonal and annual runoff per large River basin regions and season by 2100

River Basin	Scenario	Average runoff change (%)				
		Winter	Spring	Summer	Autumn	ANNUAL
North and Douro	HadCM3 2100	−0 -20	−15 -30	> −20 -40	−20 -50	Up to −20
	HadRM2 2100	+25 -50	uncertain estimates	−10 - 60	− 50 -80	+20
Vouga and Mondego	HadCM3 2100	−0 -20	−20 -80		−40 -80	− 15 -30
	HadRM2 2100	+10 -40	uncertain estimates	−10 -90		uncertain estimates
Tejo	HadCM3 2100	−0 -20	−20 -80		−40 -80	−15 -30
	HadRM2 2100	+40 -100	uncertain estimates		−80 -100	+ trend
Sado, Mira, Guadiana	HadCM3 2100	−20 -60	−40 -80	*	−50 -90	−40 -75
	HadRM2 2100	+40 -100	uncertain estimates	uncertain estimates	−80 -100	+ trend
Algarve	HadCM3 2100	−20 -60	−40 -80	*	−50 -90	−40 -75
	HadRM2 2100	+60 -130	uncertain estimates	uncertain estimates	−80 -100	+10 -75

* No value given in the document

Source: Elaborated summarizing results from SIAM report (Santos et al. 2002)

Illustration 7: Presentation of results from SIAM project. Changes in water runoff predicted for 2050 and 2100 using two models: HadCM3 (2050 & 2100) and HadRM2 (2100)

Source: Veiga da Cunha et al. 2002

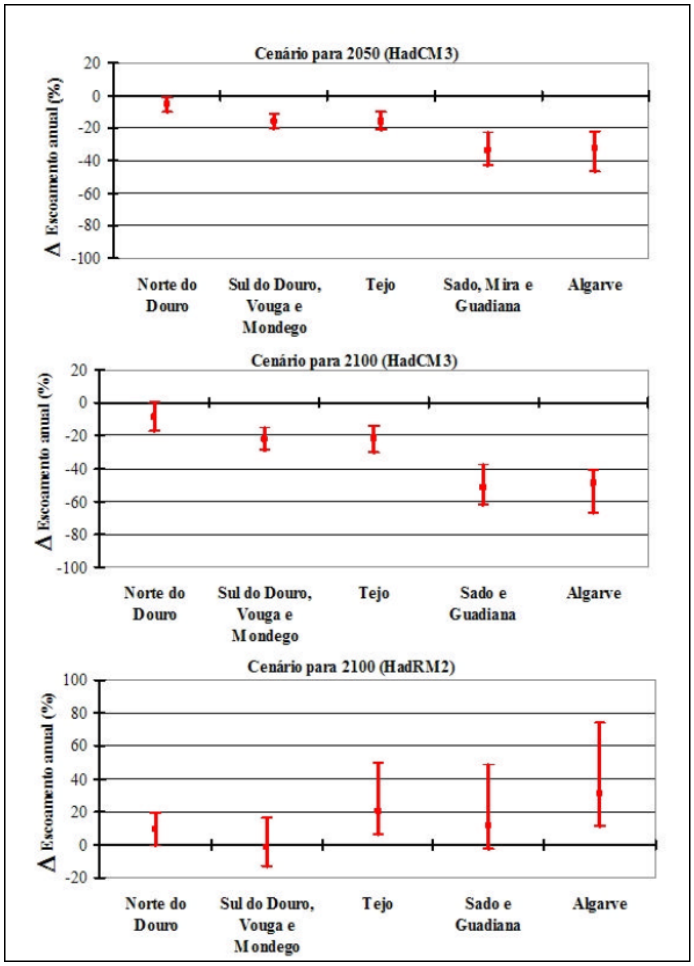
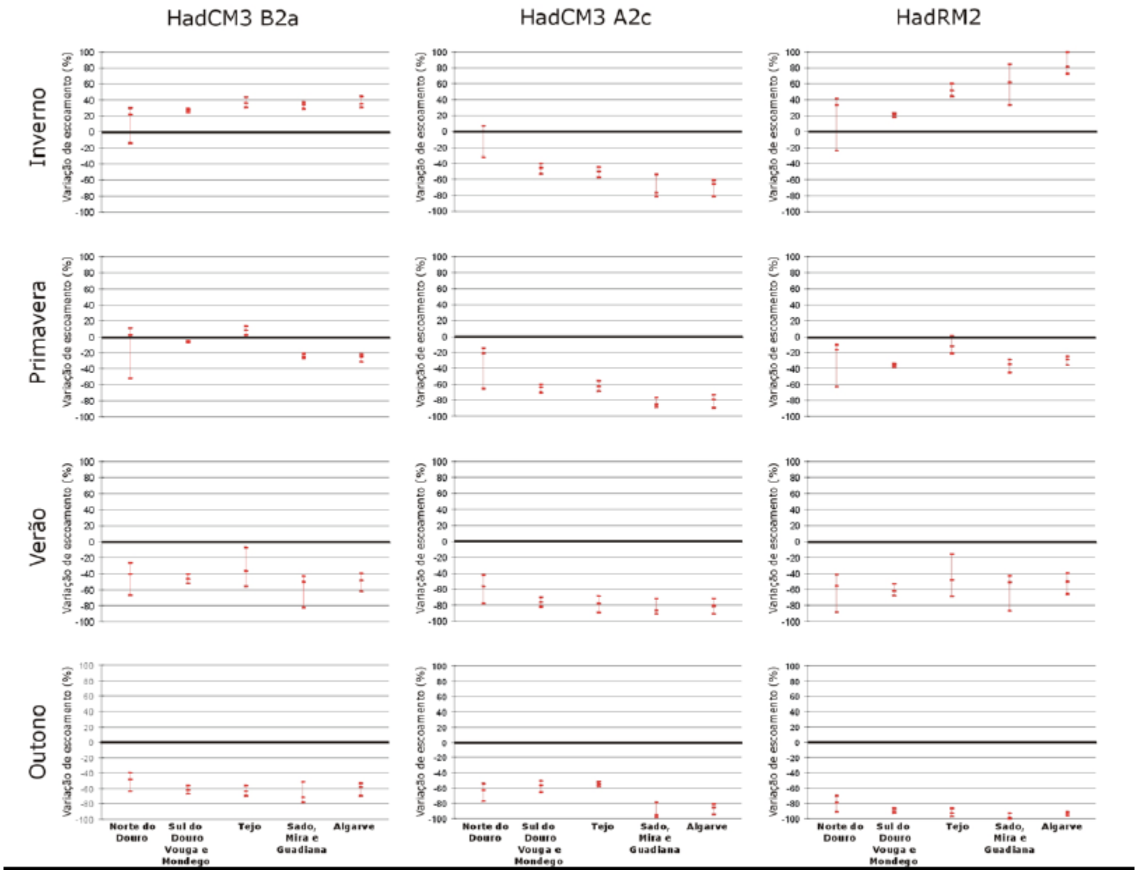


Illustration 8: Presentation of results from SIAM project. Changes in water runoff (%) predicted for 2100 (Veiga da Cunha et al. 2004)



More recently, another study (Cleto, 2008) has reviewed data from the SIAM project to analyse energy production in Portugal. In this study, water runoff was also estimated using the Temez model and results were disaggregated in four regions and four seasons. **Table 15** shows the estimated water runoff variability (%) by 2050 per region and season using to the HadCM3 climate model in this study.

Table 15: Water runoff variability (%) in 2050 per region and season (Cleto, 2008)

	Region / Season	Water runoff variability in 2050 (%) N	SD	T	G	Weighted Average Water Runoff Variability
Scenario B2	Winter	20	25	27	27	22
	Spring	-8	0	17	10	-3
	Summer	-33	-40	-30	-33	-33
	Fall	-25	-7	-3	55	-16
Scenario A2	Winter	-3	-25	-28	-52	-11
	Spring	-20	-26	-26	-68	-24
	Summer	-50	-50	-50	-68	-51
	Fall	-33	-28	-27	-22	-31
Installed Capacity		2961 MW	458 MW	484 MW	240 MW	

(ND – North of Douro, D – Douro, SD – South of Douro, T – Tejo, G – Guadiana). Adapted from SIAM (Santos et al, 2002 and 2006)

According to **Table 15**, a general runoff reduction would be expected by 2050 when applying the A2 scenario, which agrees with results of the SIAM project for the HadCM3 model. The decreasing trend of water runoff would go from -3 % in winter for the North of Douro region up to -68 % in spring and summer for the Guadiana region.

In line with this study, Kilsby et al. (2007) predicted major reductions in future flows, caused by both the increase in PET (potential evapotranspiration) and a year-round decrease in rainfall. Their results, showing year-round decreases in rainfall and stream flow are in opposition to studies suggesting that increases in winter rainfall may compensate for decreased summer rainfall.

2.5 Projections for Spanish water resources

Portugal shares five river basins with Spain (**Illustration 9**). Since the effects of climate change on Spanish temperature and precipitation are prone to have an impact on Portugal's hydrological resources, these should be also analysed to complete this review.

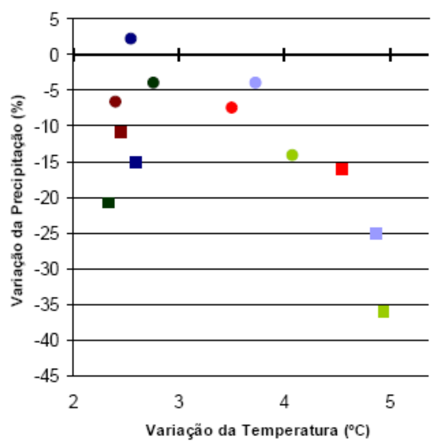
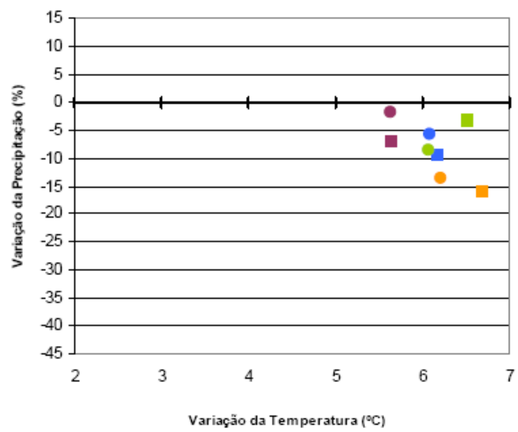
Illustration 9: National and transboundary Portuguese River basins

Source: Santos et al. 2002

The SIAM project has simulated changes in temperature and precipitation due to climate change for these shared river basins. A comparison of both climate models is given in **Illustration 10**. In general, under the two scenarios a global increasing temperature and decreasing precipitation is estimated for shared river basins, both for 2050 and 2100, except for Centre Spain by 2050 (HadCM3 B2a) which show an increase in precipitation.

Illustration 10: Temperature (s) and precipitation (y) variation (%) in shared River basins between Spain and Portugal, as predicted by hadCM3A2C and HadCM3 B2a model/scenarios

Source: Veiga da Cunha et al 2004

HadCM3	HadRM2
	

The Spanish Ministry of Environment has published a national scale study on climate change impacts. In relation to water resources, and *considering a climate scenario of average annual temperature increase by 1.0ºC and a precipitation decrease by 5 %*, the projections indicate a *decrease of average river runoff between 5 and 14 % by 2030. By 2060, this reduction of average river runoff may reach 17 % in the Peninsula*, with an increasing average annual temperature of 2.5 ºC and decreasing rainfall of 8 % (Iglesias et al. 2005).

According to another study, and following the same projections of a temperature increase of 2.5 ºC by 2060, the impact of climate change on the different river basins will be stronger on those *of the southern half of Spain*, where some may account a runoff *reduction of up to 34 % by 2060* (Ayala-Carcedo 2002).

Moreover, this study predicts decreasing annual precipitation between 2 % and 17 % for northern and southern river basin respectively, and an increased variability of interannual precipitation, which agrees with IPCC and EEA overall projections for the region.

In summary, it should be expected that a decreased runoff in the Spanish part of the international river basins could cause a reduction of water resources in Portugal.

It may be interesting to include here some consideration about hydrological series when applied to water resources planning. Two recent studies carried out in Spain on this subject have estimated that the influence of new factors altering hydrological patterns are better reflected on more recent hydrological series. So, these studies suggest that the *last 25 years are sufficiently representative to analyse water resources* while series that cover older periods may overestimate these resources (Aguilar & Del Moral 2008; Sánchez & Martínez 2008).

2.6 Impacts of water resource reduction on hydropower production in Portugal

In the perspective of this technical assessment, information about impacts of water resource reduction on hydropower production has also been compiled and briefly described hereinafter.

In general, studies predict climate change to impact hydropower production in Southern Europe on two key areas:

1. decreases in energy production from water resources due to declining resources; and
2. changes in energy consumption.

Besides, climate change may also alter the seasonal cycle in energy demand, with lower demand in winter and higher in summer, by for example increasing operations in desalination, pumping of ground water or air conditioning demand in summer in case of southern countries.

Indeed, some changes have already been observed in southern European countries, mainly Portugal and Spain, where annual energy production of some existing hydropower stations has decreased since 1970's (EEA 2008a). According to several studies (EEA 2005 and 2008a, Lehner et al. 2005, etc.) in this European region *the hydropower sector should expect a reduction of energy production of about 25 % or more by 2070*, while *IPCC predictions for the Mediterranean envisage a decline of hydropower potential*[7] *of 20 - 50%.*

In Portugal, the developed hydropower potential is dominated by reservoirs on transboundary river basins (shared with Spain). Taking into account reduced inflows from Spain, Lehner et al. (2005) have estimated a *reduction of about 18 % in gross hydropower potential in Portugal by 2070.*

In opposition to these results, the SIAM project report (2006) has suggested –although not being conclusive- that impact of climate change on hydropower production would not be significant, despite predicted reductions on precipitation and river runoff. It argues that most hydropower plants are located on northern river basins, where precipitation reduction would be less accentuated.

A study on climate change and Portuguese energy system based on the SIAM-project, has evaluated impacts in an integrated manner contributing to overcome some gaps of the SIAM project. The study used a model (TIMES_PT) which considers the Portuguese energy system from 2000 to 2050, where all the projected hydropower installations of the PNBEPH were incorporated for hydropower modelling. Using the same data as the SIAM project (HadCM3 climate model and A2 and B2 scenarios), the results of this study

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[7] Hydropower potential: theoretical possibility for electricity generation from water resources.

suggest that current Portuguese policy objectives on hydropower are overestimated in what regards the projects being implemented and the planned dams from PNBEPH since *installed capacity is estimated to experience a reduction of 15 % by 2050* (Cleto 2008a, Cleto et al. 2008b).

Also in opposition to SIAM results, this study concludes that climate change has a very important impact on the energy sector, especially in relation to hydropower production (lower water availability seriously compromises electricity production from this source) and on demand, since increases in temperature may lead to an overall reduction of demand for energy (Cleto 2008a).

Finally, it is clear that in order to fully evaluate the impacts of climate change on the water resources, it is necessary to estimate not only the impacts on the water availability but also the impacts on water demand by considering the effects on the various water uses, such as for example water for urban supply or industries. This is a complex task which depends not only on climate modifications but also on social and economic factors. For example, since 75 % of all water needs in Portugal are associated with the agriculture sector, an increase of water demand for irrigation should be expected, due to warmer temperatures, which is likely to negatively affect the hydropower production.

2.7 Conclusions

In general, most of the studies suggest an increase in average annual temperature for Portugal of about 2.5 ºC by 2050 and between 3.9 and 5.9 ºC by 2100. These warmer temperatures would be accompanied by a more or less accentuated decrease of global precipitation by 2050 leading to a decrease in water availability for all human uses, including hydropower production. Moreover, temperature and precipitation would experience a seasonal variability with warmer temperatures in summer (up to +5ºC according to some projections) and reduced monthly precipitation in summer and autumn (by up to 50 % according to some projections).

In relation to average water resource reduction, there seems to be some uncertainties at a national scale but in general a negative trend should be expected by 2050, with decreasing runoff between 10 and 50 % (depending on the region). Estimations beyond that date period seem to be less conclusive and studies present some contradictory results for water runoff variability by 2100 under different scenarios and depending on the models used. However, all models predict a decrease in water availability for spring, summer and autumn.

Some studies have also predicted a reduction of about 15 % and 18 % in hydropower potential in Portugal by 2050 and 2070 respectively, owing mainly to reduction in water resources availability (Lehnet at al. 2005, Cleto et al. 2008b).

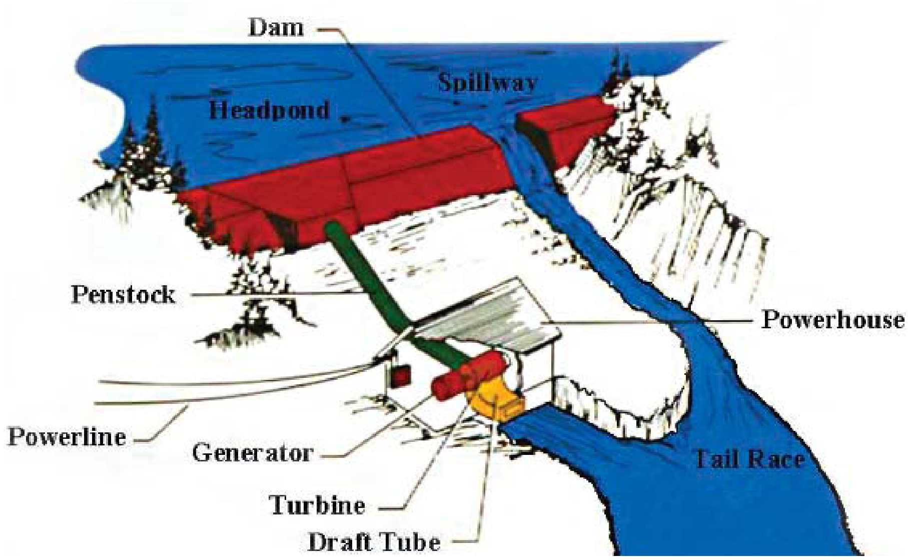
It has also been suggested by some studies that, when planning on water resources in the Iberian Peninsula, recent hydrological series of last 25 years should be taken into account to assess water resource availability, considering recent changes already observed.

3 Task 1a: What is the estimated effect on predicted energy production of considering minimum flows to maintain good ecological status below dams?

3.1 Introduction

The general principal of a hydropower installation is given in **Illustration 11**.

Illustration 11: Components of a hydropower installation



Following main items can be distinguished:

- an intake which includes trashracks, a gate and an entrance to a canal, penstock or directly to the turbine depending on the type of development;
- a canal, tunnel and/or penstock, which carries the water to the powerhouse in developments where the powerhouse is located at a distance downstream from the intake;
- the entrance and exit of the turbine, which include the valves and gates necessary to shut off flow to the turbine for shutdown and maintenance;
- a tailrace, which carries the water from the turbine exit back to the river.

The primary electrical and mechanical components of a hydro plant are the turbine(s) and generator(s).

3.2 Calculation of the energy production

Power output depends on the available water (flow) and the head (drop in elevation). The amount of energy that can be generated depends on the quantity of water available and the variability of flow throughout the year.

In the PNBEPH report the energy production is calculated using the SAPE method (Simulação de Aproveitamentos para Produção de Energia*).* As this program is not available for us, a simplified tool is developed. Taking into account the components of the model a calculation sheet is made to determine the energy production. An example of such a sheet is given in **Annex 3**.

The information regarding the different hydroelectrically installations is given in annex 3 of the PNBEPH 'Memória'.

Following data are used:

- the monthly inflow (in 10^3 m^3) during a period of 50 years (1941-91);
- one dataset characterising the mean monthly evaporation;
- the characteristics of the reservoir (height, area and volume). These are used to determine the reservoir relationships, expressed by 3 parameters representing the height (a), area (b) and volume (c).
- the head characteristics (NPAmax, NPAmin, netto head (queda util nominal));
- the energy production (GWh/year).

The energy production is calculated

- with an electrical efficiency factor of 90 %;
- a minimum flow of 3 % (based on the information of INAG, May 2009). It was stated that the detailled determination of the minimum flow an element is of the EIA;
- with the maximum net head (in reality the net head will be function of the height of the water table in the reservoir).

Table 16: Calculated energy production

	Energy production (GWh/year)		*Difference (%)*
	PNBEPH	*Calculated*	
Foz Tua (Douro)	340	335	2
Padroselos (Douro)	102	98	4
Alto Tamega (Douro)	114	111	
Daivões (Douro)	148	144	
Fridão (Douro)	299	290	
Gouvães (Douro)	153	147	4
Pinhosão (Vougo-Mondego)	106	104	2
Girabolhos (Vougo-Mondego)	99	100	1
Almoural (Tejo)	209	193	7
Alvito (Tejo)	62	60	
	1632	1582	3

In **Table 16** the energy production, calculated with the developed tool, is given and compared with the energy production found in the PNBEPH report. The total energy production of 6 hydropower installations was calculated, and a difference of 3% was found between the actual energy production and the one calculated with the developed tool. This deviation of 3% was used to calculate the energy production of the 4 other plants (data marked in green).

3.3 Reduction in energy production due to the need to maintain minimum flows

In section 1.5.2 is concluded that, taking into account the available data, the Tennant method, adapted for Portugal, is the easiest method to use in a planning stage. This method allows reserving enough water resource to maintain a minimum flow. The percentages, as given in **Table 6**, to determine the minimum flow differ from season to season and are much higher than those used in the PNBEPH report. There are also quality classes defined. To assess the impact of a higher minimum flow on the energy production, the above mentioned tool is used to calculate energy production for 2 different types of minimum flow:

- the flow with *quality fair or degrading* (see **Table 6**);
- the flow with *quality good* (see **Table 6**).

In the months where the calculated minimum flow is higher than the mean month flow, the latter one is taken for the calculation of the energy production. This was necessary for the studied cases in the months July, August and September for the flow quality good and in August for the flow quality fair.

As can be seen in **Table 17** the reduction in energy production amounts to about 20 % in the case of quality fair and about 35 % when maintaining quality good (compared to the energy production given in the PNBEPH report). When evaluating the impact of the river basins, one could conclude that for the Douro and Tejo basin the reduction in energy production is slightly higher than for the Vouga and Mondego basins.

As the energy reduction is comparable for the studied cases, the average reduction percentages for the Douro and Tejo basins are used (**Table 24**) to calculate the energy production for the other plants and this for the 2 type of flow qualities considered (green figures).

Table 17: Reduction in energy production due to the minimum flow requirements

	Energy production (GWh/year)	*Energy production (GWh/year) and % reduction in energy production taking into account minimum flow*			
	PNBEPH	*Fair*		*Good*	
Foz Tua (Douro)	340	278	18 %	221	35 %
Padroselos (Douro)	102	81	20 %	65	36 %
Alto Tamega (Douro)	114	91		73	
Daivões (Douro)	148	118		94	
Fridão (Douro)	299	238		191	
Gouvães (Douro)	153	121	20 %	96	37 %
Pinhosão (Vougo-Mondego)	106	86	19 %	69	35 %
Girabolhos (Vougo-Mondego)	99	83	16 %	68	31 %

	Energy production (GWh/year)	Energy production (GWh/year) and % reduction in energy production taking into account minimum flow			
	PNBEPH	Fair		Good	
Almoural (Tejo)	209	162	22 %	133	36 %
Alvito (Tejo)	62	49		40	
	1632	1306		1049	

It should be noted that, as the minimum flow is defined as a percentage of the average annual flow, the minimum flow will decrease in the future as the inflows will decrease due to climate change.

3.4 Conclusions

In the PNBEPH plan, it is unclear how the minimum flow is taken into account. Additional information (received in May 2009) mentioned a discharge (minimum) flow of 3 % of the average annual flow. The energy production for the different hydropower installations is therefore calculated with a minimum flow of 3 %. To maintain good ecological status below the dams, the impact of higher minimum flows on the energy production needs to be assessed.

Based on a literature review, the Tennant Method adapted to Portugal was chosen to calculate minimum flows. This method provides a good estimate of the resources needed to maintain a minimum flow, while taking into account intra-annual variability of water resources. However, for the months where the actual flow was lower than the minimum flows, data on the actual flow were used.

To determine the impact of the minimum flow a tool was developed to calculate the energy production. The energy production was calculated with an electrical efficiency factor of 90 %, assuming a maximum net head and with a minimum flow of 3 %. A deviation of 3% was found between the energy production calculated with this tool and the energy production according to the PNBEPH report.

The energy production would be reduced by about 20% in case of a minimum flow representing the quality fair and 35 % for the flow quality good.

It can be concluded that the energy production given in the PNBEPH is overestimated when a good ecological status below the dams must be realized. A detailed study to determine the minimum flow, as also stated in the PNBEPH, must still be performed, e.g. during the EIA.

The Tennant Method adapted to Portugal is easy to use in a planning stage and for policy purposes. It is recommend to define appropriate minimum flows on a case by case basis, taking into account the local information which is available to evaluate the different impacts.

4 Task 1b: What is the estimated effect in predicted energy production of considering the future reductions of resource availability due to climate change

4.1 Future scenarios

4.1.1 Introduction

The PNBEPH uses data series on resource availability from the hydrological years 41/42 to 90/91.

As more recent data are available, a first scenario uses the data series on run off related to the most recent 25 years time frame. For some installations this is the period 80/81 to 05/06 and for others 81/82 to 06/07. This scenario allows to asses the impact on the energy production of the different hydropower installations when taking into account more recent data than those used in the PBBEPH plan.

The second scenario takes into account future changes predicted due to climate changes. Here the year 2050 is used as time horizon. It is assumed that in 2050 the runoff is decreased to 80 % of the runoff characteristic for the most recent 25 year data series.

As INAG has clarified, the monthly runoff mentioned in the annexes 1 to 10 of the PNBEPH report were obtained from the corresponding River Basin Management Plans (RBMP), and were based on data from the stations available in the SNIRH. These data can be consulted on the Internet site of INAG at:

http://snirh.pt/snirh.php?main_id=2&item=1&objlink=&objrede=HIDRO

However, it was not possible to retrieve the data and to determine the relationships between hydrological data at the hydrometric stations and those at the site of the hydropower installation for all the studied hydropower installations. In addition, the additional information received in May 2009 was not easy to interpret and not very clear.

A distinct relationship was found between the run off at the site of the hydropower installation and the run off at nearby hydrometric stations for the following installations:

- Girabolhos;
- Pinhosão;
- Almourol.

For the other hydropower stations, the relation is defined between the average run off at the nearest hydrometric station over the period 1941-1991, being the period used in the PNBEPH report, and the available average runoff data characteristic for the most recent period of 25 years. This relation is used to determine the runoff data at the sites of the different hydropower installations.

4.1.2 Scenario 1: Actual runoff scenario

To make an analysis of the evolution of the flows since 1991 and to determine the influence of using a more recent period as a basis for calculations on resource availability, average runoff data characteristic for a recent time frame representing 25 years have been evaluated. The literature review with respect to not only the minimum flow (section 1.2) but also the climate change (section 2.7) showed that this period is the most suitable to make predictions.

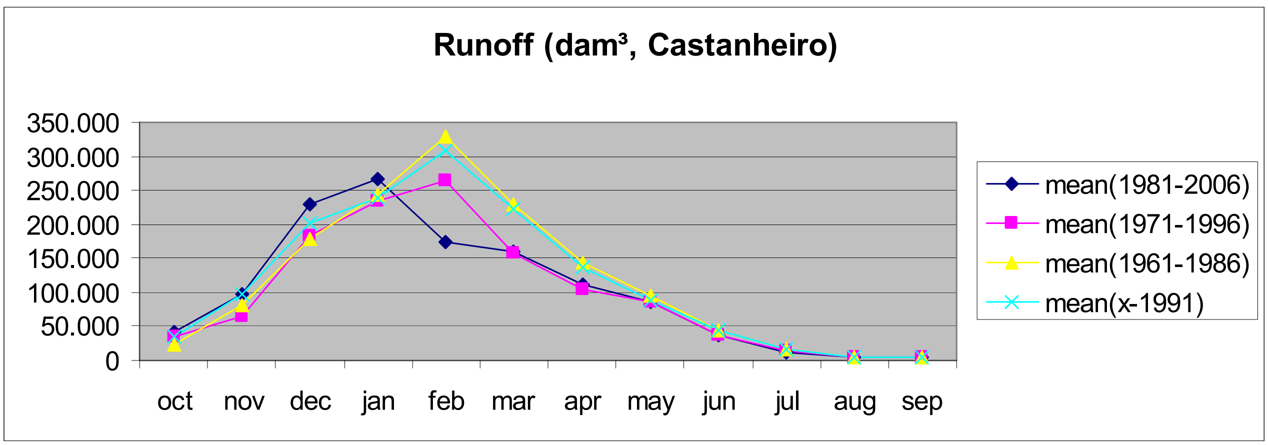
This evolution in run off will be studied using the runoff data which are available on the website of SNIRH for the hydrometric stations identified in **Annex 4**. The selection of the hydrometric stations is function of the amount of data that is available.

For the hydropower installations Alto Tamega, Fridão and Alvito not enough data and/or no recent data were available to assess the evolution in runoff.

4.1.2.1 Foz Tua (Douro)

For the hydropower installation of Foz Tua the data of the hydrometric station Castanheiro (06M/01H), situated upstream of the future hydropower installation, are used. Monthly runoff data (with some exceptions) are available for the period October 1958 until September 2006.

Graph 1: Evolution in runoff data at Castanheiro (06M/01H)



As can be observed in **Graph 1**, the runoff is slightly increases from October to January and then decreases from January to May.

It was not possible to identify a clear relationship between the runoff data at Castanheiro and those at Foz Tua. Therefore the runoff data at Foz Tua are determined by the relation between the runoff data at Castanheiro in the period 1981-2006 and the runoff data in the period 1941-1991. This relationship is expressed as a percentage and is given in **Table 18**, together with the runoff data as used in the PNBEPH report and characteristic for the hydrological years 1941-1991, the runoff data for the period 1981-2006 and those defined for the year 2050 (section 4.1.3, being 80% of the average runoff data from 1981-2006).

Table 18: Extrapolation of the runoff data (Foz Tua)

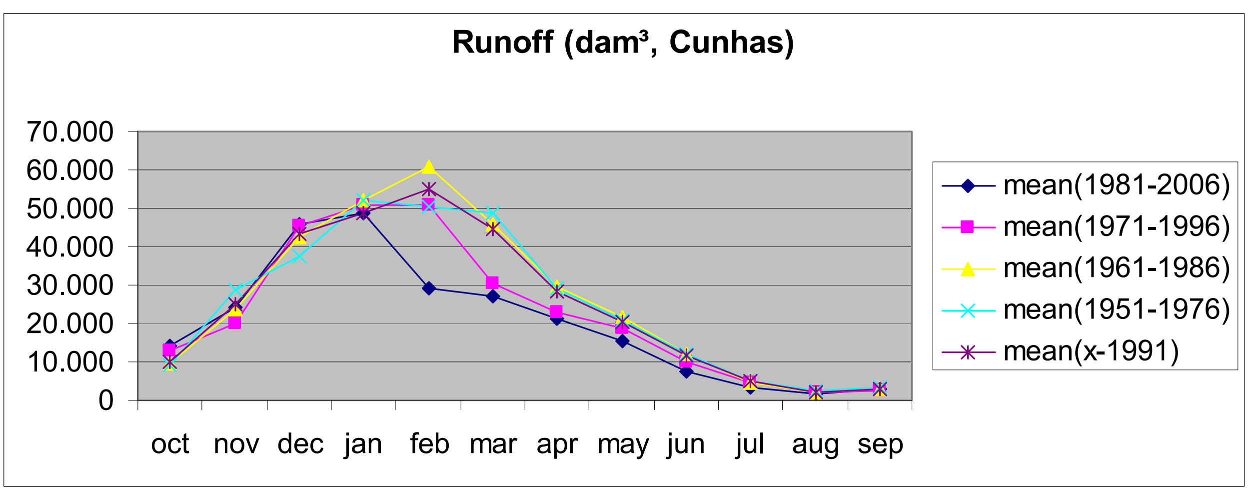
		Average runoff (m³)		
	runoff (81-06/41-91)	PNBEPH (1941-1991)	extrapol (1981-2006)	extrapol (2050)
Oct	122%	53.404.000	65.105.656	52.084.525
Nov	100%	103.670.000	103.585.724	82.868.579
Dec	114%	175.927.000	199.853.033	159.882.427
Jan	112%	205.348.000	229.380.571	183.504.456
Feb	57%	226.615.000	128.606.180	102.884.944
Mar	72%	176.877.000	127.311.782	101.849.426
Apr	82%	112.592.000	92.546.350	74.037.080
May	98%	76.483.000	75.176.436	60.141.149
Jun	84%	40.233.000	33.894.329	27.115.463
Jul	74%	16.559.000	12.291.297	9.833.038
Aug	76%	6.566.000	4.984.922	3.987.937
Sep	88%	13.115.000	11.519.937	9.215.950

The average yearly runoff for the most recent data set is 90% of the average yearly runoff of the dataset used in the PNBEPH.

4.1.2.2 Padroselos (Douro)

For the hydropower installation of Padroselos the data of the hydrometric station Cunhas (04J/04H), situated about 6 km downstream of the future hydropower installation, are used. Monthly runoff data (with some exceptions) are available for the period October 1949 until September 2006.

Graph 2: Evolution in runoff data at Cunhas (04J/04H)



As can be observed in **Graph 2**, the average runoff over the different periods is more or less the same in the months August to January. From January on to July the runoff in the period 1981-2006 is decreased compared to the other time frames considered.

The runoff data at Padroselos are determined by the relation between the runoff data at Cunhas in the period 1981-2006 and the runoff data in the period 1941-1991. This relationship is expressed as a percentage and is given in **Table 19**, together with the runoff data as used in the PNBEPH report and characteristic for the hydrological years 1941-1991, the runoff data for the period 1981-2006 and those defined for the year 2050.

Table 19: Extrapolation of the runoff data (Padroselos)

		Average runoff (m³)		
	runoff (81-06/41-91)	PNBEPH (1941-1991)	extrapol (1981-2006)	extrapol (2050)
Oct	139%	7.979.000	11.122.845	8.898.276
Nov	96%	17.271.000	16.523.527	13.218.821
Dec	106%	30.884.000	32.648.358	26.118.686
Jan	100%	34.563.000	34.576.544	27.661.235
Feb	53%	35.892.000	19.197.607	15.358.086
Mar	61%	29.493.000	18.099.435	14.479.548
Apr	75%	18.847.000	14.093.620	11.274.896
May	75%	13.651.000	10.301.252	8.241.002
Jun	66%	7.204.000	4.788.712	3.830.970
Jul	68%	3.205.000	2.192.363	1.753.891
Aug	83%	1.468.000	1.211.687	969.350
Sep	98%	2.033.000	2.001.471	1.601.177

For the hydrometric station Cunhas the average yearly runoff for the most recent data set is 82 % of the average yearly runoff of the dataset used in the PNBEPH.

4.1.2.3 Alto Tamega (Douro)

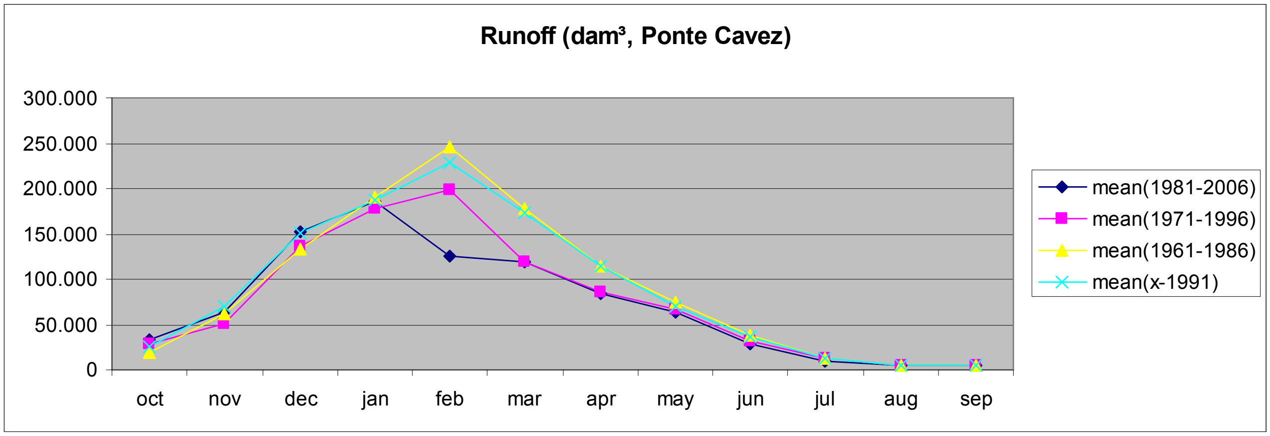
For the hydropower installation of Alto Tamega the data of the hydrometric station Parada Monteiros (04K/01H), situated downstream of the future hydropower installation, could be used. As only monthly runoff data (with some exceptions) are available for the period October 1983 until September 1991 these will give no added value to assess the evolution of the runoff.

4.1.2.4 Daivões (Douro)

For the hydropower installation of Daivões the data of the hydrometric station Ponte Cavez (04J/05H), situated downstream of the future hydropower installation, are used.

Monthly runoff data (with some exceptions) are available for the period October 1957 until September 2006.

Graph 3: Evolution in runoff data at Ponte Cavez (04J/05H)



As can be observed in **Graph 1**, the average runoff over the different periods is more or less the same in the months June to January. From January on to July the runoff in the period 1981-2006 is decreased compared to the other time frames considered. This was already the case for the average runoff in the period 1971-1996 (with exemption of February).

A reduction in runoff of 81 % is observed.

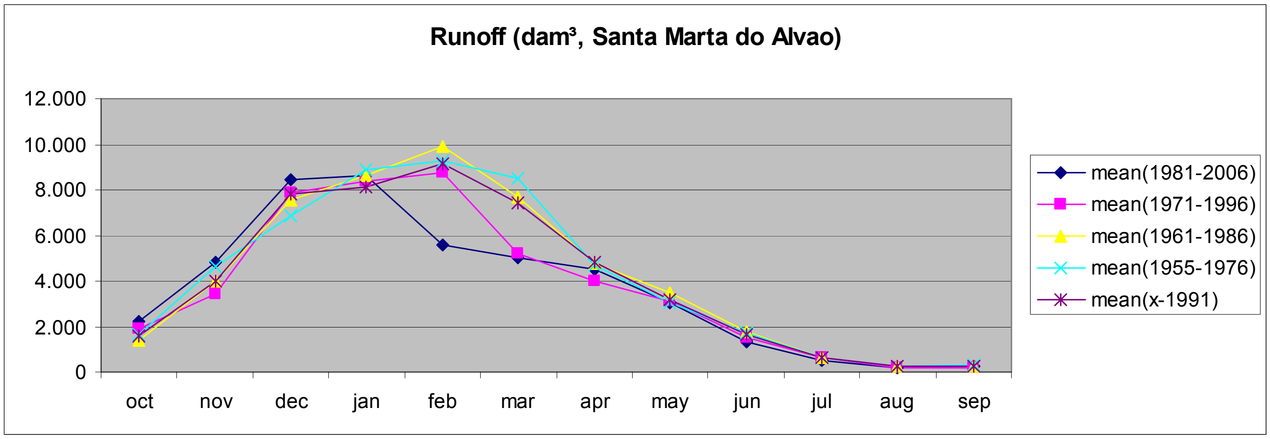
4.1.2.5 Fridão (Douro)

For the hydropower installation of Fridão the data of the hydrometric station Fridão (06I/03H), situated close to the future hydropower installation, could be used. As only monthly runoff data (with some exceptions) are available for the period October 1985 until September 2006 these will give too less added value to assess the evolution of the runoff.

4.1.2.6 Gouvães (Douro)

For the hydropower installation of Gouvães the data of the hydrometric station Santa Marta Do Alvao (05K/01H), situated about 2 km downstream of the planned hydropower installation, are used. Monthly runoff data (with some exceptions) are available for the period October 1955 until September 2006.

Graph 4: Evolution in runoff data at Santa Marta Do Alvao (05K/01H)



As can be observed in **Graph 4**, the average runoff over the different periods is more or less the same in the months May to September, slightly higher in the months October to December and lower in the period January to April.

The runoff data at Gouvães are determined by the relationship between the runoff data at Santa Marta Do Alvao in the period 1981-2006 and the runoff data in the period 1941-1991. This relationship is expressed as a percentage and is given in **Table 20**, together with the runoff data as used in the PNBEPH report and characteristic for the hydrological years 1941-1991, the runoff data for the period 1981-2006 and those defined for the year 2050.

Table 20: Extrapolation of the runoff data (Gouvães)

		Average runoff (m³)		
	runoff (81-06/41-91)	PNBEPH (1941-1991)	extrapol (1981-2006)	extrapol (2050)
Oct	139%	4.260.000	5.907.615	4.726.092
Nov	121%	8.874.000	10.757.993	8.606.394
Dec	108%	15.569.000	16.774.577	13.419.662
Jan	107%	17.050.000	18.185.546	14.548.437
Feb	61%	17.761.000	10.897.407	8.717.925
Mar	68%	14.688.000	9.926.155	7.940.924
Apr	93%	9.101.000	8.463.025	6.770.420
May	96%	6.989.000	6.713.034	5.370.427
Jun	82%	3.584.000	2.953.621	2.362.897
Jul	78%	1.660.000	1.296.631	1.037.305
Aug	79%	806.000	640.280	512.224
Sep	93%	1.026.000	953.806	763.045

The average yearly runoff in the recent data series is 92 % of those characteristic for the period 1941-91.

4.1.2.7 Pinhosão

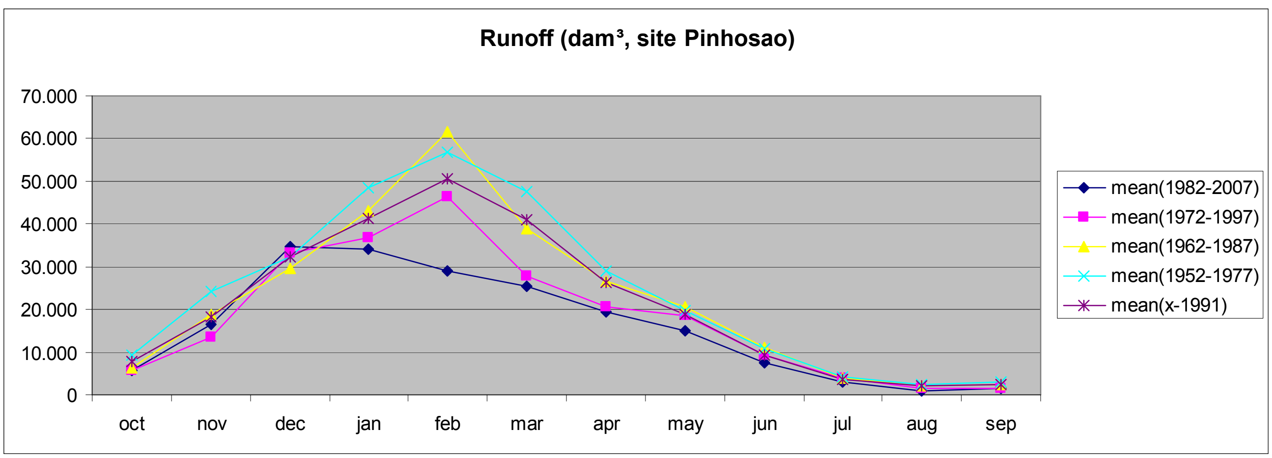
For the Pinhosão hydropower installation the water runoff is estimated using the data of the hydrometric stations Ponte Vouzela (09I/02H). Apparently, the Ponte Águeda station (10G/02H) was also used to complete some missing data at the Ponte Vouzela station. A constant relationship is identified between the runoff data of the hydrometric station Ponte Vouzela and the used water runoff data at the project site.

This relationship is constant throughout the year with a factor of 1.62.

This factor is used to estimate the runoff data at the site of the hydropower installation using the available recent data series. In the dataset some data are missing for the most recent years.

In **Annex 6** the runoff data with respect to the hydrometric station Ponte Vouzela are given, together with the runoff data used in the PNBEPH report for the period 1941/91 and these calculated for the period 1991/2008. In the calculations the data of the last hydrological year are not used.

Graph 5: Evolution in runoff data at Pinhosão



As can be seen in **Graph 5** the average runoff over the period January to May is decreased over the last years.

The calculated runoff data defined for the site of Pinhosão are given in **Table 21**.

Table 21: Calculation of the runoff data (Pinhosão)

	Average runoff (m³)		
	PNBEPH (1941-1991)	Eval. (1981-2006)	extrapol (2050)
Oct	7.699.000	5.713.692	4.570.954
Nov	18.343.000	16.584.063	13.267.250
Dec	32.112.000	34.818.191	27.854.553

	Average runoff (m³)		
	PNBEPH (1941-1991)	Eval. (1981-2006)	extrapol (2050)
Jan	40.699.000	33.993.367	27.194.694
Feb	50.035.000	28.935.038	23.148.030
Mar	41.779.000	25.354.627	20.283.701
Apr	27.141.000	19.500.276	15.600.221
May	20.035.000	14.875.935	11.900.748
Jun	10.312.000	7.438.109	5.950.487
Jul	3.872.000	2.974.252	2.379.402
Aug	2.093.000	1.010.567	808.453
Sep	2.454.000	1.424.284	1.139.427

The average yearly runoff for the most recent data set is 75 % of the average yearly runoff of the dataset used in the PNBEPH.

4.1.2.8 Girabolhos

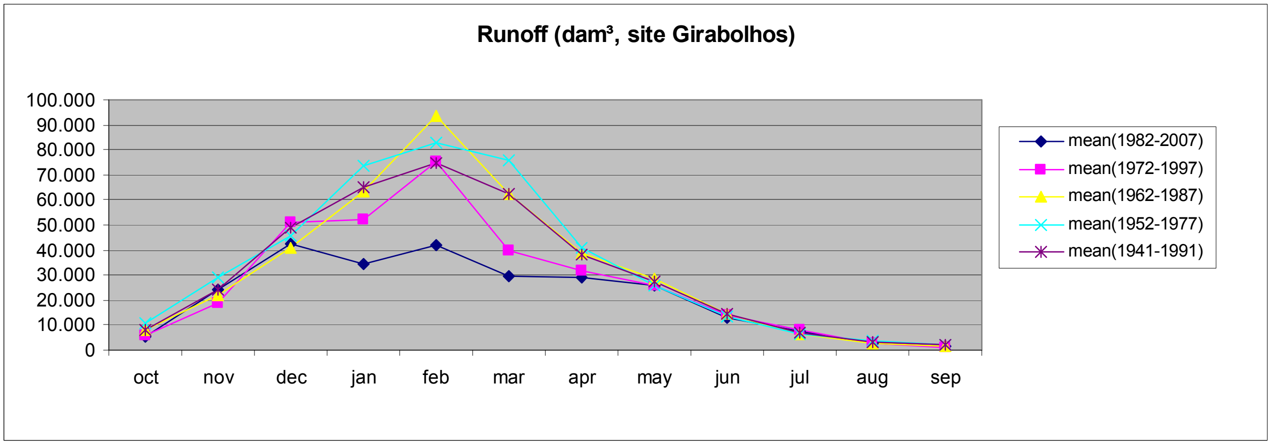
For the Girabolhos hydropower installation the water runoff is estimated using the data of the hydrometric stations Ponte Juncais (10L/01) and Nelas (10K/03). The runoff data of the hydrometric station Ponte Juncais and the used water runoff data at the project site are accurately described by a constant factor, different for each month:

Oct	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*
0,66	0,78	0,83	0,79	0,67	0,67	0,71	0,66	0,59	0,38	0,23	0,28

Using the above factors, the water runoff at the location of the hydropower plant is estimated using the available recent data series of the hydrometric station of Ponte Juncias. In the recent years the datasets are incomplete which will influence the reliability of the results.

The average runoff data have been determined for a number of successive time frames, each representing 25 years. A visual representation is given in **Graph 6**. From December to May the average runoff has been decreasing over the years. This decline is especially noticed for last 25 year period.

Graph 6: Evolution in runoff data at Girabolhos



The calculated runoff data defined for the site of Girabolhos are given in **Table 22**.

Table 22: Calculation of the runoff data (Girabolhos)

	Average runoff (m³)		
	PNBEPH (1941-1991)	Eval. (1981-2006)	extrapol (2050)
Oct	7.781.000	5.298.446	4.238.757
Nov	23.598.000	24.175.605	19.340.484
Dec	48.211.000	42.429.262	33.943.409
Jan	63.943.000	34.169.402	27.335.522
Feb	73.585.000	41.750.644	33.400.515
Mar	62.674.000	29.614.515	23.691.612
Apr	38.400.000	29.108.436	23.286.749
May	27.658.000	25.561.978	20.449.582
Jun	14.379.000	12.950.300	10.360.240
Jul	6.936.000	7.731.351	6.185.081
Aug	3.129.000	2.708.901	2.167.121
Sep	1.945.000	1.502.158	1.201.726

At Girobolhos the highest reduction in runoff, 69 %, is observed when comparing the two sets of data series.

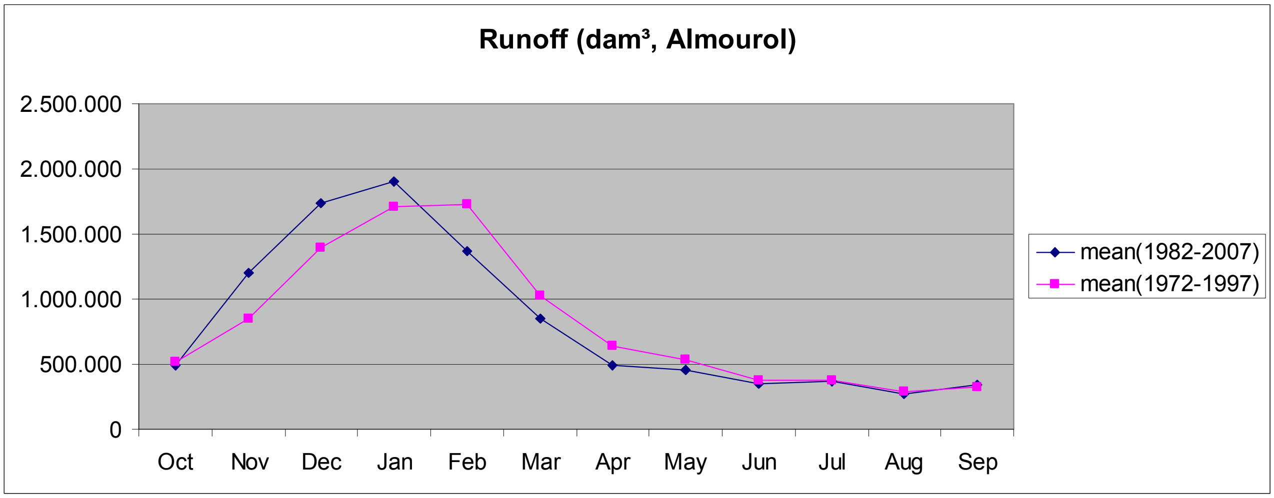
4.1.2.9 Almourol

For the Almourol hydropower installation the water runoff is estimated using the data of the hydrometric station Almourol (17G/02H). This station is situated about 0.7 km upstream the dam. A constant relationship is identified between the runoff data of this hydrometric station and the water runoff data at the project site. Data series older than 1972 are not available for this site.

This relationship is constant throughout the year with a factor 1.

This factor is used to estimate the runoff data at the site of the hydropower installation using the available recent data series. In the dataset some data are missing for the most recent years.

Graph 7: Evolution in runoff data at Almourol



As can be seen in **Graph 7** the average runoff over the period October to January is increased and from February to May decreased over the last years.

The calculated runoff data defined for the site of Almourol are given in **Table 23**.

Table 23: Calculation of the runoff data (Almourol)

	Average runoff (m³)		
	PNBEPH (1973-1991)	Eval. (1982-2007)	extrapol (2050)
Oct	525.575.000	492.239.955	393.791.964
Nov	960.254.000	1.199.256.636	959.405.309
Dec	1.532.720.000	1.735.410.783	1.388.328.626
Jan	1.899.984.000	1.906.507.435	1.525.205.948
Feb	1.743.491.000	1.369.367.913	1.095.494.330
Mar	1.100.622.000	853.629.040	682.903.232
Apr	625.011.000	492.320.800	393.856.640
May	521.875.000	458.528.292	366.822.633
Jun	386.789.000	350.548.667	280.438.933
Jul	368.567.000	364.626.348	291.701.078

	Average runoff (m³)		
	PNBEPH (1973-1991)	Eval. (1982-2007)	extrapol (2050)
Aug	292.501.000	274.087.750	219.270.200
Sep	347.087.000	346.446.522	277.157.217

Here one can conclude that the magnitude of the average yearly flow is not changed over the years.

4.1.2.10 Alvito

For the hydropower installation of Alvito the data of the hydrometric stations Foz Do Cobrao (15K02H) and Almourao (15K/0AH) could be used.

Due to the limited availability of data it gives no added value to assess the evolution of the runoff.

4.1.3 Scenario 2: Climate change scenario

To study the Impact of the climate change scenarios on energy production, concerning the "PNBEPH area" and considering the information given in section 2, it seems reasonable to foresee a likely reduction in hydropower production as a consequence of climate change effect on water resources.

To estimate the impact on energy production in 2050 the maximum predicted change in runoff, on an annual basis, as mentioned in **Table 13**, is used on the average flow data calculated for the period 1982/2007. The evaporation data were kept constant but it should be noted that also these data will change (i.e. increase) in the future.

There is chosen to work with a worst case scenario, therefore the average runoff used for the year 2050 is set equal to -20 % the average runoff data used for the most recent period.

As can be seen in **Table 13**, the change in average runoff is -10 % in stead of 20 % by 2050 for the Douro basin. The impact of this smaller reduction in runoff for the hydropower installations in the Douro is also assessed in section 4.2.

4.2 Energy production

To determine the energy production, the same method is used as described in section 3.2. The following hypotheses have been made:

- the minimum flow varies as a function of the average yearly runoff for the time frame considered;
- the evaporation is taken identical to those mentioned in annex 3 of the PNBEPH report and was not allowed to vary with the changes in runoff (thus precipitation) in each time frame; due to timing constraints the data series concerning the evaporation were not consulted.

The energy production is calculated for the following scenarios:

- actual runoff scenario: using the runoff data calculated for the most recent period (1981/2006 and 1982/2007);
- climate change scenario: using the runoff data which takes into account the impact of future climate change (for the year 2050).

For each of these scenarios 3 different situations are studied:

- minimum flow of 3 % (extra information from INAG);
- minimum flow representing a flow quality fair or degrading;
- minimum flow representing a flow quality good.

The model is used to calculate the energy production for the above mentioned scenarios with respect to 6 hydropower installations. For the 4 others, 3 in the Douro river basin and 1 in the Tejo river basin, (due to a lack of data) the average percentage of the concerned river basins Douro and Tejo is used to define the energy production (figures in green).

The results are given in **Table 25**. The energy production expressed as a percentage of the energy production in the PNBEPH report is given in **Annex 8**. **Table 24** is a detail of this annex and gives the energy production as an average percentage for the installations belonging to the same river basin. For the Douro the data with respect to 3 installations were studied, for the Vouga and Mondego, 2 hydropower installations, one for each river. For the Tejo there were only enough data available for the hydropower installation Almourol.

The results for the hydropower installations in the Vougo and Mondego basins are significantly different as the reduction in energy production seems to be higher than for the other river basins (**Table 24**).

Table 24: Possible differences in energy production in function of location (river basin)

	1941-1991			1991(82)-2006(07)			2050		
	Minimum flow								
	3 %	fair	good	3 %	fair	good	3 %	fair	good
Douro	97 %	80 %	64 %	86 %	71 %	56 %	68 %	56 %	45 %
Vougo-Mondego	98%	81 %	65 %	70 %	58 %	46 %	56 %	48 %	37 %
Tejo	93 %	78 %	64 %	87 %	73 %	60 %	69 %	58 %	48 %
3 river basins	97 %	80 %	65 %	81 %	67 %	54 %	65 %	57 %	46 %

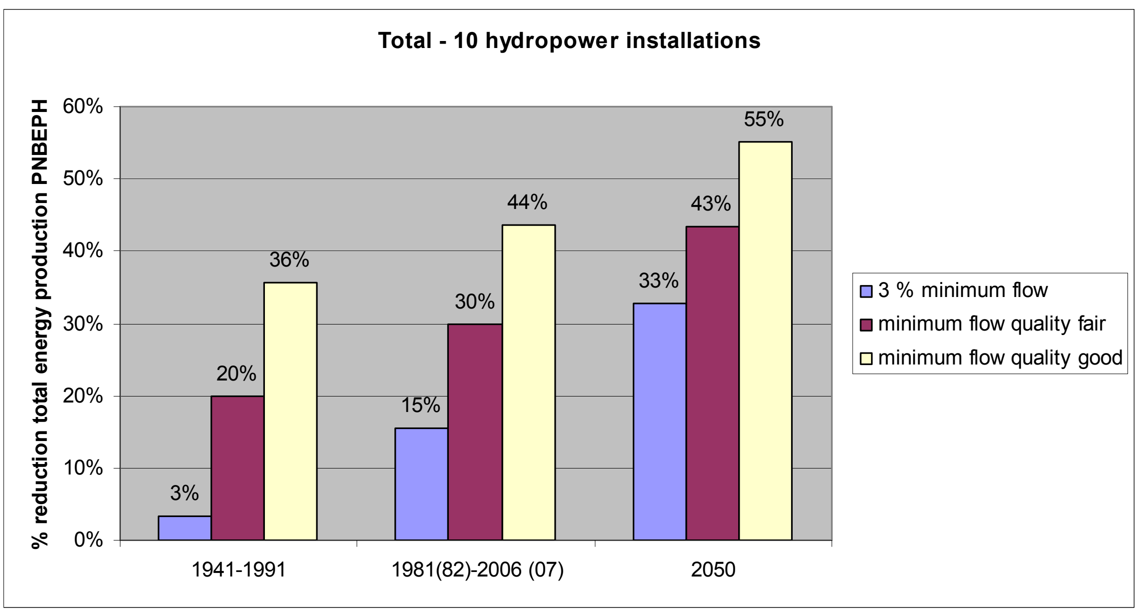
The results of the calculation of the energy production are visualized in the following graphs: **Graph 10**, **Graph 11** and **Graph 12**. The energy production in GWh/year, as given in the PNBEPH, is mentioned between brackets with the name of the hydropower installation.

In **Graph 8** the global energy reduction for the 10 hydropower installations, as a percentage compared to the total energy production in the PNBEPH report; is visualized for the different studied scenarios and situations regarding minimum flow.

The graph shows a relevant reduction in energy production when using the recent data sets. It can be concluded that the figures as mentioned in the PNBEPH are no longer up to date taking into account the decreases in runoff observed during the recent years. To verify this it is advisable to evaluate this possible reduction in energy production for a number of existing hydropower installations.

By 2050 the expected reduction in energy production is of the same magnitude as the reduction already expected today. The reduction in energy production will fall back to ± 30 % (minimum flow of 3 %) to 55 % (flow quality good) of the forecasted or designed total energy production mentioned in the PNBEPH report. These conclusions are in line with the results from some studies presented In section 2.6. In one study a reduction in energy production of about 20 to 50 % in the Mediterranean area is foreseen. Another study on climate change and Portuguese energy system based on the SIAM-project, suggests that current Portuguese policy objectives on hydropower are overestimated, since installed capacity is estimated to experience a reduction of 15 % by 2050 (Cleto 2008a, Cleto et al. 2008b). This is not in line with the results of this study.

Graph 8: % Energy reduction for the 10 hydropower installations



To assess the difference in impact on the energy production, the change in runoff by the year 2050 is also evaluated when assuming that in the Douro basin the runoff diminishes with 10 % instead of 20 %. This reduction is visualized in **Graph 9**.

As 6 of the evaluated hydropower installations are part of the Douro basin, they represent 71 % of the total energy production given in the PNEBPH. The predicted reduction in energy production is a few procents smaller when comparing with the worst case scenario presented in **Graph 8**.

Graph 9: Energy reduction for the 10 hydropower installations, taking into account a reduction in runoff of 10 %for the Douro basin.

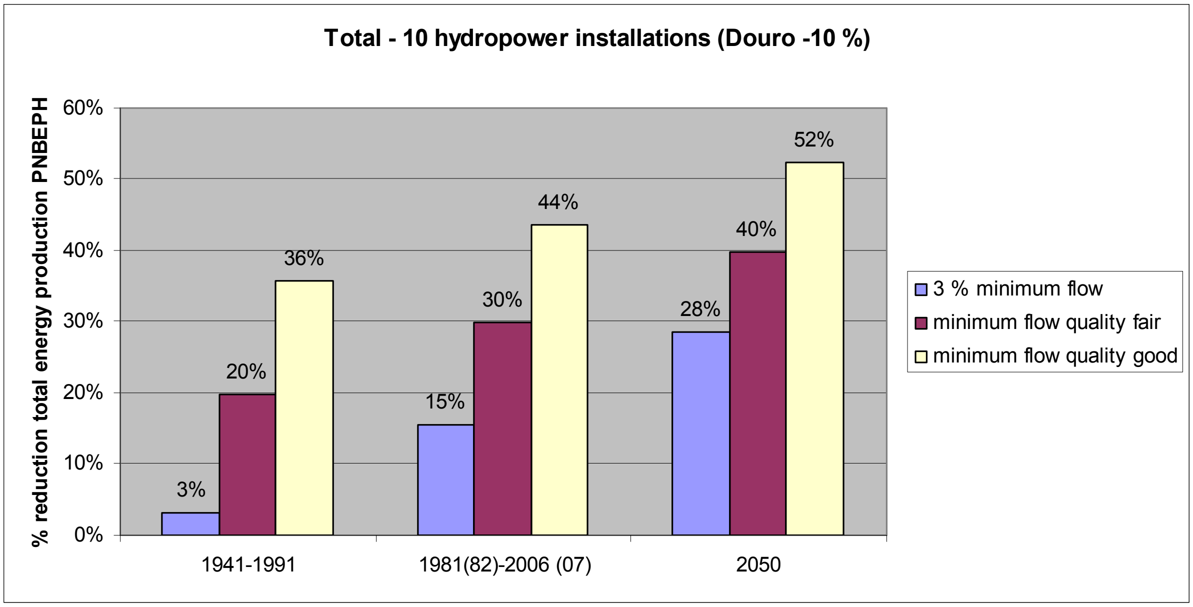
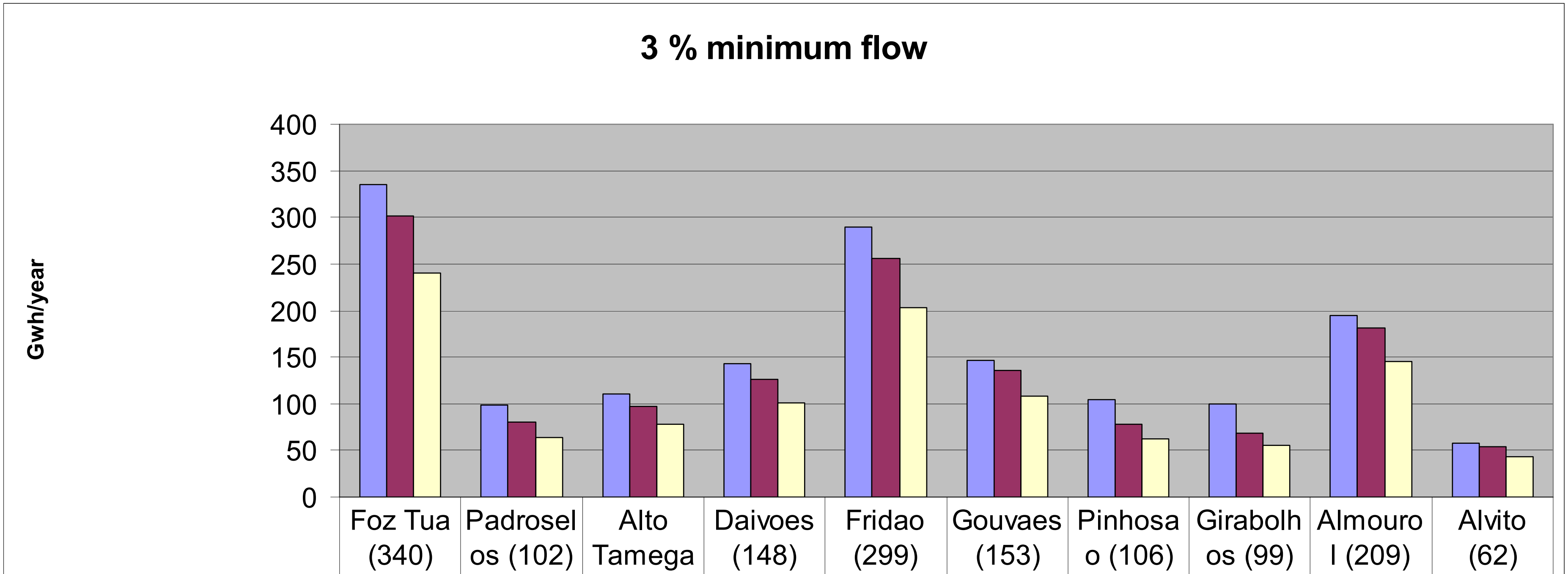


Table 25: Calculated energy production for the different scenarios

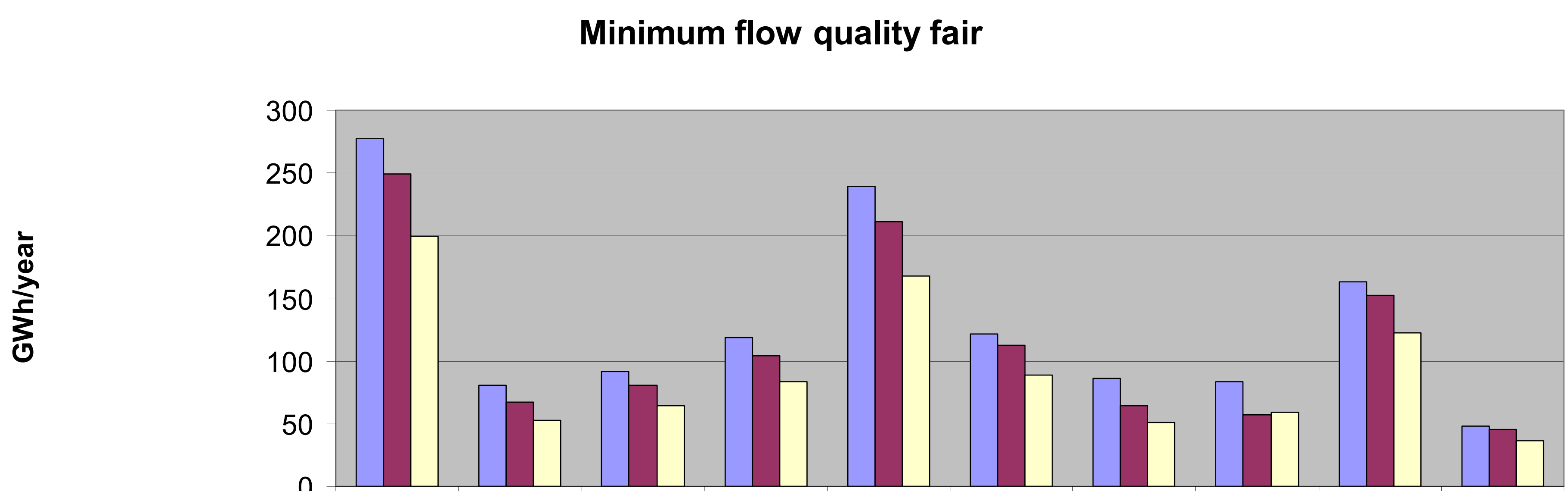
GWh/year	1941-1991				1981(82)-2006 (07)			2050		
		Minimum flow			Minimum flow			Minimum flow		
	PNBEPH	3 %	fair	good	3 %	fair	good	3 %	fair	good
Foz Tua (Douro)	340	335	277	221	301	249	200	240	199	160
Padroselos (Douro)	102	98	81	65	81	67	53	64	53	42
Alto Tamega (Douro)	114	110	91	73	98	81	64	77	64	52
Daivões (Douro)	148	143	118	94	127	105	83	101	83	68
Fridão (Douro)	299	290	239	191	256	211	168	203	168	134
Gouvães (Doruo)	153	147	121	96	136	112	89	108	89	71
Pinhosão (Vougo-Mondego)	106	104	86	69	78	64	52	62	51	41
Girabolhos (Vougo-Mondego)	99	100	83	68	69	57	46	55	59	37
Almourol (Tejo)	209	194	163	133	181	152	126	145	122	101
Alvito (Tejo)	62	58	48	39	54	45	37	43	36	30
	1632	1579	1308	1050	1380	1143	919	1098	925	734

Graph 10: Energy production with a minimum flow of 3 %



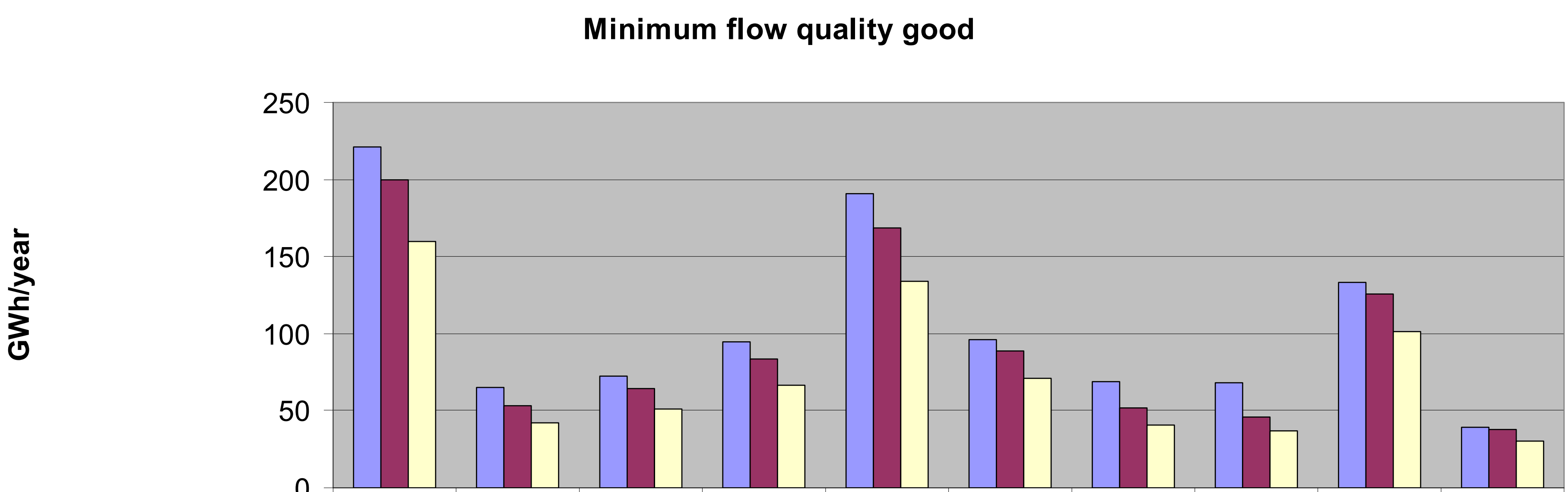
	Foz Tua (340)	Padroselos (102)	Alto Tamega	Daivoes (148)	Fridao (299)	Gouvaes (153)	Pinhosao (106)	Girabolhos (99)	Almourol (209)	Alvito (62)
1941-1991	335	98	110	143	290	147	104	100	194	58
1981(82)-2006 (07)	301	81	98	127	256	136	78	69	181	54
2050	240	64	77	101	203	108	62	55	145	43

Graph 11: Energy production with minimum flow quality fair



	Foz Tua (340)	Padroselos (102)	Alto Tamega	Daivoes (148)	Fridao (299)	Gouvaes (153)	Pinhosao (106)	Girabolhos (99)	Almourol (209)	Alvito (62)
1941-1991	277	81	91	118	239	121	86	83	163	48
1981(82)-2006 (07)	249	67	81	105	211	112	64	57	152	45
2050	199	53	64	83	168	89	51	59	122	36

Graph 12: Energy production with minimum flow quality good



	Foz Tua (340)	Padroselos (102)	Alto Tamega	Daivoes (148)	Fridao (299)	Gouvaes (153)	Pinhosao (106)	Girabolhos (99)	Almourol (209)	Alvito (62)
1941-1991	221	65	73	94	191	96	69	68	133	39
1981(82)-2006 (07)	200	53	64	83	168	89	52	46	126	37
2050	160	42	51	66	134	71	41	37	101	30

4.3 Estimation of the internal rate of return

The desirability of a project can be assessed by the calculation of the internal (economic) rate of return (IRR) and economic net present value (ENPV). This is not the only assessment which must be done. Also the compliance with the WFD Art. 4.7c requirement[8] should be taken into account in deciding on a project.

The PNBEPH includes an estimate of the Internal Rate of Return of each of the dams (see Annex 3 of the PNBEPH). Taking into account the likely reduction in energy production estimated in this task, a new calculation of the economic efficiency of the hydropower plants is performed. This is only done for the energy production calculated with the runoff data of the period 1941-1991 and for the minimum flow representing the quality fair or degrading and the quality good.

Changes in the expected cash flows, i.e. the expected yearly revenues from the sale of electricity, impact both the expected financial and economic performance of a project. In order to assess the impact of possible changes in the expected cash flows on the financial performance of the different projects for the generation of hydropower a tool is developed for calculating the financial net present value (FNPV) as well as the internal rate of return (IRR) of the projects considered.

The tool (**Annex 9**) has been set up, using the same assumptions as has been done in the original project appraisal by COBA and PROCESL:

- investment costs in equipment and civil engineering work have been taken over;
- the investment in equipment and civil engineering work is spread over 4 years: 20% in the first year, 30% in the second and the third year and 20% in the fourth year;
- 40 years of operation, starting from the fourth year;
- operation starts in year 4;
- yearly operating costs and revenues stay constant over the entire period, but are only half during the first year of operation;
- yearly operating costs have been taken over;
- after 20 years of operation (year 23) important maintenance and repair works are foreseen;
- at the end of the project horizon (year 43) the civil engineering work is still worth half its initial investment cost.

The only parameter value lacking for calculating the FNPV and IRR of the project given reduced yearly revenues from the sale of electricity are the one-off maintenance and repair costs after 20 years of operation. These costs have not been documented in the report by COBA and PROCESL. In order to overcome this data gap we have run the tool with all original parameters, including the FNPV for a given discount rate. So doing we have been able to determine the one-off maintenance and repair costs for each project.

By means of this one-off maintenance and repair cost we are able to come up with alternative values for the FNPV and FRR of the projects considered, using lower yearly

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[8] 'the reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development'

revenues from the sale of electricity. For calculating the FNPV one can easily use different discount rates.

The internal rate of return (IRR) of a project is a number, usually expressed as a percentage, which provides an indication of the (expected) net return on an investment. It equals the discount rate for which the NPV of the project is zero. Generally speaking, the higher a project's IRR, the more desirable it is to undertake the project.

For the project to be desirable for society as a whole the IRR should be greater than the social discount rate and the ENPV greater than zero.

In **Table 26** the input is given of the yearly revenues for each hydropower installation and the revenue per GWh.

Table 26: Revenu per unit GWh (PNBEPH)

PNBEPH	Energy production GWh/year	Yearly revenues (M €/year)	Revenu/GWh euro/GWh
Foz Tua	340	31,77	0,093
Padroselos	102	12,22	0,120
Alto Tamega	114	11,16	0,098
Daivões	148	13,7	0,093
Fridão	299	21,68	0,073
Gouvães	153	14,86	0,097
Pinhosão	106	10,18	0,096
Girabolhos	99	9,44	0,095
Almourol	209	11,49	0,055
Alvito	62	5,09	0,082

Using the tool the internal rate of return is calculated for each hydropower installation, taking into account the minimum flow as determined with the Tennant method and using the flow data for the period 1941/91. The results are given in **Table 27**.

Table 27: Internal rate of return taking into account the minimal flow

	Energy production (GWh/year)			Internal Rate of return (%) for a discount rate of 6 %		
	PNBEPH	Good	Fair	PNBEPH	Good	Fair
Foz Tua	340	221	277	14.4	9,3	11,8
Padroselos	102	65	81	9.7	5.7	7.5

	Energy production (GWh/year)			Internal Rate of return (%) for a discount rate of 6 %		
	PNBEPH	Good	Fair	PNBEPH	Good	Fair
Alto Tamega	114	73	91	8.3	4.6	6.3
Daivões	148	94	118	7.3	3.8	5.4
Fridão	299	191	238	13.0	8.0	10.3
Gouvães	153	96	121	11.8	7.1	9.3
Pinhosão	106	69	86	7.4	4.2	5.7
Girabolhos	99	68	83	7.3	4.4	5.9
Almourol	209	133	163	9.4	5.3	7.0
Alvito	62	40	49	5.7	2.6	3.9

When working with a minimum flow which corresponds with the quality fair, three installations have an IIR which is smaller than 6 % and a NPV of zero. From this point of view the projects Daivões, Pinhosão, Girobolhos and Alvito are not viable. For a minimum flow with quality good only 3 projects are still desirable: Foz Tua, Fridão and Gouvães.

The viability of the projects will be still smaller when the recent data series and the climate change predictions are taken into account.

4.4 Conclusions

Not only the future reductions of resource availability due to climate change are assessed but also the reductions already taken place in the years since 1991 are taken into account.

Therefore 2 scenarios are studied: an actual runoff scenario and a climate change scenario. In these scenarios only the impact of changing runoff data on the energy production is evaluated. For the evaporation the same data as those in the PNBEPH plan are used. But it should be mentioned that climate change will also have an impact on the evaporation data as evaporation will increase.

In the first scenario the reduction in energy production is evaluated when using data series characteristic for the 25 most recent years. When comparing the recent runoff data with those used in the PNBEPH a decrease in average annual runoff is observed varying from -14 % for the Douro basin to -28 % for the Mondego-Vouga basin. For the Tejo basin represented by Almourol alone no difference in average yearly runoff is observed (as only one site is studied, this is not really representative). For each of the studied stations the decrease in runoff occurs mainly at the end of the winter (from January on) and in spring. In some stations an increase in runoff is observed from late autumn to the beginning of the winter.

From this evaluation it could be derived that there is already a substantial difference in runoff which will have his impact on the energy production as given in the PNBEPH plan. This reduction in energy production varies between 15 % (minimum flow 3 %) to 43 % (flow quality good) in function of the minimum flow situation considered.

When taking into account future climate change, a worst case situation of a decrease in water resources of -20 % by 2050 is calculated. The reduction in energy production increases from 33 % (minimum flow 3 %) to 55 % (flow quality good). This reduction in runoff is calculated using the runoff data characteristic for the most recent data series of the last 25 years.

As studies mention that the reduction in water resources by 2050 will be smaller in the Douro basin than in the central basins, the difference in impact is also evaluated. The effect on the scenario 2050 is rather limited as the reduction in energy production varies between 28 % to 52 % (in stead of 33 % to 55 %).

The impact of the minimum flow scenarios on the internal rate of return is also investigated. This is only done for the data series used in the PNBEPH (period 1941-91). The results show that only a few projects still show an economic efficiency. For a minimum flow representing a flow quality good the hydropower installations Foz Tua, Fridao and Gouvaes can be considered to be viable. For the flow quality fair, this is also the case for the installations Padroselos, Alto Tamega and Almourol. When considering the climate change predictions the impact on the economic efficiency of these projects will be even greater.

It should be noted that economic efficiency is not the only criterion which must be considered in the evaluation and the selection of the most suitable projects.

TASK 2: ASSESSMENT OF IMPACTS OF THE PNBEPH

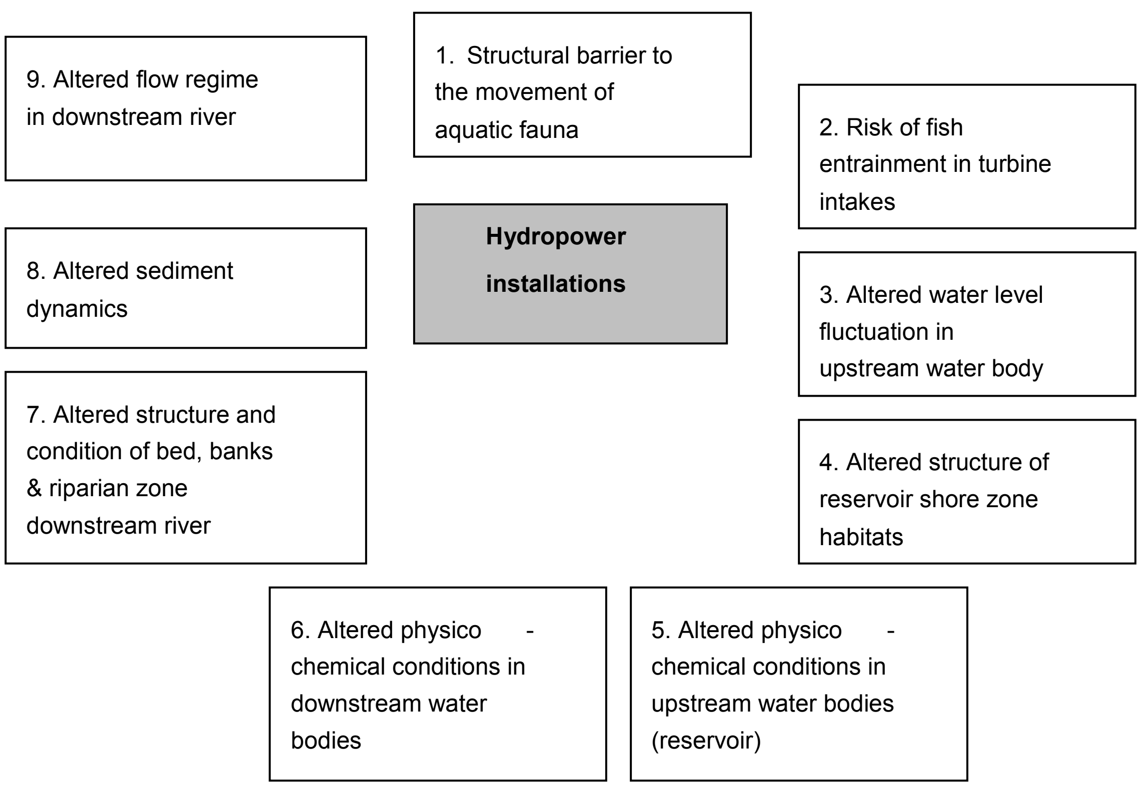
1 Task 2a: What are the main effects of hydropower dams in the water environment from the perspective of the WFD ecological status (upstream and downstream)?

1.1 State of the art on the knowledge on the impacts of hydropower plants and dams on water environment and in particular WFD ecological status

1.1.1 Introduction

The construction and operation of dams and more specifically hydropower installations is linked to unavoidable impacts on the water bodies and adjacent floodplains and wetlands. The use of water for hydropower is mainly related to hydro-morphological alterations of the water bodies (CIS, 2006). An overview of the main impacts related to hydro-morphological alterations in the aquatic ecosystem is given in Illustration 12.

Illustration 12: Main impacts of the construction and operations of hydropower installations on the aquatic ecosystem and its water bodies[1]



[1] A water body is the main unit of water to be considered by the Water Framework Directive (EC/2000/60) and is in effect a certain river stretch delineated by the EU Member State (CIS, 2006).

1.1.2 Water Framework Directive Objectives (2000/60/EC)

1.1.2.1 General

In relation to the Water Framework Directive (2000/60/EC) (WFD), the development and use of hydropower should consider the environmental objectives of the EU WFD (CIS, 2005), which main aim is to achieve good ecological status (GES) for all water bodies in the EU Member States. When the GES of water bodies cannot be achieved due to substantial hydromorphological changes and these water bodies need to be designated as heavily modified (HMWB), where one needs to reach a lower objective called the good ecological potential (GEP). This is the case particularly for reservoirs and impounded rivers.

The achievement of good ecological status, to be reached by 2015 is only one of the environmental WFD objectives, a complete list objectives s given below (**Table 28**) indicating those of particular interest to the development and use of hydropower installations in bold.

Table 28: Objectives Water Framework Directive; objectives relevant to the subject of the study are indicated in bold

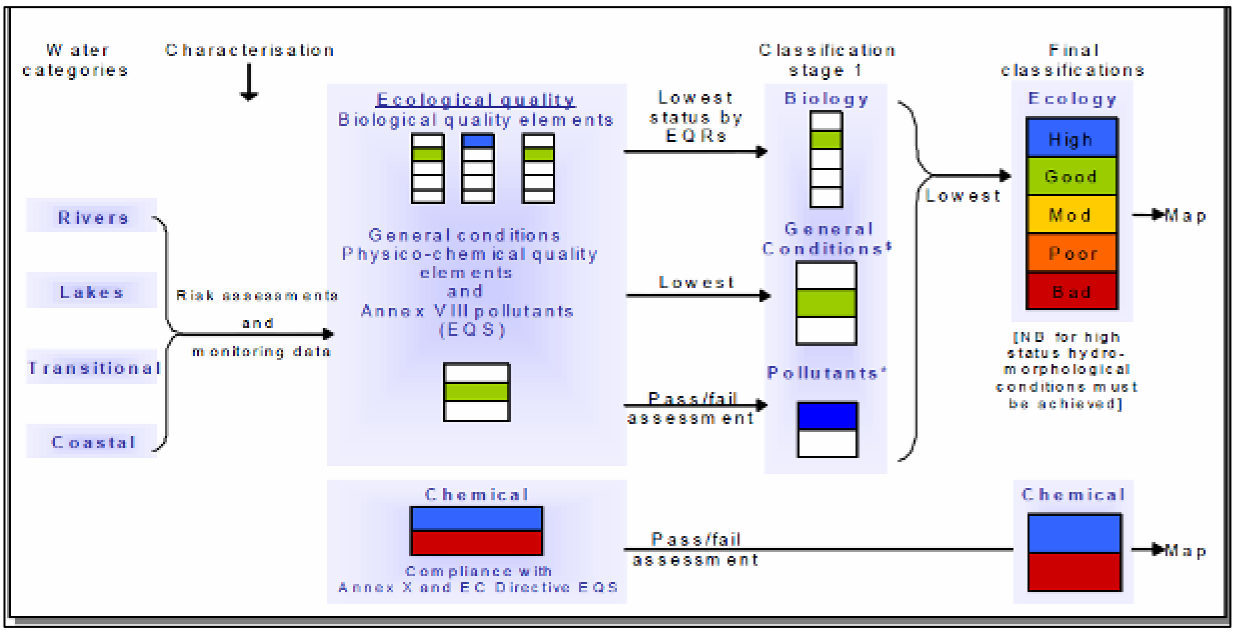
Objectives Water Framework Directive (EC/2000/60)	Relevance for determining effects of hydropower installations
1. No deterioration of status for surface and groundwaters and the protection, enhancement and restoration of all water bodies;	Yes, see task 2b
2. Achievement of good status by 2015 i.e. good ecological status (or potential) and good chemical status for surface waters and good chemical and good quantitative status for groundwaters	Yes, see task 2b
3. Progressive reduction of pollution and priority substances and phase-out of priority hazardous substances in surface waters and prevention and limitation of input of pollutants in groundwaters;	Of less importance, not part of scope of study
4. Reversal of any significant upward trend of pollutants in groundwaters;	Of less importance, not part of scope of study
5. Achievement of standards and objectives set for protected areas in Community legislation.	Yes, see task 2c

Indirectly, the Directive also demands **undisturbed migration of fish** (implicitly concluded from the continuity and fish), this will be explained in the next section 'normative definitions of status assessment under the WFD.

1.1.2.2 Normative definitions for status assessment under the WFD

The normative definition for the environmental objective of “good ecological status” is described in the Directive in great detail in Annex V, giving the details of the biological, hydro-morphological and physical-chemical elements to be considered. The overall classification including all these elements is given in **Illustration 13**:

Illustration 13: Classification of surface water bodies (CIS, 2005)



In the quality elements for status assessment of rivers are given.

Table 29: Quality elements to be used for the assessment of ecological status/potential based on the list in Annex V.1.1.1 and V.1.1.2. of the Directive (CIS N°13, 2005)

Annex V.1.1.1. RIVERS	Annex V.1.1.2. LAKES
BIOLOGICAL ELEMENTS	
• Composition and abundance of aquatic flora* • Composition and abundance of benthic invertebrate fauna • Composition, abundance and age structure of fish	• Composition, abundance and biomass of phytoplankton • Composition and abundance of other aquatic flora • Composition and abundance of benthic invertebrate fauna • Composition, abundance and age structure of fish fauna

<table>
<tr><th>Annex V.1.1.1. RIVERS</th><th>Annex V.1.1.2. LAKES</th></tr>
<tr><td colspan="2">HYDRO-MORPHOLOGICAL ELEMENTS SUPPORTING THE BIOLOGICAL ELEMENTS</td></tr>
<tr><td>• Hydrological regime: (1) quantity and dynamics of water flow (2) connection to groundwater bodies
• River continuity
• Morphological conditions: (1) river depth and width variation, (2) structure and substrate of the river bed, (3) structure of the riparian zone</td><td>• Hydrological regime: (1) quantity and dynamics of water flow, (2), residence time, (3) connection to the ground water body
• Morphological conditions: lake depth variation, quantity, structure and substrate of the lake bed
• Structure of the lake shore</td></tr>
<tr><td colspan="2">CHEMICAL AND PHYSICOCHEMICAL ELEMENTS SUPPORTING THE BIOLOGICAL ELEMENTS</td></tr>
<tr><td>• General: (1) thermal conditions, (2) oxygenation conditions, (3) salinity, (4) acidification status, (5) nutrient conditions
• Specific pollutants: (1) pollution by priority substances identified as being discharged into the body of water; (2) pollution by other substances identified as being discharged in significant quantities into the body of water</td><td>• General: (1) transparency, (2) thermal conditions, (3) oxygenation conditions, (4) salinity, (5) acidification status, (6) nutrient conditions
• Specific pollutants: (1) pollution by priority substances identified as being discharged into the body of water; (2) pollution by other substances identified as being discharged in significant quantities into the body of water</td></tr>
</table>

* Phytoplankton is not explicitly included in the list of quality elements for rivers in Annex V, 1.1.1., but is included as a biological element in V, 1.2.1. It should therefore be possible to use phytoplankton as a separate element, if needed and appropriate especially in lowland large rivers where phytoplankton may be important. The other aquatic flora specifically referred to in the normative definitions for rivers (Annex V.1.2.1) are macrophytes and phytobenthos.

The lakes classification is mentioned here as the study will also analyse existing hydropower stations and its reservoir quality for which the parameters as given in Annex V.1.1.2. are of importance in this respect.

The normative definitions for high, good and moderate ecological status in rivers are given in Table 30. These will be used as parameters to estimate the possible effects of hydropower installations on the objectives for the WFD. The effects on other categories will only be discussed when relevant and in a general way.

Table 30: Definitions for high, good and moderate ecological status in rivers

Biological Elements	High status	Good status	Moderate status
Phytoplankton	The taxonomic composition of phytoplankton corresponds totally or nearly totally to undisturbed conditions. The average phytoplankton abundance is wholly consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type-specific physicochemical conditions.	There are slight changes in the composition and abundance of planktonic taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbances to the balance of organisms present in the water body or to the physico-chemical quality of the water or sediment. A slight increase in the frequency and intensity of the type-specific planktonic blooms may occur.	The composition of planktonic taxa differs moderately from the type-specific communities. Abundance is moderately disturbed and may be such as to produce a significant undesirable disturbance in the values of other biological and physico-chemical quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months
Macrophytes and Phytobenthos	The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. There are no detectable changes in the average macrophytic and the average phytobenthic abundance.	There are slight changes in the composition and abundance of macrophytic and phytobenthic taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of phytobenthos or higher forms of plant life resulting in undesirable disturbances to the balance of organisms present in the water body or to the physico-chemical quality of the water or sediment. The phytobenthic community is not adversely affected by bacterial tufts and coats present due to anthropogenic activity	The composition of macrophytic and phytobenthic taxa differs moderately from the type-specific community and is significantly more distorted than at good status. Moderate changes in the average macrophytic and the average phytobenthic abundance are evident. The phytobenthic community may be interfered with and, in some areas, displaced by bacterial tufts and coats present as a result of anthropogenic activities.
Benthic Invertebrate Fauna	The taxonomic composition and abundance correspond totally or nearly totally to undisturbed conditions. The ratio of disturbance sensitive taxa to insensitive taxa shows no signs of alteration from undisturbed levels. The level of diversity of invertebrate taxa shows no sign of alteration from undisturbed levels.	There are slight changes in the composition and abundance of invertebrate taxa from the type-specific communities. The ratio of disturbance-sensitive taxa to insensitive taxa shows slight alteration from type-specific levels. The level of diversity of invertebrate taxa shows slight signs of alteration from type-specific levels.	The composition and abundance of invertebrate taxa differ moderately from the type-specific communities. Major taxonomic groups of the type-specific community are absent. The ratio of disturbance-sensitive taxa to insensitive taxa, and the level of diversity, are substantially lower than the type-specific level and significantly lower than for good status.

Biological Elements	High status	Good status	Moderate status
Fish fauna	Species composition and abundance correspond totally or nearly totally to undisturbed conditions. All the type-specific disturbance-sensitive species are present. The age structures of the fish communities show little sign of anthropogenic disturbance and are not indicative of a failure in the reproduction or development of any particular species.	There are slight changes in species composition and abundance from the type-specific communities attributable to anthropogenic impacts on physicochemical and hydromorphological quality elements. The age structures of the fish communities show signs of disturbance attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements, and, in a few instances, are indicative of a failure in the reproduction or development of a particular species, to the extent that some age classes may be missing.	The composition and abundance of fish species differ moderately from the type-specific communities attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements. The age structure of the fish communities shows major signs of anthropogenic disturbance, to the extent that a moderate proportion of the type specific species are absent or of very low abundance.

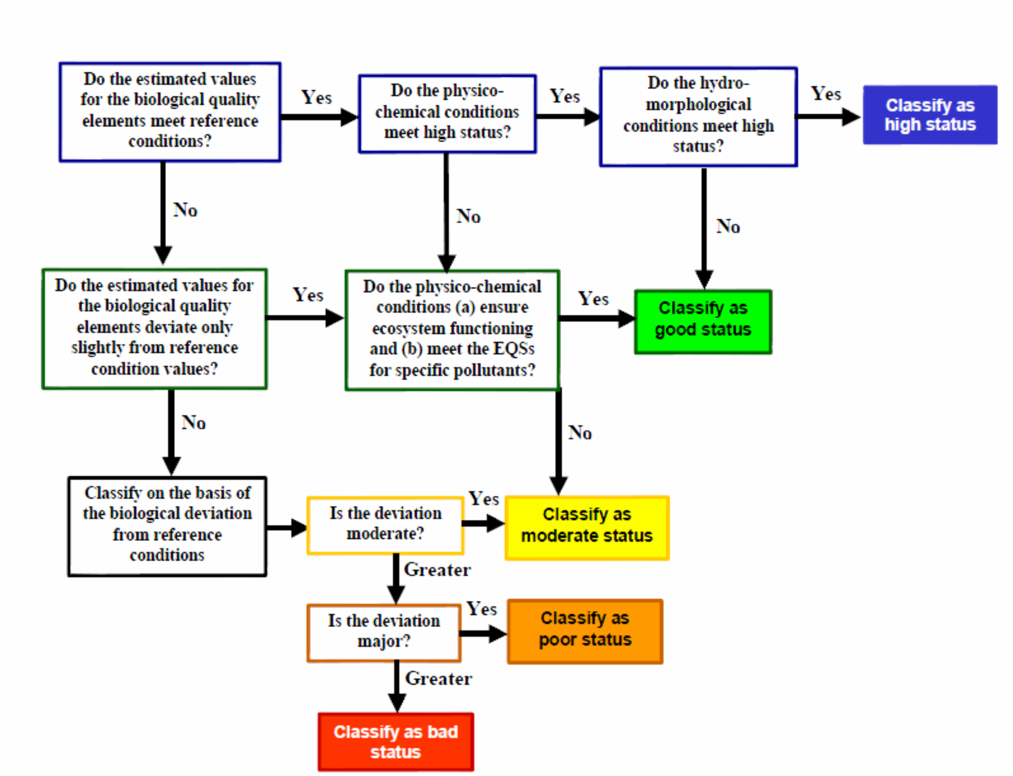
Hydro-morphological elements	High status	Good status	Moderate status
Hydrological regime	The quantity and dynamics of flow, and the resultant connection to groundwaters, reflect totally, or nearly totally, undisturbed conditions.	Conditions consistent with the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.
River continuity	The continuity of the river is not disturbed by anthropogenic activities and allows undisturbed migration of aquatic organisms and sediment transport.	Conditions consistent with the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Morphological conditions	Channel patterns, width and depth variations, flow velocities, substrate conditions and both the structure and condition of the riparian zones correspond totally or nearly totally to undisturbed conditions.	Conditions consistent with the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.

Physical-chemical elements	High status	Good status	Moderate status
General conditions	The values of the physico-chemical elements correspond totally or nearly totally to undisturbed conditions. Nutrient concentrations remain within the range normally associated with undisturbed conditions. Levels of salinity, pH, oxygen balance, acid neutralising capacity and temperature do not show signs of anthropogenic disturbance and remain within the range normally associated with undisturbed conditions	Temperature, oxygen balance, pH, acid neutralising capacity and salinity do not reach levels outside the range established so as to ensure the functioning of the type specific ecosystem and the achievement of the values specified above for the biological quality elements. Nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific synthetic pollutants	Concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use.	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<EQS)	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific non-synthetic pollutants	Concentrations remain within the range normally associated with undisturbed conditions (background levels = bgl).	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 (2) without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<EQS)	Conditions consistent with the achievement of the values specified above for the biological quality elements

The development of specific numerical criteria and classification schemes including class boundaries for the elements to be considered is described in Directive 2000/60/EC only as regards the process, and the development itself has to be done by the Member State itself. For surface waters, the classification systems should be finalised before the Member States are required to implement the monitoring systems starting at the end of 2006. The boundaries between high/good and good/moderate ecological status set by the Member States will be assessed as regards their consistency with the normative definitions in Annex V WFD and the comparability across Europe in the so-called intercalibration process. This needs to be decided by the WFD Committee two years after the publication of the register of intercalibration sites (deadline mid-2007).

As part of the achievement of good ecological status, one can see that for example for the parameter continuity need to be consistent with the achievement of the values specified above for the biological quality elements (in this aspect, fish will be the biological element to be looked at). This could be of importance in the aspects of hydropower installations that are barriers to fish. However, one could see from the below classification system (**Illustration 14**) that hydro-morphological conditions are only taken into account in the overall classification process for determining high status. The parameter that evaluates the requirement of unhindered fish migration is as such only implicitly integrated in the description of good ecological status for fish '*There are slight changes in species composition and abundance from the type-specific communities attributable to anthropogenic impacts on physicochemical and hydromorphological quality elements. The age structures of the fish communities show signs of disturbance attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements, and, in a few instances, are indicative of a failure in the reproduction or development of a particular species, to the extent that some age classes may be missing*'.

Illustration 14: Classification system (CIS N°13, 2005)



1.1.2.3 Selected WFD quality elements and/or parameters for the assessment/estimation of impact of new hydropower developments

For WFD surveillance monitoring, all relevant quality elements must be monitored; For operational monitoring programme required under the WFD however, the Member State does not need to necessarily use all biological quality elements for assessing the ecological status of a water body either. According to the WFD, Member States shall monitor parameters which are "indicative of the status of each relevant quality element" (Annex V.,1.3). Appropriate parameters for these biological quality elements need to be identified to obtain adequate confidence and precision in the classification of the quality elements (CIS N°13, 2005). To select these 'appropriate parameters' it is suggested one selects the parameters indicative of the quality elements most sensitive to the pressures to which the water bodies are subject. According to CIS guidance N°13 the sensitivity of biological elements and of the parameters monitored to estimate their condition may be considered in terms of (a) their actual sensitivity to the pressure; and (b) the degree of confidence that can be achieved in monitoring results. There are no agreed (CIS) guidelines on what elements can be considered sensitive for what certain pressure but UKTag (the body coordinating WFD implementation in the UK) has included some guidelines in its guidance on monitoring (UK Tag 12a, 2005) and these are given in Table 31.

According to the CIS Policy paper 'Exemptions to the environmental objectives under the Water Framework Directive allowed for new modifications or new sustainable development activities (WFD Article 4.7)' (CIS, 2007) the assessment of risk of deterioration should be based on the best information available on the status of those water bodies whose status is likely to be affected by the proposed project. Such information should include the latest information from the monitoring programmes required under Article 8 and information obtained from any environmental impact assessment undertaken for the project.

Table 31: Quality elements sensitive to the pressures affecting rivers (based on UK Tag 12a, 2005). Elements in light grey are of less importance for this study, these in dark grey are considered as not relevant for the study

SOURCE PRESSURE	CATEGORY OF EFFECT	EXPOSURE PRESSURE	MACROPHYTE	PHYTOBENTHOS	MACRO-NVERTEBRATES	FISH	MORPHOLOGY	HYDROLOGY	GENERAL PHYSICAL_CHEMICAL ELEMENTS
Nutrient enrichment	Primary effect on biology	• Change in nutrient concentration in defined water body. Enhanced biomass, changes to other primary producers	**x**	x				X	Nutrient suite
Organic enrichment	Primary effect on biology	• Increased organic enrichment; change in biological community structure			**X**			X	Organic suite
Hydrological	Primary effect on biology	• Changed water levels from abstraction; altered flow regime impacting biology	**X**	X	**X**	**X**	X	X	General suite
Morphological	Primary effect on biology	• Riparian and channel modification, • altered sediment characteristics (eg size), smothering and damage to river bed • affected river continuity	**X**		**X**	**X**	X	X	
Acidification		• Change in ANC & pH; change in biological community & toxicity synergies		X	**X**	**X**			Acidification suite

Table 32: Quality elements sensitive to the pressures affecting lakes (based on UK Tag 12a, 2005). Elements in light grey are of less importance for this study, these in dark grey are considered as not relevant for this study

SOURCE PRESSURE	CATEGORY OF EFFECT	EXPOSURE PRESSURE	**PHYTOPLANKTON**	**MACROPHYTES**	PHYTOBENTHOS	**MACROINVERTEBRATES**	**FISH**	MORPHOLOGY	HYDROLOGY	GENERAL PHYSICAL_CHEMICAL ELEMENTS
Nutrient (& organic) enrichment	Primary effect on biology	Change in nutrient concentration in defined water body. Enhanced biomass, changes to other primary producers	**X**	**X**	X				X	Nutrient suite
Hydrological	Primary effect on biology	Changed water levels from abstraction; altered flow regime impacting biology; concentration of nutrients	**X**	**X**		**X**		X	X	
Morphological	Primary effect on biology	Shoreline and channel modification, altered sediment characteristics (eg size), smothering and dame to river bed		**X**		**X**	X	X	X	
Acidification		Change in ANC & pH; change in biological community & toxicity synergies			X	**X**	X		X	Acidification suite

One can see that for the assessment of hydro-morphological pressure in rivers (identified as main pressure related to hydropower installations) nearly all biological elements are selected, except for phytobenthos (mainly towards morphological pressures). For the assessment of pressures in lakes, eutrophication is considered to be the main pressure with phytoplankton and macrophytes as main indicators. After the construction of the reservoir, in the first river basin management plan, the category of 'river' will be changed to 'lake' (but under the condition of heavily modified), but an important consideration is that one cannot ask the designation of heavily modified water bodies in advance of the project. However, to assess the condition before the WB is designated as a heavily modified water body, phytoplankton, although not explicitly included in Annex V.1.1.1 can be used in slower running waters and to assess the effect of hydropower on upstream water bodies. As fish is a key indicator for the hydrological and morphological condition of the whole river basin, it will also be looked at in upstream water bodies.

The greenhydro method (Bratrich & Truffer, 2001), developed to address the trade off between hydropower use and the protection and ecological enhancement of highly affected river systems, uses 2 of the WFD biological elements i.e. fish and macroinvertebrates and these are used in similar ways to the WFD. Phytoplankton and macrophytes do not form key criteria to assess the impact of hydropower use according to this greenhydro method (Ruef & Bratrich, 2001), but it is recognised in Ruef & Bratrich (2007) that the method is complementary with the requirements of the WFD.

1.1.2.4 Exemptions on WFD objectives for new developments (such as hydropower plants)

For the PNBEPH project, the objectives 1 (no deterioration), 2 (GES or GEP) and 5 (related to Protected Zones) of Table 1 are of main importance. Exemptions on objective 1 and 2 are allowed and those explained under Art 4.7 have a considerable impact on new developments and identifications such as hydropower plants. For the PNBEPH plan, Art 4.7 exemption has been applied.

'**Art 4.7** '*Member States will not be in breach of this Directive when: failure to achieve good groundwater status, good ecological status or, where relevant, good ecological potential or to prevent deterioration in the status of a body of surface water or groundwater is the result of new modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or failure to prevent deterioration from high status to good status of a body of surface water is the result of new sustainable human development activities and all the following conditions are met and all the following conditions are met: (a) all practicable steps are taken to mitigate the adverse impact on the status of the body of water; (b) the reasons for those modifications or alterations are specifically set out and explained in the river basin management plan required under Article 13 and the objectives are reviewed every six years; the reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development, and (d) the beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental option*.'

Further on 4.8 determines that effects need to be looked at beyond the water body it is located and reminds that existing other Community legislation will needs to be respected.

'**Art. 4.8** '*When applying paragraphs 3, 4, 5, 6 and 7, a Member State shall ensure that the application does not permanently exclude or compromise the achievement of the objectives of this Directive in other bodies of water within the same river basin district and is consistent with the implementation of other Community environmental legislation*.'

Note 1 (from the CIS guidance environmental objectives, CIS (2005)): WBs cannot be designated as HMWBs before the new modification has taken place because of the anticipation of the significant hydromorphological alteration.

1.1.3 Impacts of hydropower plants on the aquatic ecosystem – literature review

1.1.3.1 Nutrient enrichment in reservoirs and effects occurring when released downstream

General

In the same way as reservoirs trap river sediment, they also trap most of the nutrients carried by the river. During warm weather, algae are likely to proliferate near the surface of a highly nutrient-enriched reservoir. Through photosynthesis the (mainly blue-green) algae consume the reservoir nutrients and produce large amounts of oxygen. Summer releases from the surface layer of a reservoir will thus tend to be warm, nutrient-depleted, high in dissolved oxygen and may be thick with algae. These blooms can be toxic and cause a give unpleasant smell and taste and coat gravel beds. When algae in a reservoir die they sink to its bottom layer and consume the already limited hypolymniun oxygen. The quality of the water discharged by the dam will depend on the location of the water caption regarding the stratified water layers and the intensity of the currents generated by the water discharges. Eutrophication impacts increase with bigger permanence periods of the water in the dam. This, in turn, is determined by the rate between the water volume stored in the dam and the incoming flow (EIA Foz Tua, 2008). Warm weather releases from a dam with low-level outlets will thus be cold, oxygen-poor and **nutrient-**rich and may contain high mineral conditions (McCully, 2001). The stratification patterns developing in the reservoirs and their discharge impact on the biota downstream by physico-chemical disturbance associated with the release of waters (and sediment) derived from the hypolimnion, which are frequently nutrient-rich, cold and thermally constant (Ward & Stanford, 1979; Craig & Kemper, 1987; Pozo et al., 1997).

Portuguese situation

Within the study Ferreira & Rodrigues (2001) data collected between 1997 and 2000 for 162 large Portuguese dams were studied to determine their trophic status. Indicators selected were total phosphorous in the water column (Pt) and chlorophyllin biomass (chlorophyll a). From the original pool of dams, a final number of 83 was analysed for which enough and reliable data was available regarding the indicators selected (though not always for both indicators). Of these, only 4% of the dams were found to be oligotrophic, 28% mesotrophic and 23% eutrophic. Results obtained confirm that phosphorus is the determinant element to the eutrophication of Portuguese dams and that the regression from this trophic status depends mainly on the control of affluent discharges. Within the study Ferreira & Godinho (2002), a total of 57 of this selection of 162 Portuguese dams were identified for which phytoplankton studies are available. Knowledge about phytoplankton is generally based on inventories undertaken by universities or research institutions, without a systematic character because they result from sporadic studies, either for scientific reasons or resulting from collaboration protocols with financing entities. Presently and because of the period they refer to, these studies are only useful as historical references. For instance, in the Tejo basin, the only dam for which there is a continuous phytoplankton study since the 1950ies is Castelo de Bode, due to its integration in an international long-term monitoring programme. An historical evaluation of the trophic evolution of the dams using phytoplankton has only been done for a few dams. This has been done for Montargil, for the period 1973 – 1997 with the conclusion that the dam switched from an oligotrophic status to an eutrophic one in 24 years. Similar analysis were done by Brito & Andrade (1991a), for Castelo de Bode, who found out that between 1980 and 1990 the dam changed from an oligotrophic status to nearly mesotrophic, and by Oliveira & Monteiro (1994) for Divor dam, which maintained its eutrophic status between 1973 and 1993, with a tendency to hypereutrophy. A systematic research of this sort of phenomenon was undertaken for the Tejo basin, and they were found in the Sta Águeda, Divor, Maranhão, Magos and Montargil dams. The most well-known case is that of Divor, where 13 blooms were registered between 1974 and 1986, six of which led to massive fish deaths (Oliveira & Monteiro, 1994). Most of dominated by cyanobacteria of three very common species in Portugal: *Aphanizomenon flos-aquae*, *Microcystis aeruginosa* and *Anabaena affinis*. Andrade (1998) undertook a systematic research of the main cyanobacteria genera that occur in Portugal and the most frequent species, as well as of the occurrence of toxic cyanobacteria blooms in Portuguese waters. Apart from the cases referred above for the Tejo basin, they were also found to occur in the Douro basin (Peneireiro and Stª Maria Aguiar dams and river Coa), the Mondego basin (Fagilde and Aguieira dams), Guadiana basin (Caia, Monte Novo, Bufo (Barrancos) and Vigia dams, plus river Guadiana) and Sado basin (Roxo and Odivelas dams).

1.1.3.2 Organic changes in reservoir and river

<u>General</u>

When a reservoir is filled, the decomposition of submerged vegetation and soils can drastically deplete the level of oxygen in water. Rotting organic matter can also lead to releases of huge amounts of the greenhouse gases methane and carbon dioxide. It is given in different studies that the biological changes (mainly macroinvertebrates) below dams have to be considered not only in terms of flow regulation, but in terms of the effect that hydrological variation has on the transportation of organic matter, possible organic enrichment and substratum stability. The stratification patterns developing in the reservoirs and their discharge impacts on the biota downstream by modification of available food resources, especially through changes in the downstream transfers of particulate organic matter (Andersen & Cummins, 1979; Petts, 1984);

<u>Portuguese situation</u>

In Cortes et al. (1998) the composition of invertebrate composition downstream of the impoundment on the Balsemao and Poio dam (Douro River Basin), was looked at. The long retention of water in the artificial lake of the Balsemao reservoir (small dam) led to a greater accumulation of allochthonous organic matter, with consequences on the availability of this material below the reservoir, thus modifying the trophic structure (Cortes et al., 1998). The decrease of diversity was, however, more pronounced in the Poio, reflecting the stress caused by relatively frequent fluctuations in water flow. Also, transportation of fine sediments that fill interstitial spaces and also the occurrence of unstable substrata associated with discharge variability, were also likely contributors to the reduction of species diversity.

1.1.3.3 Hydro-Morphological changes in river and the reservoir

General: hydrological changes

Reservoir

Because they greatly multiply the surface area of water exposed to the rays of sun, dams in warm climates can lead to evaporation of huge amounts of water which is mainly lost to the river downstream. This also causes higher salt (mineral) concentrations.

The monomitic stratification patterns developing in the reservoirs and their discharge often impact in two ways on the biota downstream: (1) creation of a disruption in the hydrological patterns by daily hydropeaking, and a catastrophic increase in invertebrate drift (Gore et al., 1989; Lauters et al., 1996); and (2) diversion and water abstraction downstream of the dam, generally with flood suppression, drastically decreasing the abundance and diversity of benthic fauna (Morgan et al., 1991; Moog, 1993).

Hydropeaking

Rapidly varying flows can be generated in a hydropower installation (hydro-peaking). This gives rise to conditions that are damaging watercourse hydromorphology and aquatic biota downstream (CIS Workshop (2007): Issues Paper, WFD Hydromorphology)

Rapidly varying flows can be generated in a hydropower installation (hydropeaking). The hydropeaking aspects dealt with here concentrate on hydropeaking events of the kind occurring as a result of managing reservoirs on a daily, weekly, seasonal or annual basis (usually peak electricity production). As this intermittent operating method is primarily linked to the energy demand and not to ecological considerations, it often causes rapid and very strong discharge fluctuations in the affected sections of rivers that influence the distribution and quality of physical habitats and consequently impose huge restrictions on the living conditions of organisms: during generation-flow periods, the artificial rise in discharge levels leads to hydraulic effects such as fluvial erosion or to intensive drift and active flight behavious of organisms. After peak generation and during reduced-flow periods, organisms get stranded in dried-out areas of rivers or isolated in pools, where the decreasing concentration of oxygen can cause them to suffocate. This effect is particularly noticeable in river stretches whose natural morphology has extensive zones of shallow water, or in secondary streams that may be intermitted during low streamflow. This problem can also be exacerbated when the effects unleashed by a chain of power plants overlap on a single river section (Bratrich & Truffer, 2001).

Morphological changes

Dams and their associated reservoirs impact freshwater biodiversity via **morphological changes** by (Mc Allister et al., 2001):

Blocking movement of migratory species up and down rivers. This is explained more in detail in section A ‘the impacts of dams on fish’.

Changing turbidity/sediment levels affects species adapted to natural levels. Trapping silt in reservoirs deprives downstream deltas and estuaries of maintenance materials and nutrients that help make them productive ecosystems. This is explained more in detail in B ‘sediment effects’.

Filtering out of woody debris which provides habitat and sustains a food chain.

Floodplains provide vital habitat to diverse river biotas during highwater periods in many river basins. Dam management that diminishes or stops normal river flooding of these plains will impact diversity and fisheries.

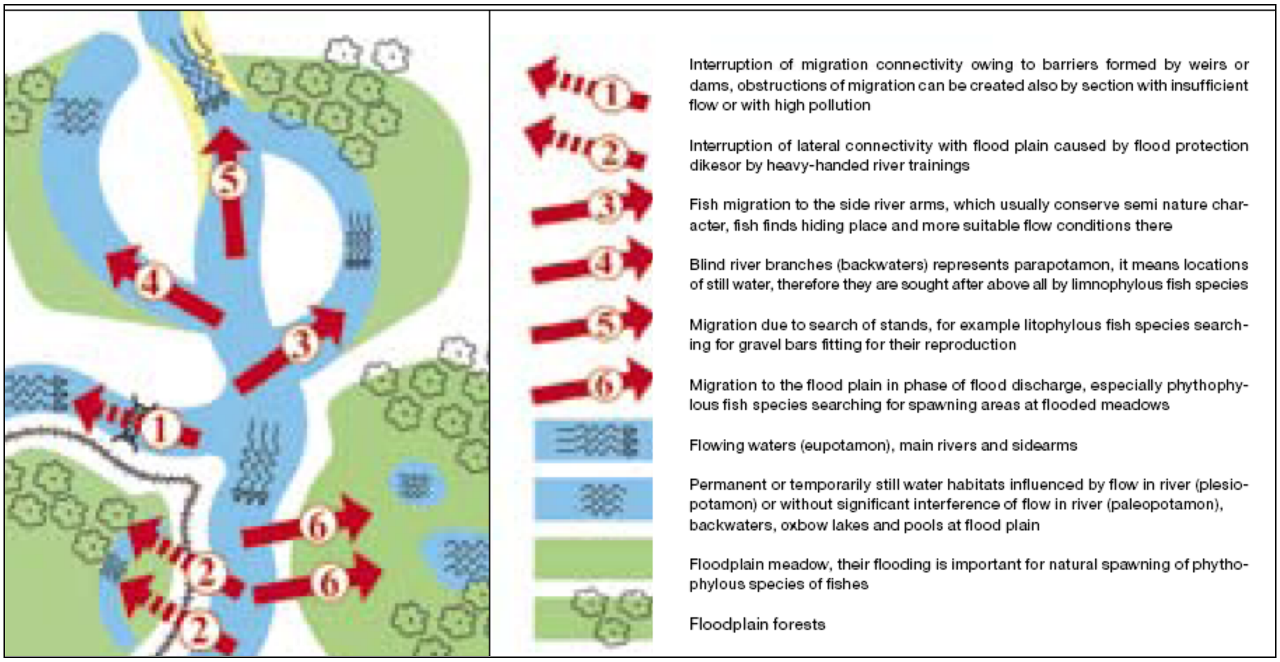
Often there is a reduction of available or suitable habitat (Erskine et al., 1999). Intense and erratic fluctuations in water discharge are generally considered as producing the most dramatic events, because the released water often erodes the river channel until armouring by medium and large cobbles occurs (Death and Winterbourn, 1995; Gore, 1996), often contributing to the **loss of habitat diversity**, with implications for the decline in the number of species (Gumiero & Salmoiraghi, 1994). Impacts on fish habitat and consequently fish populations are explained in section Effects on macroinvertebrate populations have been previously explained as part of section 1.1.3.2.

Reservoir construction often leads to many-fold increases in the area of standing water in a region and they typically **replace varied stream habitats with habitats more similar to each other.** Compared to natural lakes, reservoirs are usually shallower, more connected to other water bodies, and more laden with suspended and dissolved solids; they also have a higher and more variable flushing rate. Moreover, they typically contain unstable, recently assembled communities of stocked fish. An ecological hypothesis known as the fluctuating resource availability hypothesis suggests that these characteristics will enhance the susceptibility of reservoirs to **invasion and exotic species** tend to displace indigenous biodiversity.

A. The impacts of dams on fish will be discussed separately here, as their migratory behaviour and their habitat and flow dependence make them very vulnerable for the effects of hydro-morphological alterations caused by these hydropower stations. The main impacts can be explained as follows:

Habitat fragmentation: The loss of habitat connectivity and continuity creates obstacles to fish movements from downstream to upstream and vice-versa (longitudinal movements) and to stream tributaries (lateral movements) (**Illustration 15**). As a consequence of habitat fragmentation there is an increase of fish population fragmentation. This fact can have critical genetic consequences through the increase of inbreeding and loss of genetic diversity.

Illustration 15: Schematic illustration of lateral and longitudinal migration between refuge, feeding and spawning habitats of fish (Kroes et al., 2006)



- Hydrological changes: **Interruption and/or modification of the river flow.** Erratic flow pulses as consequence of hydropower plant operation. Migratory behaviour (e.g. Lamprey spp.; *Alosa* spp.) depends on a "**trigger flow**" that arrives to estuaries. Therefore since flow patterns are changed the **migration processes can be negatively affected. Reproduction of resident fish** can also be affect (e.g. low natural recruitment).
  The ultimate **consequence of hydrological changes** is the **reduction of habitat availability for resident and migratory fish,** mainly due to the looss of patchiness and diversity:
  - Upstream from the dam: The impact on this area is lower when compared with the changes occurring inside the reservoir and downstream from the dam.
  - Inside the reservoir: The lotic habitat is replaced by a lentic habitat, which causes:
    1. Increase of water time residence,
    2. Increase of water depth,
    3. reduction of current velocity,
    4. occurrence of thermal stratification during summer,
    5. Increase of sediment deposition inducing changes in substrata characteristics,
    6. Increase of nutrient concentration and
    7. Degradation of the riparian ecosystem. Those changes may lead to a significant reduction of resident fish and favour the exotic species over resident species. The ultimate consequence is the loss of fish biodiversity.
  - Downstream from the dam:
    1. Structural channel changes are caused by the natural flow modifications with diversity in flow patterns decreasing from source to sea. Below every

hydropower plant there is a short zone with relatively high velocities and turbulence that subsequently decreases further downstream.

2. In areas with low summer flow, the duration of the dry period for downstream habitats can be increased. Furthermore, structures can block the flow of nutrients and sediments through the river system towards the sea.
3. Food-control leads to relatively constant and fixed water levels that might prevent inunda¬tion of floodplains during seasonal floods. These habitat modifications can profoundly affect the ecology of the system (riparian vegetation, substrate features). The ultimate consequence of those changes is the reduction of fish populations caused by the loss of feeding, shelter and spawning habitats.
4. Changes in water temperature and in nutrient concentrations are caused by the water discharges from the bottom of the reservoir.
5. As a consequence of flow reduction, an increase in the intrusion of saline water in freshwater habitat can occur.

B. Sediment effects are discussed separately as well because of its significant impact on various aspects of the aquatic ecosystem: Although bedload is considered to be one of the most important factors in river ecology, only a small minority of the river systems in Central Europe nowadays have bedload regimes that are unaffected by hydrological influences. Nevertheless, a naturally diverse range of habitats is just as crucial in ecological terms as the naturally occurring high water flows in which bedload transport and channel rearrangement can take place. Disturbances play a vital role in preserving a wide variety of natural structures and species diversity. If bedload transport takes place upstream of a river impoundment, the material that gets carried into the reservoir is deposited in successive size-sorted accretions. The depositions become increasingly finer when approaching the weir. These effects can cause substantial alterations to the original channel structure, which besides homogenising the substrata can also produce siltation of the riverbed. Furthermore, decomposing sludge may form and oygen depletion may occur.

Since smaller discharges have a reduced transport capacity, sediment deposits may accumulate in diverted reaches downstream of weirs and dams. Within the diverted reaches, these sediments can only be shifted in periods of significantly higher flows. Resulting homogenisation of substrate as well as siltation can accentuate the degradation of river ecology affected by a minimum flow regime. Conversely, if there is general bedload deficit, this can lead to erosion of the downstream river bed. This can cause considerable deterioration of the riparian structures (Bratich & Truffer, 2001). This bedload deficit can also enhance coastal erosion as mentioned earlier.

Portuguese situation

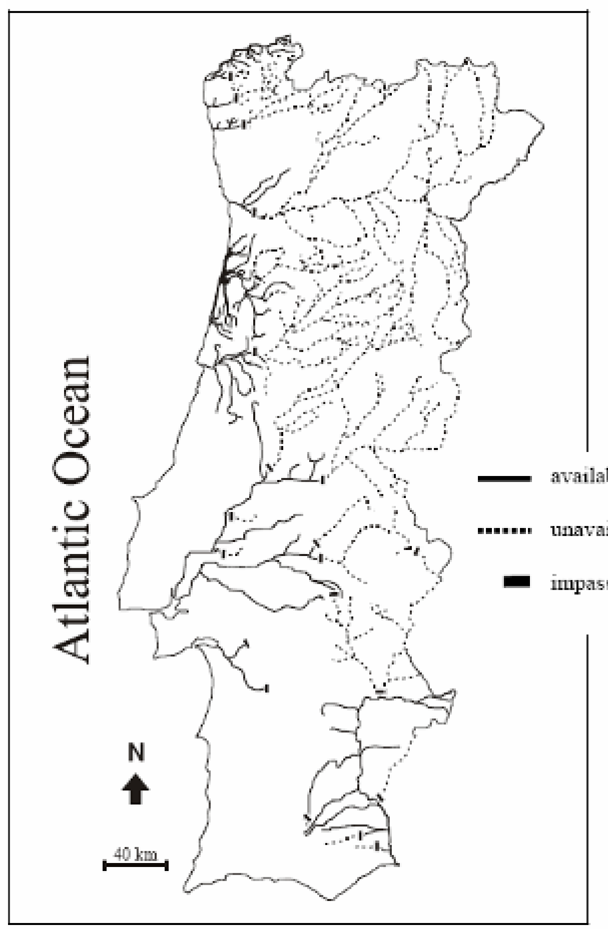
Effects of changed water levels and habitat – fish

From all vertebrates present in PNBEPH area fish are expected to be the most impacted group as discussed in the above paragraphs. In fact, the presence of dams and weirs in rivers is considered to be one of the main factors that are negatively affecting Iberian freshwater fish (Elvira 1996 in Santos et al. 2004). Portuguese rivers are impounded by almost 200 large dams and more than 3000 small weirs (Santos et al. 2004).

The majority of endemic fish, although rheophilic, are well adapted to the conditions as experienced in these systems with strong seasonal flow fluctuations, especially flow reduction in dry periods. However, their vulnerability in the refuge pools is high, especially as a result of poor water quality, water abstraction, and competition for food and space from exotic species. This has been illustrated in studies in the Guadiana river basin where thirteen reservoirs have already been constructed and a further 25 proposals have been put forward at the time of the study (2000) (Collares-Pereira et al., 2000). The situation in the mid and Northern Portuguese river basins is not as accentuated as in the Sourthern Guadiana river basin but as a consequence of these flow fluctuations, fauna and flora are under a lot of seasonal water stress (INAG, 2008).

With regard to habitat, in Almeida et al. (2002) a notorious reduction of habitat availability for sea lamprey occurred after the implementation of large dams in the main river courses in Portugal (**Illustration 16**).

Illustration 16: Habitat available to sea lamprey populations in Portuguese river basins where the species is known to occur



Effects of river regulation downstream – macroinvertebrates

In Cortes et al. (1998): Different macroinvertebrate community responses were found in the two rivers (diversity versus species composition) downstreal of the dam because of differences in the patterns of energy flow and the regularity of water discharges. Considering this last aspect, five critical components of the flow regime regulate ecological processes in river ecosystems: the magnitude, frequency, duration, timing and rate of change of hydrological conditions (Cortes et al., 1998). As referred to in Section 1.1.3.2, decrease of macroinvertebrate diversity downstream of the Poio dam (Douro river basin) was significant and was mainly **stress caused by relatively frequent fluctuations in water flow.** T**ransportation of fine sediments** was also a likely contributor to the reduction of species diversity.

Coastal erosion

The reduction of river sediment supply is the basic cause of coastal erosion in Northwest coast. The Douro River in its natural regime would supply about 1.8 million m^3/year, but this value has decreased to about 0.25 million m^3/year showing presently a cessation tendency. The reasons behind this reduction are mainly sand extraction in estuaries and along the river, but also because of dam construction. The dam construction induces sediment supply reduction in two ways: retention in reservoirs and changing the hydrological regime (Silva et al., 2007). The SEDNET report (2006) concludes that sediment deficiency in the Douro river system worsens erosion at the coast. Although there is strong evidence that commercial sediment extraction activities are largely responsible for this deficiency, this pressure is enlarged by the extra sediment retained by reservoirs from hydropower stations.

1.1.3.4 Other effects

Green House Gases Released from Dams (Kikuchi & Bingre do Amaral, 2008):

- Dam-related biomethane was identified in the 1960s.
- The emissions of greenhouse gases may take place at all dam reservoirs in the boreal and tropical regions and continue as long as the dam exists.
- Most of the greenhouse gases emitted from hydroelectric power systems are formed from organic matter trapped at the dam.
- Flooded biomass decomposes at the reservoir bottom, and this anaerobic decomposition then emits principally CO_2, CH_4 and N_2
- There is flooded terrestrial biomass and some fresh sediment formed by plankton detritus at the bottom of the reservoir. The decomposition, carried out principally by bacteria, demands oxygen at higher rates than diffusion can supply, and an anaerobic regime is established (chiefly when the reservoir is stratified).

However there are no specific references that prove contribution of Portuguese reservoirs to greenhouse gas emissions.

1.1.4 Sensitivity of river basins towards hydropower-related pressures

In the previous section the main pressures have been identified, which could be summarized as (1) changed sediment pattern, (2) changed flow and habitat conditions, (3) the barrier function, (4) changed nutrient (and organic) conditions . However, the actual impact on the existing biological communities in the Mid- and Northern Portuguese river systems will depend on factors that can be described by both natural characteristics and current existing pressures on the system.

In **Table 33**, the parameters describing the natural characteristics and the pressures of relevance for which data are available are explained. This will be used as a starting point for task 2b when analysing the main impacts from the PNBEPH dams on the Portuguese river systems.

Table 33: Table in which it is described how natural characteristics and the presence of existing pressures in a river basin (applied to the Portuguese river basins considered in the study) determine the sensibility of a certain river basin for the impact of hydropower installations

	Natural characteristics	Existing pressures
Changed sediment pattern	For small upstream rivers, the contribution to coastal erosion will be expected to be less than for large downstream rivers. For rivers in estuarine areas, any change in sediment pattern will have an effect on the coastal areas (erosion). In the heterotrophic stream ecosystems of Northern Portugal, running through silicious bedrock, the structure and function of downstream communities are strongly regulated by the transportation of particulate organic food along the river. Consequently, the continuous reduction in the provision of different fractions of POM give rise to pronounced consequences below the reservoirs (Cortes et al., 1998)	'Alteration in the sediment dynamics' has been taken up as part of the risk assessment for all river basins considered in this study (WFD Article 5 report) and as such recognised as priority pressures to be assessed and managed by the Portuguese authorities (see further Task 2b)
Changed flow conditions	The more tributaties over a certain length at close distance of the planned hydropower station, the better the possible attenuation of changed flow conditions The flow (partly determined by the size of drainage) of these tributaries also affects the possibility of attenuating changed flow. As such, numbers of tributaties over a certain length and drainage areas of these tributaties are both indicators for possible (unnatural) flow change attenuation. Problems with regard to min flow and dry-fall will be more pronounced at southern-located river basins in Portugal due to the already water shortage during dry years.	'Alterations in the flow regime' and 'water shortage' are taken up as parameters within the risk assessment (WFD Article 5 report) and as such recognised as priority pressures to be assessed and managed by the Portuguese authorities. A combination of these two parameters makes the river basin especially vulnerable to any extra change in flow. (see further Task 2b)
Changed habitat condtions	Portuguese rivers and especially the southern river basins are characterized by highly fluctuating flows during the year, low summer flows and in some occasions there are even intermittent streams. Species that are characteristic for these type of rivers are adapted to these situations up to a certain extent (adaptations physiological, life cycle-related, etc) and their survival is also dependent on the availability of refuge area. It is as such important that the natural habitat including pools etc is retained to allow fish to survive during low flow conditions.	The number of heavily modified water bodies (HMWBs) as well as artificial water bodies (designation available from the WFD Art 5 report) does give an idea on the already changed characterer of a river basin. Moreover, flow fluctuations can be more pronounced in regulated systems (for example when they have lost their floodplain areas, straightening etc) due to their lowered buffering potential. On the other hand, one could consider these systems as less sensitive to any extra impact when considering the already impoverished (and more tolerant) fauna. In contrast, for those river systems that are not artificial or heavily modified but do contain an impoverished habitat, there is less refuge for species affected by hydropower (eg at low flow conditions). Changed habitat conditions, except from alterations in the sediment dynamics and flow, are not taken up in the risk assessments (WFD Article 5 report) but other data on habitat quality are available at some sites close to the planned hydropower installations (see Task 2b)

	Natural characteristics	Existing pressures
Barrier function	The barrier function is mainly a problem for migrating species such as certain anadromous and catadromous fish. River systems that are naturally home to these migrating species (because for example they contain the spawning areas in their upstream sites) are more vulnerable towards barriers.	Existing barriers at the river basin and the presence of fish traps (and their efficiency) do give an indication on the current fragmentation of the river system Also river continuity indices do allow an assessment on the fragmentation.
Eutrophication	Spring and summer low flows exhibit the greatest eutrophication risk. The eutrophication may also depend on the sediment – one can conclude that the more fine sediment, the higher the potential for eutrophication and as such hydropower locations in the rivers downstream are more vulnerable for eutrophication by enriched sediment than those upstream (and naturally the downstream nutrient concentrations are higher than upstream. Reservoirs at downstream locations do as such have more potential for eutrophication than upstream reservoirs. The designation of nutrient vulnerable zones and nutrient sensitive zones (91/676/EEC and 91/271/EEC respectively) do give an indication of the sensitivity of the river system towards eutrophication.	The risk of eutrophication will enhance when there is already an enrichment of the river ecosystem. The existing enrichment has been assessed as part of the WFD risk assessment ('waters enriched with nitrates and phosphorus').

1.1.5 Cumulative impacts of hydropower plants in river basins

There is limited literature with regard to the cumulative impacts of hydropower installations; however, the general impacts can be rather easily defined based on the overall impacts as described under Section 1.1.3. The specific situation however is very much dependent on the type and vulnerability of the river system, the size ad the distance between each of the hydropower plants.

Changed sediment pattern: All of the reservoirs will captate the sediment and as such the sediment transport downstream will be significantly reduced. This will have significant effect on the habitat of macroinvertebrates, macrophytes etc. Depending on the size of the river basin affected and its distance to the coast, this might also contribute significantly to the effect of coastal erosion.

Changed flow and habitat conditions: A cascade of dams close to each can be seen as a cascade of reservoirs and as such the ‘natural’ habitat of the river system will be significantly reduced and it will be nearly impossible to sustain the requirements of the ‘natural’ biological populations

Barrier function: A cascade of dams with each of the dams being a barrier for fish migration do make it impossible for migrating species to survive in the river basin. Even if fish traps are considered, the efficiency of all fish traps need to be optimal to allow fish to migrate from one barrier to the other. However, using a fish traps also requests a lot of energy from fish populations and together with the changed habitat conditions at both side of each of the dams, this might make it impossible for fish populations to survive.

Eutrophication: each of the rivers has a capacity to ‘self-purify’ which means that with increased organic and nutrient load, the river is able to self-purfiy itself and brings itself back in a state with satisfying oxygen conditions for biologic life. However, if for example in the case of hydropower stations, the distance between each of the stations is rather limited and there is nearly no mixing with effluent from more natural tributaries allowed, there is very limited potential for self-purification of the river

According to the Sustainability Guidelines of the International Hydropower Association (IHA, 2004), preference should be given to development on **previously developed river basins if the cumulative and other environmental or social impacts** are less than the impacts of new development on an unregulated river system. One can indeed state that already modified streams (modifications obtained by hydropower installations or other structures in the river) could be preferable over rivers in a near-natural state, as is also stated in CIS Workshop (2007).

The SEA of the PNBEPH does recognise the importance of cumulative effects and mainly for the following reasons

- **Cumulative impacts in estuaries and coastal areas** (cumulative reduction of liquid and solid flows) should be analysed at the basin level when several dams are included in the PNBEPH for one basin. Main issues to consider include: sediment dynamics, coastal erosion and flows for fish fauna.

- **Cumulative impacts on biodiversity**. When several dams are foreseen in the PNBEPH for one basin (e.g. Tâmega river), more detailed studies on the cumulative impacts on biodiversity should be carried out at the sub-basin level. The main effects to be analysed include the fragmentation of the lotic continuum and the loss and fragmentation of terrestrial habitats by the reservoirs.
- The scale in which the SEA was undertaken and the lack of detailed information in this assessment on some particular aspects (e.g. information on species and habitats distribution where only assessed on a national scale) did not allow proper assessment of these issues and it was reported that they should be further analysed in the EIA of each project.

1.2 State of the art on the knowledge on the effects and benefits of mitigation measures

Many of the impacts as described in Section 1.1.3 can be mitigated by different measures (restoration and mitigation measures) (CIS Workshop, 2007). The good practice paper 'Good practice in managing the ecological impacts of hydropower schemes, flood protection and works designed to facilitate navigation', prepared as part of the CIS activity on WFD & Hydromorphology, includes several case studies that demonstrate measures which might contribute towards the improvement of ecological status/potential by restoration/mitigation (WFD and hydromorphological pressures – technical report, 2007). The domains of biological continuity, minimum flow, hydro-peaking, debris management, and habitat improvement are are considered essential as measures for individual sites affected by HP development. The focus of the Berlin workshop (CIS Workshop, 2007) was on the first three domains, and will as such get further attention here. Considering the great variety of restoration/mitigation measures which can be taken to reduce local impacts from hydropower (CIS, 2005), measures should then be further prioritised on the basis of local water management aims. Second, the degree of adverse ecological effects of the alterations that are associated with a particular scheme will depend on the particular characteristics of the affected water bodies. For information, a generic list of mitigating measures for water bodies heavily modified by hydropower is available from the Good Practice Paper WFD and hydro-morphology (CIS, 2006) but this has been drafted by summarising general experience from Norway and is as such not directly applicable to reservoirs and dams in Mediterranean countries.

Mitigation and restoration measures will be explained in the next section. The use of compensating measures together with mitigating measures is highly recommended. (Common Implementation Strategy Workshop, Berlin, 4-5 June 2007, Key conclusions)

1.2.1 Mitigation measures for fish migration

As explained under Section 1.1.3.3, some fish species need to migrate during certain life stages. As dams do act as a barrier for migration, specific solutions needs to be designed. To date, different technologies have been developed for fish passes. The goal is to provide better access to spawning grounds or for feeding migrations; habitat shifts, recolonisation after floods, for restoring fragmented populations (see Schmutz presentation CIS Workshop, 2007). For upstream migration, many solutions are available (e.g. fish passes and fish ladders, but also fish lifts, fish stocking, catch & carry programmes etc.) to mitigate the negative impact of migration barriers – but more work needs to be done on evaluation and monitoring of effectiveness. Much research leading to technical innovations has still to be undertaken, especially related to downstream migration in combination with turbine damage. (CIS Workshop, 2007).

The measures most widely used to enable fish to cross dams or reach additional parts of the river are:

- Fish passes (Larinier, 1992; Powers and Orsborn, 1985);
- Locks and fish elevators;
- By-pass / diversion channels around the dam;
- Harvest and transportation of fish by vehicle, boat, aircraft, etc. (Hildebrand et al., 1980).

The optimal use of any one of these measures depends upon the physical characteristics of the site and the stream, the species targeted, the geographic location and various other limiting factors.

The design criteria hydropower installations for **upstream fish migration** (Presentation, S. Schmutz, CIS workshop (2007)) of importance are:

- The size and flow discharge of fish ladders related to the size of the respective water body;
- The entrance location;
- The attraction flow;
- The minimum depth;
- The maximum flow velocity
- The dissipation energy;
- The maximum head between pools;
- The maintenance requirements.

Design criteria hydropower installations for downstream fish migration (Presentation S. Schmutz, CIS workshop (2007)) are:

- Avoiding entrainment into water intakes and guiding fish into bypass facilities;
- Physical barriers designed with a specific flow velocity and flow angle in mind and with fish-friendly intake bar spacing;
- Fish friendly turbines: operation of turbines, blade wheel diameter, the number of blades, turbine rotation speed and blade wheel and turbine stator angle.

In general, downstream migration is considered as more problematic than upstream migration. Technologies for downstream fish passage are much less advanced than for upstream passage. Downstream fish pass facilities are often only developed for certain species. Problems are that downstream migration facilities have often excessive flow requirements (costs) and that downstream migratory behaviour for most species is unknown

The document from Kroes et al. (2006) gives practical guidance for restoration of fish migration in European rivers.

Portuguese situation

Legislation prescribing the establishment of fish passes

Legislation dating back to 1893 refers to the need for the implementation of fish ways in dams and other barriers in inland waters. Fishing inland law (de 10 de Outubro de 1962) modified by Lei nº7/2008 de 15 de Fevereiro lei das pescas nas águas (Fishing on inland waters). Article 13. 'Movement of aquatic species'. Decreto-Lei nº 69/2000 de 3 de Maio modified by Decreto-Lei nº 197/2005 de 8 de Novembro (Environmental Impact Assessment). The implementation of fish passes are always prescribed in EIA as a mitigation measure of negative impact on fish populations.

The document Santo (2005) provides a comprehensive review of fish pass devices in Portugal, which includes: Situation in Portugal; Dam negative impacts on fish populations. Impact mitigation; Fish pass design, construction and maintenance; Efficiency of the fish pass implemented in Portugal.

Main issues

- The first fish pass in Portugal was built in 1950 (Belver Dam-Tejo river). It was replaced in 1987 by a lock system;
- In Portugal, despite of legislation and the existence of a large number of dams (Illustration 17) and weirs, there are only 42 fish pass (32 at PNBEPH area) at the moment;
- Although legislation requires the installation of fish passes, it does not mention that they have to be efficient for fish migration. So there are many fish passes that are not useful due to lack of maintenance or bad construction;
- 10 of the total existing fishpasses considered in this document (32) are not functioning. At least 8 of them are considered ineffective for upstream migration because of:
  - Bad functioning,
  - Design problems,
  - Maintenance problems,
  - Attraction problems or the impossibility of fish getting to the fish pass entrance;
- The more frequent target species are *Pseudochondrostoma sp.*, *Barbus sp.* and *Salmo trutta*. Some fish passes (mainly the ones built in large rivers) are also for *Petromyzon marinus, Alosa alosa, Alosa fallax* and *Anguilla Anguilla*.

Types of fish passes in Portugal

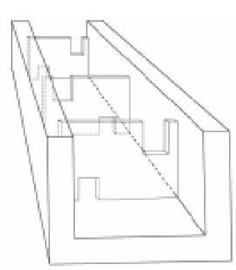


FIGURA 5.1. Desenho representativo de um dispositivo do tipo bacias sucessivas (adaptado de Larinier, 2002b)

Fish pass with notches (bacias sucessivas). This type is frequently used for small hydropower dams. Also allows otter (*Lutra lutra*) and water mole (*Galemys pyrenaicus*) passing. 32 fish pass of this type are implemented in Portugal. The maintenance is very easy and not expensive.

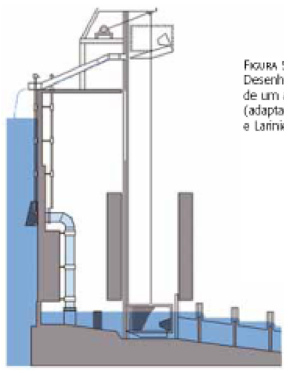


FIGURA 5.3.
Desenho esquemático de um ascensor de peixes (adaptado de Travade e Larinier, 2002)

Fish Lift - this fish pass is implemented in large dams. Two fish passes in Portugal (Touvedo Dam- R. Lima Basin (Santo, 2005) and Pedrogão Dam – R. Guadiana Basin (Alvares, 2007).

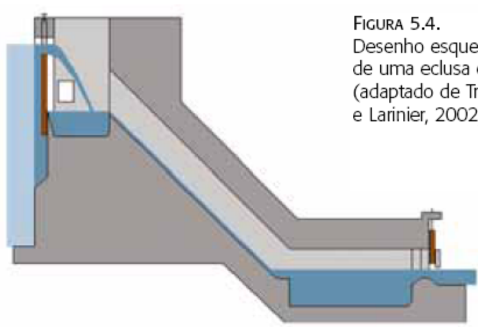


FIGURA 5.4.
Desenho esquemático de uma eclusa de peixes (adaptado de Travade e Larinier, 2002)

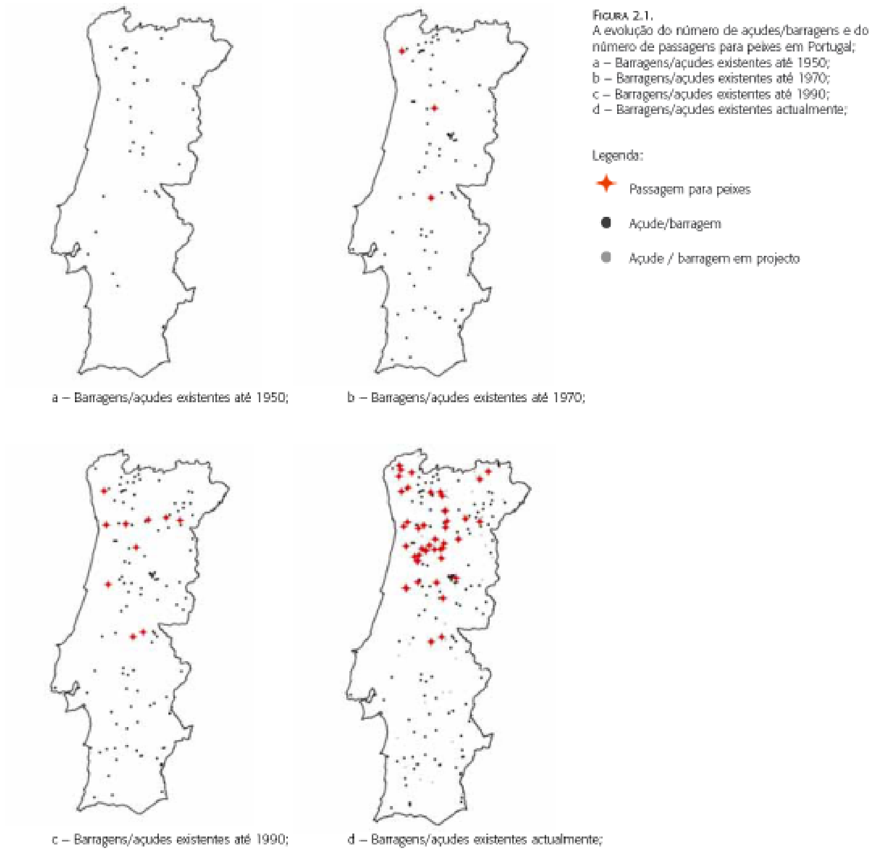
Fish lock (eclusa) pass in Portugal large dams in Douro and Belver and Fratel in Tejo

Table 34: Overview fish passes in Portuguese large dams (Santo, 2005). Data concerning Pedrogão fish pass is missing because this device was only built in 2006 (Alvares, 2007)

QUADRO 2.3. – DISPOSITIVOS DE PASSAGENS PARA PEIXES INSTALADOS EM GRANDES BARRAGENS EM PORTUGAL

RIO	APROVEITAMENTO	TIPO DE DISPOSITIVO	DESNÍVEL A VENCER	ANO DE ENTRADA EM FUNCIONAMENTO
Lima	Touvedo	Ascensor	25,0	1993
Cávado	Penide	Bacias sucessivas	7,5	1970
Douro	Crestuma-Lever	Eclusa	9,0	1986
	Carrapatelo	Eclusa	31,0	1973
	Régua	Eclusa	26,0	1973
	Valeira	Eclusa	27,0	1976
	Pocinho	Eclusa	20,0	1983
Tejo	Belver	Eclusa	12,0	1987
Mondego	Açude Ponte de Coimbra	Bacias sucessivas	4,5	1983

Illustration 17: Evolution of the number of dams/weirs and fish passes from 1950 until present



1.2.2 Sediment/debris management

Some mitigation measures are:

- Artificial scouring floods clearing mud and vegetation – effect = better spawning conditions (exposes gravel substrate for spawning).
- Flushing flows intend to wash away the harmful accumulations of boulders and gravel (The Mitigation Game, International Rivers[2])

For ecologically based bedload (sediment) management it is advisable and sensible to undertake a combined set of measures for an entire chain of power plants (similar to fish migration) (Bratrich & Truffer, 2001).

1.2.3 Mitigation of disruption of flow dynamics

For the lake (reservoir):

- stocking of fish (reservoir and river): intended to support one specific species - better fish stocks – effect = supports natural recruitment;
- new limitations on drawdown levels;
- habitat manipulations in reservoir.

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[2] http://www.internationalrivers.org

For the downstream river:

Restoration of flow hydraulics: the principle is to harness the energy with the flow and use it to recreate the morphological variability associated with its type of rivers. This can be achieved by non-structural measures or, possibly by using structures to initiate or accelerate the required ecological improvements (GES/GEP) or to artificially create habitat diversity. Before the measures are implemented it is essential to ensure they do not adversely affect sediment transport through the reach.

Examples of restoration measures are given in good practice study (CIS 2006).

Artificial discharge regimes should be avoided for ecological reasons. However, if artificial discharge regimes cannot be avoided entirely, the ecological status of the WB(s) affected can still be improved through operational modifications that attenuate the volume and frequency of artificially generated abrupt waves and avoid unduly precipitous water level fluctuations (Bratrich & Truffer, 2001).

1.2.3.1 Minimum flow

Minimum flow can cause significant changes to the abiotic and biotic conditions in and around river systems. The aim of ecologically compatible minimum flow is to ensure a discharge regime that closely reflects the natural characteristics of the river system involved. It is often impossible to make general statements about evaluating its impact, since many of the factors relevant to the assessment are dependent on local circumstances. Individual studies are therefore useful for the determination of minimum flow regulation that optimises ecological and economic imperatives. It is important to know which discharge in particular river stretch is actually significant ecologically (Green Power Publications, Issue 7).

In order to meet the criteria of Good Ecological Status (GES) or GEP (Good Ecological Potential), the minimum flow should as least leave water in the river (except in naturally dry falling rivers) and aim at maintaining and restoring the river’s type-specific aquatic community:

- Stable flow over summer
- Or variable flows designed for downstream ecology

Approaches to determine ecologically acceptable flow have been developed and are being further developed by several European countries. There is no one-size-fits-all approach - a combination with other mitigation measures is often necessary.

To assess the impact of minimum flow, other factors should be considered (e.g. tributaries connectivity, flood regime). There is not one single method to establish minimum flow release – combination is necessary. Extensive research on minimum flow is done in different Member States, but there are still gaps mainly towards ecological responses to minimum flow and interaction with morphology. It is recognised that European standards at general level are needed but with a case-specific definition of MF are needed (Common Implementation Strategy Workshop, Berlin, 4-5 June 2007, Report from Session 2 day 2)

Instream flow requirements, often expressed as percentages of the annual flow, usually give little consideration to the importance of natural seasonal flow variations: releases which raise levels during normally dry spells can even do more harm than good. Instream flow requirements also rarely allow for the releases of the occasional exceptionally large flood flows which are in essential part of most fluvial ecosystems. In general, instream flows can mitigate the effects of dams but cannot recreate the essential variability and dynamism of a wild river[3]

Portuguese situation

In Cortes et al. (2002), the effect of hydropower stations on macroinvertebrate communities is looked at. One of the conclusions is that ‘a constant flow did not reduce the detrimental effects resulting from permanent reductions in discharge caused by huge dams, especially when the water has a hypolimnetic origin. However, they believe that habitat heterogeneity acts effectively as a buffer to regulation. One of their conclusions was that to have an effective mitigation from river impoundment with hydropower generation (conclusions based on macroinvertebrate studies) there is a need to (a) adopt an environmental flow strategy, not only to stabilize baseflows, but also to reproduce the natural flow distribution and to allow for habitat and channel maintenance flow, (b) maintain habitat diversity, both in the reach (allowing a wide range of refuge for aquatic communities) and in the segment.

An overview of methods for determining minimum flows, minimum flow prescriptions and methods applied in Portugal and a proposal of methods to determine minimum flow in the PNBEPH dams are given in TASK 1 report, chapter 1.

1.2.3.2 Hydropeaking

Some studies identify serious ecological consequences of hydro-peaking (i.e. abrupt changes in discharge regime), but there are still knowledge gaps. Mitigation options are limited and often involve high costs due to the loss of peak-load capacity and their designated function. However, examples for the successful implementation of mitigation measures also exist (like coordination between hydropower plants). (CIS Workshop, 2007 - conclusions)

Hydropeaking (CIS Workshop (2007); Presentation S. Schmutz) its main effects are with regard to

- Peak flow: Flushing effects, Stranding effects, Temperature alterations
- Minimum flow: Altered habitat quality and quantity

Some of the solutions given are:

- Applying minimum flow (see separate section)
- Dampen peak flow
- Altered HP operation
- Compensation reservoir
- Coordination of power plants

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[3] http://www.internationalrivers.org

The goals that must be achieved by the mitigation measures for flow changes are the following (Bratrich & Truffer, 2001)

- Attenuation of discharge fluctuations: attenuation in regard to the frequency (on a seasonal basis, particulary in the case of spawning and migration periods) and in terms of quantity, sufficiently to ensure that no lasting qualitative and quantitative damage is caused to the naturally occurring diversity of the fish and benthic fauna in the river reaches involved. In particular, care must be taken that the water level does not fall too swiftly in the reduced-flow period and does not rise abruptly in the peak generation-flow period
- No dry-out in return flow section, so that a minimum functional habitat diversity for flora and fauna is assured (minimum flow regulations)
- No critical effects of temperature.
- No isolation of fish and benthic fauna outside the main channel: The gradient of the water level change in the receding-flow phase must be attenuated adequately to ensure that widespread isolation of the fish and benthic fauna in their refugial habitats outside the main channel is avoided. No isolated pools should be created, in which the oxygen concentration falls below critical levels.
- Preservation of habitat diversity and characteristic landscape features
- Preservation of fish habitats, particularly spawning grounds and juvenile fish habitats. No irreversible loss in the variety of fish habitat may occur, nor any serious disruption to the naturally occurring diversity and age class distribution of fish populations. Suitable spawning grounds and habitat for juvenile fish may not dry out, particularly during low flow periods.

1.2.4 Mitigation of the effects of a dam on downstream water quality

For the lake (reservoir):

See 1.2.2 ‘Sediment and debris management’

For the downstream river:

One of the advantages of spilling extra water is that it will tend to increase downstream dissolved oxygen levels. Other measures can also be taken which increase oxygenation such as artificially aerating the water passing through turbines. Another form of mitigating the effects of a dam on downstream water quality is to regulate the temperature of releases by fitting the dam with intakes which can withdraw water different levels of the reservoir.

1.2.5 Mitigation of habitat disruption

Habitat adjustments can be made and as such hiding and resting places for fish can be established. This allows the fish to seek refuge during either low flow conditions (eg by ensuring pools) or high discharges (floodplains with resting places)

1.2.6 Conclusions

The main conclusions with regard to effects and benefits of mitigation measures for hydropower stations are the following:

- Several mitigation measures for the main impacts summarized under section 1.1.3 have been identified. Regarding their potential benefit to reduce the impact of hydropower plants: fish passes, the establishment of natural flow conditions (with minimum flow as the basic requirement) and mitigating of fluctuating discharge regimes (hydropeaking) are priority.
- Practices of fish passes and minimum flow seem to be common sense. But although good practices have been published (eg CIS, 2006) the information needed is often very region-specific, and good knowledge of the natural system needs to be available (which is often tacking)
- Practicies of mitigating hydropeaking seem to be less defined in literature. The cost-effective operation of a hydropower plant while attenuating the peak flows seem to be the main problem.
- No published references to specific mitigation measures for hydropower installations in Mediterranean rivers have been found. In the EIA Foz Tua (2008) it is also stated that good guidelines for Mediterranean fish passes are currently lacking. The main problem at the moment is the low efficiency level the current fish passes are lacking at and the absence of fish passes at certain barriers which often prevents the migration of fish in the river basin at other locations than the planned hydropower station.

As part of task 2b, 2 types of mitigation measures will be looked at during the scenario analysis of the PNBEPH dams: minimum flow and fish passes.

- Scenario 1: without consideration of minimum flows, i.e. linked to the maximum energy production as predicted in the PNBEPH.
- Scenario 2: considering some mitigation measures are implemented (minimum flow only).
- Scenario 3: considering mitigation measures are implemented (both minimum flow and fish passes).

1.3 Conclusions: scope of the study, indicators and main impacts to be considered, mitigation measures evaluated

Scope of the study
For the part of the ecosystem to be considered, we only consider the effects of hydropower stations on **surface water based on the elements given in Table 30**. (no major effects on groundwater quantity and quality has been identified, although the installation and use of hydropower installations will have an indirect effect on the aquifers caused by the changed hydrological regime of the river). **Terrestrial effects** will be additionally looked at as part of the objectives related to protected zones (Task 2c)
Similarly, an **effect on specific pollutants** (as required by the WFD) has not been identified as primary impact and will not be taken into account in this study. Toxic release however can happen in the reservoir due to (1) release of chemicals bound to sediments due to changed physical-chemical conditions (2) the release of toxins by blue-green algae blooms and (3) possible contamination during

installing and operating hydropower stations
For this study, we only consider the effects of planned hydropower stations on **rivers** (running waters). **Lakes** will be looked at as part of studying the impacts **on existing reservoirs**. Taking into account the location of planned hydropower installations and the extent of impacts as described (see further on extent of impact) the impact on **transitional and coastal water bodies** as described by the WFD will only be taken into account indirectly in terms of effects of coastal erosion and effects related to fish migration.
Objectives to be assessed
The WFD **objectives Good Ecological Status** (or Good Ecological Potential) and **no deterioration in status are the key objectives that will be assessed in this study (Table 28)**. The idea of **undisturbed fish migration** will be assessed only in the case a proper fish classification tool compliant with WFD requirements is missing.
Indicators to be used
The main indicators to be used will be the biological WFD elements together with the hydro-morphological quality elements available (physical-chemical elements need to support biological communities and will as such be reflected in biological scores). The importance of each of the indicators is indicated in. For rivers the main elements to be used for estimating possible impacts by hydropower are marophytes, macroinvertebrates and fish (Table 31). To estimate the impact on existing reservoirs, we will look at available assessment based on phytoplankton, macroinvertebrates and fish communities (**Table 32**). Classification tools with the produced EQRs for these elements need to be made available by the Portuguese authorities and the assessment will be done in Chapter 4.
Impacts to be evaluated
Based on the overall literature review of hydropower impacts and the published literature available about hydropower impacts in Portuguese river basins, the major impacts to be looked for evaluating PNBEPH impacts in Portegese river basins are: • Changed sediment patterns • Changed flow and habitat conditions • Barrrier function • Changes in nutrient (and organic) conditions The actual impact will depend on the sensitivity of the river basin, which is mainly depending on its natural characteristics and the range and magnitude of existing pressures. This will be taken into account when performing the ecological impact analysis.

Effects and benefits of mitigation measures
The following mitigation measures seem to be the most effective with regard to mitigation of hydropeaking: • Fish passes • Natural flow variations • Minimum flow • Attenuation of hydropeaking However, when looking at the cost-effectiveness of the approach, especially the attenuation of hydropeaking seem to be difficult to realise. In this study, it was asked for to look at the effect of minimum flow conditions and/or fish passes and this will be looked at as part of task 2b.

2 Task 2b: What is the likely effect of each dam in the water environment from the perspective of the WFD ecological status (upstream and downstream)? What are the (accumulative) effects of each dam or group of dams in the water environment and uses in the river basins they are located, taken into account their current situation?

2.1 Methodology of evaluation

For determining the methodology of the impact evaluation on the WFD status, we have posed the following questions:

- **What are the main impacts to be considered?** This has been summarised in Section 1.1 and we will start from the four main impacts as identified in Section 1.3
- **What data are available for this study?** The applied methodology will however depend on the data available for this study and this will be further discussed In Section 2.2. Data gaps that have an effect on the objective evaluation of the study will be futher discussion in this Section.
- **How would we perform the ecological impact assessment?** Although this is mainly dependent on the available data, the starting point will be the objectives as set by the WFD and the biological elements to be considered (this has been discussed in Section 1.1.2.3 and summarised in Section 1.3.
- **What is required according to the provisions of the WFD** (2000/60/EC) and how does this need to be integrated in the SEA (2001/42/EC)?
- **How could we make an approximation of the spatial extent of effects of the hydropower dams?** We will look at upstream and downstream effects of each of the dams in Section 2.1.3
- **How could we describe the cumulative impacts?** We will discuss the cumulative impacts using fish as a key indicator (Section 2.1.4)

2.1.1 Requirements of SEA and WFD in accordance to the PNBEPH

2.1.1.1 SEA and WFD - requirements

The assessment of whether the WFD criteria are met for the PNBEPH need to be carried out in the planning stage. For plans and programmes affecting the environmental objectives of the WFD, the evaluation in accordance to 4(7) should be incorporated into Strategic Environmental Assessment (Directive 2001/42/EC) as explained in the CIS document on environmental objectives. This requirement is given in the guidance document on the SEA (SEA Guidance, 2004).The relevant section in relation to the compliance with the SEA for the PNBEPH is given below, including the reference to Annex I.

Directive 2001/42/EC Art 5.1. *Where an environmental assessment is required under Article 3(1), an environmental report shall be prepared in which the likely significant effects on the environment of implementing the plan or programme, and reasonable alternatives taking into account the objectives and the geographical scope of the plan or programme, are identified, described and evaluated. The information to be given for this purpose is referred to in Annex I. Art 5.3 Relevant information available on environmental* *effects of the plans and programmes and obtained at other levels of decision-making or through other Community legislation may be used for providing the information referred to in Annex I.*

ANNEX I
Information referred to in Article 5(1)
The information to be provided under Article 5(1), subject to Article 5(2) and (3), is the following:

a) an outline of the contents, main objectives of the plan or programme and relationship with other relevant plans and programmes;

b) the relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme;

c) the environmental characteristics of areas likely to be significantly affected;

d) any existing environmental problems which are relevant to the plan or programme including, in particular, those relating to any areas of a particular environmental importance, such as areas designated pursuant to Directives 79/409/EEC and 92/43/EEC;

e) the environmental protection objectives, established at international, Community or Member State level, which are relevant to the plan or programme and the way those objectives and any environmental considerations have been taken into account during its preparation;

f) the likely significant effects (1) on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors;

g) the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme;

h) an outline of the reasons for selecting the alternatives dealt with, and a description of how the assessment was undertaken including any difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information;

i) a description of the measures envisaged concerning monitoring in accordance with Article 10;

j) a non-technical summary of the information provided under the above headings.

(1) These effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effect

2.1.1.2 Exemption procedure WFD

According to the Portuguese authorities (Letter INAG responding on questions from EC) the WFD objectives were taken into account within the Water resources criterion (Natural Resources critical factor) using the information form Article 5 report. The classification of the water bodies made possible to locate the different projects within “under risk of not reaching the WFD objectives” areas, and also most of the projects are in rivers with some fragmentation level.

The assessment stood out the conflicts between the PNBEPH and the WFD (article 4 objectives) and proposed two solutions:

1. Analysis of article 4, point 7, of WFD (Member State not in breach of this Directive because of failure to achieve good status)
2. Identification of the main mitigation measures within the Environmental Impact Statement.

The WFD has also been taken into account within the Biodiversity critical factor (Naturalness level).

An evaluation of the impacts considered and the WFD compliance of the parameters used in the SEA of the PNBEPH and can be found in Task 3b.

2.1.1.3 WFD and the SEA Directive in relation to the expected output of Task 2b

In Section 1.3, we have summarised the scope of the study for the impact assessment to be performed in Task 2b. Here we can see that the scope set earlier based on the WFD requirements is in agreement with those set with the SEA requirements. As such, it can be concluded that the ecological impact analysis peformed as part of this task 2b should cover the gaps from the PNBEPH SEA analysis.

- With regard to the **ecological impact assessment** that is the key question for this task, we will use the data available that do allow an assessment of the **objectives** as set by the **WFD**, taking into account the quality elements that need to be considered for a compliant WFD assessment (**Fout! Verwijzingsbron niet gevonden.**). The SEA Directive indeed asks that **environmental protection objectives**, established at international, Community or Member State level, which are relevant to the plan or programme need to be looked at.
- With regard to the **impacts to be evaluated**. These are based on the literature review summarising the main impacts of hydropower stations on river basins, with special focus on published case studies from Portuguese rivers; this is summarised in Section 1.3. The SEA Directive requires to look at the **significant effects** on all parts of the environment
- The **effect of mitigation measures**, an aspect that is required for requesting exemption of achieving the WFD objectives (as given in Art 4.7 of the Directive), will be evaluated in the different scenarios considered for the measures 'minimum flow' and 'fish passes'. The SEA Directive also asks to **detail the measures envisaged** to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme;

2.1.2 Ecological assessment for the different scenario's

On the basis of the information for each of the dams and the cartography available, an expert assessment of the impacts in the water environment is performed, with 3 scenarios:

- **Scenario 1: without consideration of minimum flows, i.e. linked to the maximum energy production as predicted in the PNBEPH**

The biological elements considered for each of the main impacts are summarised in the conclusion of task 2a in Section 1.2.6. This will mainly depend on the data provided by the Portuguese authorities and the availability of other relevant data (Data availability is summarised in Section 2.2).

The assessment will be done in two ways, i.e. by analysing (1) effects of existing hydropowers on biological communities and (2) estimated effects of the planned hydropower station on the existing biological communities up to a certain distance of the locations.

- **Scenario 2: considering some mitigation measures are implemented (minimum flow only)**

The minimum flow scenario is described in Task 1a. The minimum flow defined is based on the Tennant method. The Tennant's method is adapted considering the hydrological and ecological characteristic of the rivers in the Iberian Peninsula (see Table 35 below). For Task 1 energy production has been calculated based on **good and fair quality.** It is taken into account that if the monthly natural flow statistic is lower than the calculated flow, the mean monthly flow is set as minimum flow.

Table 35: Base flow regime recommended for the Douro, Tejo and Guardiana international rivers basins (based on adapted Tennant method)

Description of flows	June-September (dry season)	April, May, October, November	December-March (humid season)
Excellent	40%	50%	60%
Good	30%	40%	50%
Fair or degrading	10%	20%	30%
Poor or minimum	10%	10%	10%
Severe degradation		0-10%	

Although having the minimum flow determined for each of the rivers, the extrapolation to what to expect in terms of fish (and other biological) communities is a difficult exercise.

A suitable ecological flow should be calculated for each particular project using a detailed method (e.g. the Flox Incremental Methodology (IFIM) as explained earlier in Task 1a in the chapter reviewing minimum flow methodologies), but this is not possible within the present study. The IFIM considers the particular features in a river stretch and the ecological needs of the fish species that are to be preserved. As such the values obtained are only valid for a particular site (dependent on river bed morphology, etc.) and for certain species. To apply such method you need to determine the "habitat preferences" for the target species in that river. "Habitat preference curves" have been determined for some species in some rivers in Spain (e,g. *Barbus bocagei, Chondrostoma polylepis* and *Leuciscus pyrenaicus* in the Tejo river), which establish the preference of each species (in the different stages of their life cycle) in relation to certain parameters (velocity, depth, substrate, refuge) of the physical habitat. We have summarised this information in **Annex 16:** Habitat preferences for some fish species (Spain and Portugal)'. Determining such habitat preferences requires detailed field studies including diving, in order to define the parameters (depth, velocity, etc.) in the areas preferred or selected by each species. A habitat modelling (simulation) can then be made considering different flow values to determine the appropriate minimum flow to allow for the maintenance of the target specie sin the river strecth.

Minimum flows are necessary, among other reasons; to **maintain suitable habitat conditions for the fish species that live in the river**, but also for the maintenance of **riparian vegetation** (e.g. riparian galleries) that depend on flood at certain times. But **you cannot set standards**, e.g. for fish species, you cannot say a species needs an X flow, this kind of generalisation is not possible. The flow required at a certain site depends on the river features at that site (width, depth, etc.) which will determine the amount of water that should be released, as minimum flow, to maintain certain habitat conditions that are adequate for certain species. You would also need to know the habitat preferences for the species you would like to maintain in the river, in terms of depth, velocity, type of substrate in the river bed, etc. In this regard, there is some literature about habitat preferences for some species in some particular rivers. This information (e.g. fish habitat preference curves) could be used for other similar rivers but cannot be extrapolated to rivers with different conditions and features.

- **Scenario 3: considering mitigation measures are implemented (both minimum flow and fish passes).**

The effect of installing a fish trap will be assessed using information on fish pass efficiency at dams and weirs, the monitoring results of fish species near the locations of the planned dams and information on their habitat requirements.

2.1.3 (Spatial) Extent of effects

2.1.3.1 Introduction

A hydropower station under operation can have an impact that reaches further than the water body the hydropower station is located in. As such, with regard to effect on the ecological status of the water bodies, one need to look at the impacts caused by the operation of a hydropower station on adjoining water bodies and even on the whole river basin. This criterion is also included in the WFD (***Art 4.8****: When applying paragraphs 3, 4, 5, 6 and 7* (art 4.7 is relevant to the extension asked for for realisation of the PNBEPH), *a Member State shall ensure that the application does not permanently exclude or compromise the achievement of the objectives of this* ***Directive in other bodies of water within the same river basin district*** *and is consistent with the implementation of other Community environmental legislation).*

Also, the World Commission on Dams (WCD) has stressed that the impacts of a dam may occur a great distance from where it is built. The environmental consequences of impoundment cannot be considered in isolation but must be considered within the context of the whole river ecosystem including the coastal zone.The impacts of a dam may occur a great distance from where it is built (Mc Cartney et al., 2000).

In this section, we will explain the development of a method for the assessment of how far the impacts of a hydropower station in operation can reach upstream and downstream. The analysis done is only relevant in terms of evaluation of the extent of effect and not with regard to the absolute numbers as the assessment made is making broad approximations. The assumptions taken in the development of the methodology do (1) neglect all other information on other pressures/natural characteristics affecting the flow conditions and (2) also do not take into account the different modes of operations during time. However, we believe the assessment made is appropriate for the scale of assessment as asked for.

2.1.3.2 Methodology

Impacts

As concluded in the report (section 1.1.3) the following impacts were defined as critical with regard to the planned hydropower stations on the river systems: (1) changed sediment patterns, (2) changed flow and habitat conditions, (3) barrier function, (4) changes in nutrient (and organic) conditions. It is for (1), (2) and (4) that one could try to give a general approximation of the length of affected river stretches upstream and downstream of the hydropower station with a subsequent effect on the ecological status of the water bodies that are located up to that distance.

Upstream

The length of impact upstream is measured by means of the length of the reservoir. One can consider that over that distance flow conditions change (flowing to standing water) as well as the habitat (riverbanks get flooded) with knock-on effects on the nutrient and organic conditions of the water in the then developed reservoir.

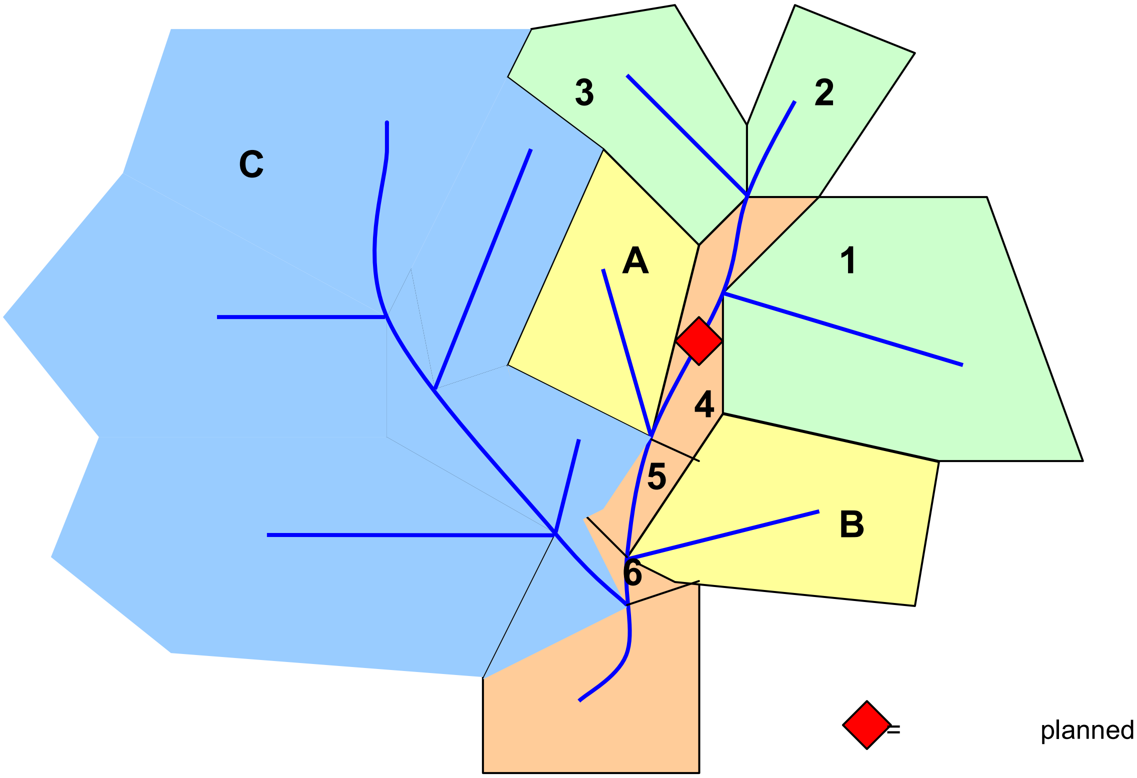
Downstream

To measure the length of impact downstream, a series of rules is needed based on some assumptions i.e. that (1) tributaries on the river downstream of the planned hydropower station can possibly attenuate the changes in flow levels (hydropeaking, min flows) caused by hydropower operation (2) that the effect of changed flow levels is negligible at the location where the river flows into an existing reservoir and (3) that the changes in flow levels (hydropeaking) also fades out over a certain distance from the hydropower station under operation (however, this rule has not been included in the applied methodology). One can consider that in the downstream reaches, the effect will consist of changed flow and habitat conditions, changes in nutrient/organic conditions and the sedimentation process. Also the barrier effect will be shown but only taking into account the stretch of river up to the nearest other dam. All these parameters will have an effect on the ecological status of the water bodies up to a certain extent downstream of the hydropower location.

With regard to the attenuation of the effect of changed flow conditions and subsequent impacts, the following rules have been followed: The size of the catchment of the tributary in comparison to the size of the catchment of the river in which the hydropower is located is considered as a way to estimate the capacity to attenuate the changes in flow levels caused by the hydropower station. The %catchment area upstream of the confluence with the tributary over the catchment area of the tributary is categorized is looked at in a cumulative way when looking to downstream affects of a range of tributaries. This is explained in **Illustration 18**.

Illustration 18: Methodology for determining of downstream attenuation of flow changes

Methodology possible attenuation downstream by confluence with tributary of river in which hydropower station is operating



When using the sub-basin delineation as done for the river basin characterization as part of Art 5 WFD river basin characterization process (Art 5 maps available from Intersig website)

Possible attenuation of confluence of river from sub-basin A

Surface area sub-basin A = X and Surface area basin area upstream of confluence with river A = Surf(1+2+3+4) = Y

1. If X/Y = 50% then no attenuation of flow changes at location of confluence
2. If X/Y = 50-100% then significant attenuation of flow changes at location of confluence
3. **If X/Y = >100% then complete attenuation of flow changes at location of confluence then distance of effect downstream is length up to confluence with tributary of river basin A.**

If (1) or (2) then assess further attenuation of confluence with river of sub-basin B

Surface area sub-basin B = Z and Surface area basin upstream of confluence with river B =Y+ 5 + A = O

4. If X/Y + Z/O = 50% then no attenuation of flow changes at location of confluence
5. If X/Y + Z/O = 50-100% then significant attenuation of flow changes at location of confluence
6. **If X/Y + Z/O = >100% then complete attenuation of flow changes at location of confluence which means that the distance of effect downstream is length up to confluence with tributary of river basin B.**

If (4) or (5) then asses further attenuation by confluence with river of sub-basin C

Surface area sub-basin C = P and Surface area basin upstream of confluence with river B = Surf (O + 6) = Q

7. If X/Y + Z/O + P/Q = 50% then no attenuation of flow changes at location of confluence
8. If X/Y + Z/O + P/Q = 50-100% then significant attenuation of flow changes at location of confluence
9. **If X/Y + Z/O + P/Q = >100% then complete attenuation of flow changes at location of confluence which means that the distance of effect downstream is length up to confluence with tributary of river basin C.**

And so on…

2.1.4 Cumulative impacts

To assess the cumulative impacts of the PNBEPH dams, the most sensitive indicator (i.e. the fish populations) has been used for assessing effects at the river basin scale. Information on fish populations currently present in the area close to the planned dams, as well as the number and location of existing dams in the river basins of the planned dams will be looked at to make an overall assessment.

2.2 Data availability for the ecological assessment of impacts on the aquatic ecosystem by the PNBEPH

2.2.1 Overview of data

Table 36: Overview of data available for the ecological assessment of impacts on the aquatic ecosystem by the PNBEPH

Natural characteristics / Impacts	Indicator	Data available	Data delivered by INAG (WFD assessments)
Information on the planned dams (PNBEPH)		**PNBEPH:** maps and technical details	
Characteristics of the river basin	River basin/ River/ Reservoir /HMWB identification	WFD Art 13 river stretches, river basins	
	Sensitivity of river basin towards additional pressures	Risk assessment data Art 5/Art 13 (SEA; Intersig and River basin level risk assessment provided by INAG) Intersig Art 5/Art 13 Sensitive and vulnerable zones (according to Nitrates Directive and UWWTD) Intersig Art 5/Art 13 (fish protection zones) Existing (and planned) dams (snirh dados de base)	In the risk assessment layer at Intersig, water bodies are designated as being 'at risk', 'not at risk' or 'yet to be determined'. (*note Art 5 risk assessment is different and it is assumed this is a preliminary risk assessment as used for the SEA. For this study we have looked to the more recent Art 13 risk assessments*). INAG has not given details on the pressures at water body scale, only an overview of pressures at river basin scale is given. Details on existing and planned dams (Usos_Barragens.xls) and the existence of fish passes (although information is incomplete) is given by INA.
	River typology	WFD river types (Art 5)	
	Reservoir typology	All reservoirs are type Norte or curso principal (Art 5)	
Overall effect (integrated evaluation)	Fish	Aquariport project: Fish densities (individuals/ha) in each of the 130 sampling sites in Douro basin: Mondego basin: Tejo Basin and Vouga basin) (Oliveira et al., 2007)	There are no WFD status assessments made for any of the biological quality elements (and no chemical and hydropmorphological status assessments either).

Natural characteristics / Impacts	Indicator	Data available	Data delivered by INAG (WFD assessments)
		Carta Piscicola Nacional: Iberian endemic spp., Portuguese endemic spp. Literature review (Oliveira, 2007): only for Tejo river basin Red list fish species + habitat requirements (www.fishbase.org) Rui Cortes et al. (2008); ADISA (2008): (EQR preliminary assessment)	We only have received data from 73 stations out of the 128 requested, and only 18 out of this 73 contain biological data (macrophytes, fish, phytoplankton, macroinvertebrates).
	Macroinvertebrates	Red list Macroinvertebrate species Cortes et al. (2008)	
	Macrophytes	Cortes et al. (2008)	
	Phytoplankton	/	
Changed sediment patterns (and general habitat conditions)			
Upstream (reservoir)		Risk assessment reservoirs (Intersig data lakes)	
Downstream		PNBEPH and SEA on coastal erosion Literature review (SEDNET report)	
Changed flow conditions (and general habitat conditions)	Fish		
Upstream (reservoir)	Fish	Fish exotic species (Carta Piscicola Nacional) Literature review (Almeida et al., 2002; Collares-Pereira et al., 2000)	
Downstream	Fish		
Barrier function	Fish (catadromous and anadromous)	Fish passing efficiency (Santo, 2005)	

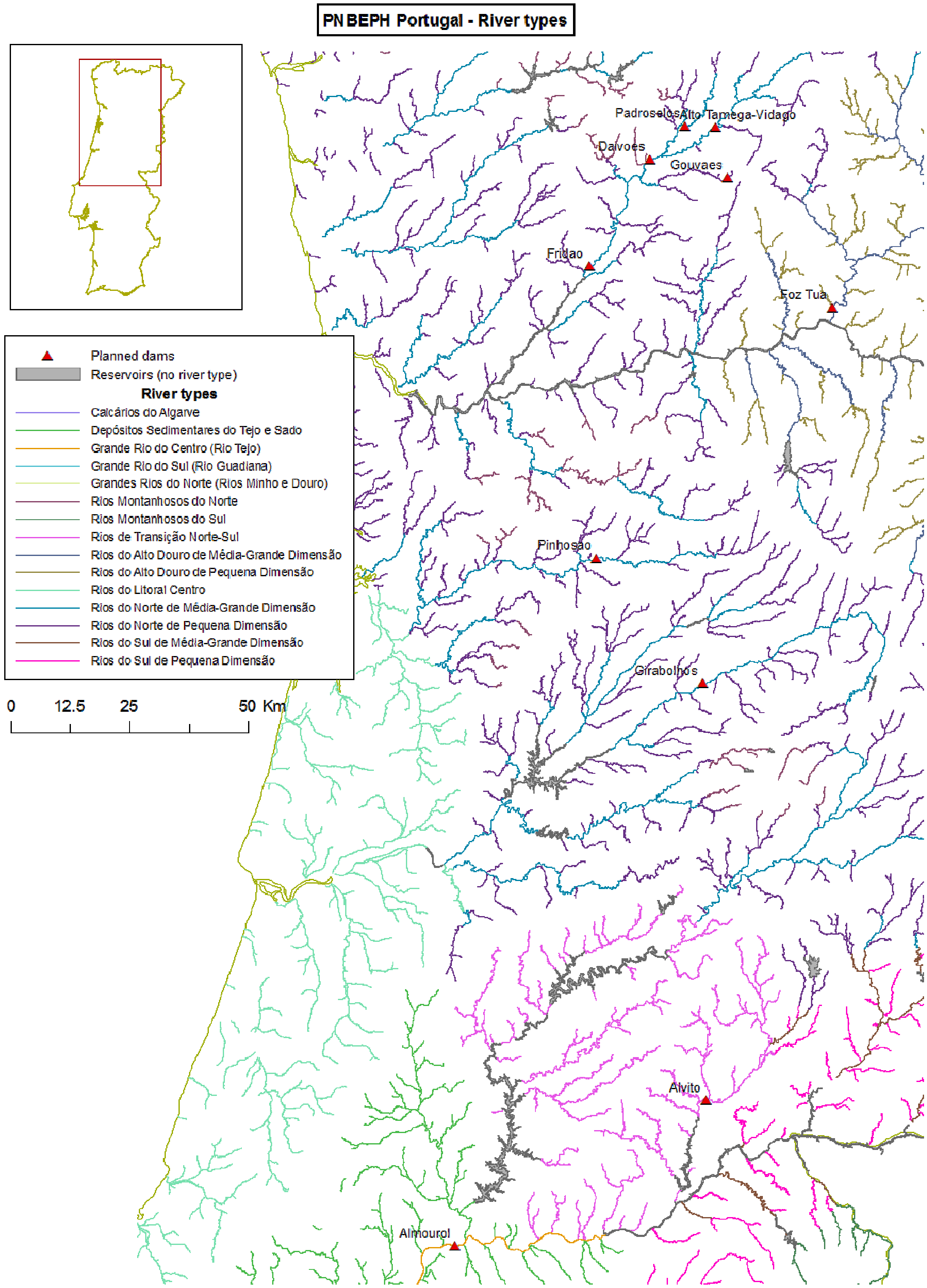
Natural characteristics / Impacts	Indicator	Data available	Data delivered by INAG (WFD assessments)
Changes in nutrient (and organic conditions)	Phytoplankton Macroinvertebrates	Literature review (Ferreira & Rodrigues, 2001; Ferreira & Godinho, 2002). Literature review (Cortes et al., 1998) Risk assessment + info from SEA Fish exotic species	
Scenario 2	Min Flow	See Task 1 review on minimum flow	
	Flow requirements biological elements (fish)	Detailed information from Tennant min flow method adapted to Portuguese river basins	
Scenario 3	Min Flow	No data available at the scale needed	
	Fish pass	Aquariport Carta Piscicola Nacional Literature review (Kroes et al., 2006 ; Santos et al., 2002) Fish passing efficiency (Santo, 2005)	

2.2.2 Description of the data to be used

2.2.2.1 River Typology (WFD, Article 5)

The natural characteristics of the river basins determine the sensitivity of the river basin and the possible impacts on the aquatic ecosystem. As part of the WFD requirements, all Member States need to set a typology as part of the river basin characterization process. Typology is defined as the characterisation of all water bodies based on physical factors and is one of the supporting factors in determining ecological status. The river typology for Portuguese rivers is given in **Illustration 19** and is mainly based on the size and the geographical position of the river basin and can be described based on the mean annual temperature, the precipitation, the altitude, dimension of the drainage area, air temperature and longitude/latitude, size and the geographical position of the rivers (INAG, I.P.,2008). The type for each of the locations of the selected PNBEPH dams is given in **Table 37**.

Illustration 19: WFD typology for Portuguese rivers (Art 13 report[4])



Layers: ART13_MRIOS_PTCONT_0_656.shp, ART5_MLAGO_PTCONT_0_237.shp, PNBEPH_dams.shp
Projection: Lisboa Hayford Gauss. Sources: INAG-InterSIG and ATECMA SL. March 2009.

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4 http://intersig-web.inag.pt/intersig/

Table 37: River type for the PNBEPH dams (Art 5, Art13)

Project/ dam	River	Affluent of	HR	River types
Foz Tua	Tua	Douro	Douro	Rivers of the upper Douro of Medium-High dimesion (Rios do Alto Douro de Média-Grande Dimensão – Tipo N2)
Padroselos	Beça	Tâmega	Douro	Northern rivers of Medium-High dimesion (Rios do Norte de Média-Grande Dimensão – Tipo N1;>100)
Alto Tâmega (Vidago)	Tâmega	Douro	Douro	Northern rivers of Medium-High dimesion (Rios do Norte de Média-Grande Dimensão – Tipo N1;>100)
Daivões	Tâmega	Douro	Douro	Northern rivers of Medium-High dimesion (Rios do Norte de Média-Grande Dimensão - Tipo N1;>100)
Fridão	Tâmega	Douro	Douro	Northern rivers of Medium-High dimesion (Rios do Norte de Média-Grande Dimensão - Tipo N1;>100)
Gouvães	Louredo	Tâmega	Douro	Northern rivers of Small dimesion (Rios do Norte de Pequena Dimensão – Tipo N1; <=100)
Pinhosão	Vouga	x	Vouga	Northern rivers of Medium-High dimesion (Rios do Norte de Média-Grande Dimensão) Tipo N1;>100)
Girabolhos	Mondego	x	Mondego	Northern rivers of Medium-High dimesion (Rios do Norte de Média-Grande Dimensão) Tipo N1;>100)
Almourol	Tejo	x	Tejo	Big rivers (Grandes rios – Tipo S3)
Alvito	Ocreza	Tejo	Tejo	North-South Transition Rivers (Rios de Transição Norte-Sul – Tipo N4)

2.2.2.2 Risk assessment data (WFD Article 5, Art13)

The river basin characterization report (art. 5 WFD) describes the methodologies and provides summary general information for each River basin district. This report summarily describes the significant pressures (point and diffuse pollution sources, water abstraction, etc.) for the 8 Hydrographical Regions (River basin districts) and then provides some information about the water bodies classified “at risk” ”doubtful” and “not at risk”, giving the corresponding numbers and percentages for each Region, but without detailed information for each river. The main parameters used for assessing the pressures are: organic matter, Nitrogen, Phosphorous, Biological Oxigen Demand, Chemical Oxigen Demand, Pollutants (priority and other).For the identification of water bodies at risk, the following elements were considered:

- Biological elements: Macroinvertebrates and Phytoplancton (chlorophyle a as indicator of biomass);
- Physical-chemical elements: Temperature and Oxigen conditions, acidification status, nutrient conditions, chemical conditions, non compliance with other EU Directives, pollutants (non priority);
- Hydro-morphological conditions.

The first risk analysis done by the INAG was in 2005 (Article 5 report - WFD) and and these preliminary risk assessment results for the WFD (Art 5) have also been used in the SEA of the PNBEPH as part of the parameter ‘Degree of naturalness of the water bodies affected by the reservoirs'. However, by the time of the report, the risk analysis for the draft RBMPs had been updated (Art 13 report[5]) and we have used this further to define the 'at risk' or 'not at risk' status of the water bodies. The risk map is given in **Illustration 20**.

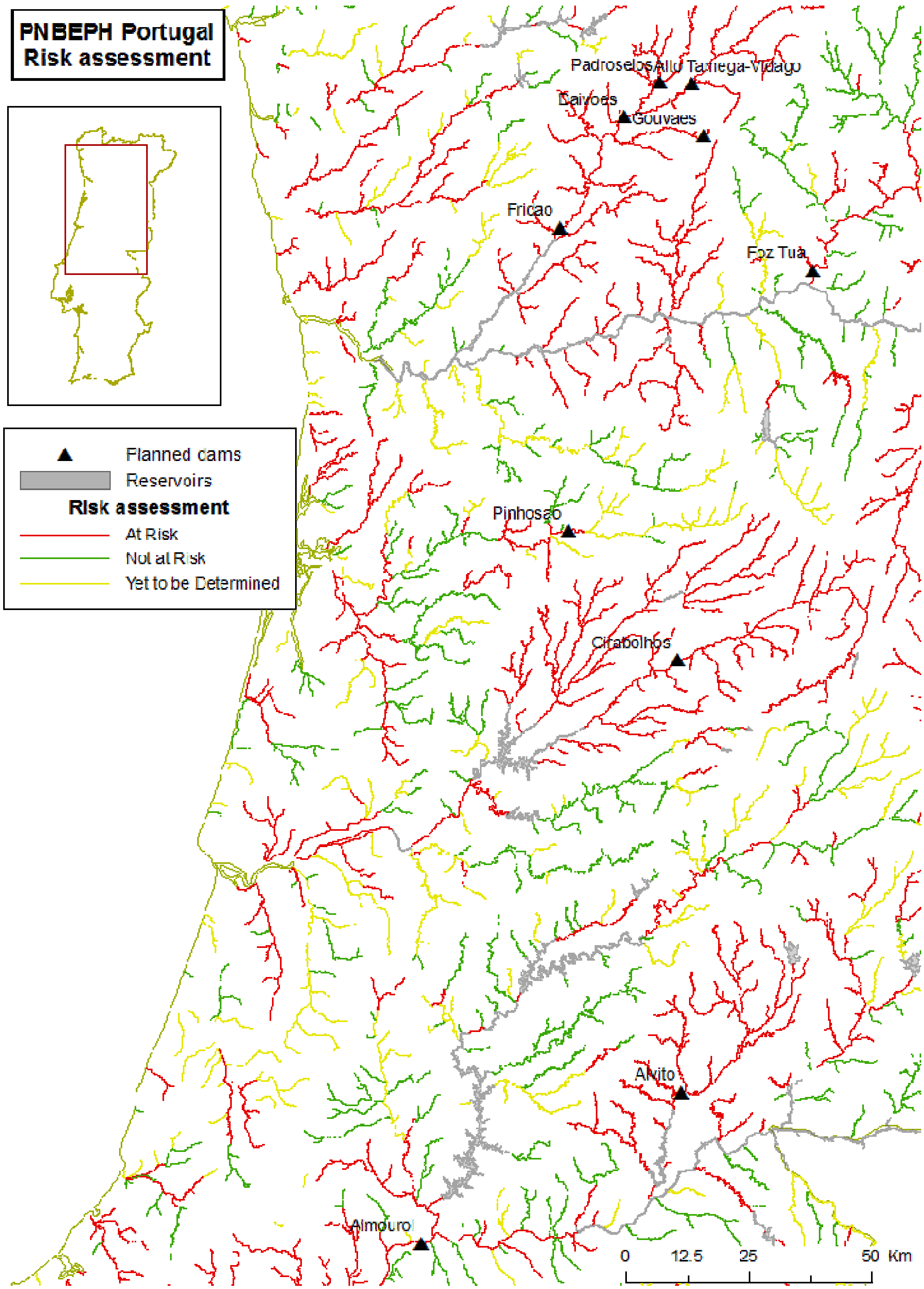
We had requested the following information from the Portuguese authorities: significant pressures and impact of human activity on the status of surface water, including:

- Estimation of point source pollution,
- Estimation of diffuse source pollution, including a summary of land use,
- Estimation of pressures on water quantity including abstractions,
- Analysis of other impacts of human activity on the status of water;

However, only a reference to the Art 5 maps were given, and an overview of pressures was given on river basin scale (**Table 38: Significant aspects to be taken into account for water management as identified during the WFD Art. 5 risk assessment analysis for the Douro (D), Vouga-Mondego (VM) and Tejo (T) river basin**

[5] http://intersig-web.inag.pt/intersig/

Illustration 20: WFD risk assessment of Portuguese rivers (Art 13)



Layers: ART13_MRIOS_PTCONT_0_656.shp, ART5_MLAGO_PTCONT_0_237.shp, PNBEPH_dams.shp
Projection: Lisboa Hayford Gauss. Sources: INAG-InterSIG and ATECMA SL. March 2009.

For the Douro, the Vouga-Mondego and the Tejo river basin, the following significant aspects to be taken into account for the Programmes of Measures to reach the objectives as set by the WFD were identified (**Table 38** provided by INAG).

Table 38: Significant aspects to be taken into account for water management as identified during the WFD Art. 5 risk assessment analysis for the Douro (D), Vouga-Mondego (VM) and Tejo (T) river basin

Significant aspects to be taken into account for water management	Região Hidrográfica		
	D	VM	T
Water supply from Spain	X		X
Waters enriched with nitrates and phosphorous	X	X	X
Alterations in fauna and flora	X	X	
Alterations in the sediment dynamics (erosion and siltation)	X	X	
Alterations in the flow regime	X		
Groundwater pollution	X		X
Degradation of coastal zones	X	X	
Water shortage	X	X	
Eutrophication	X	X	X
Floods	X	X	X
Heavy metal contimation			X
Contamination with dangerous substances and priority dangerous substances		X	X
Microbiological pollution	X	X	X
Organic pollution (BOD_5, NH_4-N)	X	X	X

2.2.2.3 Protection zones

The protection zones are displayed in **Illustration 21**. This considers the zones of Community interest (European Nature Directives), Nutrient Sensitive Zones (Urban Wastewater Treatment Directive (UWWTD)), Nutrient Vulnerable Zones (Nitrates Directive) and the fish protected zone. The sites of Community interest will be looked at as part of Task 2c and not further discussed here.

The UWWTD - Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment - concerns the collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors.

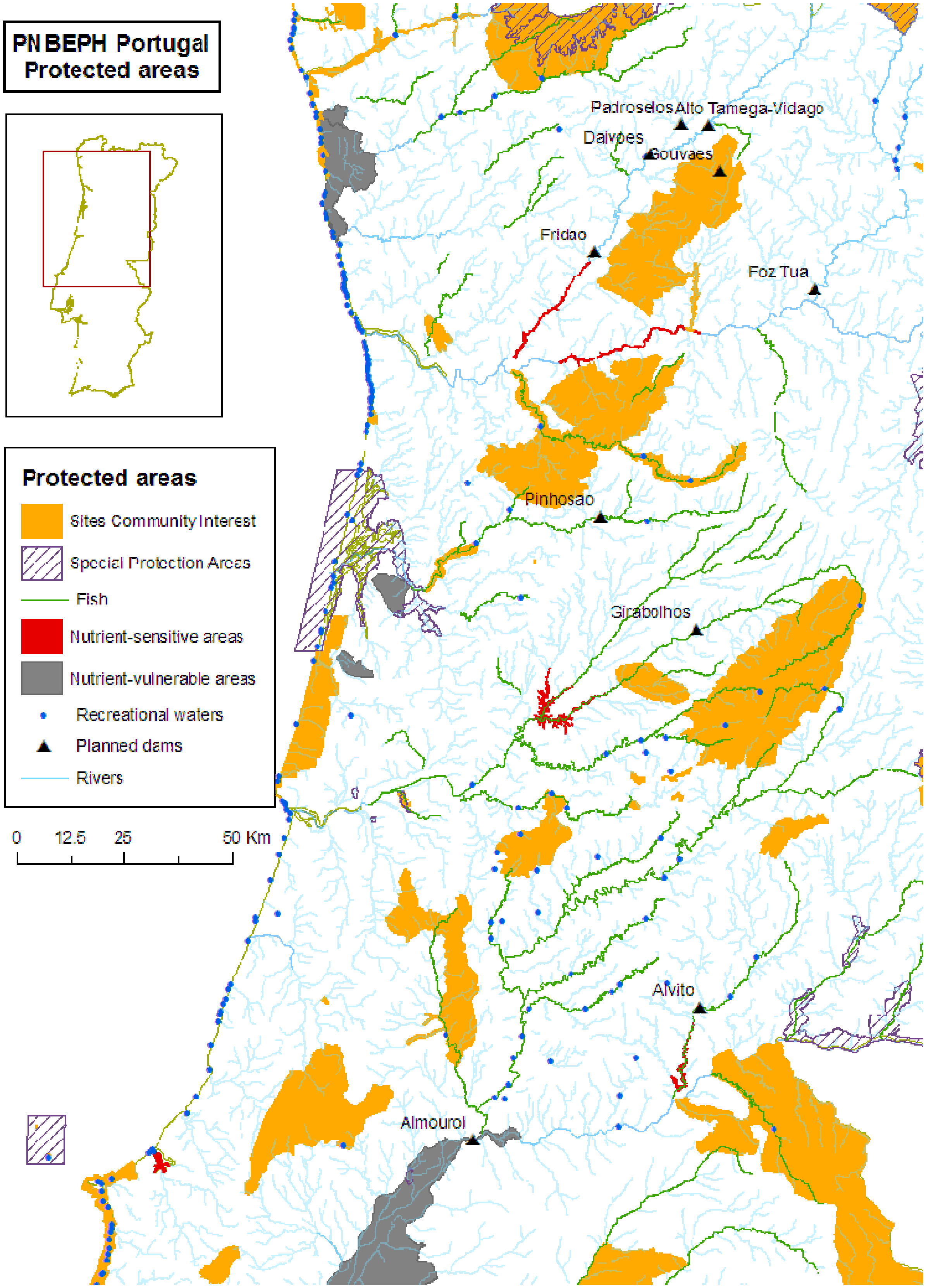
The nitrates Directive - Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources - is designed to protect the Community's waters against nitrates from agricultural sources, which are the main cause of water pollution from diffuse sources.

The delineation of the zones for these 2 Directives (sensitive zones (UWWTD) and vulnerable zones (Nitrates Directive) is discussed in Section 1.1.4 - **Table 33: Table in which it is described how natural characteristics and the presence of existing pressures in a river basin (applied to the Portuguese river basins considered in the study) determine the sensibility of a certain river basin for the impact of hydropower installations**

The risk of real impact because of nutrient enrichment in these delineated zones is higher because of the sensitivity of the zones for eutrophication.

For the fish protected zones, waters that host fish of economic importance (eg eel) are protected in this way.

Illustration 21: Protected zones



Layers: ART13_ZP_PRAI_PTCONT_1_470.shp, ART13_ZP_PISC_PTCONT_0_722.shp, ART5_MRIOS_PTCONT_0_238.shp, ART13_ZP_AVES_PTCONT_0_459.shp, ART13_ZP_HABI_PTCONT_0_460.shp, ART13_ZP_ZSEN_PTCONT_0_340.shp, ART13_ZP_ZVUL_PTCONT_0_334.shp, ART3_RIOS_PTCONT_0_188.shp, and PNBEPH_dams.shp. Projection: Lisboa Hayford Gauss. Sources: INAG-InterSIG and ATECMA SL April 2008.

2.2.2.4 List of existing dams and fish traps

To obtain information on existing dams, reservoirs and weirs located on the rivers affected by hydropower installations of the PNBEPH, the following sources of information used for the analysis are:

- Data on existing dams provided by Portuguese authorities. An extract of the dataset (only those dams in the Douro, Vouga-Mondego and Tejo River Basin selected and some features not displayed). A full list is is given in Annex 13. These are plotted on the map as 'Hydrpower Plants' displayed in **Illustration 22: Location of reservoirs and PNBEPH dams**
- WFD Art. 13 GIS file, downloaded from INAG's InterSIG website[6]. ('Dams/Reservoirs' on the map of **Illustration 22**)
- Atlas do Ambiente Digital. Ministério do Ambiente, Ordenamento do Território e Desenvolvimento Regional. Agencia Portuguesa do Ambiente[7] ('Other reservoirs' on the map of **Illustration 22**)

An overview of existing dams in the north and mid region of Portugal is given in **Illustration 22: Location of reservoirs and PNBEPH dams**

Table 39 contains a summary of dams located on the rivers affected by the planned dams, as well as the type of reservoir and the presence of fish devices. **Illustration 22** shows the location of existing dams and reservoirs and PNBEPH dams.

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6 http://intersig-web.inag.pt/intersig/

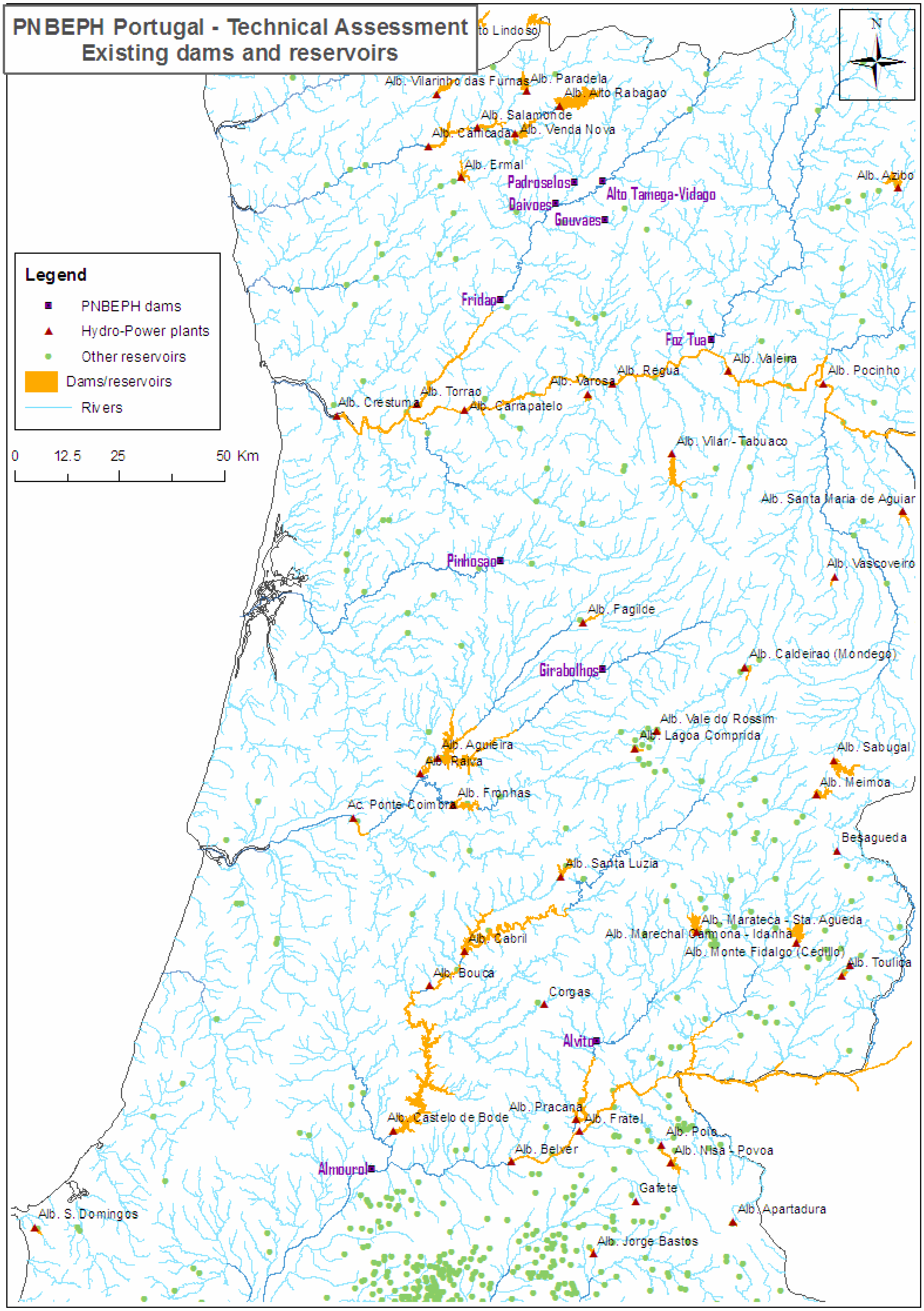
7 http://www2.apambiente.pt/atlas/est/index.jsp

Table 39: Summary of existing dams close to the PNBEPH dams

PNBEPH dams	River	Dams on the same river	Location in relation to PNBEPH dams	Type/use	Fish passes
Alto Tâmega –Vidago	Tâmega	Acude Veiga-Chaves	42,7km upstream Alto Tâmega dam.	Irrigation	no data
	Tâmega	(No name available)	31km upstream Alto Tâmega dam.	Small Hydro-power	no data
Fridão	Tâmega	Torrao	The dam is located about 30,8km downstream Fridão dam. Its reservoir extends up to 4,2km from Fridão dam.	Hydro-power. Drinking water supply	NO
Padroselos	Beça	Barragem de Bragadas	It hasn't been possible to estimate the distance to Padroselos dam since the layers available do not contain this dam.	Small Hydro-power	-
Gouvães	Louredo	(No name available)	8,8km upstream Gouvães dam.	Small reservoir. Not defined use	no data
	Louredo	(No name available)	11,5km downstream Gouvães dam.	Small Hydro-power	no data
Foz do Tua	Douro	Albufeira de Regua	Regua's reservoir occupies the Douro river stretch where the Tua river ends (about 3km from Foz Tua dam).	Hydro-power. Drinking water supply. Navigation	YES. Borland type, located on dam's central wall.
Pinhosão	Vouga	(No name available) Drizes?	7,4km downstream Pinhosão dam.	Hydro-power	NO (santo 2005)
	Vouga	(No name available) Açude de Ribafeita?	11km upstream Pinhosão dam	Hydro-power	NO
Girabolhos	Mondego	Albufeira de Aguieira	The dam is located about 51km downstream GIrabolhos. Its reservoir goes up to 28km downstream Girabolhos dam.	Hydro-power. Drinking water supply. Irrigation. Navigation	NO
	Mondego	Albufeira de Raiva	The dam is about 57,7km downstream Girabolhos dam. The reservoir goes up to 6,7	Hydro-power. Irrigation. Navigation	NO

PNBEPH dams	River	Dams on the same river	Location in relation to PNBEPH dams	Type/use	Fish passes
			km downstream Albufeira de Aguieira.		
	Mondego	Acude Ponte Coimbra	The dam is located about 90km downstream Girabolhos.	Drinking water supply. Irrigation. Navigation	YES
Almourol	Tejo	Albufeira de Belver	This dam is located about 40,1km upstream Almourol dam and its reservoir has an extension of 20,5km along the Tejo river, up to Fratel dam.	Hydro-power. Navigation.	YES
	Tejo	Albufeira Fratel	This dam is located about 60,6km upstream Almourol dam and its reservoir has an extension of 33,3km along the Tejo river, up to Monte Fidalgo (Cedillo) dam managed by Spain.	Hydro-power. Navigation.	NO
	Zezere	Albufeira Castelo de Bode	This dam is located on a Tejo river tributary, about 16,7km from Almourol dam which reservoir will extend up to this dam. This reservoir has an extension of 49km along the Zezere river.	Hydro-power. Drinking water supply. Navigation	NO
Alvito	Ocreza	Albufeira Pracana	This dam is located 25km downstream Alvito dam and its reservoir has an extension of 20km along the Ocreza river.	Hydro-power	NO

Illustration 22: Location of reservoirs and PNBEPH dams



shp files: Usos Barragens_Maio09, albu_pontos, ART13_MLAGOS_PTCONT_1_690, albu_pontos, ART5_MRIOS_PTCONT_0_238,
Sources: INAG-InterSIG, INAG, Miisterio do Ambiente - Agencia Portuguesa do Ambiente and ATECMA SL. June 2009.

2.2.2.5 River fragmentation data

To have an idea on the actual fragmentation of rivers, we can use the data made available on dams in the selected river basins and the presence of fish traps on each of these dams as explained in Section 2.2.2.4. The assessment of continuity is also available via the ecological assessment done by Cortes et al. (2008) and ADISA (2008) and is summarised in Section 2.2.2.8

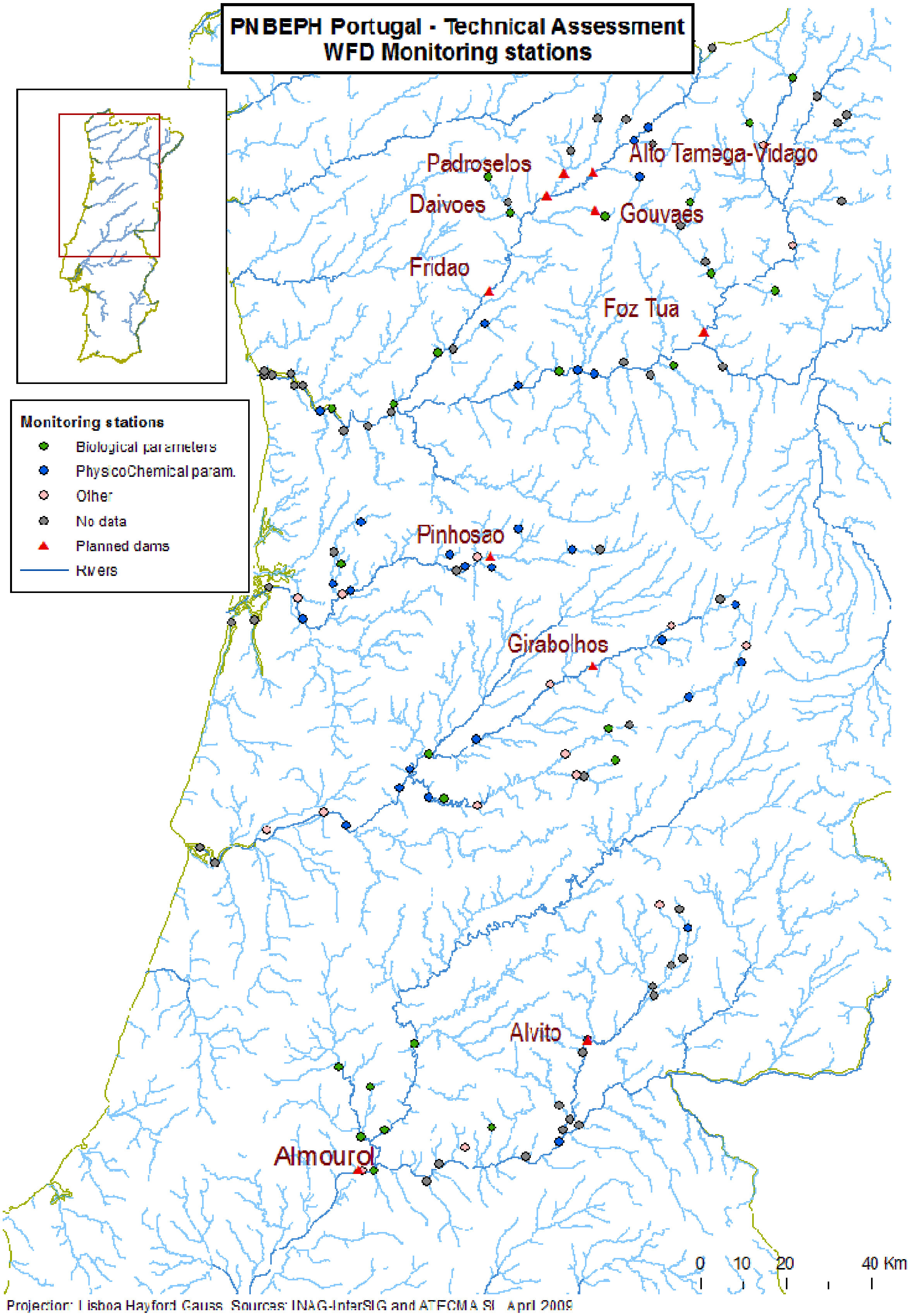
2.2.2.6 WFD monitoring data (provided by INAG)

Information on the chemical and ecological status of the surface water bodies an on the status of the protected areas and monitoring data for the 128 stations identified in Annex 12 were asked from the Portuguese authorities, including the results for the individual chemical, biological and hydromorphological parameters or indices used to determine chemical and ecological status.

The reply form the Portuguese authorities mentions that *the ecological status classification system for rivers and reservoirs is being currently defined. The classification of the ecological and chemical status of water bodies will be made during the elaboration of the River Basin Management Plans (RBMPs).* Although the draft RBMPs should have been made available by the end of December 2008, this was not done by the Portuguese authorities as work on the RBMPs (and biological classification tools were not finalised yet).

Data have been provided for 73 stations (out of the 128 requested). Information is incomplete and concerns mainly physic-chemical parameters, priority substances and other specific pollutants. Some data on Phytobenthos, Fishes, Macrophytes are provided for 18 river locations. An overview of the data available as well as locations where no data have been made available is given in **Illustration 23**

Illustration 23: WFD monitoring data provided by the Portuguese authorities



2.2.2.7 Information on fish species present in the PNBEPH area

The fish species present in the PNBEPH area, their protected status according to the Habitats Directive and the Portuguese Red Book are given in **Table 40**, together with some details on their distribution and migration behaviour.

Table 40: Fish species present in the PNBEPH area and their protected status, distribution and migration behaviour

Nº	Species	Habitats Directive	Red data Book (Livro Vermelho	Migration behaviour/ distribution
1	*Alosa alosa*	Annexes II & V	EN	Anadromous
2	*Alosa fallax*	Annexes II & V	VU	Anadromous
3	*Barbus bocagei*	Annex V	LC	Iberian endemism, potamodromous
4	*Barbus comizo*	Annexes II & V	EN	Iberian endemism, potamodromous
5	*Achondrostoma arcasii* (syn. Chondrostoma arcasii, Rutilus arcasii)	Annex II	EN	Iberian endemism
6	*Pseudochondrostoma duriense (Chondrostoma duriense)*	Annex II*	LC	Iberian endemism (Douro basin), potamodromous
7	*Achondrostoma oligolepis (Condrostoma oligolepis, Rutilus macrolepidotus)*	Annex II	LC	Portuguese endemism, potamodromous
8	*Iberochodrostoma lemmingii (Chondrostoma lemmingii)*	Annex II	EN	Iberian endemism
9	*Iberochondrostoma lusitanicum (Chondrostoma lusitanicum)*	Annex II	CR	Portuguese endemism
10	*Pseudochondrostoma polylepis (Chondrostoma polylepis)*	Annex II	LC	Iberian endemism, potamodromous
11	*Lampetra fluviatilis*	Annexes II & V	CR	Anadromous
12	*Petromyzon marinus*	Annex II	VU	Anadromous
13	*Squalius alburnoides*	Annex II	VU	Iberian endemism
14	*Anguilla anguilla*		EN	Catadromous
15	*Atherina boyeri*		DD	Short spawning migrations into estuaries in some populations. Eastern Atlantic and throughout the Mediterranean and Black Sea.

Nº	Species	Habitats Directive	Red data Book (Livro Vermelho	Migration behaviour/ distribution
16	*Cobitis calderoni*		EN	Iberian endemism
17	*Cobitis paludica*		LC	Iberian endemism
18	*Gasterosteus gymnurus***		EN	Atlantic from S France to the Strait of Gibraltar and the Mediterranean. Can include both anadromous and resident populations
19	*Liza ramada*		LC	Catadromous
20	*Salmo trutta*		LC (CR) ***	Autochthonous, non-endemic
21	*Squalius carolitertii*		LC	Iberian endemism (NW Spain and N Portugal, in the Duero, Mondego, Limia, Miño and Lérez basins)
22	*Squalius pyrenaicus*		EN	Iberian endemism.

CR: Critically endangered - EN: Endangered - VU: Vulnerable - LC: Least Concern – DD: insufficient information

* In the Habitats Directive, *Chondrostoma duriense* is considred as part of *C. polylepis*

** It can be a diadromous fish. However, for Portugal there are no data supporting this supposition.

*** Only migratory *Salmo trutta* is CR, the non-migratory form is LC. In the rivers affected by the PNBEPH it is a resident species. In Portugal, anadromous populations are not common (Oliveira 2007), the migratory *Salmo trutta* occurs only in the Lima and Minho rivers.

The information about the fish species found in and/or around the areas of the planned dams of the PNBEPH has been obtained from the following sources:

- INAG: WFD monitoring data provided to the EC (data from selected monitoring stations as given in Section 2.2.2.6)
- AQUARIPORT project (data from selected sampling sites) (Oliveira et al., 2007)
- Carta Piscicola Nacional website (CPN)8
- SEA of the PNBEPH – Annex IV.
- A map with the location of the dams and the monitoring/sampling stations from which data were obtained is gjven in Illustration 24.

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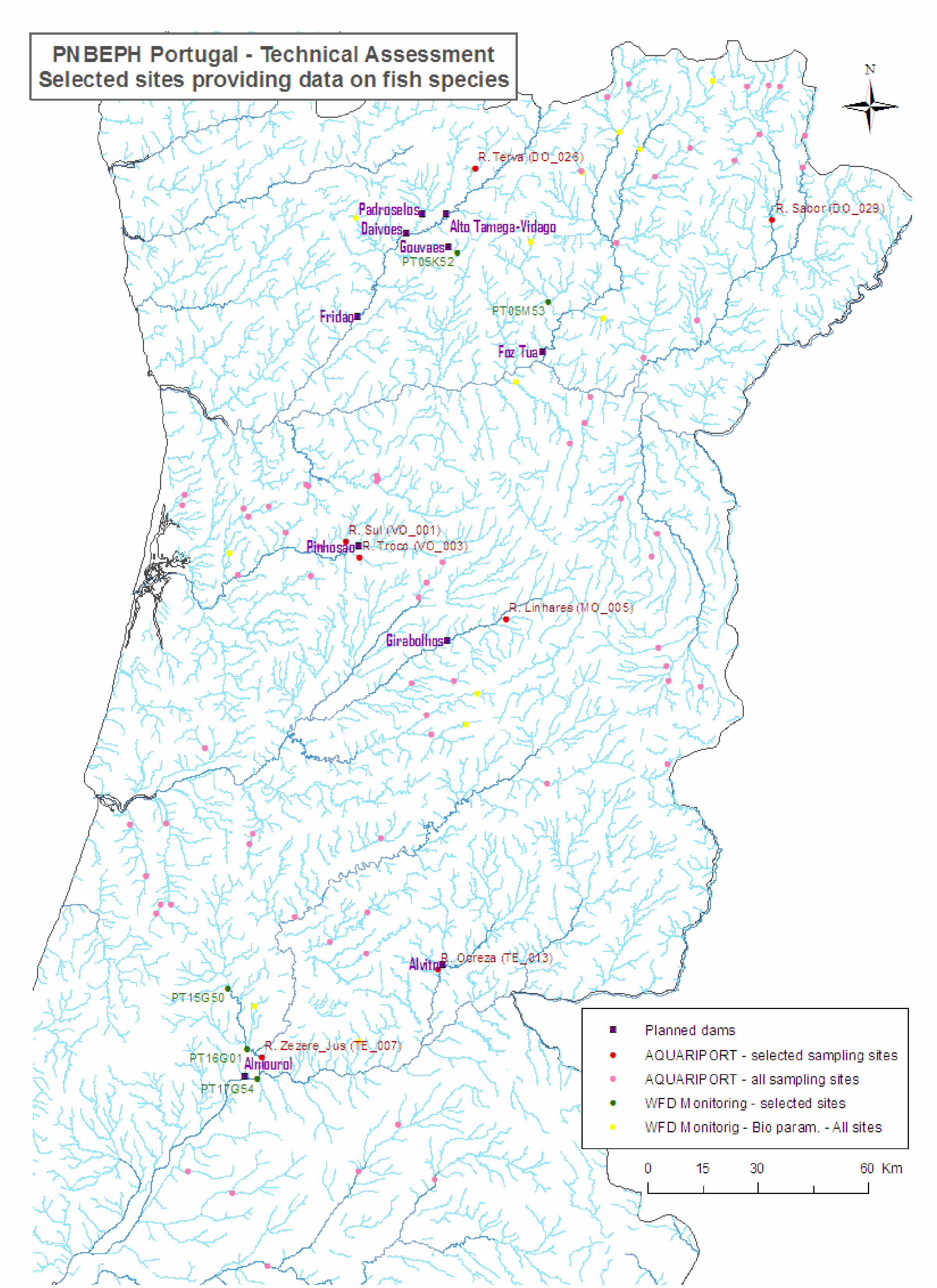
[8]http://www.cartapiscicola.org/dgf/index.cfm Note of the author: We must bear in mid that Carta Piscicola Nacional is a database that was built from about 700 bibliographic references (scientific articles, thesis, technical reports…), so it provides a reference about the possible presence of fish species in some river stretches. According to the information given in the presentation of the CPN web page, information about the occurrence of species, after 1990, is provided though the link Localizações, where the name of a river, a locality or a national road is provided. Information about the biology of the species can also be obtained through the link Espécies. The database is updated on 01/09/2007.

Illustration 24: Map with locations of fish monitoring data used for this study



Layers: ART3_RIOS_PTCONT_0_188.shp, ART5_MRIOS_PTCONT_0_238.shp. Sources: INAG-InterSIG, INAG, AQUARIPORT and ATECMA S
May 2009.

Species present in the area of each planned dam

Alto Tâmega – Vidago

Species	SEA-Annex IV	AQUARIPORT	CPN
Barbus bocagei		x	x
Chondrostoma arcasii	P		x
Chondrostoma duriense		x	x
Squalius alburnoides	C		x
Anguilla anguilla	P		x
Salmo trutta			x
Squalius carolitertii		x	x

Comments:

Data from the AQUARIPORT project concern the sampling site 'Rio Terva (DO_026)' which is located on the Terva river (affluent of the Tâmega river), about 21,5 km North of the Alto Tâmega-Vidago dam. Since the Alto Tâmega-Vidago reservoir will occupy 28 km of river, this site will be affected by the dam.

Padroselos

Species	SEA-Annex IV	CPN
Barbus bocagei		x
Chondrostoma arcasii	P	
Chondrostoma duriense		x
Squalius alburnoides	P	
Anguilla anguilla	P	x
Salmo trutta		x
Squalius carolitertii		x

Comments:

The Eel (*Anguilla anguilla*) must be almost extinct in Tâmega River. The existing individuals cannot reproduce because of habitat fragmentations cause by Torrão and other dams in Douro. *Salmo trutta* numbers decrease from up to downstream in Tâmega river and it is never dominant.

Daivões

Species	SEA-Annex IV	CPN
Barbus bocagei		x
Chondrostoma arcasii	P	x
Chondrostoma duriense		x
Squalius alburnoides	C	
Anguilla anguilla	P	x
Salmo trutta		x
Squalius carolitertii		x

Gouvães

Species	SEA-Annex IV	INAG	CPN
Chondrostoma arcasii	C		
Chondrostoma duriense		x	x
Squalius alburnoides	P		
Anguilla anguilla	P		
Cobitis calderoni	C	x	x
Salmo trutta		x	x
Squalius carolitertii		x	x

Comments:

Data from INAG refer to species found at the following 'station':

- PT05K52: The monitoring station is located about 3 km upstream the Gouvães dam.

Fridão

Species	SEA-Annex IV	CPN
Barbus bocagei		x
Chondrostoma arcasii	P	
Chondrostoma duriense		x
Squalius alburnoides	C	
Anguilla anguilla	P	x
Squalius carolitertii		x

Foz Tua

Species	SEA-Annex IV[9]	INAG	CPN
Barbus bocagei		x	x
Chondrostoma arcasii	P		
Chondrostoma duriense		x	x
Squalius alburnoides	C		x
Cobitis calderoni	C		
Salmo trutta		x	
Squalius carolitertii			x

Comments:

- Data from INAG refer to species found at two different 'stations' located near the planned dam:
- PT05M53: The monitoring station is located about 23,6 km upstream the dam, on the Tinhela river, affluent of the Tua river. Since the Foz Tua reservoir will occupy 51 km of river, this site will be affected by the dam.
- PT06N50: no species listed for this station.
- According to our expert (A. Geraldes), *Salmo trutta* is absent near the mouth of Tua river, which is close to the planned location for the dam.

Pinhosão

Species	SEA-Annex IV	AQUARIPORT	CPN
Alosa alosa	P		
Alosa fallax	P		
Barbus bocagei		x	
Chondrostoma arcasii	P	x	
Chondrostoma oligolepis		x	
Chondrostoma polylepis		x	
Lampetra fluviatilis	P		
Squalius alburnoides	P		
Anguilla anguilla	C	x	
Cobitis paludica		x	
Salmo trutta		x	

[9] SEA report: P - probable presence in the area; C - confirmed presence in the area.

Species	SEA-Annex IV	AQUARIPORT	CPN
Squalius carolitertii		x	x

Comments:

Data from the AQUARIPORT project concern the following sampling sites:

- 'Rio Sul (VO_001)': located on the Sul river (affluent of the Vouga river) about 5,8 km NW of the planned dam (downstream). Fish species found here: *Chondrostoma arcasii/Chondrostoma oligolepis, Anguilla anguilla, Barbus bocagei, Cobitis paludica, Chondrostoma polylepis, Salmo trutta and Squalius alburnoides*.
- 'Rio Troço (VO_003)': located on the Troco river (affluent of the Vouga river) about 9,7 km SE of the planned dam (downstream). Fish species found here: *Chondrostoma arcasii/Chondrostoma oligolepis, Anguilla Anguilla, Salmo trutta and Squalius carolitertii.*
- In the AQUARIPORT project, *Chondrostoma arcasii* and *Chondrostoma oligolepis* were considered together because it is almost impossible to distinguish these species only by their morphology.

<u>Girabolhos</u>

Species	SEA-Annex IV	AQUARIPORT	CPN
Chondrostoma arcasii		x	
Chosdrostoma oligolepis		x	
Salmo trutta		x	
Squalius alburnoides	C		
Squalius carolitertii			x

Comments:

Data from the AQUARIPORT project concern the following sampling site:

- 'Rio Linhares (MO_005)': located on the Linhares river (affluent of the Mondego river) about 20,6 km upstream the planned dam. Since the Alto Girabolhos reservoir will occupy 21 km of river (upstream the dam), this site will be affected by the dam.

<u>Almouorol</u>

Species	SEA-Annex IV	INAG	AQUARIPORT	CPN
Alosa alosa	C			x
Alosa fallax	C			x
Barbus bocagei		x	x	x
Barbus comizo		x		

Species	SEA-Annex IV	INAG	AQUARIPORT	CPN
Chondrostoma arcasii			x	
Chondrostoma oligolepis		x	x	
Chondrostoma polylepis		x	x	x
Lampetra fluviatilis	C			
Petromyzon marinus	C	x		x
Squalius alburnoides	P			
Anguilla anguilla	C	x	x	x
Atherina boyeri			x	
Cobitis paludica		x	x	
Gasterosteus gymnurus	P		x	
Liza ramada				x
Mugil cephalus				x
Squalius pyrenaicus	C	x	x	

Comments:

1. Data from the INAG refer to species found at the following ‘stations’:
   - PT17G54: The monitoring station is located on the Ribeira da Foz, close to the junction with Tejo river, about 3,9 km upstream the dam. Fish species found here: *Anguilla anguilla, Barbus bocagei, Chondrostoma polylepis and Petromyzon marinus*; also *Gobio gobio* and *Lepomis gibbosus* (exotic species).
   - PT16G01: The monitoring station is located on the Nabao river, affluent of Tejo river, 15,2 km upstream the dam. Fish species found here: *Anguilla Anguilla* and *Barbus bocagei;* also *Gambusia holbrooki* and *Gobio gobio* (exotic species).
   - PT15G50: The monitoring station is located on the Nabao river, affluent of Tejo river, 22 km upstream the dam. Fish species found here: *Barbus bocagei, Barbus comizo, Chondrostoma oligolepis, Chondrostoma polylepis, Cobitis paludica* and *Squalius pyrenaicus.*
2. Data from the AQUARIPORT project concern the sampling site ‘Rio Zezere_jus (TE_007)’ which is located on the Zezere river (affluent of the Tejo river), 10,3 km upstream the planned dam.
3. As regards *Iberochondrostoma lusitanicum* (*Chondrostoma lusitanicum*), according to distribution maps (see Oliveira (2007) and Robalo et al. (2008)), the species is present in the Almourol area.

<u>Alvito</u>

Species	SEA-Annex IV	AQUARIPORT	CPN
Barbus bocagei		x	

Species	SEA-Annex IV	AQUARIPORT	CPN
Barbus comizo	C	x	
Chondrostoma lemmingii	C		
Chondrostoma lusitanicum	P		
Chondrostoma polylepis		x	
Squalius alburnoides	C	x	x
Squalius pyrenaicus	C	x	x

Comments:

1. Data from the AQUARIPORT project concern the sampling site 'Rio Ocreza (TE_013) which is located on the Ocreza river, about 1,5 km downstream the planned dam.
2. According to distribution maps (see Oliveira 2007 and Robalo et al. 2008) the presence of *Iberochondrostoma lusitanicum* in Ocreza river is doubtful. The data obtained in the Aquariport project for one sampling site in this river did not confirm the presence of this species in Ocreza river. However, the occasional occurrence of the species in this river is possible.

2.2.2.8 Ecological assessment in the PNBEPH area

The ecological assessment analysis (fish results are discussed earlier in 2.2.2.7) is based on information collected from studies carried out over three years by a team of researchers from Portuguese Universities (Cortes et al., 2008; ADISA, 2008) to evaluate the ecologic and hydromorphological quality of water bodies within the scope of the WFD. It also contains data from information provided by the INAG in the framework of this technical assessment. Sampling sites from Cortes et al. (2008) are displayed in **Illustration 25**, sampling sites from INAG are plotted in **Illustration 23**. Locations of the sites used for the ecological assessment are displayed for the Douro, the Vouga-Mondego and the Tejo river basin in respectively **Illustration 26**, **Illustration 27** and **Illustration 28**.

We have considered those sampling/monitoring stations located near the PNBEPH dams in order to assess the ecological status upstream and downstream the planned dams. The data used concern EQR for fish, macro-invertebrates, and macrophytes, as well as riparian vegetation (IVR), river connectivity and habitat quality indexes. However, not all of these data were available for all of the sites. A brief description of these indexes is presented in Annex 14.

The results of the ecological assessment are summarized in **Table 41**.

Table 41: Ecological assessment of water bodies affected by PNBEPH dams

Planned dam	Sampling site	River / Typology	Location in relation to the dam	HQA	River connec-tivity	Macro-inverteb.	Macro-phytes	IVR	Fish
Alto Tâmega - Vidago	P3467191/04	Tâmega / N1	5,6 km upstream	46- High/Good	1	High	High	High	High
Alto Tâmega - Vidago	P3467181/04	Tâmega / N1	1,9 km downstream	49-High/Good	1	High	High	High	High
Alto Tâmega - Vidago	P3467051/05	Tâmega / N1	8,3 km downstream	29-Moderate/Poor	1	High	High	High	High
Daivões			7 km upstream						
Daivões	P3467171/04	Tâmega / N1	6,5 km downstream	45-Good/Moderate	1	-		-	-
Daivões	P3467131/04	Louredo (junction with Tâmega) / N1	6,5 km downstream Daivões.	59-High/Good	1	-		-	-
Gouvães	P3417021/04	Torno / N1	3 km upstream	50-High/Good	1	High	High	High	No info
Gouvães	PT05K52 (INAG)	Torno / N1	3 km upstream	53-High/Good	-	-		-	-
Pinhosão	P3466121/04	Vouga / N1	24,3 km downstream	52-High/Good	4	-		-	-
Girabolhos	P3466171/04	Mondego / N1	4 km downstream	50-High/Good	4	-		-	-
Girabolhos	P3466181/04	Mondego / N1	9,1 km downstream	45-Good/Moderate	4	-		-	-
Foz Tua	P4467051/05	Tua / N2	35,6 upstream	36-Good/Moderate	1	-		-	-
Foz Tua	PT05M53 (INAG)	Tinhela / N2	23,6 km upstream, on the Tinhela river, affluent of the Tua river.	41-Good/Moderate	-	-		-	-
Foz Tua	PT06N50 (INAG)	Ribeira Redonda / N3	29,5 km upstream	47-High/Good	-	-		-	-

Planned dam	Sampling site	River / Typology	Location in relation to the dam	HQA	River connec-tivity	Macro-inverteb.	Macro-phytes	IVR	Fish
Alvito	P3464111/04	Tejo / N4	2,2 km downstream	50-High/Good	3	Moderate	Good	Good	Moderate
Almourol	P1774041/04	Ribeira da Foz (Tejo affluent) / S3	3,9 km upstream	56-High/Good	1	Good	High	High	Good
Almourol	PT17G54 (INAG)	Ribeira da Foz / S3	3,9 km upstream, on Ribeira da Foz river, affluent of the Tejo river	56-High/Good	-	-		-	-
Almourol	PT16G01 (INAG)	Nabao / S3	15,2 km upstream, on Nabao river, affluent of teh Tejo river	43-Good/Mod	-	-		-	-
Almourol	PT15G50 (INAG)	Nabao / S3	22 km upstream the dam, affluent of teh Tejo river	55-High/Good	-	-		-	-

Illustration 25: Location of sites for ecological status assessment (Cortes & Ferreira, 2008)

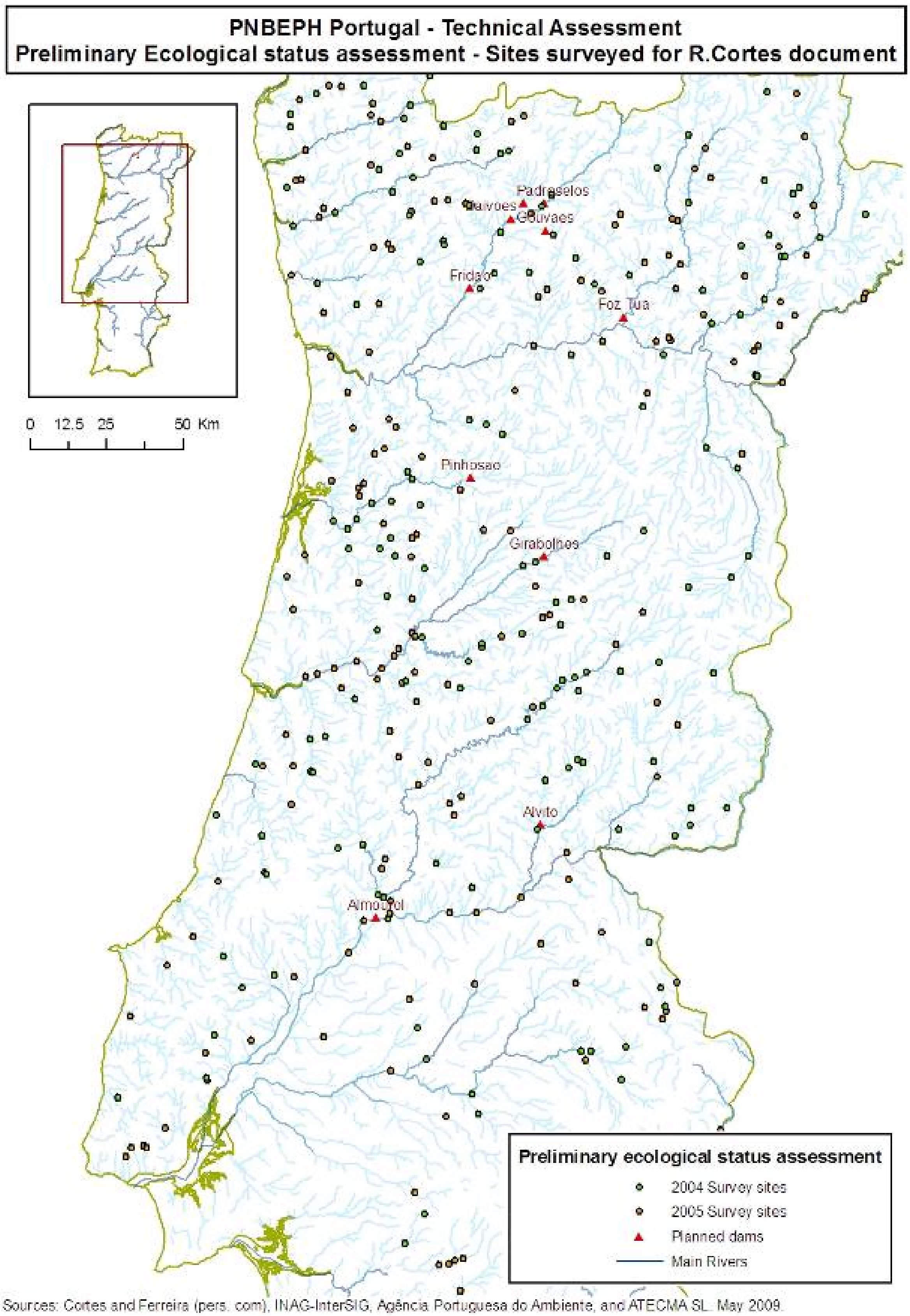


Illustration 26: Location of sites for ecological status assessment in the Douro River Basin

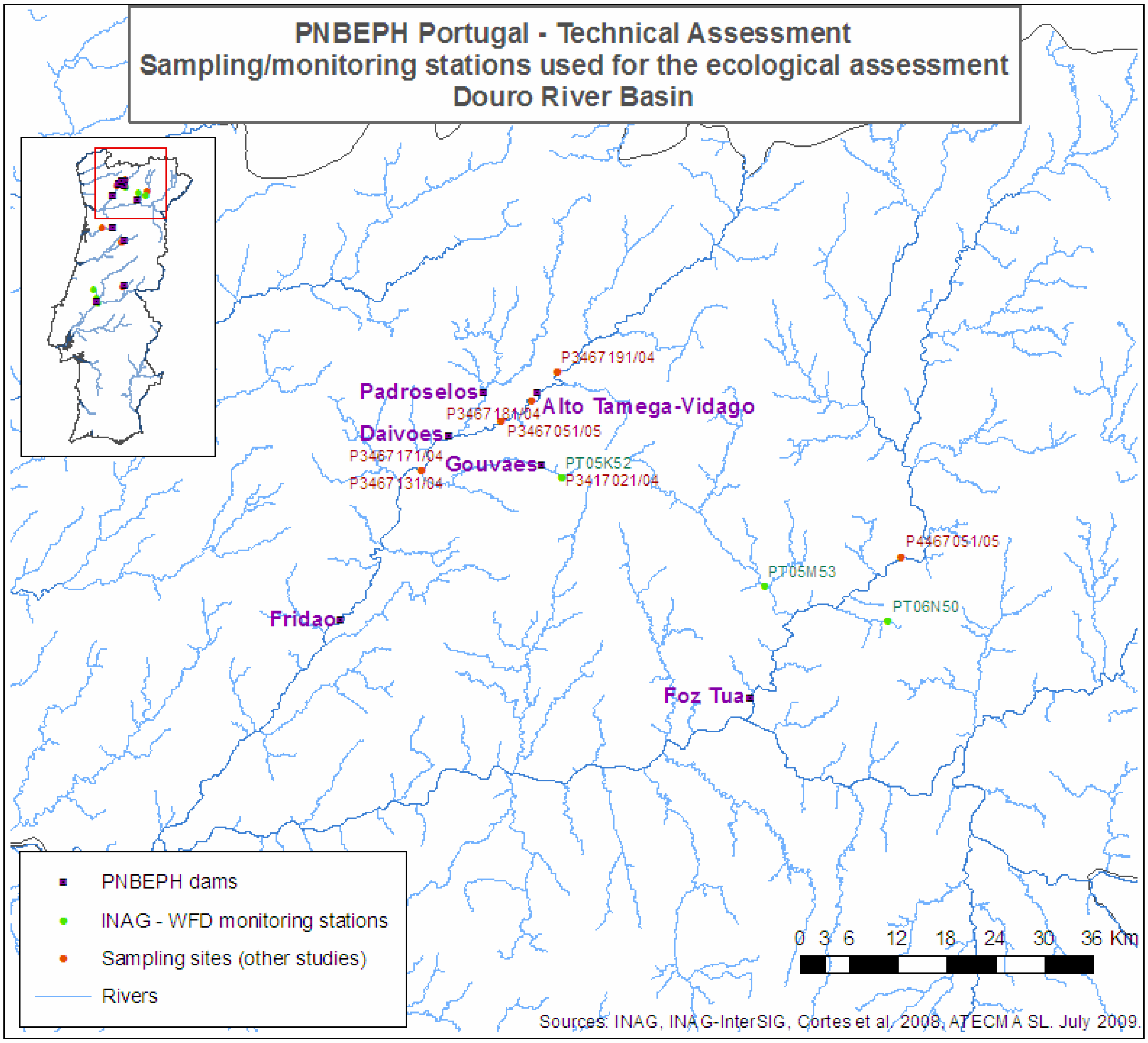


Illustration 27: Location of sites for ecological status assessment in the Vouga-Mondego river basin

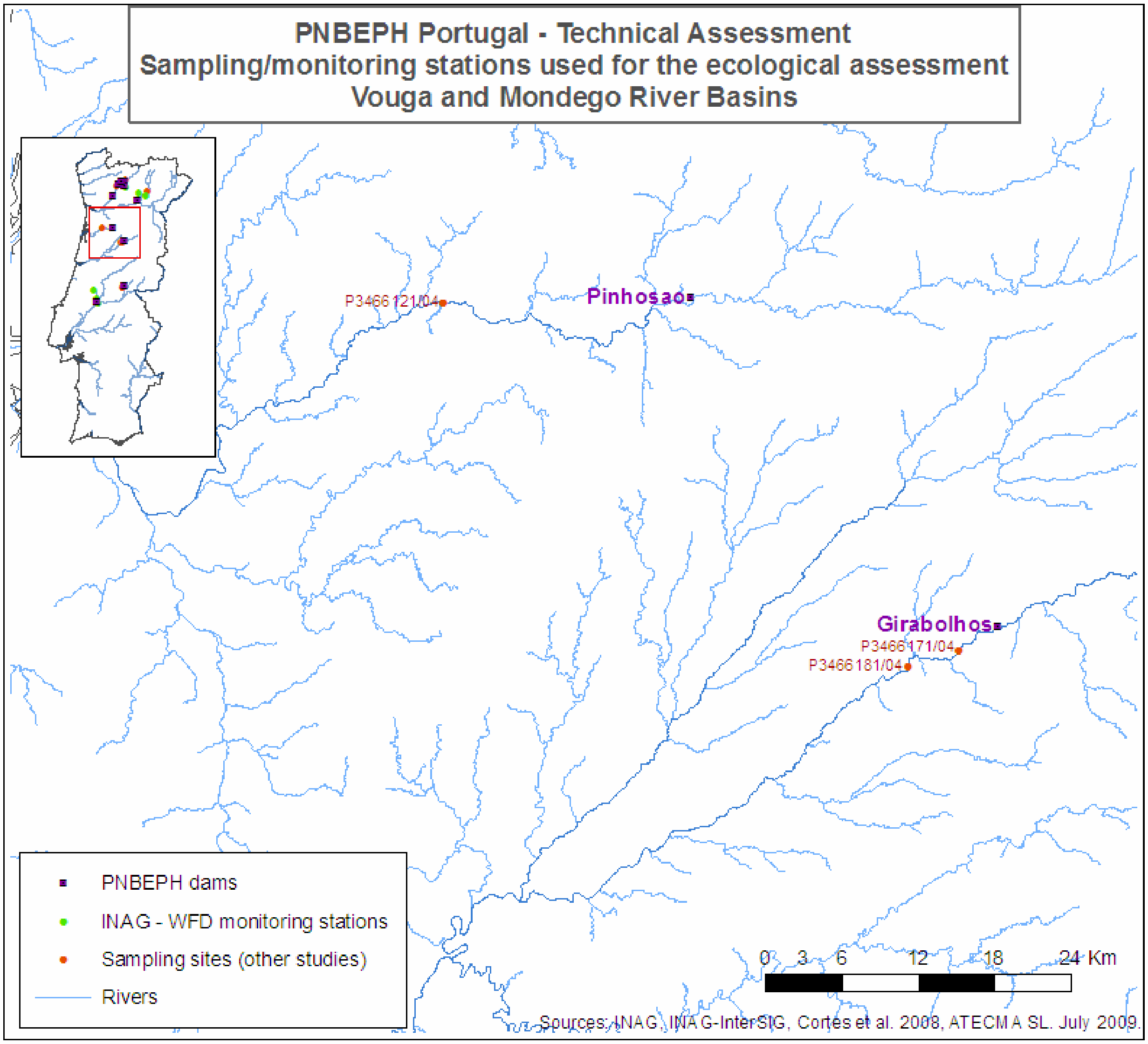
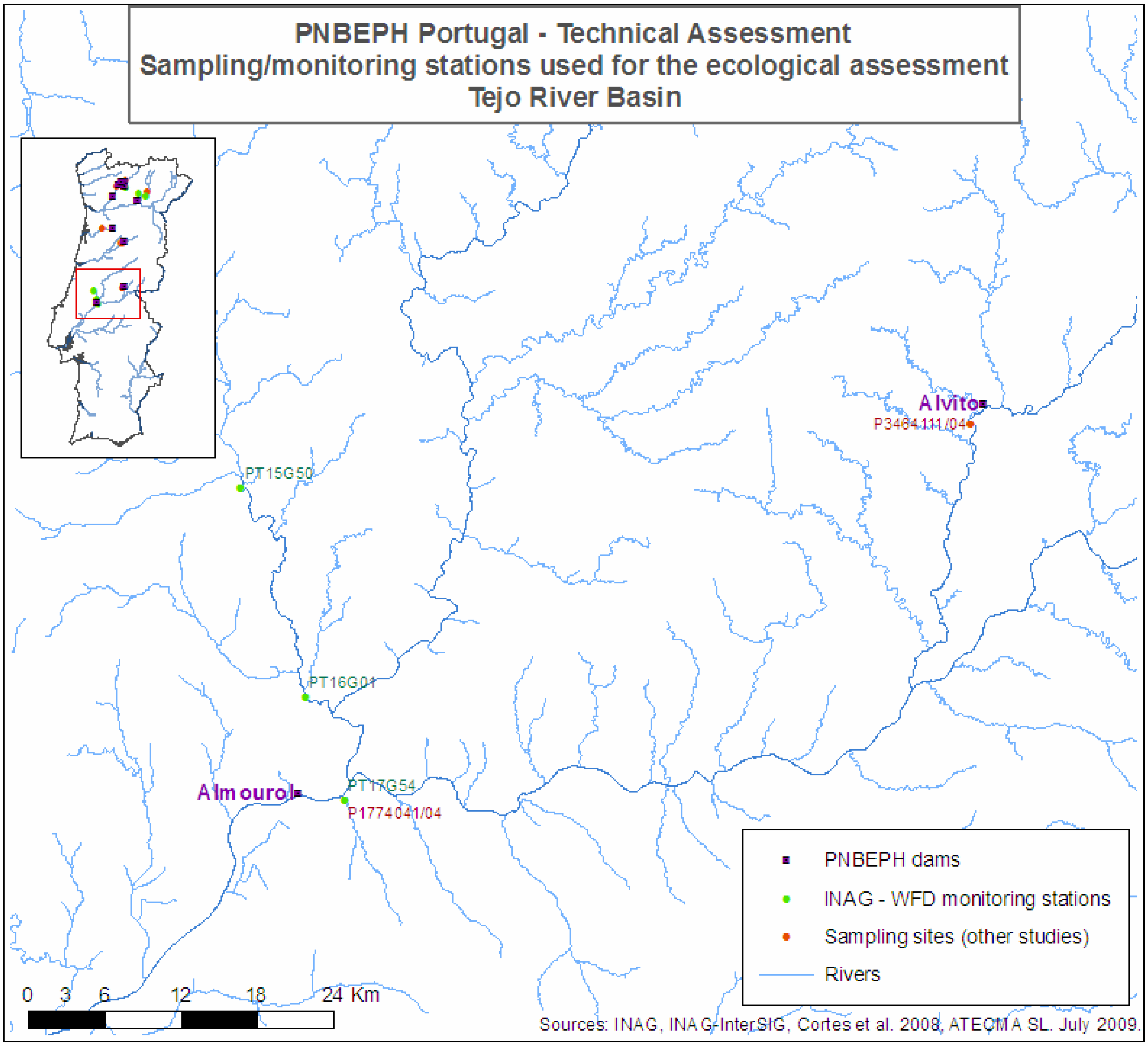


Illustration 28: Location of sites for ecological status assessment in the Tejo River Basin



2.2.2.9 Ecological assessment close to other existing dams in Northern and mid-Portugal

The following analysis is based on information collected from studies carried out over three years by a team of researchers from Portuguese Universities to evaluate the ecologic and hydromorphological quality of water bodies within the scope of the WFD. It also contains data from information provided by the INAG in the framework of this technical assessment (where INAG is indicated in brackets in the "sampling sites" column).

We have considered those sampling/monitoring stations located near the existing dams in order to assess the ecological status upstream and downstream the planned dams. The result is summarized in **Table 42**). The data used concern EQR for fish, macro-invertebrates, and macrophytes, as well as riparian vegetation (IVR), river connectivity and habitat quality indexes. The scoring system of the indices is explained in ANNEX 14). However, not all of these data were available for all of the existing dams included in **Table 39**.

Table 42: Ecological assessment of water bodies affected by existing dams in Northern and Mid-Portugal

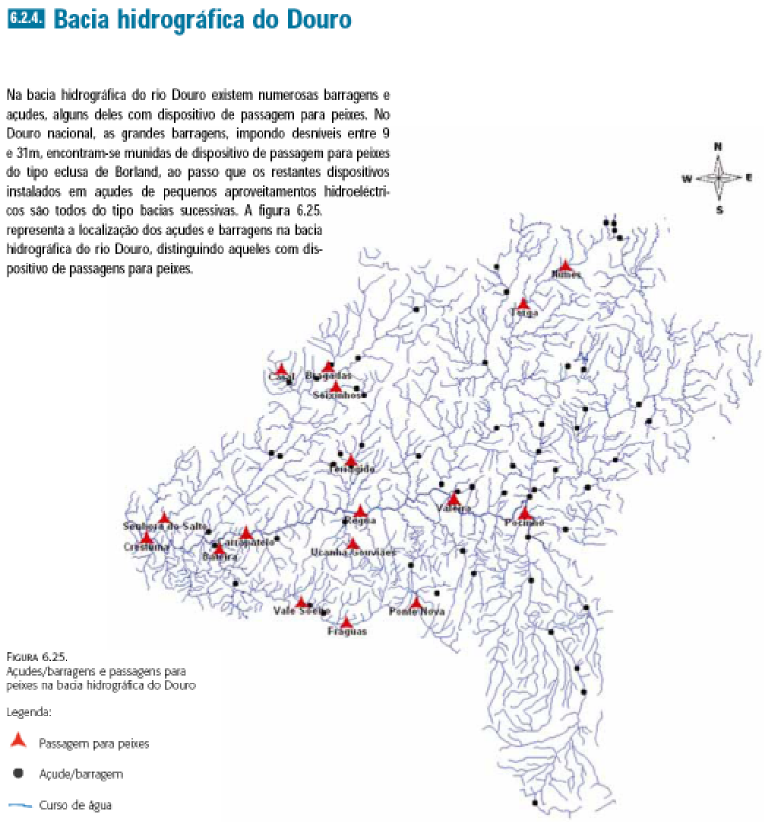
Existing dams near PNBEPH dams	On River	Sampling sites	Location in relation to the existing dam	HQA	River connec-tivity	Macro-inverteb.	Macro-phytes	IVR	Fish
Acude Veiga-Chaves	Tâmega	P3467191/04	37,1km downstream Ac. Veiga-Chaves	High	1	Moderate	High	High	High
(No name available)	Louredo	P3417021/04 PT05K22 (INAG) /	Between the reservoir and Gouvaes dam	Good	1	Good	High	High	-
(No name available)	Louredo	P3467131/04	10,2km downstream this reservoir.	High	1	High	High	High	High
Albufeira de Regua	Douro	P9047051/05	5,7km downstream Alb. Regua	No value	5	No value	No value	No value	No value
Albufeira de Aguieira	Mondego	P3466181/04	18,8km upstream Alb. de Aguieira	High / Good	4	-	-	-	-
Albufeira de Raiva	Mondego	P2636471/05	> 0,5km downstream Alb. de Raiva	Moderate / Poor	5	-	-	-	-
Acude Ponte Coimbra	Mondego	P2636491/05	About 3km upstream Ac. Ponte Coimbra	Good / Moderate	4	-	-	-	-
		P2636531/05	About 2km downstream Ac. Ponte Coimbra	Good / Moderate	4	-	-	-	

Existing dams near PNBEPH dams	On River	Sampling sites	Location in relation to the existing dam	HQA	River connec-tivity	Macro-inverteb.	Macro-phytes	IVR	Fish
Albufeira de Belver	Tejo	P8044381/05	> 0,5km downstream Alb. Belver	No value	4	No value	No value	No value	No value
		P8044371/05	17,1km upstream Belver dam (in the reservoir).	No value	4	No value	No value	No value	No value
Albufeira Castelo de Bode	Zezere	P2634101/05	3km upstream Alb. Castelo de Bode	High / Good	4	Poor	Good	Good	Poor
		P2634181/05	6,9km downstream Alb. Castelo de Bode	Good/ Moderate	2	Moderate	Good	Poor	Moderate
Albufeira Pracana	Ocreza	P3464111/04	3km upstream Alb. Pracana	High/ Good	3	Poor	Good	Good	Poor

2.2.2.10 Fish passing efficiency

Information on fish passing efficiency is obtained from Santo et al. (2005). This document provides a comprehensive review of fish pass devices, which includes: the evaluation of the efficiency of fish passes implemented in Portugal.

2.2.2.10.1 Fish passing efficiency in the Douro river basin


6.2.4. Bacia hidrográfica do Douro

Na bacia hidrográfica do rio Douro existem numerosas barragens e açudes, alguns deles com dispositivo de passagem para peixes. No Douro nacional, as grandes barragens, impondo desníveis entre 9 e 31m, encontram-se munidas de dispositivo de passagem para peixes do tipo eclusa de Borland, ao passo que os restantes dispositivos instalados em açudes de pequenos aproveitamentos hidroeléctricos são todos do tipo bacias sucessivas. A figura 6.25. representa a localização dos açudes e barragens na bacia hidrográfica do rio Douro, distinguindo aqueles com dispositivo de passagens para peixes.

FIGURA 6.25.
Açudes/barragens e passagens para peixes na bacia hidrográfica do Douro

Legenda:
Passagem para peixes
Açude/barragem
Curso de água

Potentiality for fish use: 1(Bad); 2; 3; 4; 5 (Very Good)

Fish passes that are not functioning

Dams (Locks)	Weirs (Notches)
• Carrapatelo • Régua • Valeira • Pocinho	• Terregido • Ponte Nova • Bragadas • Casal

Fish passes that are functioning

Dams (Locks)	Weirs (Notches)
• Crestuma-Lever	• Senhora do Salto • Bateira • Vale Soeiro • Fráguas • Ucanha-Gaviões • Torga

	• Nunes Terregido

2.2.2.11 Fish passing efficiency Vouga Basin

6.2.5. Bacia hidrográfica do Vouga

Na bacia hidrográfica do Vouga existem 10 dispositivos de passagem para peixes, todos eles do tipo bacias sucessivas. A figura 6.66. representa a sua localização.

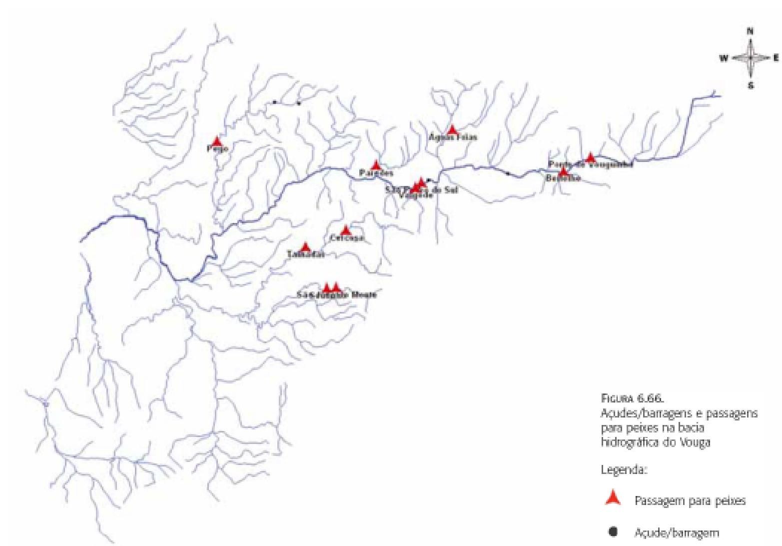


Figura 6.66.
Açudes/barragens e passagens para peixes na bacia hidrográfica do Vouga

Legenda:
Passagem para peixes
Açude/barragem
Curso de água

Fish passes that are not functioning

Dams (Locks)	Weirs (Notches)
	• Valgode • Pone Vouginha

Fish passes that are functioning

Dams (Locks)	Weirs (Notches)
	• São Pedro do Sul • Soutinho • S. João do Monte • Pego • Cortez/Talhadas • Paredes • Águas Frias

Potentiality for fish use: 1(Bad); 2; 3; 4; 5 (Very Good)

2.2.2.11.1 Fish passes efficiency in the Mondego river basin

6.2.6. Bacia hidrográfica do Mondego

Na bacia hidrográfica do Mondego existem 4 dispositivos de passagens para peixes, todos eles do tipo bacias sucessivas. A sua localização encontra-se representada na figura 6.94..

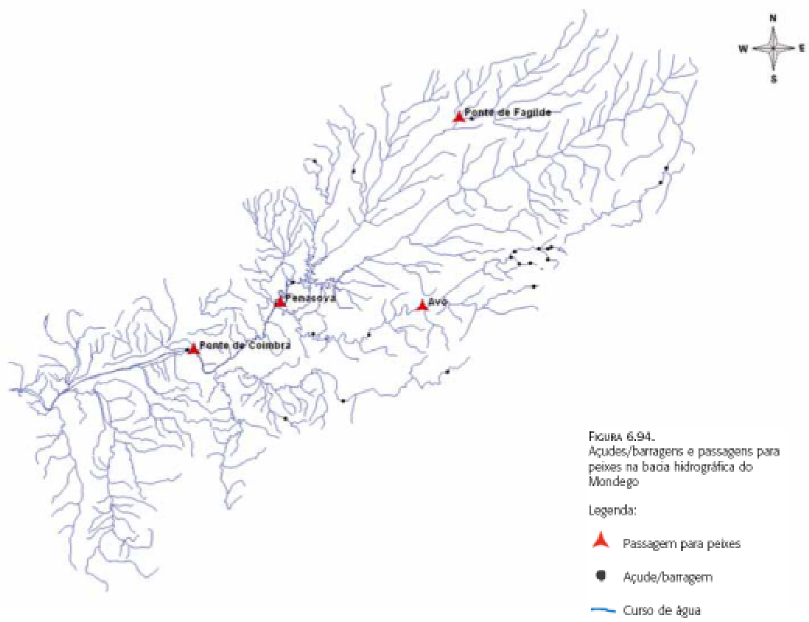


FIGURA 6.94.
Açudes/barragens e passagens para peixes na bacia hidrográfica do Mondego

Fish passes that are functioning

Dams (Locks)	Weirs (Notches)
	• Ponte de Coimbra* • Penacova • Avô • Ponte Fagilde

Potentiality for fish use: 1(Bad); 2; 3; 4; 5 (Very Good)

* obstacle for sea lamprey. They are transferred to upstream by elements of Forestry Police.

2.2.2.11.2 Fish passing eficiency in Tejo River Basin

6.2.7. Bacia Hidrográfica do Tejo

Na bacia hidrográfica do Tejo existem 36 grandes barragens construidas (INAG - SNIRH), sendo que apenas uma delas possui dispositivo de passagem para peixes – a barragem de Belver, no rio Tejo que possui uma passagem para peixes do tipo eclusa de Borland. Para além desta, existem dois outros dispositivos do tipo bacias sucessivas, nos pequenos aproveitamentos hidroeléctricos de Janeiro de Cima e Caldas de Manteigas, no rio Zêzere. A localização das passagens para peixes existentes nesta bacia hidrográfica encontra-se representada na figura 6.102..

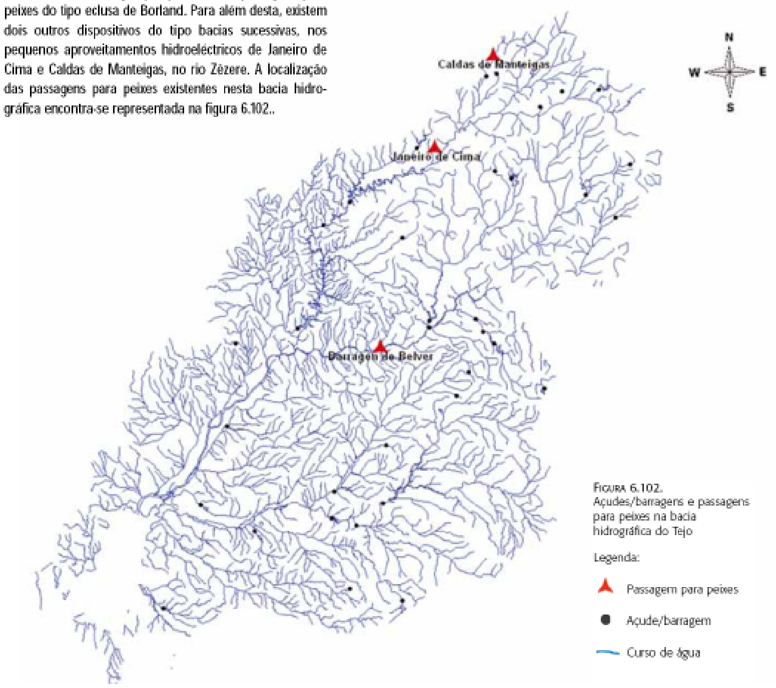


Figura 6.102.
Açudes/barragens e passagens para peixes na bacia hidrográfica do Tejo

Fish passes that are functioning

Dams (Locks)	Weirs (Notches)
• Belver	• Janeiro de Cima • Caldas de Manteigas

Potentiality for fish use: 1(Bad); 2; 3; 4; 5 (Very Good)

2.3 Results

2.3.1 Scenario 1

2.3.1.1 Ecological assessment in selected stations near the existing dams in the Douro, Vouga-Mondego and Tejo river basin

The analysis of the existing dams is based on the information as given in 0.

Although there is certainly a lack of data to provide a full assessment of the quality near other dams, due to the inexistence of a targeted monitoring programme towards the effects of hydropower plants on the biological community, it was still possible to observe the following:

(1) Large hydropower stations seem to have the most detrimental effects on river quality (eg Belver, Regua, Castello de Bode dam in comparison to the dams in the Louredo river;

(2) There seems to be an important barrier effect on most of the locations monitored (based on the continuity scores given)

(3) Macroinvertebrate community data and fish score worse in terms of ecological status than macrophytes and in some cases also the riparian vegetation. With regard to the main impacts from hydropower on rivers as defined earlier (i.e. changed sediment patterns, changed habitat and flow conditions, changed nutrient (and organic conditions), it is clear these 2 groups can be considered as the most sensitive towards disturbances caused by hydropower operation. However, as mentioned earlier in 2.2.2.2, the WFD risk assessment data were not available from individual water bodies so we have currently no clear idea on the additional pressures at the locations analysed.

(4) There are no phytoplankton results available so we could not see any effects of eutrophication based on the data available. However, previous studies have shown that the trophic status often changed to a meso or eutrophic system after a certain period (see Section 1.1.3.1).

2.3.1.2 Ecological assessment in selected stations near the PNBEPH dams

The effects are detailed for each parameter used in the assessment (based on data from the ecological assessment as given in 2.2.2.7 and 2.2.2.8).

Table 43 PNBEPH – Overview of main potential impacts identified on hydro-morphological and biological elements (based on data from ecological assessment and other relevant data from the WFD implementation)

DAMS (river stretch affected = reservoir length upstream dam)	Fish species potentially affected[10]	River connectivity	Potential effects on Habitat quality & biological elements	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas	Other
ALTO TÂMEGA – VIDAGO Tâmega River (28 km)	6 species from Red Data Book *(including 4 sp from Habitats Directive)* *Barbus bocagei,* *Chondrostoma duriense , Squalius alburnoides, Squalius carolitertii, Anguilla anguilla,* *Chondrostoma arcasii.*	Currently good river connectivity. Migration of potamodromous species could be affected.	Deterioration of habitat quality (currently high/good), riparian vegetation (high) and biological elements: fish, macroinver-tebrates and macrophytes all currently in high status, in this river stretch.	One of the 3 dams planned in the Tâmega river. 5 dams planned in Tâmega sub-basin, in the upper area of this sub-basin, where fish species of conservation interest occur. Only another big dam currently exists on Tâmega river, 30,8 km downstream Fridão as well as a weir and a small hydropower upstream the planned location for this dam. At the river basin scale there are 67 dams (existing and planned) and the upper section of the Tâmega rive presents a critical water quality associated with diffuse pollution from farming.		Reversible system (two reservoirs): Increases the difficulty of minimum flow maintenance.

[10] Fish species with confirmed presence are in black (according to SEA of PNBEPH or to monitoring data from INAG and Aquariport project), probable presence is in blue (CPN).

DAMS (river stretch affected = reservoir length upstream dam)	Fish species potentially affected[10]	River connectivity	Potential effects on Habitat quality & biological elements	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas	Other
PADROSELOS Beça river (10 km)	3 species from Red Data Book *(incl. 2 sp. from Habitats Directive)* *Chondrostoma arcasii, Squalius alburnoides,* *Anguilla anguilla*	The dam will create a barrier to fish species.		One of the 5 dams planned in Tâmega sub-basin, in the middle area of this sub-basin, where there are still good conditions for fish species of conservation interest. No other big dams currently exist in Beça River, except for one small hydropower. At a river basin scale there are 67 dams.		Reversible system (two reservoirs): Increases the difficulty of minimum flow maintenance
DAIVÕES Tâmega River (19 km)	3 species from Red Data Book *(incl. 2 sp. from Habitats Directive)* *Squalius alburnoides, Chondrostoma arcasii. Anguilla anguilla*	Currently good river connectivity. The dam will create a barrier to fish species.	Deterioration of habitat quality (currently good/moderate), riparian vegetation (high) and biological elements: fish, macroinvertebrates and macrophytes all currently in high status.	One of the 3 dams planned in the Tâmega river. One of the 5 dams planned in Tâmega sub-basin, in the upper area of this sub-basin, where there are still good conditions for fish species. Only one other big dam currently exists on Tâmega river, 30,8 km downstream Fridão dam), as well as a weir and a small hydropower upstream the planned location for this dam. At a river basin scale, there are 67 dams (existing and planned).		Reversible system (two reservoirs): Increases the difficulty of minimum flow maintenance
GOUVÃES Louredo river (3,7 km)	7 species from Red Data Book (incl. 3 sp. from Habitats Directive)	Currently good river connecti-vity. Migration of potamodro-mous species could be	Deterioration of habitat quality (currently high/good), riparian vegetation (high) and biological elements:	One of the 5 dams planned in Tâmega sub-basin. No other big dams currently exist in Louredo River, only a weir upstream and a small hydropower downstream this	Dam/reservoir included in a Natura 2000 area and Natural Park	Reversible system (two reservoirs): Increases the difficulty of

DAMS (river stretch affected = reservoir length upstream dam)	Fish species potentially affected[10]	River connectivity	Potential effects on Habitat quality & biological elements	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas	Other
	Chondrostoma arcasii, Chondrostoma duriense, Squalius alburnoides, Anguilla anguilla, Cobitis calderoni, Salmo trutta, Squalius carolitertii	affected. The dam will create a barrier to fish species.	macroinvertebrates and macrophytes currently in high status.	dam's location. Small dams will also be built up in Poio, Viduedo and Olo rivers for water diversion to the Gouvães dam, as part of the project under the PNBEPH. At a river basin scale, there are 67 dams (existing and planned).	(Alvao-Marao).	minimum flow maintenance.
FRIDÃO Tâmega river (40 km)	3 species from Red Data Book (incl. 2 sp. from Habitats Directive) *Chondrostoma arcasii, Squalius alburnoides, Anguilla anguilla*	The dam will create a barrier to fish species.		One of the 3 dams planned in the Tâmega river. One of the 5 dams planned in Tâmega sub-basin, in the middle area of this sub-basin, where there are still good conditions for fish species. Only one other big dam currently exists on Tâmega river, the Albufeira de Torrao, 30,8 km downstream Fridão, a reservoir that extends up to 4,2 km from Fridão dam. A weir and a small hydropower are also found in the upper section of this river. At a river basin scale, there are 67 dams (existing and planned).		
FOZ TUA Tua river (51 km)	6 species from Red Data Book (incl. 4 sp. from	Currently good river connectivity upstream The dam	Deterioration of habitat quality (currently good) upstream the dam, in	No other big dams currently exist in the Tua river. Regua's reservoir occupies the Douro river stretch		Reversible system (two reservoirs):

DAMS (river stretch affected = reservoir length upstream dam)	Fish species potentially affected[10]	River connectivity	Potential effects on Habitat quality & biological elements	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas	Other
	Habitats Directive) *Barbus bocagei, Chondrostoma duriense, Squalius alburnoides, Cobitis calderoni, Salmo trutta, Chondrostoma arcasii*	will create a barrier to fish species. The dam. Migration of potamodro-mous species could be affected.	the area that will be affected by the reservoir. Moreover, upper stretches of this river are in good condition, with water quality demanding species and protected species and tributaries.	where the Tua river ends (about 3km from Foz Tua dam). At a river basin scale, there are 67 dams (existing and planned).		Increases the difficulty of minimum flow maintenance
PINHOSAO Vouga river (8 km)	12 species from Red Data Book (incl. 8 sp. from Habitats Directive) *Alosa alosa, Alosa fallax,* Barbus *bocagei, Chondrostoma arcasii, Chondrostoma oligolepis, Chondrostoma polylepis, Lampetra fluviatilis, Squalius alburnoides, Anguilla anguilla, Cobitis paludica, Salmo trutta,*	This dam could create a significant barrier for migratory species *(Anguilla anguilla* and *Petromyzon marinus)* in a river that is almost unregulated (there is only a small weir of the Ribafeita small HP).		No other big dams exist in the Vouga River, only two small hydropower dams: one upstream (Ribafeita) and the other one downstream the dam's planned location (Drizes). At a river basin scale, there are 43 dams and weirs (existing by 1999).	This dam could have adverse effects on the Rio Vouga Natura 2000 site (PTCON0026) and would also possibly affect an estuarine zone with high ecological value (Ria de Aveiro/ Reserva Natural das Dunas de São Jacinto); Ria de Aveiro is classified as a SPA (Natura 2000). Habitats degradation could occur in this estuarine area as a consequence of the reduction in water flow, which could also increase the intrusion of salt water in the	

DAMS (river stretch affected = reservoir length upstream dam)	Fish species potentially affected[10]	River connectivity	Potential effects on Habitat quality & biological elements	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas	Other
	Squalius carolitertii				freshwater habitat.	
GIRABOLHOS Mondego river (21 km)	4 species from Red Data Book (incl. 3 sp. from Habitats Directive) *Chondrostoma arcasii,* *Chosdrostoma oligolepis, Salmo trutta,* *Squalius alburnoides*	Currently there is no good river connectivity downstream the dam (4). The dam will create another barrier to fish species in this highly fragmented river.	Deterioration of habitat quality (currently high/good) downstream the dam (4 km)	Three dams currently exist in the Mondego river. At a river basin scale, there are 27 dams (existing).	The dam could have negative effects on wetlands and riparian habitats included in a Natura 2000 site (PTCON0027 - CARREGAL DO SAL) located about 17,5 km downstream this planned dam.	Reversible system (two reservoirs): Increases the difficulty of minimum flow maintenance
ALMOUROL Tagus river (36 km)	15 species from Red Data Book (incl. 10 sp. from Habitats Directive): *Alosa alosa, A. fallax, Barbus bocagei, B. comizo, Chondrostoma arcasii, C. oligolepis, C. polylepis,* *Lampetra fluviatilis,* *Petromyzon marinus,* *Anguilla anguilla, Atherina boyeri, Cobitis paludica,*	Currently there is a good river connectivity; the dam would create a significant barrier for numerous migratory species (anadromous and catadromous) that curently use the Tejo river (currently the first obstacle in this river is the Belver dam, located about 30 km upstream the	Deterioration of habitat quality (currently high/good - 3,9 km upstream the planned dam), riparian vegetation (high), macroinver-tebrates (good), fish (good) and macrophytes (high) status.	Almourol would add to other two big dams currently existing on the Tagus river (Belver and Fratel, about 40 and 60 km upstream Almourol respectively), and at a river basin scale, there aer other 51 existing dams. Nowadays the first obstacle to fish migration in Tejo river is the Belver dam. Fish can reach some tributaries (e.g. Sorraia and Divor) located below the Belver dam (Oliveira 2007). With the implementation of the Almourol dam, the area of “free migration” is strongly reduced. It would include a	The dam could have some effect on the Tagus estuary, which is also designated as Natura 2000 site (PTCON0009)	

DAMS (river stretch affected = reservoir length upstream dam)	Fish species potentially affected[10]	River connectivity	Potential effects on Habitat quality & biological elements	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas	Other
	Gasterosteus gymnurus, Squalius pyrenaicus, Squalius alburnoides	Almourol planned dam.		new dam in a section of the Tagus river that currently does not present fragmentation and it would affect migratory species in this river. The habitat of threatened resident species such as *Squalius pyrenaicus*, *Squalius alburnoides* will be also negatively affected.		
ALVITO Ocreza (38 km)	7 species from Red Data Book (incl. 6 sp. from Habitats Directive): *Barbus bocagei* *Barbus comizo* *Chondrostoma lemmingii* *C. polylepis* *Squalius alburnoides* *S. pyrenaicus, Chondrostoma lusitanicum*	Currently there is not a good river connectivity downstream the dam (value: 3 at about 2,2, km downstream the planned dam). The dam will create a barrier to fish species.	Deterioration of habitat quality (currently high/good - 2,2km downstream), riparian vegetation (good), macroinver-tebrates (moderate), fish (moderate) and macrophytes (good) status.	As a consequence of this project implementation, a reduction of the habitat of resident species such as *Barbus comizo, Iberochondrostoma lemmingii, Squalius pyrenaicus, Squalius alburnoides, Iberochondrostoma lusitanicum* (all endangered species) is expected. At a river basin scale, other 51 dams are found in the Tejo River Basin.		

Some general conclusions about main impacts of the PNBEPH on fish species and natural areas

The rivers stretches under the scope of PNBEPH have a low regulation/alteration degree. Consequently, they still have large suitable areas of feeding, shelter and spawning habitat for fish and therefore, can be considered as biodiversity refuges. The occurrence of threatened species such as *Squalius alburnoides*, *Cobitis calderoni* and *Achondrostoma* arcasii were reported in many of the areas affected by the PNBEPH.

Many of the areas affected by the PNBEPH dams have been assessed in high/good status in a preliminary ecological assessment carried out in Portugal as part of the WFD implementation. Several sites have a high status according to EQRs obtained for fish fauna and other biological elements (see following section).

In general, **impacts on fish species can be considered significant.** <u>22 fish species included in the Portuguese Red Data book</u> occur in the river stretches affected by the PNBEPH, of which 13 species are protected under the Habitats Directive.) 9 species are endangered or critically endangered. The planned dams will surely cause a loss of suitable habitats for those species, including the destruction of spawning and reproduction areas. Besides, the loss of river connectivity contribute to species genetic erosion and consequently to fish population fitness reduction. It is true that some of resident species such as *Barbus spp.* and *Pseudochondrostoma spp*. can also occur in reservoirs. However, the long term prevalence of these species is not guaranteed because the loss of river connectivity caused by dams prevents their migratory movements to upstream tributaries. Besides, even though reproduction is possible the accentuated water level fluctuations occurring in this kind of reservoirs will jeopardize the reproduction success.

In particular, some <u>migratory species</u> will be adversely affected by some dams, which will create an insurmountable barrier taking into account the low efficiency of existing fish passes for this king of dams. This is especially remarkable in the case of Almourol in the Tejo river, which would impose a new barrier to the existing migratory species that are currently present in this area (currently the first obstacle in this river is the Belver dam, located approx. 30 km upstream Almourol). The Pinhosão dam can also create a barrier for migratory species in the Vouga river, which currently has a low regulation (only other two small dams, one of for hydropower production). Currently, in the national context these rivers have the largest areas with suitable habitat for large migratory fish.

The effects of these dams, including water flow reduction, sediment retention and cumulative effects when considering other existing dams, will adversely affect some important <u>estuarine areas</u>, such as the Ria de Aveiro (Vouga estuary) and the Tejo estuary, which are also Natura 2000 areas, this is further discussed in task 2c (Besides, as a consequence of flow reduction, an increase of the intrusion of salt water in freshwater habitat might occur but this has not further looked at as part of this study)

The Tâmega river will be strongly affected by the construction of 3 dams in its upper part, while currently only one big dam (Albufeira de Torrao) is present in its lowest reach, close to its confluence with the Douro river.

The Tâmega sub-basin has currently a low regulation (only five small dams + Albufeira de Torrao in the lowest part of the Tâmega river) and its degradation will significantly increase with the construiction of five new dams under the PNBEPH: Padroselos, Alto Tâmega (Vidago), Daivões, Fridão and Gouvães. This could have significant effects on the fish populations of conservation interest that inhabit the main river and its tributaries (*Chondrostoma duriense, Squalius alburnoides, Squalius carolitertii, Anguilla anguilla, Chondrostoma arcasii, Barbus bocagei, Cobitis calderoni, Salmo trutta, Squalius carolitertii*).

At the River Basin level, the degradation of suitable habitats for fish species of conservation interest will be remarkable in particular in the Douro basin, considering the high number of already existing reservoirs in this river basin (67 according to SNIRH-INAG). The lack of suitable measures to reduce and mitigate the impacts in the existing dams (e.g. lack of fish passes or inefficient devices) and the difficulties for the implementation of mitigation measures for the new planned dams (e.g. there are not know efficient fish passes for some species and for this king of dams) will inevitably cause further degradation of aquatic habitats and water quality, with a probable significant impact on the loss of biodiversity. The new planned dams under the PNBEPH plus the Sabor dam (currently under construction) will cause cumulative impacts and increase the environmental degradation of Douro river basin

Other river basin, as the Vouga will on the contrary suffer from the introduction of a new dam with significant impact in a river that is currently almost unregulated. This will cause significant deterioration of aquatic habitats and fish populations. 12 fish species included in the Red Data Book (including 8 sp. from the Habitats Directive) have been identified only in the area affected by the Pinhosao dam, which indicates the diversity of fish species present in this river basin. A significant barrier to migratory species (Anguilla anguilla and Petromyzon marinus) will be introduced with the construction of the Pinhosao dam on the Vouga river. Adverse effects on protected areas will also be introduced with the building of a new dam in the Vouga river, in particular on a Natura 2000 site that includes a stretch of the river Vouga (Rio Vouga Natura 2000 site - PTCON0026) and on an estuarine zone with high ecological value (Ria de Aveiro, also classified as a SPA under Natura 2000). Habitats degradation could occur in this estuarine area as a consequence of the reduction in water flow, which could also increase the intrusion of salt water in the freshwater habitat.

As regards the Mondego basin, the dam will create another barrier to fish species in the main river which currently has no good river connectivity downstream the dam. The Mondego river basin has a significant river fragmentation at present, owing to the presence of several dams (at least eight big dams) on the main rivers of this basin. Nevertheless, several protected fish species are present in the area that will be affected by the new dam planned under the PNBEPH (Girabolhos), including one endangered species (*Chondrostoma arcasii*) and one vulnerable species (*Squalius alburnoides*). Deterioration of the habitat quality, which currently is good close to the new dam location (i.e. at 4 km downstream the dam, according to a preliminary ecological assessment; Cortes & Ferreira, 2008) can be expected from the building of this new dam. Furthermore, likely adverse effects on a wetland area included in Natura 2000 (Carregal do Sal - PTCON0027) which is located at about 17,5 km downstream the Girabolhos dam.) can be also predicted

As far as the Tejo river basin is concerned, a new dam on the lower reach of the Tejo (Almourol) will certainly have very significant negative impacts on the habitats of at least 15 fish species included in the Portuguese Red Data Book (including 10 species from the Habitats Directive) some of which are migratory species *(Lampetra fluviatilis, Petromyzon marinus, Anguilla Anguilla*) that currently have no other obstacles up to the area where the new dam will be built up (currently the first obstacle in this river is located about 30 km upstream the Almourol planned dam). With the implementation of the Almourol dam, the existing fish migration area will be strongly reduced in the Tejo, in a section of the river that currently does not present fragmentation and has high/good habitat quality conditions. Building up two new big dams in this river basin (Alvito and Almourol) will also have significant cumulative effects at the river basin scale, where other 51 dams are present. Almourol could also have adverse effects on the Tejo estuary, a high nature value area that has been designated as Natura 2000 site.

A recurrent problem to all dams is the introduction of exotic species. In reservoirs environment exotic species have frequently competitive advantage over the autochthonous species becoming dominant. Therefore, it is expected that the substitution of autochthonous species by exotic species become a reality in new reservoirs. This will certainly leads to the increasing of the rates of fish biodiversity loss in Portugal.

Other recurrent problem in reservoirs is the risk of eutrophication, leading to the increase of the probability of harmful algal blooms occurrence and therefore to habitat degradation and ultimately to biodiversity loss.

Other impacts (common to all dams) that have not been commented on above but should also be taken into account are the following:

- Degradation of riparian areas;
- Affection of terrestrial habitats (fragmentation with can put in risk terrestrial species);
- Landscape degradation.

For the Foz Tua information was available on possible impacts via the EIA Foz Tua (2008). However, the EIA minimizes the reduction of water quality that will take place as the possible impacts by the Foz Tua dam are assessed by using as reference for estimations of water quality two dams located in an area with a much higher precipitation and taking for granted the improvement of the effluents from the existing industrial infrastructures and urban settlements in the Tua basin.

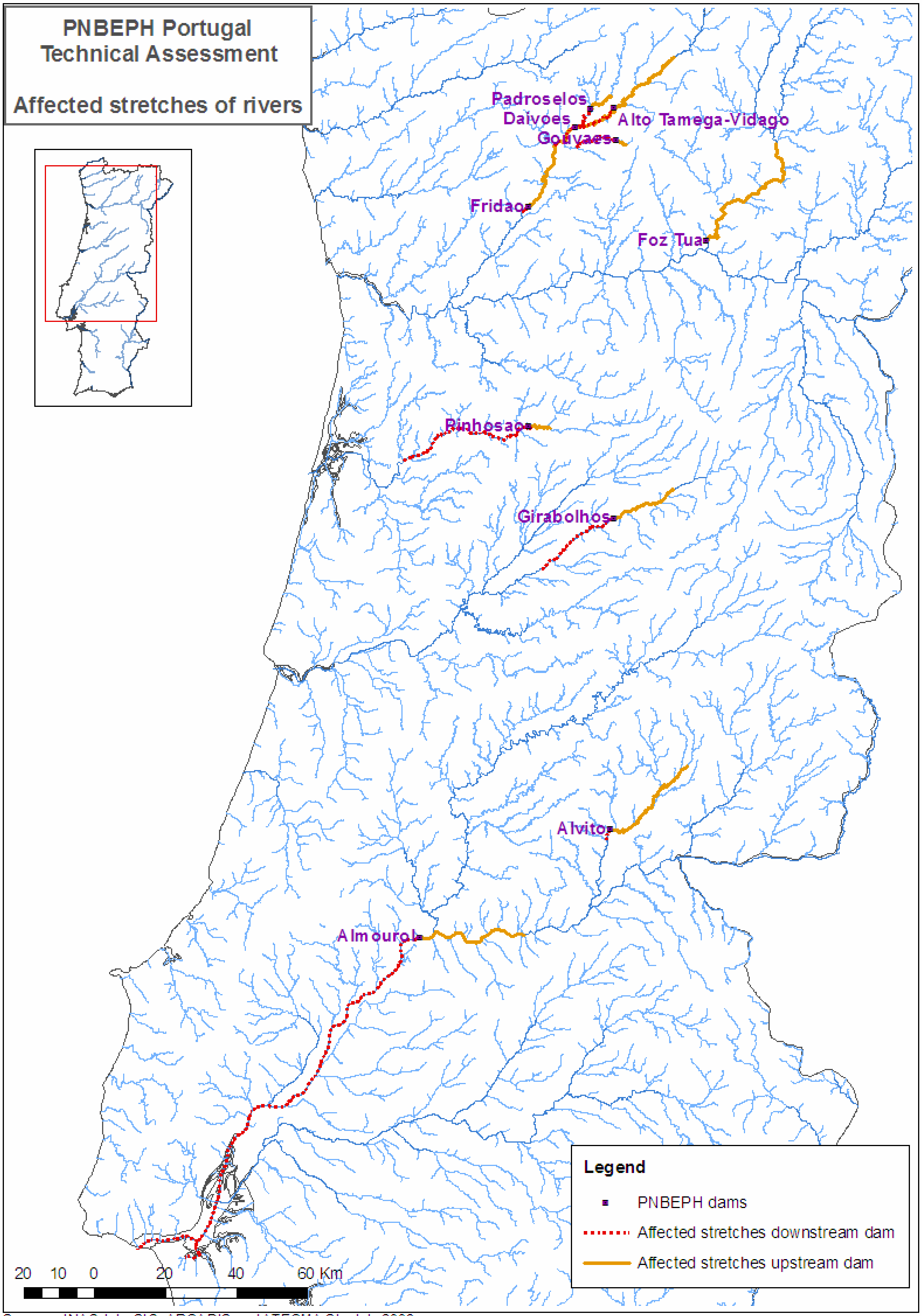
The impacts on flora and fauna are proficiently assessed by the EIA, but no relevance is given to the fact that the reservoir will cause significant negative impact to natural habitats types, flora and fauna species and aquatic ecosystems. As regards the mitigation/ compensation measures proposed, the implementation of a minimum ecological flow is not considered necessary as the distance between the Régua reservoir (downstream the Foz Tua dam) is considered too small (about 120 m) and the loss of fluvial habitat under is therefore considered minimal, which according to the EIA does not justify the implementation of a minimum flow. Also the implementation of fish passes is questioned due to the absence of migrating species because of other existing migration barriers at dams downstream in the Douro basin and because of technical difficulties. In face of these facts, the EIA proposes that river connectivity should be promoted downstream, namely by tackling the main (and first) obstacle to fish migration in the river Douro basin, the Crestuma-Lever dam. However, in our opinion, the reduction of obstacles should not be restricted to the first large obstacle (Crestuma-Lever) but be enlarged to the remaining dams so that an effective river connectivity can be achieved at basin level.

Finally, the cumulative impacts of the Foz Tua dam project are not described in the EIA, which considers that an evaluation of such impacts is not the role of an EIA but that of a SEA.

2.3.1.3 Estimated length of affected stretches

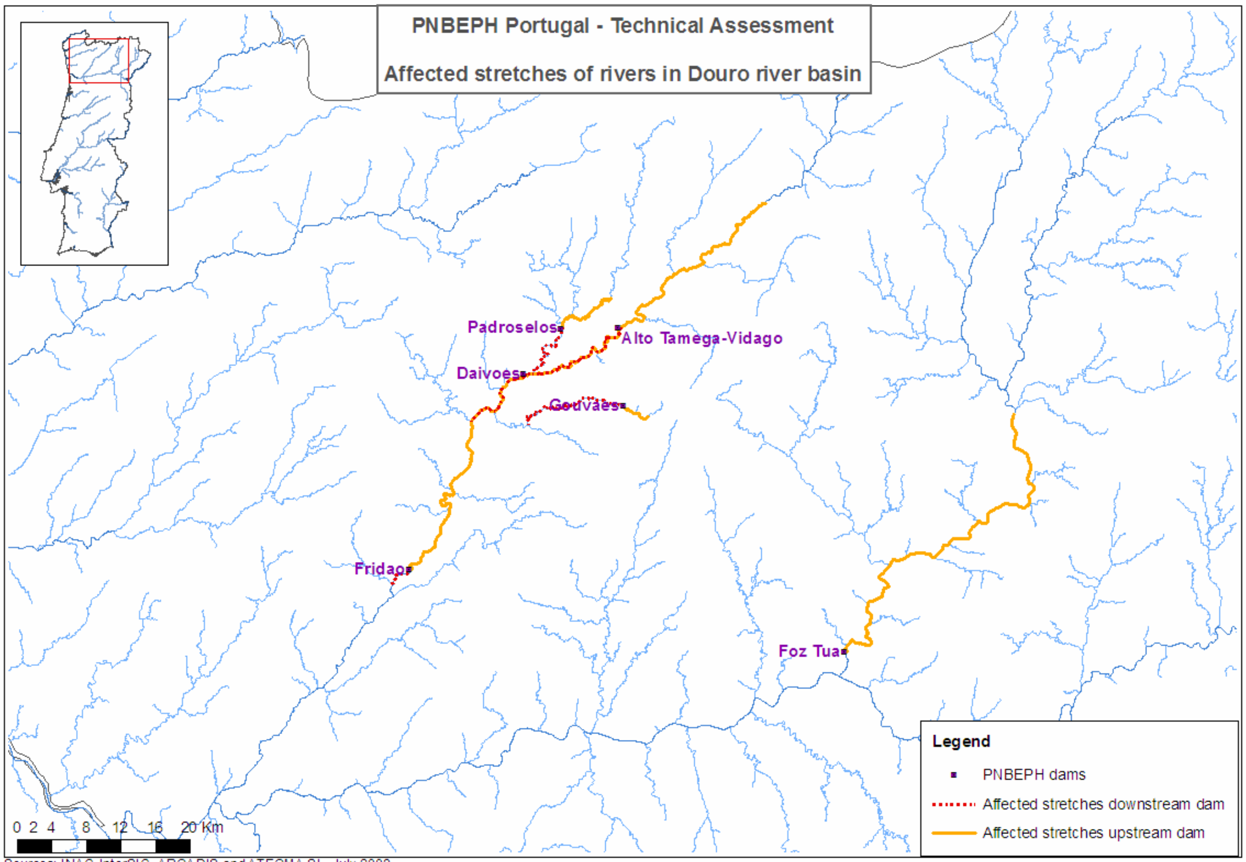
The results of the estimated affected length upstream and downstream of the planned hydropower station are displayed in Illustration 29 where the affected river stretches (upstream and downstream) for each of the selected hydropower stations from the PNBEPH coloured. A more detailed map of the affected river stretches within the Douro River Basin is given in **Illustration 30**.

Illustration 29: Affected stretches of rivers (based on the calculations given in Table 44, Table 45, Table 46 and Table 47)



Sources: INAG-InterSIG, ARCADIS and ATECMA SL. July 2009.

Illustration 30: Affected stretches of rivers (based on the calculations given in Table 44 and Table 45)



Sources: INAG-InterSIG, ARCADIS and ATECMA SL. July 2009.

Table 44: Results of the calculations performed for determining the affected length of river stretches downstream on the main river of the planned hydropower station in the Douro River Basin (based on the methodology - see Illustration 18)

	Douro river basin confluences downstream of planned hydropower	River Type tributary (WFD type)	Basin area upstream of confluence (ha)	Sub-basin area (ha)	% sub-basin area /total river basin area upstream of confluence	Distance from planned hydropower (m)
Padroselos	Eastern branch Tâmega	Medium-Large	33776	91715	271.54	10037
Tâmega-Vidago	Ribeira do Ouro	Small	86387	1308	1.51	5757
	Western branch Tâmega	Medium-Large	91715	33776	36.83	16250
	Ribeira de Caves	Mountain	93545	3086	40.13	26780
	Louredo	Medium-Large	97226	16382	56.98	33914
	Ouro river	Medium-Large	114976	17457	72.16	37760
	Rio de Veade	Medium-Large	136936	3958	75.05	47490
	Rio Cabril	Medium-Large	136936	6259	75.51	47490
	Rio da Vila	Medium-Large	143619	3967	78.27	52744
	Ribeira de Santa Natalia	small	151999	7411	83.15	53797
	Albufeira Torrao		**151999**			54944
Daivões	Ribeira de Moimenta	Mountain	20262	1629	8,04	2747
	Ribeira de Caves	Mountain	22092	3086	22.01	3396
	Louredo	Medium-Large	25773	16382	85.57	6684
	Ouro river basin	Medium-large	43523	17547	125.88	10530
Fridão	Ribeira de Santa Natalia	small	151999	7411		3106
	Albufeira Torrao					5400
Gouvães Rio Louredo	Southern branch rio Louredo	small	4248	6424	151,22	1721
	Eastern Branch Tâmega River		**9958**			7741

	Douro river basin confluences downstream of planned hydropower	River Type tributary (WFD type)	Basin area upstream of confluence (ha)	Sub-basin area (ha)	% sub-basin area /total river basin area upstream of confluence	Distance from planned hydropower (m)
Gouvães Rio Olo	Ribeira de Fervença	small	5568	1659	29,80	9019
	Rio do Siao	Small	6469	1093	16,90	12671
	Ribeira de Beja	small	9145	296	3,24	24509
	Albufeira Torra		**11482**			34047
Gouvães Rio Poio	Rio Louredo	small	1083	8011	739,70	4049
	Eastern Branch Tomega River	Medium large	**9958**			7741
Foz Tua	Douro (Albufeira Regua)	Medium-Large	**672**			3182

Legend: % sub-basin to basin area/total river basin area upstream of confluence: Green = % sub-basin / total basin area low (0-50% cumulative) and no effect of attenuation of hydropeaking/low flows by the tributary expected; Orange = % sub-basin / total basin medium (50 to 100%) and moderate attenuation effect of flow changes by tributary. Red = % sub-basin / total basin area high (>100%cumulative) and no effect of attenuation by tributary to changed flow in stream with hydropower expected.

Distance from planned hydropower: light blue: significant attenuation of flow changes at location of confluence but still minor effect of changes in flow due to hydropower activity. Bright blue: from this distance onwards no effect expected as complete attenuation is obtained.

Table 45: Results for the calculated effect upstream and downstream on the main river of the planned hydropower station and features of the affected river stretches in the Douro River Basin

	Tua	Padroselos	Alto Tâmega	Daivões	Fridão	Gouvães
River flow at hydropower location (hm3/yr)	1207	203	664	1090	1790	101
Upstream effect	**51**	**10**	**28**	**19** (but only 11 km to Padroselos)	**40km**	**Gouvães dam: 3.7km** **Ribeira Viduedo: 0,080** **Rio Alvadia: 0,22** upstream and about 0,2 of the Ribeira Favais **Rio Olo: 0,8km**
Downstream effect (km)	**3,18**	**10,03**	**54,94**	**10,53**	**5.4**	**Gouvães: 1,72** **3 dams diversions:** **Rio Louredo: ?** **Rio Olo: 34,05** **Rio Poio: 4,05**
Downstream attenuation by	Douro river (Albufeira Regua)	Eastern branch Tâmega river	Western branch Tâmega river	Ouro river	Albufeira Torrao	3 diversions: Gouvães dam: Rio Louredo: Southern Branch Rio Louredo Rio Louredo: Rio Olo: Albufeira Torra Rio Poio: Rio Louredo
Protected zone (fish)	no	no	Yes, 2.6km upstream	no	no	no
HMWB	no	no	no	no	no	no
Nutrient Sensitive zone	no	yes	yes	yes	yes	yes
Vulnerable zone UWWTD	yes	no	no	no	no	no
At risk (WFD)	yes	yes	yes	yes	yes	yes

Table 46: Results of the calculations performed for determining the affected length of river stretches downstream on the main river of the planned hydropower station in the Vouga-Mondego and Tejo River Basin (based on the methodology – see Illustration 18)

	Vouga-Mondego and Teje river basin confluences downstream of planned hydropower	River Type tributary (WFD type)	Basin area upstream of confluence (ha)	Sub-basin area (ha)	% sub-basin area /total river basin area upstream of confluence	Distance from planned hydropower (m)
Pinhosão	Ribeira de Pinho	small	38715	1099	2.84	1818
	Rio Sul	medium-large	40620	11555	31.29	4087
	Rio Troço	small	52241	6037	42.84	4555
	Ribeira de Ribama	small	58802	3594	48.95	6734
	Rio Zela	small	63900	1838	51.83	12627
	Ribeiro da Ponte de Mézio	small	66785	1719	54.40	17660
	Rio Valoso	small	68858	6314	63.57	19855
	Ribeira da Gaia	small	79363	1579	65.56	26999
	Rio Texeira	small	82103	7292	74.44	28933
	Rio Lordelo	small	94927	2476	77.05	31499
	Rio Gresso	small	97911	1138	78.21	33624
	Ribeira de Salguiera	small	100922	1153	79.35	38757
	Rio Mau	small	104231	3078	82.30	47623
	Ribeira de Alombada	small	107512	2420	84.55	49022
	Rio Caima	medium-large	110722	19848	102.48	51760
Girabolhos	Ribeira dos Tourais	small	100970	3321	3.29	8374
	Afluente do Rio Mondego	small	125135	1397	1.08	10790
	Rio do Castelo	small	125748	6018	4.61	11404
	Rio de Mel	small	127450	3110	2.25	13820

	Vouga-Mondego and Teje river basin confluences downstream of planned hydropower	River Type tributary (WFD type)	Basin area upstream of confluence (ha)	Sub-basin area (ha)	% sub-basin area /total river basin area upstream of confluence	Distance from planned hydropower (m)
	Ribeira de Arca	small	130844	1040	0.72	22054
	Rio Seia	Medium-large	132397	19094	12.96	26968
	Albufeira Aguieira					31405
Alvito	Alvito – Ribeira de Froia		99223	3930	3.96	1842
Alvito	Alvito - Ribeira da Serzedinha		103381	6038	5.84	3615
Alvito	Albufeira Pracana					3615
Almourol	Ribeira de Tancos		937098	2630	0.28	1215
Almourol	Ribeira Ponte da Pedra		940627	7618	1.09	6338
Almourol	Ribeira do Vale da Vaca		949058	5840	1.71	12436
Almourol	Rio Almonda		957953	21281	2,22	22366
Almourol	Rio Alviela		980897	27402	3.93	23381
Almourol	Ribeiro de Cabanas		1010684	11361	5.05	32966
Almourol	Ribeira de Mugo		1025469	106748	15.46	36646
Almourol	Vala de Salvaterra		1135611	20046	17.23	37959
Almourol	Rio de Valverde		1155657	92200	25.21	37959
Almourol	Riio da Ota		1250708	28611	27.5	42646
Almourol	Vala do Carregado		1280639	11838	28.42	44714
Almourol	Vala do Esteiro do Ruivo		1293193	3547	28.69	47192
Almourol	Ribeira de Santo António		1303122	1057	28.77	56582
Almourol	Ribeira da Silveira		1305441	2633	28.97	58632
Almourol	Rio Sorraia		1314325	526146	69	72184

	Vouga-Mondego and Teje river basin confluences downstream of planned hydropower	River Type tributary (WFD type)	Basin area upstream of confluence (ha)	Sub-basin area (ha)	% sub-basin area /total river basin area upstream of confluence	Distance from planned hydropower (m)
	Rio Trancao		1846636	35269	70.91	72184
	All estuarine parts of the Tejo branches bundled as one sub-basin. Distance from planned hydropower downstream is to closest coastal site		1894236	69096	74.55	91877

Legend: % sub-basin to basin area/total river basin area upstream of confluence: Green = % sub-basin / total basin area low (0-50% cumulative) and no effect of attenuation of hydropeaking/low flows by the tributary expected; Orange = % sub-basin / total basin medium (50 to 100%) and moderate attenuation effect of flow changes by tributary. Red = % sub-basin / total basin area high (>100%cumulative) and no effect of attenuation by tributary to changed flow in stream with hydropower expected.

Distance from planned hydropower: light blue: significant attenuation of flow changes at location of confluence but still minor effect of changes in flow due to hydropower activity. Bright blue: from this distance onwards no effect expected as complete attenuation of the flow changes is obtained.

Table 47: Results for the calculated effect upstream and downstream on the main river of the planned hydropower station and features of the affected river stretches in the Vouga-Mondego and Tejo River Basin

	Pinhosão	Girabolhos	Alvito	Almourol
River flow (hm3/yr)	257	141	318	11300
Upstream effect (km)	**8**	**21**	**38**	**36**[11]
Downstream effect (km)	**51,76**	**31,41**	**3,62**	**91,88**
Downstream attenuation by	Tributary (rio Lordelo)	Albufeira Aguieira	Albufeira Pracana	Coast[12]
Protected zone (fish)	Yes (all length downstream effect, all length reservoir	Yes (all length downstream effect, all length reservoir and further upstream)	Yes (all length reservoir)	Yes, upstream over length of 8,26km
HMWB	No	No	Yes	Yes, except for length 33km downstream
Nutrient Sensitive zone	No	Yes	Yes	No
Vulnerable zone UWWTD	No	No	no	Yes, upstream over length of 26,08km downstream of Almourol and 11,76km upstream of Almourol.
At risk (WFD)	For 63.03% at risk	yes	Yes	Yes, main part at risk
Note		Albufeira Aguiera and Albufeira Raiva more downstream	Albufeira Marateca upstream (12.3km)	Upstream Albufeira Castelo de Bode at 17,86km; Albufeira Belver at 43,32m; Albufeira Fratel at 65,34m; Albufeira Pracana at 67,38km

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[11] Tributaries of Tejo river will also be directly affected by the reservoir as shown on the PNBEPH maps Annex 9.

[12] Problem of salwater intrusion will be an issue here.

Evaluation

Planned dams for the Douro river basin

For the planned dams in the Douro river basin, located at the Tâmega river (Fridão, Daivões, Padroselos, Tâmega-Vidago) and the Gouvães dam on the Rio Louredo, a tributary of the Tâmega river, the effects reach a significant distance upstream and the reservoir length is considerable except for the Gouvães dam which is located on a smaller stream with subsequent less flow but this dam receives water from 3 other branches in the Tâmega river basin and as such has 3 extra sites affected consequently.

With regard to the downstream effect, the effects are contained within the Tâmega sub-river basin itself, but due to the planned dense network of hydropower dams, nearly the complete Tâmega river basin will be impacted and as such significant effects on the ecological status will be obvious. As one can see from the results of Table 1, the Tâmega sub-river basin affected we talk about has a surface area of nearly 200.000ha, which is the basin area upstream of Albufeira Torrao which would finally absorb the flow fluctuations produced by the upstream located Fridão reservoir.

All rivers in the Tâmega river basin are located in a nutrient sensitive zone, and as such effects caused by nutrient enrichment will have a significant impact in this area. The area is also already at risk so any extra impact will make the situation worse.

For the Tua dam, although the upstream effect is very extensive (the reservoir will be 51km of length), the downstream effect is negligible due to the presence of the Regua reservoir in which the water of the hydropower station is diverted to.

Planned dam for the Vouga river basin (Pinhosão)

For the planned Pinhosão dam, the effects are significant mainly due to the length of affected fish protected zone that will be impacted upstream and downstream of the hydropower location. Combined with the possible barrier effect of the dam, the changed flow conditions will certainly threaten the fish considerably over a distance of nearly 60kms.

Planned dam for the Mondego river basin (Girabolhos)

For the planned Girabolhos dam, the effects upstream and downstream of the hydropower location are in a fish protected zone, a nutrient sensitive zone and an area that is already at risk. The effects will as such be significant over a large area.

Planned dams for the Tejo river basin

For the Almourol dam, we calculated that the hydropower installation will have an effect up to the coastal area, but we have to take into account that the flow fluctuations will also naturally fade out over a certain distance. However, due to the large capacity of the dam, one can conclude the effects on sedimentation processes and quality of the river in general will certainly reach up to the coastal zone, especially as there are 2 other hydropower stations located close to the Almourol location upstream.

For the Alvito dam, the effect downstream is attenuated at short distance from the dam due to the reservoir of another hydropower dam but the dam is also located in fish protected zone and nutrient sensitive zone, but objectives as set by the WFD will be lowered due to the heavily-modified water body designation.

2.3.2 Scenario 2: Minimum flow

As explained earlier in Task 1a and in the Methodology section of task 2b (2.1.2), there is a lack of information on the methodology for defining minimum flows. Morover, most methodologies are based on a detailed model that requires a huge amount of location-specific information. Minimum-flow settings are very location specific and as such defining a minimum flow based on actual fish requirements will need to be done case by case. Because of the information not being available and the modelling being out of the scope of the study, a scenario analysing the effects and potential benefits of minimum flows is as such not feasible.

A few notes with regard to the PNBEPH itself and some of its features that determine the need for a set minimum flow:

- Most (7, all except Fridão, Almourol and Alvito) of the dams are reversible systems. Reversible hydro power systems can be explained as follows: the water pass the turbine of the first dam and it is retained by the second and then if necessary is re-pumped again to upstream the first dam to produce again hydropower. Theoretically the water can be retained indefinitely in this system without going to downstream. This could cause the flow to be very low at the outflow of the system and could pose problems at natural low water levels. For this reason a set minimum flow would ensure an ecological acceptable flow.
- For the Foz Tua specifically, the following information is given in the EIA: The implementation of a Minimum Ecological Flow is not considered necessary as the distance between the Régua dam influence area and the Foz Tua dam results in a maximum length of 120m of dry river bed downstream of the dam. According to the EIA, the loss of fluvial habitat under these circumstances is minimal and does not justify the implementation of a minimum flow. It adds that this estimation is for a limit situation and that the normal situation is for a maximum of 30m between the Foz Tua dam and the Régua influence area. However, it is difficult to imagine that a dry river bed over a certain area would not mean any loss of fluvial habitat. The statement given in the EIA of the Foz Tua is contested by this study.
- Applying the mitigation measure on fish pass is of no use when the flow conditions are not optimal. As such, relevant minimum flow conditions are essential for fish passes to work efficiently.
- The presence of other significant pressures (such as for example eutrophication in the Douro estuary; bad habitat quality in parts of the Tâmega river basin; siltation of the spawning habitat due to sedimentation in the reservoir etc) could hinder the establishment of a healthy population even if minimum flow conditions are set. The optimal conditions are described by all aspects of the physical habitat and flow conditions are the main but not the sole parameter to consider/

For this analysis, we can only conclude that minimum flow settings are a basic requirement for maintaining healthy biological populations (with a focus on fish communities), and even more important is the requirement of natural flow variations in the river system.

2.3.3 Scenario 3: minimum flow and fish passes

2.3.3.1 Considerations

In this analysis we are mainly looking to the potential of surviving of migrating fish and look to the fish pass as a mitigation measure to overcome the migration barriers (one of the main impacts of hydropower stations as defined in Task 2a). However, one still needs to look at the broader scale, where the effort to overcome the fish pass, the changed habitat upstream and downstream of the dam and the completely changed flow conditions will all contribute to the success of the fish pass. Next to these considerations, the limiting condition will also be the optimal design and operation of the fish pass itself. A last aspect of consideration is that fish passes do require minimum flow.

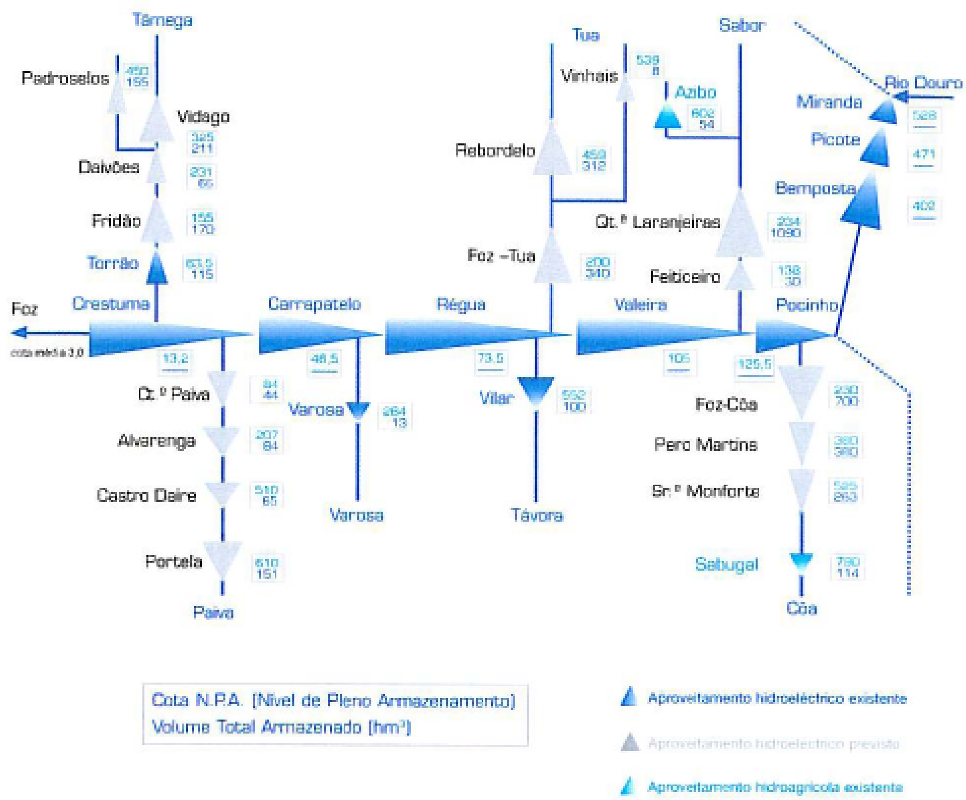
2.3.3.2 Analysis of existing fish passes in Douro river basin and benefits of installing a fish pass in the PNBEPH planned dams in the Tâmega sub-basin and Tua river.

Tãmega sub-basin (Douro River Basin)

- There is a high number of already existing reservoirs in Douro river basin (57, see Section 2.2.2.4 and **Illustration 31**), however, Tâmega sub-basin is one of the last "almost unregulated" affluent of Douro River. Therefore, Tâmega and their affluents can constitute an ecological refuge for autochthonous and endemic fish species from the Douro River Basin. From that point of view, a fish pass would certainly be of great importance for fish to allow migration.
- The occurrence of threatened and Iberian endemic species such as *Squalius alburnoides*, *Cobitis calderoni and Achondrostoma arcasii* were reported.
- From the cascade of dams, one can see that Torrão and Crestuma dams are the two downstream of the planned dams in the Tâmega sub-basin. According to the fish passing efficiency results as given in Section 0, the **Crestuma dam scores bad with regard to fish passing efficiency**, the Torrão dam has not been evaluated.
- Although fish passing installations should be present at all planned dams, priorities with regard to fish traps should be given depending on their location (the more downstream, the more importance a good working fish trap) and if they are located on the way to a fish protected zone. From that aspect, the Fridão, Daivões and the Gouvães dams are absolutely required to have a good working fish pass.
- Despite of the existing Torrão Dam on the Tâmega river mouth and the existence of organic pollution/ eutrophication problems, the river areas that will be affected by the construction of new dams have good habitat quality. Besides data from Ecological assessment (Table 41) showed the existence of high scores fish communities suggesting the existence of well structured fish communities and good habitat conditions for this particular group.
- From the Tables in Section 2.2.2.7 'Information on fish species present in the PNBEPH area', one can see that the migrating Eel species are still present in Gouvães and Fridão. However, it is assumed that the existing individuals of the Eel cannot reproduce because of habitat fragmentations caused by Torrão and other dams in Douro. Also *Salmo trutta* numbers decrease from up downstream in Tâmega river and it is never dominant.

- Seven dam projects (all except Fridão, Almourol and Alvito) consist of two reservoirs (reversible systems), for which minimum flow requirements are essential as explained earlier in Section 2.3.2

Illustration 31: Cascade of dams (realised and planned) in the Douro river basin



Foz Tua (Dour River Basin)

- For the Foz Tua dam, the Regua, Carrapatelo and Crestuma dams are downstream of the planned Foz Tua dam. **Regua and Carrapatelo fish passes are both not functioning while Cresuma dam functions badly.** This is also explained in the EIA Foz Tua (2008) from which it is concluded that there is no fish pass needed at the Foz Tua dam.
- Biological index based on fish community has a moderate score. Similarly to Tâmega data indicate that Tua has good habitat conditions for fish.
- Although *Salmo trutta* has been recorded by INAG near the Foz Tua, it is considered to be absent near the mouth of the river (personal communication).
- According to the EIA Foz Tua, the following evaluation of the need for a fish pass has been given: the implementation of fish passes is questioned due to the absence of migrating species because of the malfunctioning of other existing migration barriers at dams downstream in the Douro basin and also because of technical difficulties: topography, the height of the wall and the little efficiency of sluices demonstrated in other Douro dams makes the elevator the only possibility but there is no experience with elevators for such height differences. Additionally, the elevator should be located on the left bank, which would imply the building of a derivation

circuit that would have excessive costs and possible relevant impacts on other environmental components, as well as the maintenance of a minimum flow.

- In face of these facts, the EIA proposes that river connectivity should be promoted downstream, namely by tackling the main (and first) obstacle to fish migration in the river Douro basin, the Crestuma-Lever dam.
- According to a recent inventory of fish passes in Portugal (Santo, 2005), in spite of the high number of large and small dams in the country, only a mere 39 include fish passing devices. Even so, the sluice passes of Douro have been demonstrated to be highly inefficient (Bochechas 1995 and Santo 2005).
- Cyprinids in the Douro seem to be adapted to the situation and have become residential in the Douro lakes. Moreover, one of the migrating species who is amphibiotic, the 'koornaarvis' developed certain adaptations called 'land-locking' and as such he doesn't need to migrate to coastal zones during life

2.3.3.3 Analysis of exsisting fish passes in the Vouga Basin and benefits of installing a fish pass for the Pinhosão dam

- The projected dam is located upstream from the first obstacle for fish migration (Drizes)
- Five diadromous species are present in this basin: *Petromyzon marinus* (this is not mentioned in 2.2.2.7 but it is recorded by Andrade et al. 2007 and Almeida et al. 2002), *Lampetra fluviatilis, Anguilla anguilla, Alosa alosa* and *Alosa fallax*. The habitat of those migratory has been decreasing for several decades in Portugal (Cabral et al, 2006). According to the map of existing dams as given in **Illustration 22** and with exception of Drizes, Ribafeita, São Pedro do Sul weirs, the main course of Vouga River is not regulated. Only São Pedro do Sul weir has been evaluated as having a score 2 on fish passing efficiency (ranging from 1 (bad) to 5 (very good). However, one can still consider this river presents a high degree of connectivity
- The river has a high habitat quality index. Therefore, this basin still has important areas of suitable habitat for resident fish (e.g. *Squalius alburnoides, Achondrostoma arcasii*).

2.3.3.4 Analysis of existing fish passes in the Mondego river basin and benefits of installing a fish pass for the Girabolhos dam.

- According to INAG there are around 27 dams in Mondego river basin. According to the map of existing dams as given in Illustration 22, there are only 2 dams downstream of the planned Girabolhos dam (i.e. Aguieira Dam and Raiva Dam) and the Mondego area further downstream is not regulated, except for one weir upstream of Raiva dam which is badly functioning (Pointe de Coimbra) (note: Ponte de Coimbra is reported to be an obstacle for sea lamprey but they are transferred to upstream by elements of Forestry Police. However, we have not found records of sea lamprey in our data (See Section 2.2.2.7)).
- The river has high habitat quality.

2.3.3.5 Analysis of existing fish passes in the Tejo river basin and benefits of installing a fish pass at Almourol and Alvito river basin

Almourol

- Nowadays the first obstacle to fish migration in Tejo river is the Belver dam which is upstream of Almourol. Fish can reach some tributaries (e.g. Sorraia and Divor) located below the Belver dam (Oliveira 2007). However, with the implementation of the Almourol dam, the area of “free migration” will be strongly reduced (and the habitat of threatened resident species such as *Squalius pyrenaicus*, *Squalius alburnoides* will be also negatively affected)
- Good habitat quality and fish index with high score
- It is believed that the area downstream of Belver dam *Petromyzon marinus* would migrate and it is (together with some sites in the Vouga river basin) one of the last places where populations of the sea lamprey exist (see **Illustration 16: Habitat available to sea lamprey populations in Portuguese river basins where the species is known to occur**).

Alvito

- Belver and Pracana dam are both downstream of Alvito dam. We do not have an evaluation available of fish passing efficiency on the Pracana dam but the Belver dam has a score 2 with regard to fish passing efficiency on a scale from 1 (bad) to 5 (very good).
- As a consequence of this project implementation, a reduction of the habitat of resident species such as *Barbus comizo, Iberochondrostoma lemmingii, Squalius pyrenaicus, Squalius alburnoides, Iberochondrostoma lusitanicu*m is expected.
- Good habitat quality and fish index with moderate score.

2.3.3.6 Conclusions

The following elements can be highlighted:

- Tâmega sub-basin is one of the last “almost unregulated” affluent of Douro River and can be seen at a last refuge for migrating species although the Crestuma dam is already acting as a migration barrier and there is a problem with eutrophication and migration. It is also assumed that populations on migrating species (trout and eel) in this sub-basin are nearly non-existing and are certainly decreasing in numbers the more upstream in the river basin. From that aspect there are 2 important points to consider:
- Cumulative impacts: although fish passes could be installed at the different hydropower locations at the Tâmega sub-basin, this demands a huge effort from the fish populations to overcome the cascade of these obstacles and this also requires the fish passes to work in an optimal way
- The bottleneck for success of the fish passes in the Tâmega sub-basin will also be the current pollution (eutrophication/saprobiation) and the existing barrier at the Torrão and Crestuma dam. These effects are already noticeable in the fish monitoring results analysed.
- For the **Foz Tua,** more information is available because of the EIA process. One of the conclusions of this EIA is that because of the absence of migrating species together with the cost of installing a fish pass, it is not part of the plan. From our

analysis we can indeed see that indeed both Regua and Carrapatelo dam are both not functioning while Cresuma dam functions badly.

- For the Vouga river basin, because 5 migrating species are still present in this are, the instalment of a fish pass at the **Pinhasão dam** would be an absolute requirement to guarantee free migration of these species, especially when one considers the high habitat quality of the river Vouga. The Vouga river basin would also be one of the only river basins that still hosts *Peteromyzon marinus*, a red list (Vulnerable status) and Habitat Directive Annex 2 species (see **Illustration 16**).
- At the Mondego river basin, we could find no migrating species and there is also 2 dams and a weir upstream of the planned location.
- For Almourol, the area upstream of Belver dam is of high importance for migrating species (including *Petromyzon marinus*) and is as such extremely valuable. There is currently no fish migration barrier in this area.
- For Alvito, the current bottleneck area already existing: Belver dam and also possibly Pracana dam. The current area is more of importance for residence fish.

2.3.4 Cumulative impacts

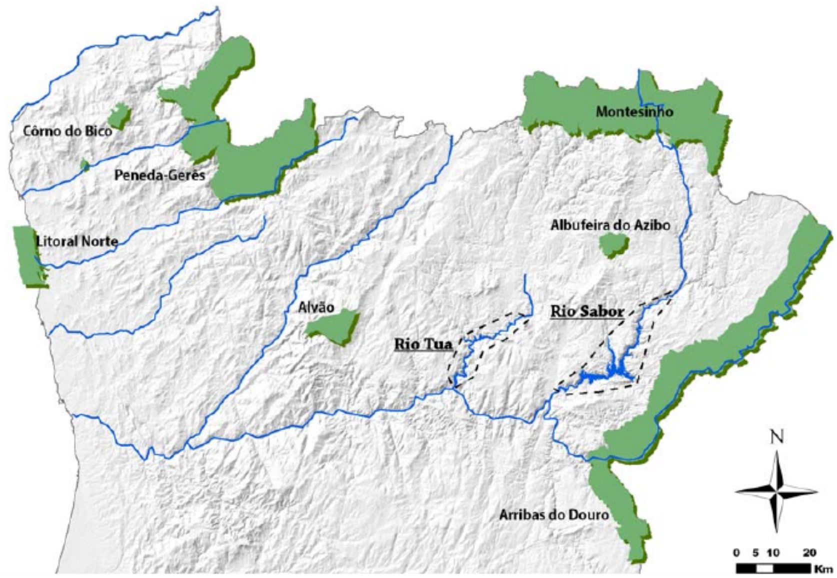
To assess the cumulative impacts of the PNBEPH dams, we have focussed on the most sensitive indicator to assess effects at the river basin scale which is the fish population. In this section, the cumulative impacts for each of the river basins are highlighted.

2.3.4.1 Cumulative impacts Douro River Basin

Stressing points

- High number of already existing reservoirs in Douro river basin (67, see Section 2.2.2.4 and **Illustration 31: Cascade of dams (realised and planned) in the Douro river basin**). From those maps it should be stressed that Tâmega sub-basin is one of the last “almost unregulated” affluent of Douro River. Therefore, Tâmega and their affluents can constitute an ecological refuge for autochthonous and endemic fish species from the Douro River Basin.
- The occurrence of threatened species such as *Squalius alburnoides*, *Cobitis calderoni and Achondrostoma arcasii* (not confirmed in Tua) were reported.
- In the EIA of the Foz Tua, cumulative impacts are not described. However, the addenda to the EIA report approaches this issue, under request of the CA (= evaluation commission Comissão de Avaliação). However, it considers that an evaluation of cumulative impacts at such a large scale is not the role of an EIA but that of a SEA (Strategical Environmental Assessment), which in this case has already been undertaken for the whole PNBEPH. It should be taken into account that the impacts of the Foz Tua dam do need to be looked at together with the other existing dams in the Douro River Basin.

Illustration 32: Location of the reservoirs foreseen in river Tua (as described in the PNBEPH project) and river Sabor (Baixo Sabor dam)



Water quality degradation on the Douro from Miranda to Picote to Benposta) in the Douro River basin is caused by the location of the dams in a sequence after each other ("cascade situation") with no significant lotic section in between that allows for re-oxygenation between the sequential artificial lentic systems created by the dams. (source: EIA Foz Tua). This illustrates the potential cumulative effects that can happen at the other planned locations in the Tâmega river basin.

2.3.4.2 Cumulative impacts Vouga River Basin (Pinhosão)

Stressing points

- Five diadromous species are present in this basin: *Petromyzon marinus* (is missing in Final fish species document but it is mentioned in Andrade et al 2007 and Almeida et al 2002), *Lampetra fluviatilis*, *Anguilla anguilla*, *Alosa alosa* and *Alosa fallax*. The habitat of those migratory has been decreasing for several decades in Portugal (Cabral et al, 2006).
- According to **Illustration 22** in which existing dams are displayed and with exception of Drizes, Ribafeita, São Pedro do Sul weirs (Santo, 2005), the main course of Vouga River is not regulated. Therefore, this river presents a high degree of connectivity and also a high habitat quality index.
- This basin still has important areas of suitable habitat for resident fish (e.g. *Squalius alburnoides*, *Achondrostoma arcasii*).
- The projected dam is located upstream from the first obstacle for fish migration. (i.e. Drizes).
- The projected dam can increase eutrophication problems.

2.3.4.3 Cumulative impacts Mondego River Basin (Girabolhos)

Stressing points

- According to INAG there are around 27 dams in Mondego river basin. According to **Illustration 22**, Aguieira and Raiva Dam as well as Ponte de Coimbra weir are downstream of Girabolhos planned dam.
- High habitat quality.
- The projected dam can increase eutrophication problems

2.3.4.4 Cumulative impacts Tejo River Basin

Stressing points

- Almourol: Nowadays the first obstacle to fish migration in Tejo river is the Belver dam. Fish can reach some tributaries (e.g. Sorraia and Divor) located below the Belver dam (Oliveira 2007). With the implementation of the Almourol dam, the area of "free migration" is strongly reduced. The habitat of threatened resident species such as Squalius pyrenaicus, Squalius alburnoides will be also negatively affected.
- Almourol: Good habitat quality and fish index with high score
- Almourol: The projected dam can increase eutrophication problems
- Alvito: As a consequence of this project implementation, a reduction of the habitat of resident species such as *Barbus comizo*, *Iberochondrostoma lemmingii*, *Squalius pyrenaicus*, *Squalius alburnoides*, *Iberochondrostoma lusitanicum* is expected.

2.3.4.5 Cumulative impacts on fish populations – overall evaluation

As a consequence of the large number of reservoirs existing in the Douro Basin, autochthonous and endemic fish species had reduced their distribution considerably. Besides, migratory fish are almost extinct. The construction of these dams will lead to the loss of important habitat areas with very good conditions for fish. These areas can be crucial for maintaining the fish biodiversity left in the river Douro. Therefore, an additional reduction of populations of threatened and endemic species is expected (Cabral et al 2006). It is true that some resident species can also occur in reservoirs (e.g. barbel and nase). However, according to Godinho et al. (1998) & Collares-Pereira et al. (2007) this fact will not guarantee the long term preservation of these species, because they have migratory movements towards the upstream small tributaries during the period of reproduction. Therefore, as a consequence of more impoundment/habitat fragmentation the disruption of the life cycle of these species can be expanded. The loss of river connectivity also contribute to the genetic isolation of some fish populations contribution for genetic diversity loss and consequently to the reduction of species fitness.

Taking into account the Tua location and the location of dams in Douro River the maintenance of connectivity between Tua/Douro could be crucial for the reproduction of autochthonous/endemic dwelling fish populations from Régua Reservoir and from upstream Valeira Dam.

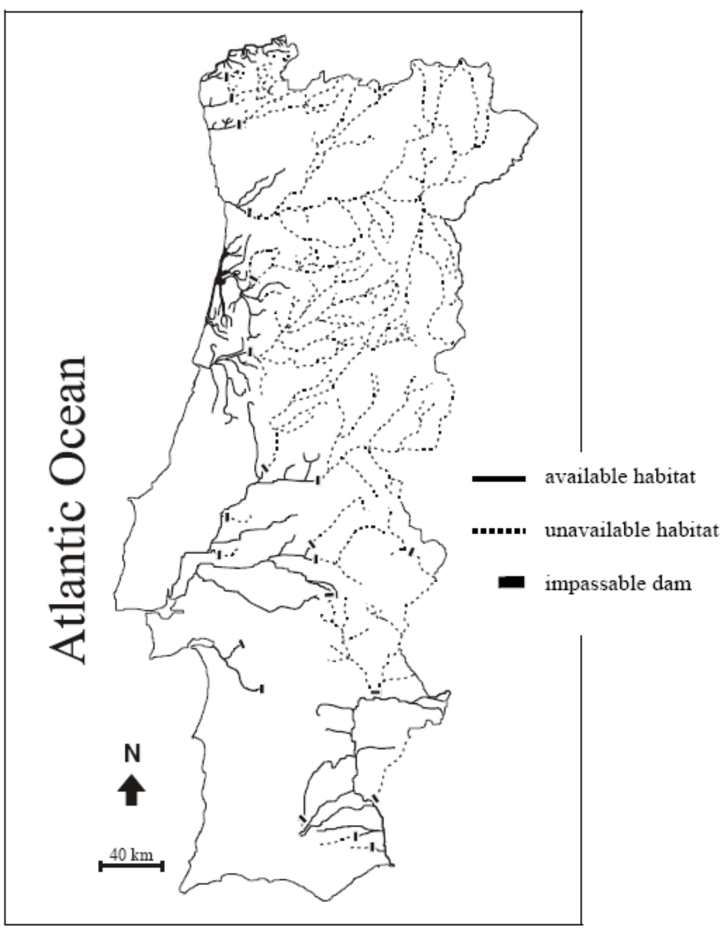
Water quality degradation downstream from the Tua river confluence in the Douro River basin (on the Douro from Miranda to Picote to Benposta) is caused by the location of the dams in a sequence after each other ("cascade situation") with no significant lotic section in between that allows for re-oxygenation between the sequential artificial lentic systems created by the dams. (source: EIA Foz Tua)

The same considerations could also be made for the other river basins. Girabolhos (Mondego) and for Alvito (Tejo) areas can provide suitable habitat for fish species that still are occurring in the dams located upstream in both basins. If Girabolhos and Alvito building become a reality large areas of suitable habitat for resident fish species will be lost. There are already 27 dams in the Mondego river basin, most of these (25) are located downstream of the planned dam.

Almourol and Pinhosão dams will cause further impacts as consequence of the degradation of the last suitable areas for large migratory fish in Portugal. Considering **Illustration 33** (Almeida et al., 2002) it can be concluded that downstream Belver dam (Tejo) and Drizes weir (Vouga) can be the most important areas still existing for sea lamprey and for other migratory endangered species.

Furthermore, reservoirs have good habitat conditions for the exotic species. These species have competitive advantages over most autochthonous and endemic fish becoming dominant in many reservoirs (e.g. Godinho et al., 1998; Geraldes & Teixeira personal observation). Therefore, it is expected that the substitution of autochthonous species by exotic species become a reality in PNBEPH dams increasing the rates of fish biodiversity loss in Portugal.

Illustration 33: Habitat available to sea lamprey populations in Portuguese river basins where the species is know to occur (Almeida et al., 2002)



2.4 Conclusion

Scenario 1

Table 45 provides an overview of the impacts of planned hydropower stations on connectivity, habitat quality and biological elements, and protected areas. When comparing the magnitude of the impact, the extent of effect and the cumulative impacts caused, we can make the following conclusions:

- Five of the planned dams in the Douro River Basin (Padroselos, Alto Tâmega-Vidago, Daivões, Fridão and Gouvães) cause the Tâmega river basin to be affected as whole and as such have the largest cumulative impact. They will cause significant deterioration of the middle section of this river basin, which is currently in relative good status. Also the planned Tua dam will cause deterioration of one of the last unaffected rivers in the Douro River Basin. The planned dams in the Douro River Basin have therefore the largest cumulative impacts, which add to those already caused by other existing 60 dams in this basin.
- With regard to the impact caused on natural river systems, it is expected Almourol (in the Tejo river basin) and Pinhosão (in the Vouga river basin) will have the greatest impact, considering the unaffected state of these river stretches at the moment, the lack of migration barriers, and the important habitat area for migrating fish.
- When looking at the impact on natural protected areas, the Tejo estuary as well as the Gouvães area should be considered. The specific impacts caused by the Almourol dam, which is predicted to have an effect up to the coastal area, as well as the Gouvães dam, which has 3 diversions and has significant effects on a protected area where it is included, are discussed in detail in Task 2c.
- For the length of effect, those dams that have a significant effect due to the length of the flooded area (=the reservoir) upstream are in order of length impacted: Almourol, Pinhosão, Foz Tua and Fridão. However, the length of the reservoir corresponds to the maximum area that will be flooded so the actual impact could be lower. With regard to downstream effects Almourol, Alto Tâmega-Vidago, Pinhosão and Gouvães can be considered as the most important ones. As regards the total length of effect, certainly Almourol and Alto-Tâmega-Vidago are the most extensive.

As a conclusion, when taking all criteria into account for defining the impacts caused by each of the dams on its upstream and downstream area, the **cascade of dams in the Tâmega sub-basin** (and if looked at individually the **Alto Tâmega-Vidago** and the **Gouvães** in particular), the enormous effect of the **Almourol** dam on the Tejo river and its estuary, as well as the significant impact caused by the **Pinhosão** dam on the almost unaffected Vouga river (especially towards migrating fish) can be included in the list of dams of the PNBEPH project that are likely to impact the aquatic ecosystem in the most extensive and significant way.

Table 48 Summary of impacts of planned hydropower stations on connectivity, the habitat quality and the biological elements, the natural protected resources and this with a focus on the extent of effect and the cumulative impacts

DAMS (river stretch)	Potential effect on River connectivity	Potential effects on Habitat quality & biological elements	Extent of effect (main river stretch affected)	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas
ALTO TÂMEGA –VIDAGO Tâmega River	Crestuma dam and Torrão dam are important migration barriers for the Tâmega sub-basin. Migration of mainly potamodromous species could be affected.	Deterioration of habitat quality, riparian vegetation and biological elements: fish, macroinver-tebrates and macrophytes all currently in high status. 6 fish species from Red Data Book *(including 4 sp from Habitats Directive)*	28 km upstream lengh of main river affected (=size of reservoir at full level) 55 km downstream length of effect Maximum extent (river stretch affected); 82 km	One of the 3 dams planned in the Tâmega river. 5 dams planned in Tâmega sub-basin, in the middle area of this sub-basin, where fish species of conservation interest occur. Only a big dam (Torrão) currently exists on Tâmega river, 30,8 km downstream Fridão.	
PADROSELOS Beça river	The dam will create a barrier to fish species.	3 fish species from Red Data Book (including 2 spp. From Habitats Directive)	10 km upstream lengh of main river affected (=size of reservoir at full level) 10 km downstream length of effect Maximum extent (river stretch affected); 20 km	One of the 5 dams planned in Tâmega sub-basin, in the middle area of this sub-basin, where there are still good conditions for fish species of conservation interest. No other big dams currently exist in Beça River.	
DAIVÕES Tâmega River	Currently good river connectivity. The dam will create a barrier to fish species.	Deterioration of habitat quality (currently good/moderate), riparian vegetation (high) and biological elements: fish, macroinvertebrates and macrophytes all currently in high status. 3 fish species from Red Data Book (incl. 2 species from Habitats Directive)	19 (but only 10 up to Padroselos) km upstream lengh of main river affected (=size of reservoir at full level) 10 km downstream length of effect Maximum extent (river stretch affected); 29 km	One of the 3 dams planned in the Tâmega river. One of the 5 dams planned in Tâmega sub-basin, in the middle area of this sub-basin, where there are still good conditions for fish species. Only another big dam currently exists on Tâmega river, 30,8 km downstream Fridão.	

DAMS (river stretch)	Potential effect on River connectivity	Potential effects on Habitat quality & biological elements	Extent of effect (main river stretch affected)	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas
GOUVÃES Louredo river	Currently good river connectivity. Migration of potamodromous species could be affected. The dam will create a barrier to fish species.	Deterioration of habitat quality (currently high/good), riparian vegetation (high) and biological elements: macroinvertebrates and macrophytes currently in high status. 7 fish species from Red Data Book (incl. 3 sp. from Habitats Directive)	Gouvaes dam + 3 diversions. Total length of effect upstream = 5 km Total length of effect downstream = 40 km Maximum extent (river stretch affected): 45 km	One of the 5 dams planned in Tâmega sub-basin. Water diversions from Poio, Viduedo and Olo rivers are planned, which also include small dams construction in those rivers. No other big dams currently exist in Beça River.	Dam/reservoir included in a Natura 2000 area (Alvão-Marão).
FRIDÃO Tâmega river	The dam will create a barrier to fish species.	3 fish species from Red Data Book (incl. 2 sp. from Habitats Directive)	40 km upstream lengh of main river affected (=size of reservoir at full level) 5 km downstream length of effect Maximum extent (river stretch affected): 45 km	One of the 3 dams planned in the Tâmega river. One of the 5 dams planned in Tâmega sub-basin, in the upper area of this sub-basin, where there are still good conditions for fish species. Only another big dam (Torrão) currently exists on Tâmega river, the Albufeira de Torrao, 30,8 km downstream Fridão, a reservoir that extends up to 4,2 km from Fridão dam.	
FOZ TUA Tua river	Currently good river connectivity upstream of this planned dam, which will create a barrier to fish species. Migration of potamodro-	Deterioration of habitat quality (currently good) upstream the dam, in the area that will be affected by the reservoir. 6 fish species from Red Data	51 km upstream lengh of main river affected (=size of reservoir at full level) 3 km downstream length of effect Maximum extent (river	No other big dams currently exist in the Tua river. Regua's reservoir occupies the Douro river stretch where the Tua river ends (about 3km from Foz Tua dam).	

DAMS (river stretch)	Potential effect on River connectivity	Potential effects on Habitat quality & biological elements	Extent of effect (main river stretch affected)	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas
	mous species could be affected.	Book (incl. 4 sp. from Habitats Directive)	stretch affected): 54 km		
PINHOSÃO Vouga river	This dam could create a significant barrier for migratory species *(Anguilla anguilla* and *Petromyzon marinus)* in a river that is almost unregulated (there is only a small hydropower station downstream: Drizes).	12 fish species from Red Data Book (incl. 8 sp. from Habitats Directive)	8 km upstream lengh of main river affected (=size of reservoir at full level) 52 km downstream length of effect Maximum extent (river stretch affected): 60 km	No other big dams exist in the Vouga River (only two small HP dams).	Likely adverse effects on the Rio Vouga Natura 2000 site (PTCON0026) and on an estuarine area with high ecological value,t he Ria de Aveiro which is classified as a SPA (Natura 2000)..
GIRABOLHOS Mondego river	Currently there is no good river connectivity downstream the dam. The dam will create another barrier to fish species in this highly fragmented river.	Deterioration of habitat quality (currently high/good) downstream the dam (4 km) 4 fish species from Red Data Book (incl. 3 sp. from Habitats Directive)	21 km upstream lengh of main river affected (=size of reservoir at full level) 31 km downstream length of effect Maximum extent (river stretch affected): 51 km	Three dams currently exist in the Mondego river.	Likely negative effects on wetlands and riparian habitats in a Natura 2000 site (PTCON0027 – Carregal do Sal) located about 17,5 km downstream this planned dam.
ALMOUROL Tagus river	Currently there is a good river connectivity; the dam would create a significant barrier for numerous migratory species (anadromous and catadromous) that curently use the Tejo river (currently the first obstacle in this river is the Belver dam, located	Deterioration of habitat quality (currently high/good - 3,9 km upstream the planned dam), riparian vegetation (high), macroinver-tebrates (good), fish (good) and macrophytes (high) status. 15 fish species from Red Data Book (incl. 10 sp. from	36 km upstream lengh of main river affected (=size of reservoir at full level) 91 km downstream length of effect Maximum extent (river stretch affected): 127 km	Almourol would add to other two big dams currently existing on the Tagus river (Belver and Fratel, about 40 and 60 km upstream Almourol respectively). Nowadays fish can reach some tributaries (e.g. Sorraia and Divor) located below the Belver dam (Oliveira 2007). With the	The dam could have some effect on the Tagus estuary, which is also designated as Natura 2000 site (PTCON0009)

DAMS (river stretch)	Potential effect on River connectivity	Potential effects on Habitat quality & biological elements	Extent of effect (main river stretch affected)	Cumulative impacts (river and sub-basin level)	Impact on natural protected areas
	about 30 km upstream the Almourol planned dam.	Habitats Directive)		implementation of the Almourol dam, the existing fish migration area will be strongly reduced in the Tejo, in a section of the river that currently does not present fragmentation. The habitat of threatened resident species such as *Squalius pyrenaicus* and *Squalius alburnoides* will be also negatively affected.	
ALVITO Ocreza (38 km)	Currently there is not a good river connectivity downstream the dam (value: 3 at about 2,2, km downstream the planned dam). The dam will create a barrier to fish species.	Deterioration of habitat quality (currently high/good - 2,2km downstream), riparian vegetation (good), macroinvertebrates (moderate), fish (moderate) and macrophytes (good) status. 7 fish species from Red Data Book (incl. 6 sp. from Habitats Directive):	38 km upstream lengh of main river affected (=size of reservoir at full level) 4 km downstream length of effect Maximum extent (river stretch affected): 42 km	As a consequence of this project implementation, a reduction of the habitat of resident species such as *Barbus comizo, Iberochondrostoma lemmingii, Squalius pyrenaicus, Squalius alburnoides,* and *Iberochondrostoma lusitanicum* (all endangered species) is expected.	

For the **ecological assessment of the impact of PNBEPH dams on river basins**, fish were mainly used because of their indicator role and the data available (only limited data were available on other elements): With the implementation of the PNBEPH a loss of fish habitat, an important barrier effect and consequently a reduction of threatened species populations is expected. Therefore, the objectives of WFD concerning the maintenance/restoration of the ecological integrity of aquatic ecosystems will not be achieved in the areas affected by the programme.

Ecological assessments peformed close to **existing dams** also show that the overall fish status was mainly poor to moderate. The barrier effect is also shown by the poor scores on connectivity. The effect of changed sediment patterns might be illustrated by the poor macroinvertebrate scores close to exsting dams, especially the larger ones. Ecological assessments with regard to the expected effects on reservoirs were not available, but earlier studies summarised in the literature review in Task 2a have pointed to the eutrophication and siltation effects impacting in an important way the biological communities.

With regard to the (spatial) **extent of effect**, for the Tâmega sub-basin, the whole river basin will be affected by the changed flow conditions and subsequent impacts. As the Tâmega river basin is located in a nutrient sensitive zone, eutrophication effects are expected in an area which is already recognised as being at risk for organic and nutrient enrichment. The Foz Tua dam will be the only barrier for the Tua river, close to the confluence with the Douro and as such determines largely the fauna expected in the whole Tua sub-basin. The downstream effect however is attenuated by the presence of the Regua reservoir. For both the Pinhosão dam in the Vouga river and the Girabolhos dam in the Mondego river basin, the effects are significant in length of affected river mainly due to the length of affected fish protection zone that will be impacted upstream and downstream of the dam. For the planned dams in the Tejo river basin, the largest impact will be caused by the Almourol dam in terms of extent, due to the large capacity of the dam its expected effects will reach the coastal zone. For the Alvito dam, the effects downstream are attenuated by Pracana hydropower dam, but its location in a fish protected and nutrient sensitive zone are of importance here.

With regard to the **cumulative effects**, the following conclusions were made: As a consequence of the large number of reservoirs existing in the Douro Basin, autochthonous and endemic fish species had reduced their distribution considerably. Besides, migratory fish are almost extinct. The construction of five dams in the Tâmega river basin will lead to the loss of important habitat areas with very good conditions for fish. These areas can be crucial for maintaining the fish biodiversity left in the river Douro. Therefore, an additional reduction of populations of threatened and endemic species is expected (Cabral et al 2006).Water quality degradation upstream from the Tua river confluence in the Douro River basin (on the Douro from Miranda to Picote to Benposta) is caused by the location of the dams in a sequence after each other ("cascade situation") with no significant lotic section in between that allows for re-oxygenation between the sequential artificial lentic systems created by the dams. Similar considerations could also be made for the other river basins. Girabolhos (Mondego) and for Alvito (Tejo) areas can provide suitable habitat for fish species that still are occurring in the dams located upstream in both basins. The building of these two dams will caus the loss of large areas of suitable habitat for resident fish species. There are already 27 dams in the Mondego river basin, near all (except for two) located upstream of the planned dam. Almourol and Pinhosão dams will cause further impacts as consequence of the degradation of the last suitable areas for large migratory fish in Portugal. Also, if Almourol were built the river would be a continuum of dams and reservoirs up to Spain. Furthermore, reservoirs have good habitat conditions for the exotic species. These species have competitive advantages over most autochthonous and endemic fish becoming dominant in many reservoirs (e.g. Godinho et al., 1998; Geraldes & Teixeira pers. Com/). Therefore, it is expected that the substitution of autochthonous species by exotic species become a reality in PNBEPH dams increasing the rates of fish biodiversity loss in Portugal.

Scenario 2

The design of adequate ecological flows is essential to maintain a good ecological status and preserve the biological elements that are present in the river. Often, fish species are used as indicators for estimating adequate ecological flows in a river stretch. The best methodology for defining minimum flows is based on a detailed model that requires determining habitat preferences (in terms of depth, velocity etc) for Iberian fish and a huge amount of location-specific information (as it has been discussed in the chapter on minimum flows under Task 1). This kind of methods allow for the maintenance of suitable conditions for fish species and are considered appropriate to preserve the biological communities that occur in the river. Some experiences based on the application of these methods have been developed in Portugal and are presented in ANNEX 16. However, because of the lack of information and the modelling being out of the scope of the study, a scenario analysing the effects and potential benefits of minimum flows is as such considered as not feasible. Nevertheless, it must be stressed that *including minimum flows in the operation of the dams planned under the PNBEPH is certainly needed in order to mitigate their effects on the fish communities that have been identified along the river stretches located downstream of the dams***.** Further on, it is necessary to implement minimum flows to allow proper functioning of the fish pass (included as an essential mitigation measure as well).

Scenario 3

Fish passes are a mitigation measure of the negative impacts on fish populations. Despite the existing legislation they are still not being implemented in the majority of dams and weirs and a large percentage of the implemented fish pass are not effective. Fish passes also do require appropriate minimum flow. Based on the fish monitoring data and the information available on fish passing efficiency and fish habitat requirements, the following conclusions were made:

The Tâmega sub-basin, especially in its middle section, is one of the last "almost unregulated" affluent of Douro River and can be seen at a last refuge for migrating species. The Torrão and Crestuma dam are already acting as a migration barrier and there is also a problem with eutrophication and migration. Fish passes are a necessary mitigation measure but it is not guaranteed that, taking into account the cascade of dams and the current eutrophication pressure that migrating fish will be able to get up to the upper reaches of the Tâmega sub-basin.

For the **Foz Tua,** more information is available because of the EIA process (EIA Foz Tua, 2008). One of the conclusions of this EIA is that because of the absence of migrating species together with the cost of installing a fish pass, it is not part of the plan. However, fish pass improvement at dams in the Douro river basin downstream of the Tua confluence is certainly priority because of the long-term objective of improving continuity in the Douro River Basin, and the evidence that resident species such as *Pseudrochondrostoma sp.* and *Barbus sp.* are using fish passes to migrate to the upper courses of the Tua River.

For the **Vouga river basin**, because 4 migrating species are still present in this area, the instalment of a fish pass at the **Pinhasão dam** would be an absolute requirement to guarantee free migration of these species, especially considering the high habitat quality of the river Vouga. The Vouga river basin is also one off the few river basins that still host *Peteromyzon marinus*. At the **Mondego river basin**, there were no migrating species monitored and there are 2 dams and one weir downstream of the planned location for the Girabolhos dam. However, resident species also use fish passes and are affected by migration barriers, thuis it is still essential to implement fish passes as a mitigation measure.

For **Almourol,** there is currently no fish migration barrier in this area (until Belver dam), so a fish pass would be an absolute requirement as the area up to the next dam is hosts *Petromyzon marinus.*

For **Alvito,** the current bottleneck is the Belver dam and also possibly Pacrana dam (no fish pass efficiency report available). The area is currently of importance for resident fish and fish pass efficiency improvement in downstream dams would be a priority here.

3 Task 2c: Analysis of likely (cumulative) impacts of each dam or group of dams on nature values protected by the European Nature Directives

3.1 Likely effects on Natura 2000 sites and on habitats and species protected under the European Nature Directives

This chapter analyses the likely effects of the PNBEPH on Natura 2000 sites and on species and habitats protected under the Habitats Directive (92/43/EEC[13]) and the Birds Directive (78/409/EEC[14])

In Portugal, a Sectoral Plan for Natura 2000 (Plano Sectorial da Rede Natura 2000[15]) has been elaborated by the Ministry of Environment and Land Use Planning (January 2006), which sets the objectives and management guidelines for the preservation of the Natura 2000 sites and the species and habitats protected under the Birds and Habitats Directives (hereinafter also referred to as Nature Directives). This plan is a territorial management instrument that must be implemented by all public administrations in Portugal.

The analysis of effects of the PNBEPH presented in this chapter is based on the information provided in this Sectoral Plan on the conservation objectives, threats and management guidelines described for each Natura 2000 site and for the habitats and species included in the Nature Directives.

The information delivered to the European Commission for the designation of the Natura 2000 sites (as included in the EC Natura 2000 database) and the information provided in the framework of the Member States reporting on the conservation status of habitats and species protected under the Habitats Directive[16] (in accordance with article 17) has also been taken into account in this evaluation.

Information about fish species from the Habitats Directive provided by INAG (form selected monitoring stations used in the WFD implementation), the AQUARIPORT project (data from selected sampling sites[17]) , Carta Piscicola Nacional website (CPN[18]) and

[13] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

[14] Council Directive of 2 April 1979 on the conservation of wild birds(79/409/EEC)

[15] http://www.icn.pt/psrn2000/

[16] http://biodiversity.eionet.europa.eu/article17

[17] Aquariport: National programme for the monitoring of fish resources and evaluation of ecological quality of rivers carried out by the Directorate General of Forest Resouurces. .325 sampling stations are included in the Porgramme for the monitoring of fish communitoes, bethic macroinvertebrates and hydrooprhological conditions. 190 stations had been sampled until 2007. Fish data obtained form stations located near the PNBEPH dams have been used in this evaluation).

[18] The CPN webisite provides information about occurrence of fish species in some localities and river stretches near the planned dams (http://www.fluviatilis.com/dgf/?nologin=true; http://www.cartapiscicola.org/)

other relevant sources (e.g. scientific articles, technical reports) has also been used in this evaluation.

Other information from studies and inventories of animal species, in particular concerning the Alvão Marão site, has also been considered in this assessment.

3.1.1 Provisions of the Habitats Directive (92/43/EEC) for the assessment of likely effects on Natura 2000

In accordance with article 6.3 of the Habitats Directive, for any plan or project that is likely to significantly affect a Natura 2000 site, an appropriate assessment of its effects on the integrity of the site should be carried out. A plan or project can only be authorised after having ascertained that it will not have an adverse effect on the integrity of the site. When certain conditions are met (there are no other alternatives and there are imperative reasons of overriding public interest for carrying out the plan or project), the provisions of article 6.4 can be applied and the plan or project may be authorised if all necessary compensatory measures to guarantee the coherence of the Natura 2000 network are taken.

An appropriate assessment of the PNBEPH in accordance with these provisions has not been carried out, as it was considered that the Programme would not have effects on the integrity of any Natura 2000 sites, according to the information given in the SEA about this subject (see section 1.2 below).

Article 6, paragraph (3) of the Habitats Directive (92/43/EEC):

Any plan or project not directly connected with or necessary to the management of the site but **likely** to have a **significant effect** thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the **site's conservation objectives**. In the light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it **will not adversely affect the integrity of the site** concerned and, if appropriate, after having obtained the opinion of the general public.

3.1.2 The SEA of the PNBEPH: assessment of effects on Natura 2000 sites

The SEA of the PNBEPH considered biodiversity as a critical factor. Four criteria were used in the assessment[19] :

- C1 : effects of the PNBEPH projects on the protected areas (incl. Natura 2000 network)
- C2 : potential impact of each project on threatened species
- C3 : potential impact on species insufficiently covered by the Natura 2000 network.
- C4 : evaluation of degree of naturalness of the water bodies affected by the reservoirs.

[19] See Chapter 4 in Annex IV to the Environmental Report (Relatorio Ambiental- Annexo IV).

C1 criterion (protected areas) is split into two sub-criteria:

- Overlapping with protected areas
- Level of effect on the protected areas (e.g. effects on the site integrity)

According to this assessment, option D (the one finally selected) will have lower conflict with protected areas than options A (overlapping with nine protected areas), and B (overlapping with seven protected areas). It is however acknowledged that option D introduces a dam in a section of the Tejo river that currently does not present fragmentation and it would affect migratory species in the Tejo river (as also does option C in the Vouga river) and would also affect species insufficiently covered by Natura 2000.

In option D, the Gouvães dam is overlapping with a protected area (Alvão-Marão Natura 2000 site and Natural Park). The SEA mentions that the Gouvães project will have no effects on the integrity of the site (page 26 of the SEA report, Relatorio Ambiental - Anexo IV). Less than one page is devoted to this subject in the SEA report, where only a few habitats and species are mentioned for this Natura 2000 site and it is concluded that the project will not affect the integrity of the site as less than 0.5% of the habitat of Community interest "Galicio-Portuguese oak woods with *Quercus robur* and *Quercus Pyrenaica* oak woods (9230) would be affected by the dam, and there will not be important fragmentation effects on the site. Apparently, only the direct overlapping with habitats of Community interest of the main dam (two smaller dams for water storage and derivation purposes in other two rivers are also included in Gouvães project) has been considered. Other potential effects seem to have not been properly considered, such as the potential effects on the aquatic habitats and on habitats and species that are dependant on the aquatic environment and on maintenance of good ecological status and a natural hydrological regime.

In our opinion the level of effect on the protected areas (e.g. effects on the site integrity), which was considered under C1 criterion in the SEA, has not been properly evaluated, in what concerns the effects of Gouvães on the Alvão-Marão Natura 2000 sites.

Having considered from the beginning that the Gouvães project woul not affect the integrity of Alvão-Marão Natura 2000 site, an appropriate assessment in accordance with article 6.3 of the Habitats Directive has not been carried out. This does not to fully comply with the provisions of the article 6.3 of the Habitats Directive, which require that a first screening is carried out for any plan or project in order to determine whether it is likely to have a significant effect on a Natura 2000 site, either individually or in combination with other plans or projects. If it cannot be ascertained that it will not have a significant effect, then an appropriate assessment of its implications for the site in view of the site's conservation objectives must be carried out. In our opinion, there are reasonable scientific reasons to consider that this project could have significant effects on the site concerned, or at least this risk cannot be excluded on the basis of objective information. Therefore, an appropriate assessment should have been carried out, as prescribed in the Habitats Directive and the relevant EC guidance documents[20] .

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[20] Managing Natura 2000 sites. The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC" (2000)

The appropriate assessment should analyse in detail the effect on the integrity of the Natura 2000 sites, taking into account the possible effects of all the proposed activities on the habitats and species for which the sites are designated and the conservation objectives identified in those sites.

The SEA of the PNBEPH analysed the overlapping of the dams with protected areas and with Natura 2000 sites and identified the **overlapping of the Gouvães dams with the site Alvão-Marão,** but it did not consider other possible effects on Natura 2000 sites downstream or upstream the dams (one main dam and two smaller dams are foreseen). The SEA concluded that the Gouvães project would not affect the integrity of the Alvão-Marão Natura 2000 site without having carried out an appropriate assessment.

According to our evaluation, it is important to stress the **recognised relevance of the site for the conservation of aquatic and riverine fauna, including several species of Community importance** (see section 2.1 for more details), **several of which are Iberian endemics,** two of them with unfavourable conservation status both at global and national level: *Chioglossa lusitanica* (Vulnerable in PT and ES, Nearly Threatened according to IUCN) and the Pyrenean Desman *Galemys pyrenaicus* (Vulnerable in PT and globally according to IUCN). Taking into account that wet and riparian areas cover 78,171 ha, only 0,13 % of the site's area, and that the infrastructures foreseen not only directly destroy several kms of such habitats along 4 different rivers, but impose fragmentation to the lotic system on which both species depend, **impacts on the integrity of the site should be carefully assessed**. According to the information provided by the PNBEPH, Gouvães dam alone, despite being considered a small dam, will submerge 31% of the total main water course length (3,7 km submerged upstream, from a total river length of 12 km, length of influence downstream and on affluent brooks not provided). For river Olo, 12,5% of the river length will be submerged by the subsidiary Olo dam (again, length of influence downstream and on affluent brooks not provided).

In our opinion, the cumulative barrier effect of Gouvães together with other dams and other infrastructures (such as roads, highways and windfarms) at local and regional level must also be carefully assessed, regarding especially relevant species such as the Iberian Wolf *Canis lupus* (HD annex II and IV), *Felis silvestris* (HD annex IV), the Pyrenean Desman, *Galemys pyrenaicus* (HD annex II and IV) plus a series of other small carnivores and amphibians that although not in the directives have an important role in the global ecosystem.

The ICNB (Institute for Conservation of Nature and Biodiversity) issued an opinion during the consultation on the PNBEPH SEA[21] , the main points being:

"Assessments of plans and projects significantly affecting Natura 2000 sites. Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC" (2002). "Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC" (2007). All documents are available via: http://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm

[21] See Relatorio de Consulta no ambito da Avaliaçao Ambiental. PNBEPH. 2007. Availiable via: http://www.inag.pt

- Under criterion C1 (Classified Areas), the incompatibility with Planos de Ordenamento of protected areas and with the Natura 2000 Sectoral Plan should be taken into account (remark refused by the SEA Public Consultation Report). Under criterion C2 (threatened species particularly dependant on the lotic ecosystem), only the species with a Vulnerable or higher status according to the Portuguese Red Data Book were taken into account, which is not correct (remark refused by the SEA Public Consultation Report which nevertheless considers that a more detailed analysis should be undertaken under the EIA of each dam);
- ICNB considered that the implementation of the foreseen projects in the river Tâmega basin will increase the already existing fragmentation in the main water line (the SEA Public Consultation Report agrees but proposes no measures to prevent it);
- **ICNB considers that Gouvães will affect the integrity of Alvão Natural Park** and that the Olo dam and corresponding flow derivation is not in conformity with the Douro Basin Plan nor with the regulation of the Natural Park (the SEA Public Consultation Report proposes that the maintenance of the Olo derivation dam should be evaluated under the EIA, together with other alternatives);
- ICNB proposed to replace Gouvães by another two dams, Srª de Monforte and Castelo de Paiva (remark refused by the SEA Public Consultation Report which considers that the integrated analysis takes into account other factors apart from biodiversity, the first proposal has a low economic interest and is located in an area of important cultural heritage and the second one is not adequate because it would imply the breaking of a river continuum still not intervened and the affection of the SCI Rio Paiva and the SPA Vale do Coa);
- ICNB proposed the elimination of either Padroselos or Vidago as a way to reduce the fragmentation effect (remark refused by the SEA Public Consultation Report because it would mean a deviation from the PNBEPH target regarding installed voltage);
- ICNB proposes a series of requests to be fulfilled under the EIA, namely the need for an enlarged assessment of alternatives, the evaluation of cumulative impacts with all the already existing or approved hydraulic or hydroelectric projects (including small hydropower dams) in the same river basins, detailed impact assessment regarding *Galemys pyrenaicus*, *Chioglossa lusitanica*, *Emys orbicularis*, fish fauna, fauna dependant on adjacent terrestrial corridors, freshwater invertebrates and natural river and riparian habitats, plus the safeguard of passage points for *Canis lupus*.

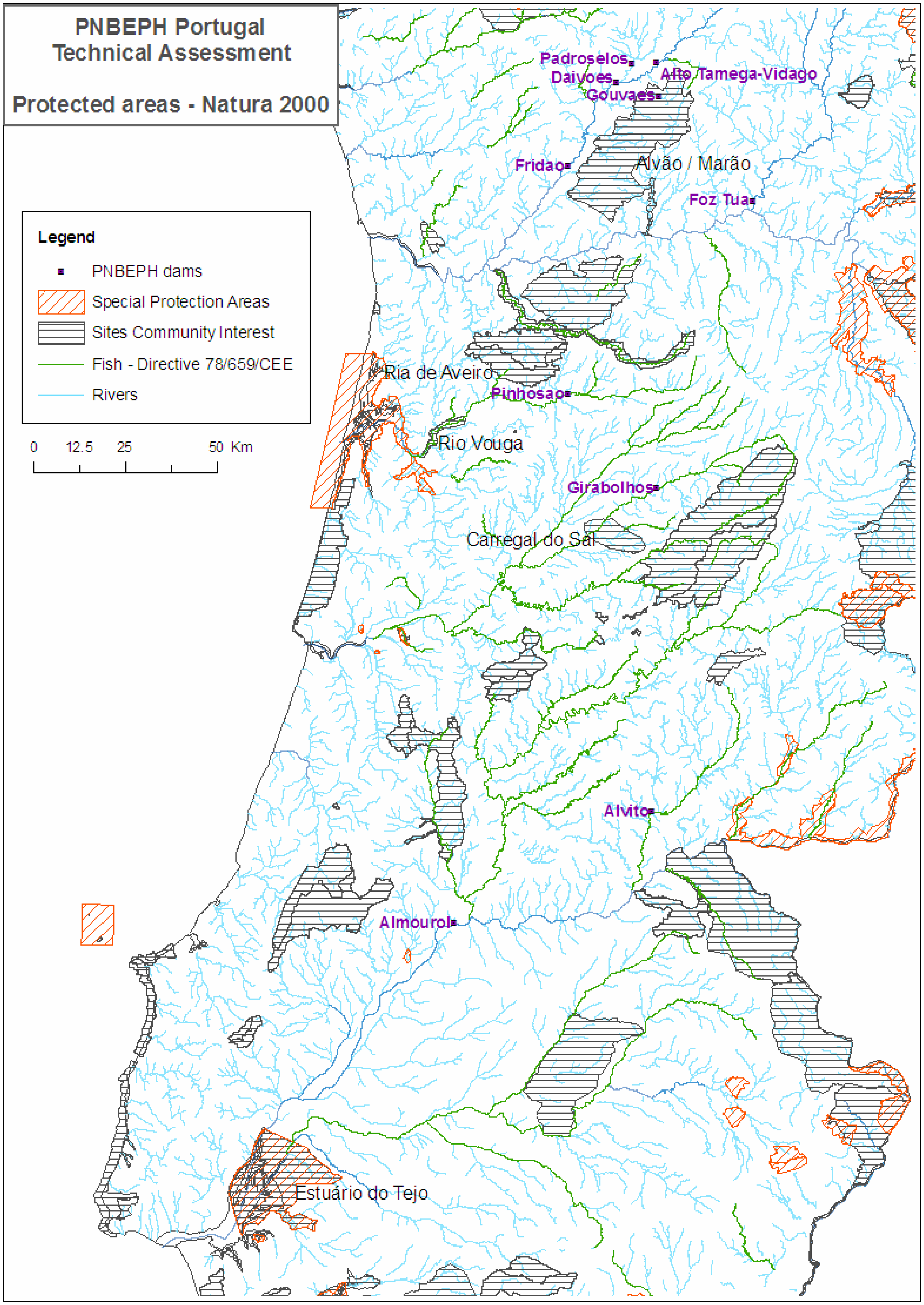
3.2 Likely effects on Natura 2000 sites

Effects on Natura 2000 sites may occur not only where the dams are overlapping with those sites and will directly affect the habitats and species that motivated the sites designation and their conservation objectives, but also where some effects of the dams, in particular on habitats and species that depend on the aquatic environment, can be appreciated at a certain distance, on other Natura 2000 sites that may be located upstream or downstream of the dams.

To carry out this analysis we have considered Natura 2000 sites that have been designated for aquatic and riparian habitat sand species that are overlapping with the rivers affected by the PNBEPH dams. We have also considered estuarine protected areas existing downstream the dams, which could be affected by the reduction in water flow, sediment retention and modification of water quality caused by the dams. Based on this, we have identified five sites that could be potentially affected by the construction and operation of the HP projects included in this programme (see **Illustration 34** and **Table 49**).

These sites' main features and the likely effects of the PNBEPH projects on them are discussed in detail in the following sections. The main identified effects concern the most relevant habitats and species of community interest occurring at those sites which depend on the maintenance of certain water flow and quality conditions.

Illustration 34: Map of protected areas including Natura 2000 areas



shp files: ART13_ZP_AVES_PTCONT_0_459, ART13_ZP_HABI_PTCONT_0_460, ART13_ZP_PISC_PTCONT_0_722, ART5_MRIOS_PTCONT_0_238. Sources: INAG-InterSIG and ATECMA SL June 2009.

Table 49: Natura 2000 sites likely to be effected by the Dams of the PNBEPH

Natura 2000 site (Code)	HP project (distance to the site)	Likely effects	Habitats likely to be adversely affected	Species dependant on aquatic and/or riparian habitats likely to be adversely affected
Alvão-Marão (PTCON0003)	Gouvães (within the Natura 2000 site)	Destruction of terrestrial and riparian habitats in the area that will be flooded by the reservoir. Reduction and degradation of riparian and aquatic habitats and species. Loss of corridors and species connectivity. Fragmentation of populations. Barrier effect. The dam will submerge 31% of the total main water course length (3,7 km submerged upstream, from a total river length of 12 km). For river Olo, 12,5% of the river length will be submerged by the subsidiary Olo dam.	3120 Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with *Isoetes* spp. 3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* 3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation 4030 European dry heaths 6220 * Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea* 6230 * Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe) 8220 Siliceous rocky slopes with chasmophytic vegetation 91B0 Thermophilous *Fraxinus angustifolia* woods 91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) 9230 Galicio-Portuguese oak woods with *Quercus robur* and *Quercus Pyrenaica*	Mammals: *Galemys pyrenaicus*,*Lutra lutra*,*Canis lupus*; several bat species: *Miniopterus schreibersii, Myotis blythii, Myotis emarginatus, Myotis myotis, Rhinolophus ferrumequinum, Rhinolophus hipposideros,* Amphibians: *Chioglossa lusitanica*; Reptiles: *Emys orbicularis, Mauremys leprosa, Lacerta schreiberi* Fish: *Squalius alburnoides (Rutilus albornoides), Achondrostoma arcasii (Rutilus arcasii), Pseudochondrostoma duriense (Chondrostoma duriense),* Invertebrates: *Oxygastra curtisii* (in brackets: species former names)

Natura 2000 site (Code)	HP project (distance to the site)	Likely effects	Habitats likely to be adversely affected	Species dependant on aquatic and/or riparian habitats likely to be adversely affected
			92A0 *Salix alba* and *Populus alba* galleries	
Rio Vouga (PTCON0026)	Pinhosão (approx. 36,8 km upstream the Natura 2000 site)	Possible reduction and degradation of riparian and aquatic habitats and species. Fragmentation of populations. Barrier effect.	3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation 3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba* 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* 91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers	*Unio crassus, Alosa alosa, Alosa fallax, Pseudochondrostoma polylepis (Chondrostoma polylepis), Lampetra planeri, Petromyzon marinus, Squalius alburnoides, Achondrostoma oligolepis (Rutilus macrolepidotus), Chioglossa lusitanica, Lutra lutra*
Carregal do Sal (PTCON0027)	Girabolhos (approx. 18,8 km upstream the Natura 2000 site)	Reduction and degradation riparian and aquatic habitats and species.	3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* 3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation 91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) 92A0 *Salix alba* and *Populus alba* galleries	*Pseudochondrostoma polylepis, Achondrostoma oligolepis, Chioglossa lusitanica, Galemys pyrenaicus, Lutra lutra* *Lacerta schreiberi*

Natura 2000 site (Code)	HP project (distance to the site)	Likely effects	Habitats likely to be adversely affected	Species dependant on aquatic and/or riparian habitats likely to be adversely affected
Ria de Aveiro (PTZPE0004)	Pinhosão (approx. 60 km upstream the Natura 2000 site)	Indirect effects: retention of sediments in the dam, reduced water flow. Changes in the hydrological conditions in the site. Potential degradation of important habitats for bird species of Community importance.	Wetlands habitats of importance for bird species of Community importance (Annex I of Birds Drective) and migratory species.	*Ixobrychus minutus, Ardea purpurea, Platalea leucorodia, Melanitta nigra, Pandion haliaetus* *Himantopus himantopus, Recurvirostra avosetta, Charadrius hiaticula, Charadrius alexandrinus, Sterna albifrons* Marine migratory birds
Estuário do Tejo (PTCON0009 & PTZPE0010)	Almourol (88 Km)	Reduced water flow and retention of sediments in the dam, reduced water flow. Changes in the hydrological conditions in the site. Potential degradation of important habitats for species of Community importance	1110 Sandbanks which are slightly covered by sea water all the time 1130 Estuaries 1140 Mudflats and sandflats not covered by seawater at low tide 1150 * Coastal lagoons 1210 Annual vegetation of drift lines 1310 *Salicornia* and other annuals colonizing mud and sand 1320 *Spartina* swards (*Spartinion maritimae*) 1410 Mediterranean salt meadows (*Juncetalia maritimi*) 1420 Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*) 1430 Halo-nitrophilous scrubs (*Pegano-Salsoletea*) 3120 Oligotrophic waters containing very few minerals generally on sandy soils of the West	*Alosa alosa. Alosa fallax, Pseudochondrostoma polylepis, Lampetra fluviatilis, Petromyzon Marinus, Emys orbicularis, Mauremys leprosa, Lutra lutra* *Ixobrychus minutus, Egretta garzetta, Ardea purpurea, Platalea leucorodia, Phoenicopterus roseus, Anser anser, Anas Penélope, Anas crecca, Pandion haliaetus, Himantopus himantopus, Recurvirostra aboceta, Glareola pratincola, Charadrius alexandrinus* Migratory birds (Passeriformes) present in reed beds and riparian galleries

Natura 2000 site (Code)	HP project (distance to the site)	Likely effects	Habitats likely to be adversely affected	Species dependant on aquatic and/or riparian habitats likely to be adversely affected
			Mediterranean, with *Isoetes* spp. 3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation 3160 Natural dystrophic lakes and ponds 3170 * Mediterranean temporary ponds 3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation 3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba* 6420 Mediterranean tall humid grasslands of the *Molinio-Holoschoenion* 91B0 Thermophilous *Fraxinus angustifolia* woods 92A0 *Salix alba* and *Populus alba* galleries	

** Priority habitats and species are indicated with asterisk*

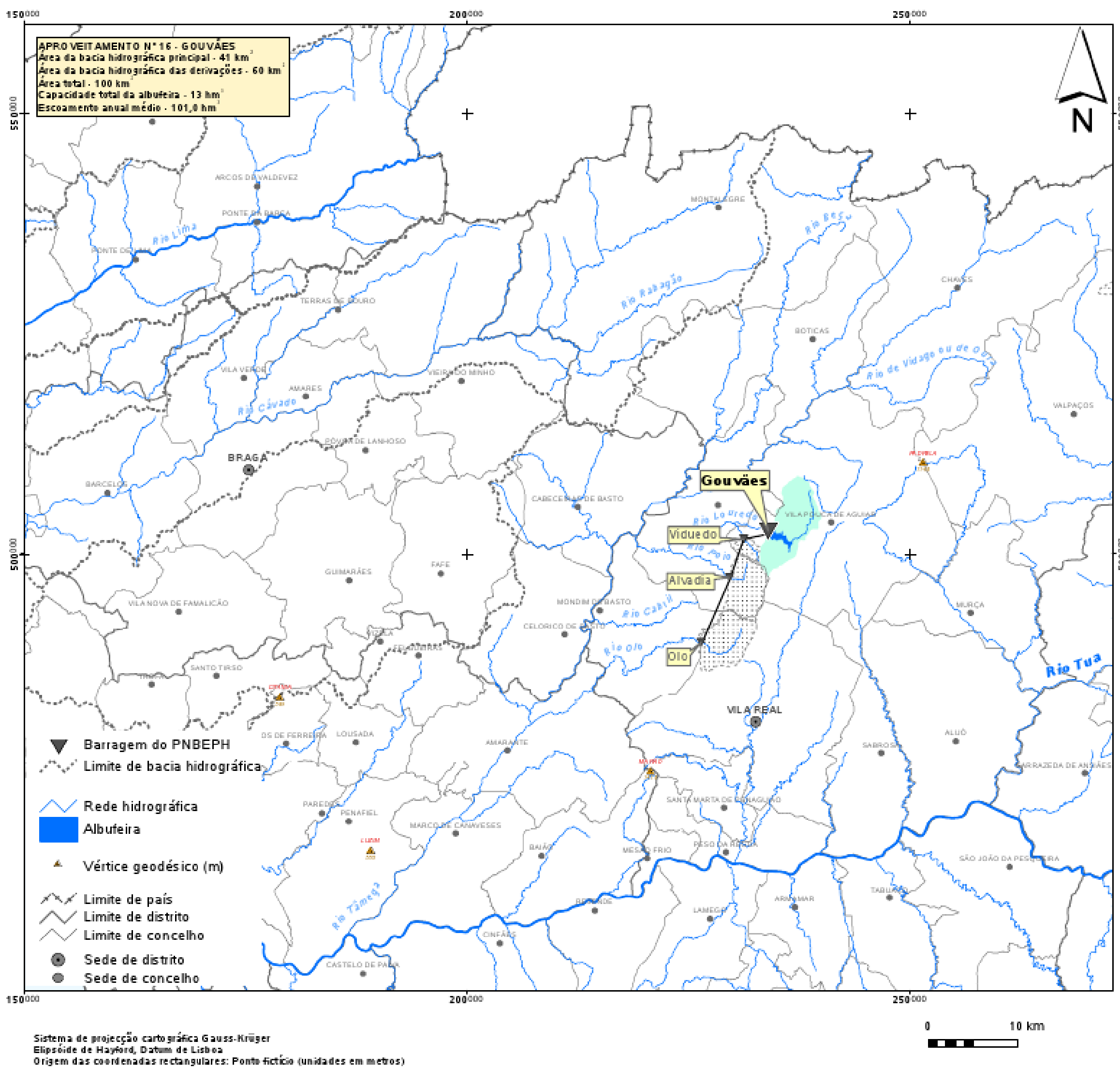
3.2.1 GOUVÃES – LIKELY EFFECTS ON “ALVÃO-MARÃO” NATURA 2000 SITE

Brief description of the Gouvães infrastructure

The Gouvães dam is one out of the 10 large dams foreseen by the Portuguese National Programme for Dams with High Hydropower Potential (PNBEPH). It will be located on Torno river, the uppermost stretch of river Louredo, located in the Tâmega river sub-basin (Douro basin). It is to note that out of the 10 large dams foreseen, 6 are located in this basin, 5 of them (including Gouvães) in the same Tâmega sub-basin.

The Gouvães HP infrastructure is composed of one main dam (at river Louredo) and two smaller dams for water storage and derivation purposes (one in Alvadia river and another one at Olo river) **Illustration 35.** Water will also be derived from river Viduedo. The infrastructure is wholly located inside the Natura 2000 SCI Alvão-Marão (PTCON0003) and partly inside the national protected area Parque Natural do Alvão (Olo river dam).

Illustration 35: Location of the Gouvães dam and the hydraulic circuits



Summary of the conclusions of the SEA of the PNBEPH concerning the Gouvães project

The SEA of the PNBEPH only considered the overlapping of the Gouvães project with the SCI (no mention to the AlvãoNatural Park) and concluded that the building of this dam will not affect the integrity of the site. When looking at the list of species with "high national conservation status" present in the area and taking into account impacts evaluation on biodiversity (under criterion C2) then we can resume 3 fish species, one amphibian (*Chioglossa lusitanica*) and mammals (*Galemys pyrenaicus* and bat roosts in the submerged areas).

According to the evaluation of impacts of human activities over water bodies undertaken by INAG, although affected by a moderate lotic fragmentation (due to the presence of Torrão dam in the lower Tâmega section), river Louredo is identified as one of the rivers presently at risk of failing to comply with the environmental objectives of the WFD.

The SEA states that Gouvães has a high probability of eutrophication since the dam would be located in a "sensitive area for eutrophication" (Zone nº3 - "Albufeira do Torrão", according to DL 149/2004 of 22 June) and the corresponding hydrographic basin has a considerable agricultural occupation (23%).

Reasons that led to the designation of SCI Alvão-Marão

According to the Natura 2000 Sectoral Plan, the SCI Alvão-Marão has an area of 58 788 ha, 13% of which is also designated under national law (Dec. Lei n.º 237/83 de 8 de Junho) as a Natural Park (Parque Natural do Alvão).

The regulation of the Plano de Ordenamento of the Alvão Natural Park, under article 7, forbids the following activities:

- "(...) the modification of the natural draining network and the quality of superficial and subterranean waters and respective flow, except regarding actions of scientific nature or management which are duly authorised by ICNB." (point d)
- "the installation of small dams, dams or any hydroelectrical projects in the sections of the river basins located inside the intervention area of the Plano de Ordenamento do Parque Natural do Alvão for purposes other than public water supply, except from micro-generation limited to 150 kw." (point s)

According to this regulation, the Gouvães infrastructure, as long as it includes the Olo dam and derivation canals, stands as illegal.

A total of 29 natural habitats (of which 7 priority ones), 5 plant species and 13 animal species (of which one, **Canis lupus*, is priority) led to the designation of Alvão/Marão as an SCI, according to the Resolution of the Minister's Council nº 142/97 of 28th August 1997. Of these, the sectoral plan highlights the following:

- HD annex I habitat 7140 (Transition mires and quaking bogs) due to its singularity at national level where they occur only punctually
- HD annex I priority habitat 4020* (Southern Atlantic wet heaths with Erica ciliaris and *Erica tetralix* and/or *Ulex minor*)

- The extremely rare HD annex II plant *Marsilea quadrifolia*, which has here it's single occurrence area in Portugal
- HD annex II plant *Veronica micrantha*, which is in a precarious conservation status in the country
- HD annex II and IV priority Iberian Wolf, *Canis lupus*, which has a very important stronghold in the mountain area which core is this SCI, pack density being here one of the higher in the country (together with those of the neighbouring SCIs Montesinho/Nogueira and Serras da Peneda e Gerês
- The relevance of the site for the conservation of the aquatic and riverine fauna, especially for the Pyrenean Desman (*Galemys pyrenaicus*), the Otter (*Lutra lutra*) – both under HD annex II and IV -, *Rutilus arcasii* (Iberian endemic, HD annex II), *Lacerta schreiberi* and *Chioglossa lusitanica* (both Iberian endemics and listed under HD annex II and IV)
- The occurrence of several threatened bat species, a wintering roost of *Myotis blythii* and *Rhinolophus ferrumequinum* being of special importance (HD annex II).
- The occurrence of HD annex II *Oxygastra curtisii*, this SCI being one of the few areas where the species is present in Portugal.

Main Species and Habitats Potentially Affected

The sectoral plan identifies the most relevant threats to the integrity of the Alvão-Marão SCI, among which are the degradation of water quality, the felling of oakwoods, invasive plant species (including aquatic ones), opening of roads and small dams, all of them foreseen as side-effects of the Gouvães dam project. Indeed, this project goes against the following management guidelines proposed by the sectoral plan for this specific SCI:

- The **preservation of oakwoods** and other natural forest areas, which still have an important role as refuge and breeding areas for the Iberian Wolf;
- The strict protection of some natural habitats of high value such as bogs, birch woods, laurel woods and some grasslands.
- The **preservation of water lines and riparian vegetation**, which are fundamental to the conservation of fauna species associated to such environments, with special emphasis on the river Corgo mouth, the only known area of occurrence of *Marsilea quadrifolia.*
- To promote the natural regeneration of some of the natural habitats, including riparian ones **91B0 (Fraxinus angustifolia woods) and the priority 91E0* (Residual alluvial forests).**
- To ensure the maintenance of an ecological flow in waters hosting the following HD species: *Chondrostoma polylepis*, *Galemys pyrenaicus*, *Lutra lutra*, *Mauremys leprosa*, *Rutilus alburnoides* and *Rutilus arcasii*
- To **condition the building of infrastructures** affecting the following HD habitats and species: 4030; 6220*; 6230*; 7140; 8220; 9330; *Narcissus asturiensis*, *Veronica micrantha*, *Canis lupus* (namely large infrastructures in sensitive areas; to guarantee the free circulation of the species and it's prey), *Chioglossa lusitanica*; *Galemys pyrenaicus*; *Lacerta schreiberi* (namely building of new roads or enlargement of existing ones near water lines), *Barbastella barbastellus; Rhinolophus ferrumequinum; Rhinolophus hipposideros* (namely regarding the location of highway intersections with regard to roosts of national importance), *Miniopterus schreibersi; Myotis blythii* and

Myotis myotis (namely regarding the location of windfarms with regard to roosts of national importance)

- To **condition the building of small dams** *(açudes)* in sensitive areas for the following habitats and species: 3260 91E0* *Veronica micrantha Galemys pyrenaicus Rutilus alburnoides, Chondrostoma polylepis Rutilus arcasii*
- To **condition the building of dams** in sensitive areas for the following habitats and species: 3260 91E0* *Veronica micrantha, Canis lupus, Galemys pyrenaicus Rutilus alburnoides, Lacerta schreiberi, Chondrostoma polylepis Rutilus arcasii*
- To **condition water transfers** (important for *Galemys pyrenaicus, Chondrostoma polylepis, Rutilus alburnoides, Rutilus arcasii*)
- To condition water captions in areas of occurrence of the following habitats and species: 3260, 7140, *Chioglossa lusitanica, Chondrostoma polylepis, Galemys pyrenaicus, Lutra lutra, Mauremys leprosa, Oxygastra curtisii, Rutilus alburnoides, Rutilus arcasii* (in the most sensitive areas during the low rainfall months)
- To **improve the permeability of dams/small dams** to: Galemys pyrenaicus (through adequate lateral streams or fish ladders), Chondrostoma polylepis, Rutilus alburnoides, Rutilus arcasii (through inclusion of adequate fish passes)
- To **condition interventions in the water line banks and beds** in areas of occurrence of the following habitats and species: 3120, 3260, 91E0*, 9230, 92A0, *Mauremys leprosa, Chioglossa lusitanica, Oxygastra curtisii. Galemys pyrenaicus; Lacerta schreiberi, Lutra lutra, Chondrostoma polylepis, Rutilus alburnoides, Rutilus arcasii*
- To **preserve and restore the native riparian vegetation** in areas of occurrence of the following species: *Barbastella barbastellus; Chioglossa lusitanica; Chondrostoma polylepis; Galemys pyrenaicus; Lacerta schreiberi; Lucanus cervus; Lutra lutra; Mauremys leprosa; Miniopterus schreibersi; Myotis blythii; Myotis emarginatus; Myotis myotis; Oxygastra curtisii; Rhinolophus ferrumequinum; Rhinolophus hipposideros; Rutilus alburnoides; Rutilus arcasii*
- To **monitor and maintain or improve the water quality** in areas of occurrence of the following habitats and species: 3120; 3130; 3260; 6410; 7140; *Marsilea quadrifolia; Chioglossa lusitanica; Lacerta schreiberi; Lutra lutra; Mauremys leprosa; Oxygastra curtisii Chondrostoma polylepis; Rutilus alburnoides; Rutilus arcasii, Galemys pyrenaicus, Barbastella barbastellus; Miniopterus schreibersi; Myotis blythii; Myotis emarginatus; Myotis myotis; Rhinolophus ferrumequinum; Rhinolophus hipposideros*

The sectoral plan recommends several specific guidelines, some of which would be important to check whether they overlap with the location of any of the three dams or associated projects foreseen under the Gouvães project:

- To consolidate important mine galleries for *Miniopterus schreibersi; Myotis blythii*; *Myotis emarginatus*; *Myotis myotis*; *Rhinolophus ferrumequinum*; *Rhinolophus hipposideros*
- To conserve and restore the existing breeding areas of *Chioglossa lusitanica*
- To define protection areas for *Veronica micrantha* and especially safeguard the population near Pontido, which holds around 33% of the known plants (Pontido is a village located around 1 km away from the East limit of the main dam)
- To maintain and restore habitats contiguous to 6410 and 91E0* in areas of occurrence of *Marsilea quadrifolia, Veronica micrantha, Euphydryas aurinia; Galemys pyrenaicus;*

Chondrostoma polylepis; Rutilus alburnoides; Rutilus arcasii (and to establish ecological corridors)

- To restore wet and riparian areas in areas of occurrence of *Mauremys leprosa*, *Rhinolophus ferrumequinum*; *Rhinolophus hipposideros* and *Euphydryas aurinia*

Iberian Wolf

The Iberian Wolf is a priority species under the Habitats Directive, listed in annexes II, IV and V and classified as Endangered according to the Portuguese Red Data Book (Cabral et al. 2005).

The Portuguese wolf population is estimated in 55 to 60 wolf groups (meaning 200-400 individuals), divided in two isolated sub-populations, one North of Douro river with the larger number of groups (about 50), and in contact with the Spanish population; and the other to the South of this river, with approximately 6 to 9 groups (Pimenta et al. 2005).

The area between rivers Tâmega and Tua, which includes the SCI Alvão-Marão and Gouvães, hosts 12 confirmed wolf groups, only one of them (Sombra) with confirmed breeding in the last national census (Pimenta et al. 2005).

Although the Gouvães dam and associated smaller dams, given their dimensions, do not, by themselves, probably represent a major threat to the Iberian Wolf populations in the region, the cumulative impacts with other existing and foreseen infrastructures does certainly represent a significant problem in terms of barrier effect. Taking into account the average size of wolf vital areas, its strong mobility and its distribution area, the conservation and management of this species cannot depend on the implementation of measures inside N2000 areas alone, but must be approached at the broader scale of its distribution area. Even if taken alone, the Alvão-Marão area and its surroundings are already affected or foreseen to be affected by the following major infrastructures:

- A7/IC5 highway/motorway (existing, part of it crosses the Natura 2000 Alvão-Marão Site);
- A24/IP3 highway/main itinerary (existing, part of it crosses the Natura 2000 Alvão-Marão Site);
- IP4 main itinerary (with a w-e orientation, it isolates this area from the Douro International SCI, also designated for the Wolf, and from the sub-population south of river Douro)
- Several windfarms, both inside and around the Natura 2000 Alvão-Marão Site
- Several large and medium sized dams (59 dams already built in the Douro river basin alone, including one in Tâmega, 8 new ones foreseen, 6 under the PNBEPH, plus Baixo Sabor and Andorinhas, both inside N2000 sites designated for the Wolf)
- High Speed Train, north line

The monitoring of the highway/motorway stretches crossing SCI Alvão-Marão, in the framework of the conditions imposed following the EIA (Neves and Trabulo, s/d) shows the area occupied by wolves has been decreasing since the beginning of the monitoring: in 2005 the presence of wolves was detected in 94% of the grid composing Alvão sub-area, regressing to 81% in 2006 and to 68% in 2007. The presence of wolves along the corridors of both the motorways under study (A24 and A7) was reduced in 2007, especially in the areas surrounding A24. The data evolution since 2005 and the results obtained during 2007 point to a reduction in the wolf's usage of the area under study, as well as to the decrease in the intensity of use concerning areas that are still occupied. The 2007 monitoring enabled the monitoring team to continue identifying two stable groups of wolves in the Alvão sub-area (Vaqueiro and Padrela) and another one whose condition is more unstable (Sombra). According to the document the instability of the Sombra group is quite disturbing in terms of preservation of the species, since this is the only group of wolves identified in the Northern area of Serra do Alvão, which used to be a source of dispersing animals to more unstable areas, such as Minhéu, Falperra or the Westernmost slope of Alvão.

Galemys pyrenaicus

Galemys pyrenaicus is a vulnerable species (IUCN, 1994 and Cabral et al. 2005 in ICNB 2006) in all its world range, restricted to the North of the Iberian Peninsula and the Pyrenees. The Pyrenean population is not connected with the remaining North Peninsular population and the populations of the Spanish Central Mountain Chain are isolated from the remaining distribution area (Cantabrian Mountain Chain, Iberian System, Asturias, Galicia and Portugal).

In Spain, the species is in strong decline in the Central Mountain Chain, some populations having gone extinct (Blanco 1998 in ICNB 2006) and populations decline with high extinction risk is evident in other areas too according to Nores et al. 2002 (in ICNB 2006). In the French Pyrenees, populations are highly fragmented and some have disappeared (Bertrand 1994 in ICNB 2006).

According to the Portuguese Natura 2000 Sectoral Plan, it is presently under regression at national scale, both regarding population size and global distribution area. This regression is more evident in the East, South and West limits of the species distribution area but other cases of probable population decline have been detected in the core of the distribution area due to habitat fragmentation, namely in the basins of rivers Lima and Cávado. The whole PT population is estimated in less than 10.000 mature individuals scattered among isolated sub-populations, the great majority of which have less than a few hundreds of individuals.

In Portugal, the species is present in the river basins North of the river Douro (Minho, Âncora, Lima, Neiva, Cávado, Ave and Leça), in the main Douro sub-basins except the most inland ones, in the high and medium sections of the Vouga and Mondego basins and in the higher sections of river Zezere (Tejo basin) (Queiroz et al. 1998 in ICNB 2006).

The Sectoral Plan identifies as threats to the conservation of the species all activities susceptible of causing significant change to the aquatic and riparian ecosystems and their artificialization. <u>The most important threat is he building of dams</u> both in terms of magnitude and significance. <u>Water pollution and eutrophication, the destruction of river banks and the natural riparian vegetation</u> are associated threats.

The Sectoral Plan points out the already existing numerous dams and small hydric dams as the main cause for the decline and regression of the species in Portugal, <u>due to the</u>

loss of large areas of habitat upstream, the reduction or alteration of the habitat downstream, the fragmentation of populations due to the barrier effect and the breaking of the river continuum.

The building of other infrastructures in the vicinity of water lines, such as roads, bridges, recreational areas, hydro-electrical stations and pipelines etc. are also important threats that lead to the reduction of food availability (due to increased turbidity and silting) and shelter (due to bank and vegetation destruction).

The over-exploitation of water resources - namely through water caption for irrigation or water transfer/derivation for dam supply – causes the reduction of water flows, increasing the concentration of pollutant substances and deeply modifying the habitat characteristics adequate for the species (flow speed, temperature, oxygen, nutrient and other substances concentration, etc.). Particularly during the dry season, the water flow may be insufficient to support the macroinvertabrate communities on which the feeding of G. pyrenaicus depends. Such cases have been registered mainly in the interior of the country. When such situations occur in ecologically isolated basins such as small sub-basins of the upper section of the river Douro, already separated from the remaining basin by existing dams, the future natural re-colonisation is not possible and the species becomes locally extinct.

The conservation objectives set by the Sectoral Plan for *Galemys pyrenaicus* are the maintenance or increase of the species populations, the maintenance of the present distribution area, the maintenance of interspecific diversity, the promotion of the continuity between populations and the habitat restoration.

The Sectoral Plan determines that *Galemys pyrenaicus* should be considered a priority target species for management in all the water lines enclosed by Natura 2000 where the species is present, except Carregal do Sal and Romeu. The management guidelines set by the Plan are the following:

- To condition the building of new medium and large dams (wall higher than 10 m and or dam area larger than 1.000 m) as well as of smaller dams that may imply very significant negative impacts on the species and/or the SCI.
- In those cases where the building of the new dam is unavoidable and no viable alternatives exist, adequate minimisation/mitigation measures must be implemented which must be determined on a case by case basis but should generically include a) the adoption of the alternative that has least impacts, b) the installation of aquatic fauna passes which can be used by the Pyrenean Desman (preferably Nature-Like Fishways or Natural Bypass Channels), c) the implementation of an ecological flow regime defined monthly and using the most appropriate methods, d) installation of protection systems to avoid mortality in derivation conducts, turbines, etc., e) installation of systems to reduce impact of discharged flows, f) restoration of hills, banks, margins and riparian vegetation in the areas affected, g) restoration of other sectors of the same water course / Galemys SCI affected by the project (compensation measure).
- To undertake an ecological rehabilitation of large and small dams already built by adopting some of the measures mentioned above and in extreme cases where habitat

restoration and the rehabilitation of the river continuum demands it, to demolish those dams.

- To implement effective monitoring and surveillance procedures in the main existing hydraulic structures in order to detect and assess potential infractions and ensure the fulfilment of the foreseen ecological requirements.
- To maintain or improve the water quality so that it reaches a status favourable to the conservation of the species (as defined under Decreto-Lei nº 236/98, of the 1st of August: “Normas de qualidade aplicáveis às águas piscícolas”).
- To condition water transfers between different and naturally isolated river basins where populations of the species are present.

Gouvães directly affects two of the 28 sites identified by ICNB (Quaresma et al. 1998) as *Galemys pyrenaicus* Important Conservation Sites: the main dam is located in the limit of one of the sites (nº12, Tâmega, classified as a B conservation status regarding aquatic and riparian habitats, with a good conservation status, with small changes regarding it's natural state); one of the derivation dams (Alvadia) is located inside this site and the Olo derivation dam is in the core of the site nº 13 (Olo). Taken together, 4 out of the 5 dams foreseen by the PNBEPH for the Tâmega river sub-basin will destroy 5 different sections of these two important sites for *G. pyrenaicus*. Additionally, 2 more out of the 10 dams foreseen (hence a total of 6 dams), will affect another two important sites for *G. pyrenaicus*, nº 23 (Vouga), affected by Pinhosão dam and nº 26 (Mondego), affected by Girabolhos dam. If we take into account that the Baixo Sabor large dam (which was left out of the PNBEPH but approved despite location inside SCI and SPA) will also affect a fifth important site for the species (nº 15, Sabor), then the impact of the PNBEPH on *G. pyrenaicus* can be considered significant, possibly very significant if taken cumulatively with the already existing dams located in the river basins hosting important sites for conservation of *G. pyrenaicus*:

<u>Minho / Âncora</u> (3 important sites): 4 dams already built (plus several “small hydric dams”)

<u>Lima</u> (3 important sites): 2 dams already built (plus several “small hydric dams”)

<u>Neiva</u> (1 important site): no large dams, but at least one “small hydric dam”

<u>Cávado</u> (2 important sites): 6 dams already built (plus several “small hydric dams”)

<u>Ave / Leça</u> (2 important sites): 5 dams already built (plus several “small hydric dams”)

<u>Douro</u> (11 important sites): 59 dams already built, including one in Tâmega (plus many “small hydric dams”), 8 new ones foreseen (6 under the PNBEPH, plus Baixo Sabor and Andorinhas, both inside N2000 sites designated for *G. pyrenaicus*)

<u>Vouga</u> (2 important sites): 4 dams already built (plus several “small hydric dams”), 1 new one foreseen under the PNBEPH

<u>Mondego</u> (3 important sites): 28 dams already built (plus several “small hydric dams”), 1 new one foreseen under the PNBEPH

<u>Tejo</u> (1 important site): 52 dams already built (plus several “small hydric dams”), 2 new ones foreseen, one of them under the PNBEPH

Chiroptera (bats)

According to a detailed inventory of the bat species in Parque Natural do Alvão (Bicho, 1994) undertaken under a Life-Nature project, which also covered areas outside the park and inside the SCI, 15 bat species are present in the area.

It will be important to investigate the possible overlap of the following colonies / important habitats with any of the three dams or associated projects foreseen under the Gouvães project:

Myotis myotis (HD annex II and IV): the species is referenced for the area (Palmeirim and Rodrigues, 1992).

Myotis blythii (HD annex II and IV): one very important colony (for this is a species undergoing strong regression in PT) is located in Campanhó, a few km to the South of one of the smaller associated dams

Myotis mystacinus (HD annex IV): the only known Portuguese colony of this species (around 30 individuals) is located inside the Alvão Natural Park.

Myotis daubentonii (HD annex IV): two roosts (one of them a breeding roost) were located near Lamas de Olo (Lams de Olo is a village located around 1 km away from the East limit of one of the smaller associated dams).

Myotis nattereri (HD annex IV): one of the 4 colonies of the country is located here and it is the northernmost one.

Hypsugo savii (HD annex IV): unknown in PT since 1910 was also identified inside the Natural Park area.

Tadarida teniotis (HD annex IV): the only localised colony of this species (around 185 individuals, which since then has increased threefold) is also located inside the Natural Park.

The remaining species identified in the area of the Alvão Natural Park were: *Rhinolophus ferrumequinum, R. hipposideros, Barbastella barbastellus, Miniopterus schreibersi* (HD annex II and IV)*, Pipistrelus pipistrelus, P. kuhli, Eptesicus serotinus, Nyctalus leisleri* (HD annex IV).

Apart from the monitoring of the colonies identified, this study recommends the protection of the roosts and the conservation of the surrounding areas, namely wet and riparian areas, as well as agricultural areas, which coincide with the main feeding areas.

A more recent survey of 2004 (van der Wal et al. 2004) identified 3 additional species: *Myotis emarginatus* (HD annex II and IV), *Plecotus auritus* and *P. austriacus* (HD annex IV) and several roosts located in old bridges over river Olo. This study provides the locations of all the roosts inventoried, some of which are in the vicinity of either of the two smaller associated dams (Olo and/or Alvadia).

Recently, a 2-stage survey was implemented in order to evaluate the impact of large dams on bat populations in South Portugal, as well as to define minimization and compensation measures (Rebelo and Rainho 2008). The survey used the Alqueva dam as a case study and concluded that its construction caused major changes in the region, mainly due to the deforestation and submersion of a large area. Bat activity was surveyed prior to and after the deforestation and flooding of the area, mainly through the use of ultra-sound detectors. The results show a clear decline in bat activity over the area submerged; islands within the reservoir seem to be the only remaining foraging areas. Furthermore, bat activity increased in the area surrounding the reservoir. In this area, bats used similar foraging habitat types during both stages of the survey, confirming the importance of riparian habitats as foraging areas. Bat populations of this region were thus affected simultaneously by the disappearance of riparian habitat, extensive loss of roosts and the creation of a vast homogeneous habitat that is rarely used for foraging. The study concludes that in projects of this dimension, the future of bat communities is clearly dependent on the preservation of roosts and the most important habitats surrounding the reservoir. It also clearly shows that riparian areas are the most important habitat for bats in this study area, showing greater diversity of species and a higher number of bat passes than in any other habitat type. Several works have shown that this habitat is of extreme importance for bat conservation in Europe (e.g. Vaughan et al. 1997 in Rebelo and Rainho 2008, Grindal et al. 1999 in Rebelo and Rainho 2008, Russo & Jones 2003 in Rebelo and Rainho 2008) and seems to be essential to the conservation of threatened species such as *Rhinolophus ferrumequinum* and *Myotis nattereri* (Jones 1990 in Rebelo and Rainho 2008, Siemers & Schnitzler 2000 in Rebelo and Rainho 2008). Although the creation of small reservoirs (e.g. ponds) may create riparian habitats, this is frequently not the case in large dam schemes where the water level variation results in a strip of barren land at its margins which is unsuitable for the development of vegetation.

Dragonflies and Damsels

A total of 22 dragonfly species were inventoried for Alvão Natural Park (van der Wal et al. 2004), including HD annex II and IV *Oxygastra curtisii*. A more recent study (Moreira 2006) confirmed the presence of this species, though it didn't detect its presence in the surroundings of the dam infrastructure. River Olo is pointed out as an area of great diversity, where species typical of both lentic and lotic habitats cohexist.

Amphibians and Reptiles

Inventories undertaken in the SCI Alvão-Marão between 1999 and 2001 (Sequeira et al. s/d, Carretero et al. 2002) recorded a total of 11 amphibian species and 19 reptile species, which means a considerable diversity (more than 60% of the total number of amphibian and reptile species present in the country, marine species excluded). In fact, this Natura 2000 site is situated in a privileged position regarding the amphibian and reptile communities since it is located in a region of transition between ecosystems under Mediterranean and Atlantic climatic influence.

The species inventoried include 12 species listed in the Habitats Directive:

- *Chioglossa lusitanica* (annex II and IV, Vulnerable according to PT and ES Red Data Books): an Iberian endemic restricted to the Northwest of the Peninsula, in this SCI it is absent from the river Corgo valley, Falperra mountain and central area of the Alvão mountain, as it does not strive in areas of Mediterranean climate influence but depends on humid areas of Atlantic climate influence as are those affected by the Gouvães project (preferably around steep permanent water courses with abundant riparian vegetation).

- *Triturus marmoratus* (annex II and IV, Least Concern according to PT Red Data Book): restricted to the Iberian Peninsula and South France; it is present in the area affected by the Gouvães project.
- *Lacerta schreiberi* (annex II and IV, Least Concern according to PT Red Data Book): endemic of northwest Iberia, in Portugal it has a continuous distribution to the north of river Tejo, with several isolated population nuclei in mountainous areas of the South and Centre; it is present throughout the SCI - including the area affected by the Gouvães project - where it is absent only in the most Mediterranean areas of the river Corgo valley.
- *Discoglossus galganoi* (annex II e IV, Not Threatened according to PT Red Data Book): endemic of the Western Iberian Peninsula, in Portugal it is present across the country, although in fragmented population nuclei; it is not common in the SCI Alvão/Marão, it's presence in the area affected by Gouvães is not confirmed.
- *Mauremys leprosa* (annex II e IV, Least Concern according to PT Red Data Book): present in the Iberian peninsula, North Africa and some areas of South France; in Portugal it has a continuous distribution South of river Tejo; not common in the SCI, it's presence in the area affected by Gouvães is not confirmed.
- *Coronella austriaca* (annex IV, Vulnerable according to PT Red Data Book): present in Europe and East Asia; in Portugal it occurs mainly in the mountainous regions of the North and Centre; not common in the SCI, its presence in the area affected by Gouvães is not confirmed.
- *Alytes obstetricans* (annex IV, Least Concern according to PT Red Data Book): present in the Iberian Peninsula, France, Belgium, Germany, Switzerland and Morocco. In Portugal it's distribution is practically continuous in the north half of the country; it is present in the area affected by the Gouvães project.
- *Bufo calamita* (annex IV, Least Concern according to PT Red Data Book): it has a vast EU distribution and in Portugal it is present throughout most of the country; present in the area in the area affected by the Gouvães project.
- *Hyla arborea* (annex IV, Least Concern according to PT Red Data Book): it has a vast EU distribution, in Portugal it is present across the country, although in fragmented population nuclei, except from the southeast region; it is the less abundant amphibian species in this SCI and it's presence in the area affected by Gouvães is not confirmed.
- *Rana iberica* (annex IV, Least Concern according to PT Red Data Book): endemic of the Northwest quadrant of the Iberian Peninsula, in Portugal it is present in the whole Northwest, except from one isolated nucleus South of the Tejo river; it is present throughout the SCI, including the area affected by Gouvães.
- *Chalcides bedriagai* (annex IV, Least Concern according to PT Red Data Book): Iberian endemic, it has a fragmented distribution in Portugal, it's presence in the area affected by Gouvães is not confirmed.
- *Coluber hippocrepis* (annex IV, Least Concern according to PT Red Data Book): vastly distributed across Iberia, Sardinia and North Africa, in Portugal it occurs mostly to the south of Douro river, in the SCI it is restricted to the most Mediterranean areas, those affected by Gouvães not included.

The building of new dams, because it leads to habitat destruction and modification, represents a major threat to reptiles and amphibians, as they are highly conditioned in physiological and ecological terms, they have restricted mobility and a reduced dispersion ability. Habitat loss or the degradation of its quality has negative consequences, among others, on population size, distribution area and genetic variability and it may lead to local extinction cases.

The SCI Alvão/-Marão is already affected by large infrastructures that cause habitat destruction, direct mortality and barrier to dispersion, namely dams, roads (N-2, N-15, N-304, IP4 among others), and windfarms. According to Carretero et al. 2002, the conservation of the reptiles and amphibians at SCI level implies that the management of the SCI should focus on the preservation of native riparian vegetation, the conservation of aquatic habitats (namely by ensuring a good water quality) and the control of large infrastructure building.

Fish

As regards species included in the Habitats Directive, data from the PNBEPH SEA and data delivered by INAG (obtained from sampling on a monitoring station located 3 km upstream the foreseen Gouvães dam), indicate a total of 3 fish with confirmed or probable presence in the area:

- *Pseudochondrostoma duriense* (confirmed presence), considered as part of P. polylepis in the Habitats Directive), an Iberian endemic with a decreasing trend (Eionet) inhabits medium reaches in areas with current mainly in affluents of low altitude and substrate of intermediate granulometry. Juveniles prefer areas with lime and sand, they select deeper zones in Summer-Autumn and less deep areas in Spring-Winter. Also found in reservoirs. Major threats are pollution, sand and gravel extraction, introduction or expansion of allocthonous species, over-exploitation and/or regulation of river systems and destruction of riparian vegetation. Dams construction is a serious threat.
- *Chondrostoma arcasii* (*Achondrostoma arcasii*), an Iberian endemic with a confirmed presence in the area, with a decreasing trend (Eionet) typical of shallow areas with gravel and cobble and low macrophyte density in low order streams with rapid current, clean waters and coarse substrate. It occurs in mountain lakes and also reservoirs. This species is particularly vulnerable owing to its very local distribution and the possible hybridation with species of the same genus. Major threats to this species are pollution, sand and gravel extraction, introduction of allochtonous species, regulation of hydrological systems, destruction of riparian vegetation.
- *Squalius alburnoides*, an Iberian endemic with a probable presence in the area, decreasing in the Mediterranean region (Eionet), with a reduction of the population up to 50% in the last decade (PSRN2000). It selects permanent and intermittent narrow and shallow streams, also found in reservoirs but not in unpolluted waters or degraded rivers. Major threats to this species are pollution, sand and gravel extraction, introduction of allochtonous species, over-exploitation and/or regulation of hydrological resources, dams and weir construction.

3.2.2 PINHOSÃO – LIKELY EFFECTS ON “RIO VOUGA” NATURA 2000 SITE (2769 ha)

Pinhosão dam is located approximately 37 km upstream the “Rio Vouga” Natura 2000 site. The water flow reduction caused by this dam might cause the degradation of wetland and riparian habitats and species occurring in this site. Also the possible degradation of water quality caused by this dam could adversely affect the ecological status in the site.

Site Description. Reasons that led to the site designation

The Vouga river is the main water course that feeds the Ria de Aveiro estuary (Natura 2000 site, see following section). The site hosts a weel preserved riparian gallery (habitat type 91F0) and some patches of the priority habitat 91E0*.The river is important for the conservation of migratory fish species, as *Alosa alosa* and *Alosa fallax*. It is ne of the few locatuions with cionfirmed presence of *Lampetra planeri*. It also has significant importance for *Lutra lutra* and the Golden striped salamander (*Chioglossa lusitanica*).

Main habitats and species potentially affected

Habitats

3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation

3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*

91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)

Fauna species, HD Annex

Unio crassus II

Alosa alosa II

Alosa fallax II

Chondrostoma polylepis II

Lampetra planeri II

Petromyzon marinus II

Rutilus alburnoides II

Rutilus macrolepidotus II

Chioglossa lusitanica II, IV

Lutra lutra II, IV

Main threats for the site identified in the Natura 2000 Sectoral Plan

Regularisation of the water course owing to the building of hydraulic infrastructure, agricultural pressure, domestic, agrarian and industrial sewage, water captions, invasive exotic flora, sand extraction.

Management guidelines proposed in the Natura 2000 Sectoral Plan

Management guidelines mainly address the conservation of migratory fish species, in particular their spawning areas, being therefore focused on the preservation of the aquatic environment and the riparian habitats.

The most relevant management guidelines in relation to particular habitats and species are listed below:

- Monitoring, maintenance/improvement of water quality: 3150; 3270; 3280; 6410; *Chioglossa lusitanica; Lacerta schreiberi; Lutra lutra; Unio crassus; Alosa alosa; Alosa fallax; Chondrostoma polylepis; Lampetra planeri; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus*.
- Conservation/recovery of riparian vegetation: *Alosa alosa; Alosa fallax; Chioglossa lusitanica; Chondrostoma polylepis; Lacerta schreiberi; Lampetra planeri; Lutra lutra; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus.*
- To condition interventions in the streams margins and bed: 3270; 3280; 91E0*; 91F0; 9230; 92A0; *Alosa alosa; Alosa fallax; Chioglossa lusitanica; Chondrostoma polylepis; Lacerta schreiberi; Lampetra planeri; Lutra lutra; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus; Unio crassus*
- To condition the building of small dams (weirs) in sentive zones: 91E0*; 91F0; *Alosa alosa; Alosa fallax; Chondrostoma polylepis; Lampetra planeri; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus; Unio crassus*
- To condition the building of dams in sentive zones: 3280; 91E0*; 91F0; *Alosa alosa; Alosa fallax; Chondrostoma polylepis; Lacerta schreiberi; Lampetra planeri; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus; Unio crassus.*
- To guarantee an ecological flow: *Alosa alosa; Alosa fallax; Chondrostoma polylepis; Lampetra planeri; Lutra lutra; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus; Unio crassus*
- To guarantee the migration/movement of fish species improving fish passage in dams/weirs: *Alosa alosa; Alosa fallax; Chondrostoma polylepis; Lampetra planeri; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus (installation of adequate fish passes).*
- To condition water caption: *Alosa alosa; Alosa fallax; Chioglossa lusitanica; Chondrostoma polylepis; Lampetra planeri; Lutra lutra; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus; Unio crassus* (in the most sensitive areas and during the months with lower rainfall).
- To condition drainage: 6410; 6420; 91E0*; *Chioglossa lusitanica* (in the most sensitive areas)
- To condition fishing: *Alosa alosa; Alosa fallax; Petromyzon marinus* (in the most sensitive areas and in certain periods; maximum quantity and minimum size)
- To regulate drainage and sand/gravel extraction in the river: *Alosa alosa; Alosa fallax; Chondrostoma polylepis; Lampetra planeri; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus* (these activities should be forbidden in the spawning areas during the whole year and in the remaining areas during Spring).

Specific guidelines:

- Create new reproduction areas, conserve and recover existing reproduction areas: *Alosa alosa; Alosa fallax*
- *Chioglossa lusitanica*: conserve/recover already identified mines and galleries.
- *Petromyzon marinus*: recover spawning areas.
- *Unio crassus*: establish a programme for reintroduction/reinforcement of population.
- Prevent introduction of non native species/control existing ones:
- 3150; 3270; 4030; 91F0; 9330;
- *Alosa alosa; Alosa fallax; Chioglossa lusitanica; Chondrostoma polylepis; Lampetra planeri; Petromyzon marinus; Rutilus alburnoides; Rutilus macrolepidotus* (implement programmes for the control and eradication of invasive exotic vegetation in the river margins, promoting its replacement by native species).
- *Lacerta schreiberi* (remover exotic vegetation on a 50 m strip on river margins).
- *Unio crassus* (control illegal introduction of potencial competitors)
- Maintenance / recovery of contiguous habitats: 6410; 6430; 91E0*.

3.2.3 GIRABOLHOS DAM – LIKELY EFFECTS ON "CARREGAL DO SAL" NATURA 2000 SITE (9 554 ha)

Girabolhos dam is located approximately 20 km upstream the "Carregal do Sal" Natura 2000 site. The water flow reduction caused by this dam might cause the degradation of wetland and riparian habitats and species occurring in this site. Also the possible degradation of water quality caused by this dam could adversely affect the ecological status in the site.

Site Description. Reasons that led to the site designation

The site is formed by granitic elevations carved by rivers, among which the Mondego river is remarkable. It hosts an Iberian endemic plant that is exclusively present in this site: *Narcissus scaberulus*. The site is also important for the conservation of Chioglossa lusitanica a vulnerable amphibian species which is endemic to the Iberian Peninsula.

Main habitats and species potentially affected

<u>*Habitats*</u>

3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*

3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation

91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)

92A0 *Salix alba* and *Populus alba* galleries

<u>*Fauna species, HD Annexes*</u>

Chondrostoma polylepis II

Rutilus macrolepidotus II

Chioglossa lusitanica II, IV

Lacerta schreiberi II, IV

Galemys pyrenaicus II, IV

Lutra lutra II, IV

Main threats for the site identified in the Natura 2000 Sectoral Plan

Degradation of water quality, forest fires, non selective clearing of pine woods, disturbance caused by human activities.

Management guidelines proposed in the Natura 2000 Sectoral Plan

The most relevant management guidelines for this assessment are the improvement of water quality and the maintenance of the natural conditions in the river margins.

Other relevant management guidelines in relation to certain habitats/species are included below:

- To condition building of infrastructures: 5230*; 5330; 6220*; 8130; 8220; 9330; *Chioglossa lusitanica; Galemys pyrenaicus; Lacerta schreiberi* (in the building of new roads or enlargement of existing ones, avoid the proximity to streams).
- To condition the building of small dams (weirs) in sentive zones: 3260; 91E0; *Chondrostoma polylepis; Galemys pyrenaicus; Rutilus macrolepidotus*
- To condition the building of dams in sentive zones: 3260; 91E0; *Chondrostoma polylepis; Galemys pyrenaicus; Lacerta schreiberi; Rutilus macrolepidotus; Narcissus scaberulus.*
- To guarantee the maintenance of an ecological flow: 3260; *Chondrostoma polylepis; Galemys pyrenaicus; Lutra lutra; Rutilus macrolepidotus.*
- To improve water passage in dams/weirs: *Galemys pyrenaicus; Alosa alosa; Lampreta fluviatilis; Chondrostoma polylepis; Rutilus macrolepidotus* (installation of appropriate passes).
- To condition water transfers: *Chondrostoma polylepis; Galemys pyrenaicus; Rutilus macrolepidotus.*
- To conserve/ recover the native riparian vegetation: *Chioglossa lusitanica; Chondrostoma polylepis; Galemys pyrenaicus; Lacerta schreiberi; Lutra lutra; Rutilus macrolepidotus*.
- To conditions interventions in the river margins and bed: 3130; 3260; 91E0; 9230; 92A0; *Chioglossa lusitanica; Chondrostoma polylepis; Galemys pyrenaicus; Lacerta schreiberi; Lutra lutra; Rutilus macrolepidotus*.
- Monitoring, maintenance/imporvement of water quality: 3130; 3260; *Chioglossa lusitanica; Lacerta schreiberi; Lutra lutra; Chondrostoma polylepis; Rutilus macrolepidotus; Galemys pyrenaicus.*
- To condition water caption: 3260; *Chioglossa lusitanica; Chondrostoma polylepis; Galemys pyrenaicus; Lutra lutra; Rutilus macrolepidotus.*
- To condition drainage: 3130; 91E0; *Chioglossa lusitanica* (in the most sensitive zones).
- To regulate the use of weirs and ponds: 3130.
- To regulate drainage and sand/gravel extraction: 3130; 8130; 8220; *Narcissus scaberulus; Chondrostoma polylepis; Rutilus macrolepidotus* (forbid such activities in

the reproduction areas); *Galemys pyrenaicus* (forbid such activities in the rivers during the species reproduction period, form March to July).

Specific guidelines

- To maintain/recover contiguous habitats:
  3130; 6430; 91E0
  Galemys pyrenaicus (guarantee ecological corridors)
  Chondrostoma polylepis; Rutilus macrolepidotus (guarantee the fluvial continuum)
- Prevent the introduction of non native species / control the existing ones: *Chioglossa lusitanica; Chondrostoma polylepis; Galemys pyrenaicus; Rutilus macrolepidotus* (implement a programme for the control of invasive species in the river margins, promoting their replacement by native species); *Lacerta schreiberi* (remove exotic plant species on a 50 m strips in the river margins).

3.2.4 PINHOSÃO – LIKELY EFFECTS ON "RIA DE AVEIRO" NATURA 2000 SITE (51.406 ha)

Pinhosão dam is located approximately 60 km upstream the "Ria de Aveiro" Special Protection Area (designated under the Birds Directive). The reduction of water flow and retention of sediments in the Pinhosão dam could cause changes in the hydrological conditions in this site and a degradation of important habitats for bird species of Community importance that motivated the designation of this site.

Site Description; reasons that led to the site designation

The Ria de Aveiro is an important wetland designated under the Birds Directive. It is made up by a complex of lagoons formed by a network of canals and marshes of low depth. These wetlands are linked to the sea though a sand bar in the coast and are important feeding and reproduction areas for many bird species. The site hosts currently a population of over 20.000 aquatic birds, with 173 species, which include many species of Community importance (Annex I of Birds Directive).

<u>Species included in Annex I of the Birds Directive and migratory species occurring in the site</u>

Ixobrychus minutus

Ardea purpurea

Platalea leucorodia

Melanitta nigra

Milvus migrans

Circus aeruginosus

Pandion haliaetus

Himantopus himantopus

Recurvirostra avosetta

Charadrius hiaticula

Charadrius alexandrinus

Calidris alpina

Sterna albifrons

Marine migratory birds

Main threats for the site identified in the Natura 2000 Sectoral Plan

A number of threatening factors that modify the natural dynamics of the ecosystems have been identified in the Ria de Aveiro, among which are worthy of note those causing a reduction or significant alteration of wetland habitats, such as the drainage and transformation of the wetland for agrarian use and the transformation of saltpans into aquaculture. Also, the increase of tourism in the area and the construction of associated infrastructure (new roads, buildings, etc.) contribute to the destruction of natural habitats.

Other factors that induce significant changes in the dynamic of the estuary are also remarkable, such as the drainage works made for the Aveiro port, which cause an increase of erosion and a consequent reduction in the feeding resources for aquatic birds. A reduced water quality has also been reported as a result of the high concentration of organic matter and micro-organisms, and the pollution from mercury, TBT and bio-toxins. The effects are particularly serious for aquatic birds owing to bio-accumulation of pollutants in their tissues. The water pollution comes from diverse sources, among which agriculture and cattle raising are the most important.

Management guidelines proposed in the Natura 2000 Sectoral Plan

The management of the Ria de Aveiro SPA should be directed to the conservation of aquatic birds and migratory birds present in the site. The maintenance and restoration of wetlands and their mosaic of habitats is considered a priority. The coexistence of feeding habitats (ponds and saltpans), nesting and resting habitats (marshes) and migration corridors (riparian galleries and small woods), should be promoted and their long term maintenance should be guaranteed.

The preservation of marine habitats should also be assured.

The water quality should be improved through better control of polluting emissions. As regards nitrate pollution caused by agriculture, an action programme for the vulnerable area nº2, for the protection of the Aveiro aquifer, shall be accomplished.

Specific guidelines

- To condition drainage:

  Ardea purpurea; Circus aeruginosus; Ixobrychus minutus; migratory birds present in reed beds and riparian galleries

- Monitoring/Maintenance/improvement of water quality:

  Ardea purpurea; Calidris alpina; Charadrius alexandrinus; Charadrius hiaticula; Circus aeruginosus; Himantopus himantopus; Ixobrychus minutus; Melanitta nigra; Pandion haliaetus; migratory birds present in reed beds and riparian galleries; Platalea leucorodia; Recurvirostra avosetta; Sterna albifrons

- Conservation/recovery of native riparian vegetation:

  Ixobrychus minutus; Milvus migrans; migratory birds present in reed beds and riparian galleries; *Platalea leucorodia*

- Conservation/recovery of aquatic vegetation:

  Ardea purpurea; Circus aeruginosus; Ixobrychus minutus; migratory birds present in reed beds and riparian galleries
- Recovery of wetlands:

  Ardea purpurea; Himantopus himantopus; Ixobrychus minutus; Pandion haliaetus; migratory birds present in reed beds and riparian galleries
- Control of water levels in nesting areas:

  Ardea purpurea; Himantopus himantopus
- Creation of new reproduction sites, conservation/recovery of exiting ones:

  Charadrius alexandrinus; Circus aeruginosus; Himantopus himantopus; Pandion haliaetus; Recurvirostra avosetta; Sterna albifrons

3.2.5 ALMOUROL – LIKELY EFFECTS ON "ESTUÁRIO DO TEJO" NATURA 2000 SITE (44 609 ha (terrestrial area = 26.795 ha + marine area = 17.814 ha)

Almourol dam is located approximately 88 km upstream the "Estuário do Tejo" Special Protection Area (designated under the Birds Directive) and Site of Community Importance (designated under the Habitats Directive). The reduction of water flow and retention of sediments in the Almourol dam could cause changes in the hydrological conditions in this site and a potential degradation of habitats for species of Community interest that motivated the designation of this site.

Site Description. Reasons that led to the site designation

The "Estuário do Tejo" (Tagus estuary) is an important wetland designated both under the Birds and the Habitats Directives and 33% of the site is also classified as a Nature Reserve. It is one of the biggest estuaries in Europe, with a privileged location for the occurrence of migratory species during their migration between Northern Europe and Africa. It regularly hosts more than 100.000 wintering aquatic birds, from about 2000 different species including 46 species from Annex I of the Birds Directive.

It is also an important site for migratory fish species as *Alosa alosa*, *Alosa fallax* (the biggest population of this species is found in the Tagus Basin), *Petromizon marinus* and *Lampetra fluviatilis* (this is the only location where the presence of this species is confirmed). The site is also important for the otter (*Lutra lutra*).

Habitats

1110 Sandbanks which are slightly covered by sea water all the time

1130 Estuaries

1140 Mudflats and sandflats not covered by seawater at low tide

1150 * Coastal lagoons

1210 Annual vegetation of drift lines

1310 Salicornia and other annuals colonizing mud and sand

1320 Spartina swards (*Spartinion maritimae*)

1410 Mediterranean salt meadows (*Juncetalia maritimi*)

1420 Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)

1430 Halo-nitrophilous scrubs (*Pegano-Salsoletea*)

3120 Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with *Isoetes spp.*

3150 Natural eutrophic lakes with Magnopotamion or Hydrocharition-type vegetation

3160 Natural dystrophic lakes and ponds

3170 * Mediterranean temporary ponds

3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation

3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*

6420 Mediterranean tall humid grasslands of the Molinio-Holoschoenion

91B0 Thermophilous *Fraxinus angustifolia* woods

92A0 *Salix alba* and *Populus alba* galleries

Fauna species, Annexes of the Habitats Directive

Alosa alosa II

Alosa fallax II

Chondrostoma polylepis II

Lampetra fluviatilis II

Petromyzon marinus II

Emys orbicularis II, IV

Mauremys leprosa II, IV

Lutra lutra II, IV

Fauna species, Annex I of the Birds Directive and migratory species

Ixobrychus minutus

Egretta garzetta

Ardea purpurea

Platalea leucorodia

Phoenicopterus roseus

Anser anser

Anas penelope

Anas crecca

Pandion haliaetus

Himantopus himantopus

Recurvirostra avosetta

Glareola pratincola

Charadrius alexandrinus

Migratory birds (Passeriformes) present in reed beds and riparian galleries

Main threats for the site identified in the Natura 2000 Sectoral Plan

Water pollution from urban and agrarian sources, urban and tourism pressures are the main threats identified for this site.

Management guidelines proposed in the Natura 2000 Sectoral Plan

The management of the site should be mainly oriented to the preservation of the different habitats associated to the estuarine environment and to the conservation or recovery of the freshwaters. The riparian vegetation should be improved and maintained and the interventions in the margins and the bed of the water courses should be prevented, as they are critical for the conservation of numerous animal species.

As regards aquatic birds and migratory birds present in reed beds and riparian galleries, the conservation of their habitats should be promoted. A diversity of natural and semi-natural habitats should be maintained and priority should be given to the preservation of the feeding resources of target species (most representative species of the SPA) by preventing significant modification of the fish and benthic invertebrate communities

Specific guidelines

Bird species

- Conservation/recovery of aquatic vegetation:
  Anas crecca; Ardea purpurea; Chlidonias hybridus; Circus aeruginosus; Circus cyaneus; Ixobrychus minutus and migratory birds present in reed beds and riparian galleries (Passeriformes)
- Conservation/recovery of riparian vegetation:
  Ixobrychus minutus; Milvus migrans; migratory birds (Passeriformes) present in reed beds and riparian galleries; *Platalea leucorodia*
- Control of water levels in nesting areas:
  Ardea purpurea; Himantopus himantopus
- Creation of new reproduction areas, conservation/recovery of existing ones: *Charadrius alexandrinus; Himantopus himantopus; Sterna albifrons; Chlidonias hybridus; Sterna albifrons; Circus aeruginosus; Pandion haliaetus; Recurvirostra avosetta*
- Recovery of wetlands:
  Anas crecca; Anas penelope; Ardea purpurea; Chlidonias hybridus; Egretta garzetta; Glareola pratincola; Ixobrychus minutus; Limosa limosa; Milvus migrans; migratory birds (Passeriformes) present in reed beds and riparian galleries.

Other species (Habitats Directive)

- Creation of new reproduction areas, conservation/recovery of existing ones: *Alosa alosa; Alosa fallax; Petromyzon marinus* (recovery of spawning areas)
- Recovery of wetlands:
  Emys orbicularis; Mauremys leprosa.

3.3 Effects on species and habitats protected under the Habitats and Birds Directives

Potential effects on species and habitats of Community interest are identified taking into account the available information about their occurrence in the area of the PNBEPH. Species and habitats that depend on aquatic and riparian environments are considered, with particular attention to fish species of community interest and other species that inhabit relatively well conserved rivers (e.g. the otter Lutra lutra and the Pyreneen desman *Galemys pirenaicus*).

The conservation status of species and habitats included in the Habitats Directive has been recently assessed by all EU member states (in accordance with article 17 of the Habitats Directive) and national reports were submitted to the Commission in 2007-2008, which include information about range, distribution, population, status and trends. These reports are available form the EIONET web page (http://biodiversity.eionet.europa.eu/article17) and have been used in this technical assessment.

Other information sources are also used to identify the effects on species and habitats of community interest in the area of the PNBEPH, including national and scientific reports on their distribution and ecological requirements.

Cumulative effects, taking into account other existent and projected dams are assessed at different scales (river, sub-basin, river basin, regional). In particular, the cumulative impact of barriers to fish migration has been considered with some detail. Also as the barrier effect to medium sized and large mammals, particularly the Iberian Wolf, has been considered.

3.4 The SEA of the PNBEPH: assessment of effects on habitats and species protected under the Nature Directives

C2 criterion considers the impacts on protected species classified at least as vulnerable in the Portuguese Red List: fish, amphibian, reptiles, birds and mammals (some of which are also included in the Habitats Directive). For each species, the presence and the conservation status according to the Portuguese Red List were taken into account. Fish species considered in this assessment are indicated in page 31 of the Environmental Report-Annex IV. In relation to migratory fishes, the existing dams in the larger basins are conditioning its presence. For example *Petromyzon marinus* was just detected in Almourol (Tejo river) and *Lampetra fluviatilis* is still present in Pinhosão (Vouga river). Finally, the *Anguilla anguilla* is likely to be present in Alto Tâmega (Vidago), Daivões, Fridão, Padroselos and Gouvães, according to the SEA.

C3 criterion is used to assess the potential impact on some habitats and species included in the Habitats Directive for which the European Commission has determined that the Natura 2000 network does not include sufficient areas for guarantying their conservation (see the list in annex 1). Values for each habitat/species: (1 – confirmed presence; 0,3 – likely presence and 0 - absence) are determined for each project.

C4 criterion (degree of naturalness - WFD). The level of current human pressure on water bodies for which the PNBEPH includes a hydroelectric project is assessed. Two sub-criteria have been taken into consideration: analysis of impacts from human activities on surface waters and degree of existing lotic fragmentation. The analysis of impacts from human activities on surface waters (WFD) is done in accordance with the first risk analysis done by the INAG in 2005 (Article 5 report).

According to this assessment, all the water bodies of the dams included in option D (finally selected) were at risk.

The degree of river fragmentation level is assessed on the basis of large dams presence within the basin and sub-basin; the fragmentation is considered: high (Alvito, Girabolhos), moderate (Foz-Tua, Padroselos, Daivões, Alto Tâmega-Vidago, Fridão, Gouvães, Pinhosão) or low (Almourol).

QUADRO 4. 14

Grau de fragmentação lótica preexistente

EMPREENDIMENTO	FRAGMENTAÇÃO LÓTICA	BARRAGENS PREEXISTENTES
Assureira	Elevada	Alto Lindoso
Atalaia	Reduzida	Sem barragens na sub-bacia
Sra de Monforte	Reduzida	Sem barragens na sub-bacia
Pêro Martins	Reduzida	Sem barragens na sub-bacia
Sampaio	Moderada	Baixo Sabor
Mente	Moderada	Cachão
Rebordelo	Moderada	Cachão
Foz-Tua	Moderada	Cachão
Castro Daire	Reduzida	Sem barragens na sub-bacia
Alvarenga	Reduzida	Sem barragens na sub-bacia
Castelo Paiva	Reduzida	Sem barragens na sub-bacia
Padroselos	Moderada	Torrão
Alto Tâmega (Vidago)	Moderada	Torrão
Daivões	Moderada	Torrão
Fridão	Moderada	Torrão
Gouvães	Moderada	Torrão
Póvoa	Moderada	Aç. Drizes; Aç. Ribafeira
Pinhosão	Moderada	Aç. Drizes; Aç. Ribafeira
Asse-Dasse	Elevada	Ac. Pateiro; Aguieira
Girabolhos	Elevada	Aguieira
Midões	Elevada	Aguieira
Almourol	Reduzida	Sem barragens a jusante (Fratel e Belver a montante)
Santarém	Reduzida	
Erges	Reduzida	Sem barragens na sub-bacia
Alvito	Elevada	Marateca; Pracana (Belver e Fratel no Tejo)

As above-mentioned, the **cumulative impacts have not been assessed in the SEA** of the PNBEPH, although the SEA report recommends that more detailed studies on the cumulative impacts on biodiversity should be carried out at the sub-basin level

According to the SEA, the scale in which assessment was undertaken and the lack of detailed information on some particular aspects (e.g. information on species and habitats distribution were only assessed on a national scale) did not allow proper assessment of some issues that should be further analysed, in particular:

- Cumulative impacts in estuaries and coastal areas (cumulative reduction of liquid and solid flows) should be analysed at the basin level when several dams are included in the PNBEPH for one basin. Main issues to consider include: sediment dynamics, coastal erosion and flows for fish fauna.

- Cumulative impacts on biodiversity. When several dams are foreseen in the PNBEPH for one basin (e.g. Tâmega river), more detailed studies on the cumulative impacts on biodiversity should be carried out at the sub-basin level. The main effects to be analysed include the fragmentation of the lotic continuum and the loss and fragmentation of terrestrial habitats by the reservoirs.

The EIA of the projects included in the PNBEPH should carry out more detailed studies on the following issues:

- Distribution and abundance of habitats and species.
- Mitigation measures. The EIA should define in detail the appropriate mitigation measures for each dam included in the PNBEPH, however, some guidelines are provided in relation to:
  1. *River continuum*, in particular when migratory species are present, mitigation measures to allow their migration should be undertaken; nevertheless, the report considers that there is limited knowledge about this kind of mitigation measures for fish species of Mediterranean ecosystems, as most of them are designed for salmons (which will be inefficient for other species), and therefore admits that in some cases it might be unfeasible to carry out such measures.
  2. *Ecological flows* should be designed in the EIA of each project, according to best practice available for Mediterranean ecosystems. This aspect shall be particularly considered in the basins where several projects will be carried out and the mitigation measures should take into account the cumulative effects on the rivers and the estuaries affected. Ideally the water for ecological flows should be taken from independent hydraulic circuits to those used for bottom discharge so as to avoid the release of water with inappropriate temperature and quality conditions.
  3. *Compensation measures* shall be defined for unavoidable impacts in accordance with detailed studies to be carried out in the EIA for each dam.

Furthermore, Chapter 5.3 (Water resources) of the SEA Report - Annex IV includes a section about the interaction between the PNBEPH and the WFD where the following issues are analyzed:

- Water bodies at risk (see Quadro 5.7)
- Effects on hydromorphological, biological and physic-chemical elements.

There is a reference to the derogations under Art. 4.7 of the WFD (see page 78). The derogation for the PNBEPH is justified due to "sustainable development activities". The justifications to this derogation are presented on pages 79-82. Mitigation measures are to be precisely identified within the EIA but some summary guidelines are indicated in this section, which concern the river continuum, the ecological flows and other compensation measures (as described in the Environmental Assessment Report).

Results of the assessment of impacts on Biodiversity

The biodiversity assessment according to the four criteria defined for this critical factor concluded that options A and B present significant conflict with national and international objectives on nature conservation and options C and D present lesser impacts on nature conservation objectives.

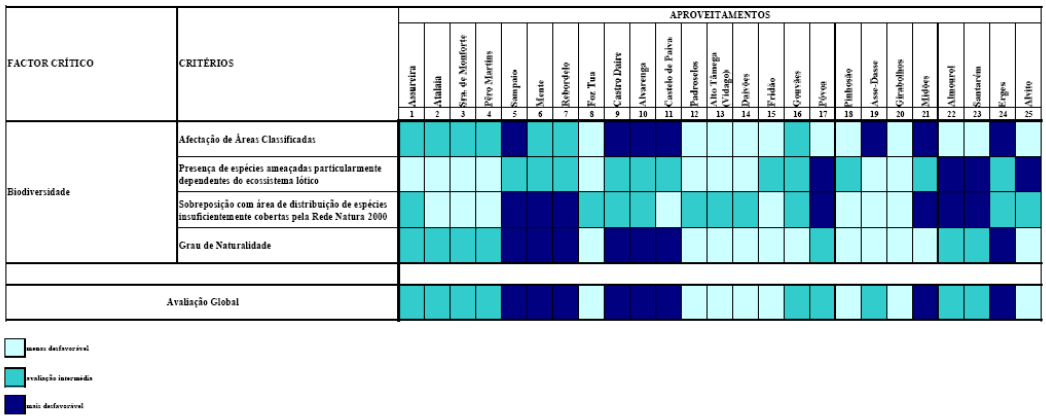
QUADRO 5.8

Avaliação das opções estratégicas no âmbito da Biodiversidade

	OPÇÃO A	OPÇÃO B	OPÇÃO C	OPÇÃO D
Biodiversidade	--	--	-	-

QUADRO 4.18

Resultados da avaliação dos aproveitamentos para o factor crítico Biodiversidade



The main advantages and disadvantages for the four strategic options in relation to Biodiversity critical factor are also presented in this section (see Quadro 5.9), but it is not clear why option D (the one finally selected) is better than option C as far as impact on biodiversity are concerned.

QUADRO 5.9

Vantagens e desvantagens das opções estratégicas no âmbito da Biodiversidade

OPÇÃO	VANTAGENS	DESVANTAGENS
Opção A	Tem menor número de empreendimentos do que as restantes opções, mas apresenta níveis de conflito com a biodiversidade mais elevados.	Sobreposição com nove áreas classificadas. Afectação potencial da integridade de duas áreas classificadas. Impactes potenciais sobre espécies e habitats considerados de conservação prioritária no espaço comunitário pela Directiva Habitats. Claro conflito com a legislação nacional e com a legislação comunitária (Directiva Aves e Habitats), com reflexos directos na operacionalidade da Opção, em termos de calendário de implementação e cenários de financiamento.
Opção B	Tem menor número de empreendimentos do que as Opções C e D, mas com níveis de conflito com a biodiversidade mais elevados.	Sobreposição com sete áreas classificadas. Afectação potencial da integridade de três áreas classificadas. Impactes potenciais sobre espécies e habitats considerados de conservação prioritária no espaço comunitário pelas Directivas Aves e Habitats. Claro conflito com a legislação nacional e com a legislação comunitária (Directiva Aves e Habitats), com reflexos directos na operacionalidade da Opção, em termos de calendário de implementação e cenários de financiamento.
Opção C	Menores conflitos com áreas classificadas. Não se prevê a afectação da integridade de nenhuma área classificada.	Introduz uma grande barragem numa bacia que actualmente não apresenta esse nível de fragmentação (rio Vouga). Impactes potenciais sobre espécies de peixes migradoras no rio Vouga, com estatuto de ameaça elevado em Portugal e insuficientemente cobertas pela Rede Natura 2000 (conflito potencial com a Directiva Habitats)
Opção D	Menores conflitos com áreas classificadas. Não se prevê a afectação da integridade de nenhuma área classificada.	Introduz uma grande barragem no troço principal do Tejo, que actualmente não apresenta fragmentação até esse ponto. Impactes potenciais sobre espécies de peixes migradoras no Tejo, com estatuto de ameaça elevado em Portugal e insuficientemente cobertas pela Rede Natura 2000 (conflito potencial com a Directiva Habitats)

3.5 Identification of species included in the Nature Directives that are potentially affected by the PNBEPH

From the information collected and analysed in this technical assessment, a number of species from the Habitats and Birds Directives that will be potentially affected by the PNBEP are identified. We have considered their occurrence in Natura 2000 sites surrounding the PNBEPH dams and their connectivity needs to predict possible effects.

As above mentioned, this assessment mainly concerns species and habitats that depend on aquatic and riparian environments, with particular attention to fish species of community interest and other species that inhabit relatively well conserved rivers (e.g. the otter Lutra lutra and the Pyreneen desman *Galemys pirenaicus*). Other terrestrial species could also be affected by these dams in particular when important areas for their conservation (e.g. breeding and feeding areas) will be flooded by the reservoirs but owing to the lack of detailed information about the distribution of such areas for this evaluation, we have not been able to assess the potential effects on them.

The identification of likely effects on the species considered in this evaluation is summarised in **Table 50**.

Table 50: Main species and habitats protected under the Habitats and Birds Directives which might be affected by the PNBEPH

HABITATS	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
3120 Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with *Isoetes* spp.	- Gouvães (on Alvão-Marão site) - Almourol (on Estuário do Tejo)	Habitat destruction due to transformation in lentic system (reservoir) Habitat degradation owing to changes in the hydrological regime and water quality caused by the dam	None Ecological flow
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*	- Gouves (on Alvão-Marão site) - Girabolhos (on Carregal do Sal site)	Habitat destruction due to transformation in lentic system (reservoir) Habitat degradation owing to changes in the hydrological regime and water quality caused by the dam	None Ecological flow
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	- Gouvães - Girabolhos (on Carregal do Sal site) - Almourol (on Estuário do Tejo)	Habitat destruction due to transformation in lentic system (reservoir) Habitat degradation owing to changes in the hydrological regime and water quality caused by the dam	None Ecological flow
3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation	- Pinhosão (on Rio Vouga site)	Habitat destruction or degradation owing to changes in the hydrological regime and water quality caused by the dam	Ecological flow
3280 Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*	- Pinhosão (on Rio Vouga site) - Almourol (on Estuário do Tejo)	Habitat destruction or degradation owing to changes in the hydrological regime and water quality caused by the dam Ecological flow	Ecological flow

HABITATS	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
4030 European dry heaths	- Gouvães (on Alvão-Marão site)	Habitat destruction due to flooding (reservoir)	None
6220 * Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	- Gouvães (on Alvão-Marão site)	Habitat destruction due to flooding (reservoir)	None
6230 * Species-rich *Nardus* grasslands, on silicious substrates in mountain areas	- Gouvães (on Alvão-Marão site)	Habitat destruction due to flooding (reservoir)	None
8220 Siliceous rocky slopes with chasmophytic vegetation	- Gouvães (on Alvão-Marão site)	Habitat destruction due to flooding (reservoir)	None
91B0 Thermophilous *Fraxinus angustifolia* woods	- Gouves (on Alvão-Marão site) - Almourol (on Estuário do Tejo)	Habitat destruction due to flooding (reservoir) or habitat degradation oeing to reduction of water flow	None Ecological flow
91E0 * Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*	- Gouvães (on Alvão-Marão site) - Pinhosão (on Rio Vouga site) - Girabolhos (on Carregal do Sal)	Habitat destruction due to flooding (reservoir) or habitat degradation owing to reduction of water flow	None Ecological flow
91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and	- Pinhosão (on Rio Vouga site)	Habitat destruction or degradation owing to reduction of water flow	Ecological flow

HABITATS	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
Ulmus minor, *Fraxinus excelsior* or *F. angustifolia*, along the great rivers			
9230 Galicio-Portuguese oak woods with *Quercus robur* and *Quercus Pyrenaica*	- Gouvães (on Alvão-Marão site)	Habitat destruction due to flooding (reservoir) Or habitat degradation owing to reduction of water flow	None Ecological flow
92A0 *Salix alba* and *Populus alba* galleries	- Girabolhos (on Carregal do Sal) Almourol (on Estuário do Tejo)	Habitat destruction or degradation owing to reduction of water flow	Ecological flow
Coastal and halophytic habitats (including estuaries, etc.	- Almourol (on Estuário do Tejo)	Habitats degradation due to reduced water flow and retention of sediments in the dam	Ecological flow, release of sediments
3150 Natural eutrophic lakes, 3160 Natural dystrophic lakes and ponds, 3170 * Mediterranean temporary ponds	- Almourol (on Estuário do Tejo)	Habitat destruction or degradation owing to reduction of water flow	

SPECIES (category of threat in Red Data Book) (conservation status)*	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
MAMMALS			
Galemys pyrenaicus (Vulnerable – RDB) (Inadequate – art. 17 report)	Gouvães (on Alvão-Marão site) - Girabolhos (on Carregal do Sal)	Habitat destruction due to flooding (reservoir) Habitat degradation owing to hydrological and geomorphological changes caused by the dam	None Ecological flow
Lutra lutra (Least Concern- RDB) (Favourable CS)	- Gouvães (on Alvão-Marão site) - Pinhosão (on Rio Vouga site) - Girabolhos (on Carregal do Sal)	Habitat destruction due to flooding (reservoir) Habitat degradation owing to hydrological and geomorphological changes caused by the dam	None Ecological flow
Several bat species	- Gouvães (on Alvão-Marão site)	Habitat destruction due to flooding (reservoir) Habitat degradation owing to hydrological and geomorphological changes caused by the dam	None Ecological flow
Canis lupus (Endangered – RDB)	- Gouvães (on Alvão-Marão site) - Pinhosão (on Rio Vouga site) - Padroselos - Daivões - Alto Tâmega-Vidago - Fridão - Foz Tua	Habitat destruction Destruction of prey habitat Cumulative barrier effect (both for the species and its prey)	None Mammal passes
FISH			

SPECIES (category of threat in Red Data Book) (conservation status)*	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
Alosa alosa (EN) (Bad CS)	Pinhosão (probable in the dam area, confirmed in Rio Vouga Natura 2000 site) Almourol (Estuário do Tejo)	Habitat destruction or degradation (reproduction and spawning areas) Obstacle to fish migrations (anadromous) Fragmentation of populations	None Fish passes (doubtful efficacy) and ecological flow
Alosa fallax (VU) (Bad CS)	Pinhosão (probable in the dam site, confirmed in Rio Vouga Natura 2000 site) Almourol (dam area and Estuário do Tejo)	Habitat destruction or degradation (reproduction and spawning areas) Obstacle to fish migrations (anadromous) Fragmentation of populations	None Fish passes (doubtful efficacy) and ecological flow
Barbus bocagei (LC) (Inadequate CS)	Alto Tâmega-Vidago Foz Tua Pinhosão Almourol Alvito	Habitat destruction or degradation Obstacle to reproductive migrations Destruction or degradation of riparian vegetation areas (selected by this species) Changes in hydrological conditions (current) required for reproductive migrations (potamodromous) Fragmentation of populations	None Fish passes (doubtful efficacy) and ecological flow
Barbus comizo (EN) (Bad CS)	Almourol Alvito	Habitat destruction or degradation (spawning areas) Obstacle to seasonal migrations (potamodromous) Fragmentation of populations	None Fish passes (doubtful efficacy) and ecological flow
Pseudochondrostoma duriense (Chondrostoma duriense)	Alto Tâmega-Vidago Gouvães	Habitat destruction or degradation Changes in hydrological conditions required by the species	None Ecological flow

SPECIES (category of threat in Red Data Book) (conservation status)*	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
(LC) (Inadequate CS)	Foz Tua	Obtscle to local migrations (potamodromous) Fragmentation of populations	Fish passes (doubtful efficacy)
Iberochodrostoma lemmingii *(Chondrostoma lemmingii)* (EN) (Bad CS)	Alvito	Habitat destruction or degradation (not present in reservoirs) Fragmentation of populations	None Ecological flow Fish passes (doubtful efficacy)
Iberochodrostoma lusitanicum *(Chondrostoma lusitanicum)* (CR) (Bad CS)	Alvito (porbable)	Habitat destruction or degradation (not present in reservoirs) Fragmentation of populations (high fragmentation lareday existing)	None Ecological flow Fish passes (doubtful efficacy)
Pseudochondrostoma polylepis *(Chondrostoma polylepis)* (LC) (Inadequate CS)	Pinhosão - Girabolhos (on Carregal do Sal) Almourol (dam area and Estuário do Tejo) Alvito	Habitat destruction or degradation Changes in hydrological conditions required by the species (swift current). Obstacle to reproductive migrations to upstream shallow areas (potamodromous)	None Ecological flow Fish passes (doubtful efficacy)
Lampetra fluviatilis (CR) (Bad CS)	Pinhosão (probable) Almourol	Habitat destruction or degradation (reproduction areas, suitable areas for larvae). Obstacle to fish migrations (anadromous).	None Ecological flow Fish passes (doubtful efficacy)

SPECIES (category of threat in Red Data Book) (conservation status)*	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
Lampetra planeri (CR) (Bad CS)	Pinhosão (Rio Vouga) Almourol (Estuário do Tejo)	Habitat destruction or degradation (very sensitive, it requires particular conditions in the river bed as it lives burrowed under the sediment most of its life). (Never found in reservoirs) Obstacle to reproductive migrations. Fragmentation of populations.	None Ecological flow Fish passes (doubtful efficacy)
Petromyzon marinus (VU) (Inadequate CS)	Pinhosão (Rio Vouga) Almourol (dam area and Estuário do Tejo)	Habitat destruction or degradation (reproduction and spawning areas) Obstacle to reproductive migration (anadromous)	None Ecological flow Fish passes (doubtful efficacy)
Squalius alburnoides (Rutilus alburnoides) (VU) (Bad CS)	Alto Tâmega-Vidago Padroselos (prob.) Daivões Gouvães (probable) Fridao (prob.) Foz Tua Pinhosão (probable in the dam area, confirmed in Rio Vouga Natura 2000 site) Girabolhos Almourol (probable) Alvito	Habitat destruction or degradation (requires narrow and shallow streams with current and macrophytes cover, selects unpolluted waters)	None Ecological flow
Achondrostoma arcasii (Rutilus	Alto Tâmega-Vidago (probable)	Habitat destruction or degradation (its preferred habitat varies along	None

SPECIES (category of threat in Red Data Book) (conservation status)*	DAMS (effects on site)	LIKELY EFFECTS	POSSIBLE MITIGATION
arcasii) (EN) (Bad CS)	Padroselos (prob.) Daivões (prob.) Gouvães Fridao (prob.) Foz Tua (probable) Pinhosão Girabolhos Almourol	the lyfe cycle) Changes in hydrological and hydromorphological conditions required by the species (small streams with clean waters and coarse substrate; juveniles in shallow areas with little current while the adults are found in deeper areas). Fragmentation of populations	Ecological flow
Achondrostoma oligolepis (Rutilus macrolepidotus) (LC) (Inadequate CS)	Pinhosão Girabolhos Almourol	Habitat destruction or degradation (arge variety of habitats with preference by small to medium streams with slow current and shallow waters, not usual in reservoirs). Obstacle to reproductive migrations (potamodromous)	None Ecological flow Fish passes (doubtful efficacy)

Categories of therat: CR: Critically endangered - EN: Endangered - VU: Vulnerable - LC: Least Concern – DD: insufficient information

* Conservation status for each species is indicated as reported by Portuguese authorities to the Commision, in 2007, in accordance with the porvidions of article 17 of the Habitats Directive.

In brackets species former names

3.6 Conclusion

It is evident that the PNBEPH will cause significant impacts on species protected under the Natura directives. It will also have a considerable direct impact on a Natura 2000 site (Alvão-Marão), which has not been properly assessed, and some indirect impacts on other four Natura 2000 sites (Rio Vouga, Carregal do Sal, Ria de Aveiro and Estuário do Tejo), which have not been considered at all in the SEA. The opinion expressed by the ICNB (national authority on biodiversity conservation) considered that the Couvaes dam would have a significant adverse effect on the Alvão-Marão Natura 2000 site, but the SEA did not take this opinion into account. Therefore, at least in this case, the effects on the site integrity (criterion C1.2) could have not been properly assessed.

The SEA included the impact on species included in the Portuguese Red List (those classified at leas as “vulnerable” were considered under criterion 2) but only considered the presence of those species in the areas affected by the dams and did not consider the critical areas or the areas important for the conservation of those species.

The presence of threatened species in areas that currently have a low fragmentation and a high level of naturalness, assessed under criterion C4 (linked to WFM) is not given sufficient consideration in the SEA, and this criterion has a low relative weight in the assessment.

Furthermore, cumulative impacts have not been evaluated, as acknowledged in the SEA, while it is also evident that the five dams planned in the Tâmega sub-basin (four of them in the river Tâmega) will have significant cumulative impacts in a section of this sub-basin, which currently has relative good conditions and a low level of fragmentation. It should be taken into account that despite the existence of organic pollution/eutrophication problems[22] , the river areas that will be affected by the construction of new dams have currently a good habitat quality. Data from a preliminary ecological assessment[23] carried out in Portugal showed high scores for biological indexes based on macro-invertebrates, macrophytes and fish data in the Tâmega river, which suggests the existence of well structured fish communities and good habitat conditions for this group.

The criteria used in the evaluation of effects on biodiversity in the SEA and the values assigned to these criteria seem not sufficient to detect these potential significant impacts. Also adequate mitigation measures have not been sufficiently described. The SEA mentions that mitigation measures should be defined in detail in the EIA of each dam and only some general guidelines are provided in relation to 1) River continuum (although it is considered that there is limited knowledge about the possible mitigation measures for fish species of Mediterranean ecosystems and therefore admits that in some cases these

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[22] Eutrophication in the Torrão Dam on the Tâmega river, downstream Fridao dam, and in the upper area of the Tâmega basin, where the Veiga de Chaves dam (42,7km upstream Alto Tâmega-Vidago dam) is in meso-eutrophic state.

[23] Cortes *et al.*, 2008. Qualidade Ecológica das águas Doces Superficiais - Bacia Hidrográfica do Douro. Relatório Final. INAG, Instituto da Água, Lisboa.

ADISA, Associaçao para o Desenvolvimento do Instituto Superior de Agronomia. 2008. Qualidade Ecológica de Sistemas Fluviais Portugueses. Bacias Hidrográficas do Tejo e Ribeiras do Oeste. Relatório Final – Parte II. INAG, Instituto da Água, Lisboa.

measures might be not viable), 2) Ecological flows (they should be designed in the EIA of each project, according to best practice available for Mediterranean ecosystems) and 3) Other mitigation measures shall be considered taking into account particular natural values. Compensation measures shall also be defined for unavoidable impacts in accordance with detailed studies to be carried out in the EIA for each dam.

GLOSSARY

CIS	Common Implementation Strategy
EIA	Environmental Impact Assessment (85/337/EEC)
GEP	Good Ecological Potential
GES	Good Ecological Status
HMWB	Heavily Modified Water Body
HQA	Habitat Quality Assessment
IFIM	Flow Incremental Methodology
INAG	Instituto da Água
IPPC	Integrated Pollution Prevention and Control
PNBEPH	Programa Nacional de Barragens com Elevado Potencial Hidroeléctrico Portuguese National Programme for Dams with High Hydropower Potential
RBMP	River Basin Management Plan
SEA	Strategic Environmental Assessment (2001/42/EC)
SWOT	Strenghts, Weaknesses, Opportunities and Threats Analysis
WB	Water Body
WFD	Water Framework Directive (2000/60/EC)
UWWTD	Urban Wastewater Treatment Directive (91/271/EEC)

Task 3: Assessment of alternative options

1 Task 3a: What is the estimated increase in capacity that can be achieved through upgrading existing hydropower installations?

1.1 Introduction

Taking into account the provisions of Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market, the percentage of electric power generated from renewable sources must be increased. In 2020 a total capacity of 7.000 MW_e should be installed. This can be realized by:

- The upgrading of existing hydropower installations;
- The construction and realization of planned new dams;
- The construction of new installations with a total capacity of 2000 MW_e.

Regarding the upgrading potential of the existing hydropower installations a general approach has been applied. Within the context of this study, it was not possible to assess the upgrading potential of each individual hydropower station in detail.

1.2 Current situation

1.2.1 Existing installations

INAG provided a file '4_Usos_Baragens_Mai09', containing a list of 105 dams (Annex 1). The purpose of these dams is multiple, and besides producing clean renewable electricity all year round, reservoirs are also serving other practical and recreational purposes such as managing seasonal floods, protecting people and properties, and providing a steady source of water for drinking and irrigation. Reservoirs are also used for fishing and recreational navigation. For each of these dams the type of use is mentioned:

- water supply (drinking water, irrigation);
- navigation and recreational use;
- energy production (43 hydropower installations).

Only the dams used to produce energy are selected for further evaluation. An overview is given in Annex 2, including a map with their location.

A second source of information that has been used is the register of dams ('Barragens de Portugal') available on the following website:

http://cnpgb.inag.pt/gr_barragens/gbportugal/AA.HTM#A.

On this website information is given regarding 168 dams in Portugal. For 64 of these dams energy production is mentioned as one of the uses. Also the smaller hydropower installations are included.

Only 30 dams are found on both of these lists, and some discrepancies were detected between the characteristics mentioned in the 2 databases.

- The hydropower installations mentioned on the website, represent a global maximum capacity of 4322 MW_e. However, for at least 10 installations the maximum capacity is not given.
- On the other hand, according to the data provided by INAG the given hydropower installations represent a total maximum capacity of 4461 MW_e. Also from this source data are lacking for some installations.
- In the PNBEPH report a total installed capacity of 4950 MW_e is mentioned.

1.2.2 Planned hydropower installations

Plans currently have been established for the adaptation of 6 hydropower installations (**Table 1**). For 3 of them, construction works have already started (Picote, Bemposta and Alqueva). Once realized, the total capacity will be increased by 1837 MW_e. In most cases, the total capacity of the hydropower plants will be at least double of the current capacity.

Table 1: Foreseen upgrading of existing hydropower installations (data INAG May 2009)

	Start	Status	Maximum capacity (MW_e)	Increase in capacity (MW_e)
Albufeira Venda Nova	1951	In study	281	736
Albufeira Salamonde	1953	In study	42	90
Albufeira Paradela	1956	Foreseen	54	318
Albufeira Picote	1958	Under construction	195	246
Albufeira Miranda	1960	Already finalized in 1995??	369	
Albufeira Bemposta	1964	Under construction	240	191
Albufeira Alqueva	2002	Under construction	260	256
Total				1837

Two additional facilities (not mentioned in the database provided by INAG, but mentioned in supplementary information of May 2009), are under construction:

- Ribeiradio/Ermida hydropower plant on the River Vouga with a capacity of 70 MW_e;
- Baixo Sabor hydropower plant in the Douro Basin with a capacity fo 170 MW_e (reversible operation possible).

This represents an additional increase of 240 MW_e.

When all the above mentioned projects will have been realized, the total capacity will be at least 6538 MW_e (= 4461 + 1837 + 240).

Hence, to achieve the target of 7000 MW_e by 2020, an additional 500 MW_e should be installed. When using the figure of 4950 MW_e, as mentioned in the PNBEPH, a total capacity of 7027 MW_e is achieved, also assuming that all the projects will be realized.

In the PNBEPH report however, a total capacity of 1100 MW_e is targeted, and consequently 10 possible sites for new hydropower plants are proposed. .

1.3 Characteristics of the existing hydropower installations

In **Annex 18** a printout is given of the data provided by INAG. For the further assessment however, only the data in **Annex 19** have been used and more specifically the following parameters are taken into account:

- the start of exploitation;
- the maximum (installed) capacity P (MW_e);
- the designed energy production (GWh_e);
- the average electricity production (GWh_e);
- the type of turbines;
- the actual efficiency.

1.3.1 Type of hydropower installations

The hydropower facilities in Portugal mainly include dams aiming at increasing the head, or to control the water flow by storing water for future use in reservoirs (storage hydropower). Others produce electricity by directly using the river's water flow (run-of-river). Some hydropower plants also use pumped storage systems, which retain the water for re-use in the production of electricity during periods of high demand.

The hydropower installations can hence be classified as:

- *Run-of-river hydropower installations*: A run-of-river facility uses the river directly without modifying the flow and has little or no water storage capacity. The amount of electricity produced varies according to the flow: in springtime when the river fills up due to heavy rainfall, the power production is high, and at the end of the summer when it dries up, the power production is low.
- *Storage hydropower installations*: A hydropower installation with storage includes a reservoir and generally produces more energy than a run-of-river project of the same size because it retains the excess water for use in periods when it is scarce. Storage hydropower is unique among energy sources because of its operational flexibility. If there is an increased electricity demand, a plant can respond almost immediately by releasing more water through the turbines.
  Additional power stations can be located downstream of a reservoir in a cascade development. Each downstream station can then use the water stored in the reservoir when it is released.
- *Pumped storage hydropower installations*: Pumped storage is an efficient way to store energy for future use. Excess electrical energy (for example, energy generated at night) is used to pump water uphill to a storage reservoir. During the day, or at other times when energy is needed, the water is released and converted back into electricity in the hydro station. Pumped storage facilities, like all storage facilities, can respond to changing electricity demand within seconds, making them an ideal backup for variable wind and tidal power.

In Portugal most installations are storage installations. At least 2 installations are also reversible: Torrão and Aguieira. Most of the planned new hydropower installations are also pumped storage installations (with the exception of Fridao, Almourol and Alvito).

1.3.2 Start of exploitation of existing hydropower stations

Depending on the start of exploitation, the dams can be subdivided in 3 classes:

- Class 1: over 50 years in operation (before 1961): 19 installations;
- Class 2: between 30 and 50 years in operation (between 1961 and 1979): 12 installations;
- Class 3: less than 30 year in operation (not older than 1979): 12 hydropower installations.

The oldest hydropower installation dates from 1924.

The lower limit is determined based on the assumption that all pre-1960 installations need upgrading. The upper limit is based on a theoretical service life of 30 years (which is rather long for industrial plants but is realistic for hydropower installations) (Hydropower in Canada. Past present and Future, 2008).

As almost no information is available on possible refurbishments or upgrading that has already taken place during the time of exploitation, this aspect is not taken into account.

Table 2: Global assessment of some characteristic parameters

	Class 1	Class 2	Class 3	Total
Number	19	12	12	43
Total max. capacity (MW_e)	1152	1615	1695	4461
Designed electricity production (GWh_e)	3807	5259	2882	11948
Average electricity production 1993/2008 (GWh_e)	3009	4357	2521	9887
Average actual efficiency (%)	94.5	93.8	94.4	94.2
Ratio average to designed elect. product. (%)	79	83	87	81

1.3.3 Maximum capacity, designed and average energy production

The maximum capacity P (MW_e) is the installed capacity or power. The energy production E (GWh_e) represents the amount of electricity produced over a certain period of time.

Theoretically, the maximum energy production that can be generated per year is equal to the installed capacity P multiplied by 8760 (365 days, 24 hours a day), assuming that the flow and head as designed are available at all times.

However, hydropower installations are usually not operated at full load continuously, as they are subject to water limitations in time. Because hydropower installations can respond quickly to changing load needs and are therefore able to follow the ups and downs of the system throughout the day, they are partly/largely used as “peak shaving” installations (also more interesting from an economical point of view). Therefore the designed energy production differs from the potential maximum production.

In general the actual production varies each year from about 25 % to 45% of the maximum rated output of the units due to water availability (drought or flood years, etc.) and system/grid requirements. For the Portuguese dams this is not the case. The actual production in Portugal is about 83 % of the designed energy production which is higher than the general percentages mentioned above (**Annex 19**).

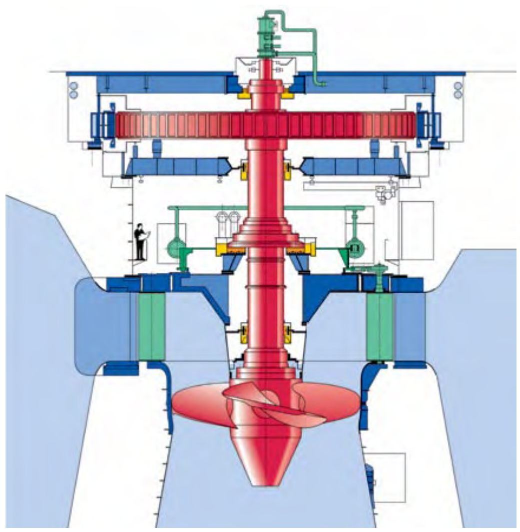
As shown in **Table 2**, the 19 oldest hydropower installations (class 1) represent a maximum capacity which is the smallest compared to the other two classes. When comparing the average electricity production in the period 1993 till 2008 with the designed electricity production, 79 % efficiency is achieved. For the class 2 hydropower installations this average efficiency is 83 %, reaching 87 % for the newest hydropower installations. These percentages are lower than the efficiency figures given by INAG. It should be noted that it may not be correct to compare these figures, as it is not clear what exactly is meant by the average actual efficiency data given by INAG.

1.3.4 Types of turbines

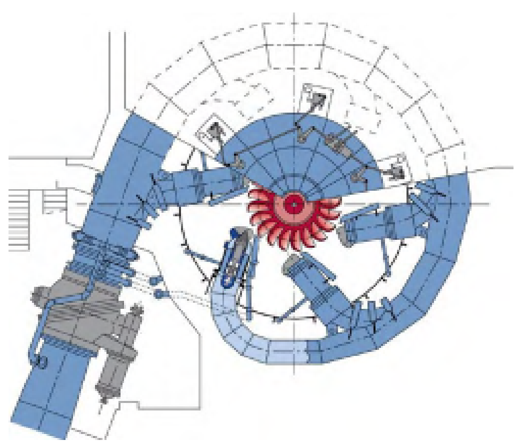
There are several types of turbines. A certain type of turbine is selected to convert the water flow into electricity with maximum efficiency, depending on the available head.

In Portugal the following types of turbines are installed in the hydropower installations:

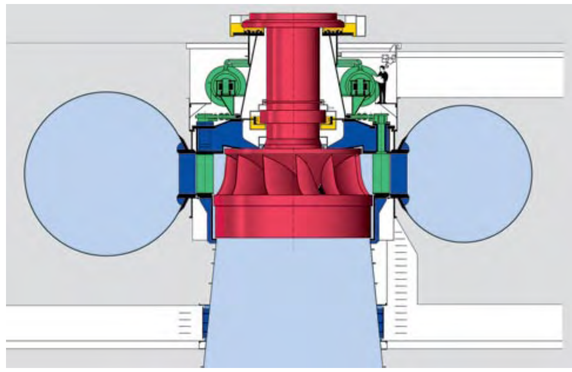
- The Kaplan type is a propeller-type turbine with adjustable blades. It allows for efficient power production in low head applications. There are 9 hydropower installations equipped with one or more turbines of the Kaplan type.



- The Pelton type uses the impulse of water falling into buckets. It is the turbine most indicated for high head sites.
  The Pelton turbine is used in 3 hydropower installations, in one hydropower installation it is used in combination with a Francis turbine;



- The Francis turbine is the most common turbine today. It operates in a head range of ten meters to several hundreds of meters.
  This type of turbine is used in most of the hydropower installations in Portugal (42 plants)..



In the dataset, delivered by INAG (**Annex 18**), the type and the number of turbines are included.

1.4 Assessment of the upgrading potential

1.4.1 Background

Hydropower plants have rather low operational and maintenance costs. In addition, they have a very long service life, lasting an average of 30 years, which can be extended further with refurbishment works. In addition to extending the service life of hydropower facilities by decades, the rehabilitation of installations can provide an opportunity to improve the electrical efficiency of facilities and increase their capacity. This can be obtained by (http\\www.ieahydro.org):

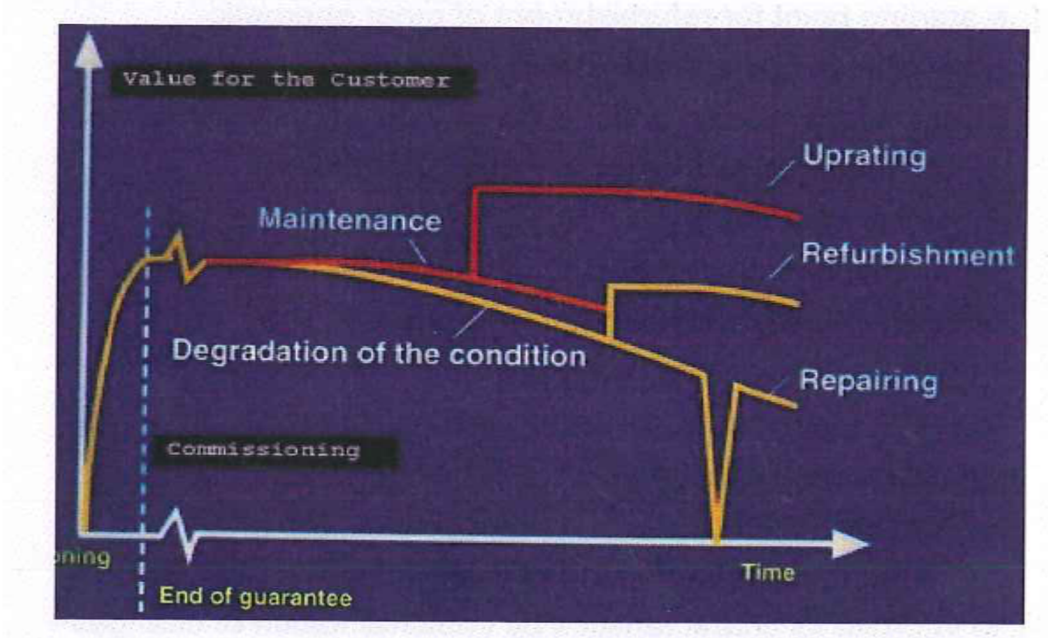
- Turbine upgrading by runner replacement: for pre-1960 turbines, it is frequently possible to obtain output increases up to 30 percent by replacing existing runners with runners of improved design;
- Generator upgrading: the former requirement that generators deliver rated output with no more than a 60°C temperature increase, and the conservative safety factors provided by early generator manufacturers, result in the possibility of substantial increases in generator capacity by installing new windings, using modern insulation technology which can provide increased electrical capacity with the same physical size as earlier manufactured windings;
- A better control and management of the hydropower installation.

Facilities can easily be upgraded to benefit from the latest technologies (BATNEEC). Hence it is often possible to increase the capacity of older units by installing new stator windings and improved runners, and by upgrading various auxiliary equipment. However, a cost benefit analysis will be decisive. Aside from technical limitations, the economic value of the increased capacity is most important in justifying a refurbishment. The practical limit of upgrading is reached when the cost of replacing the equipment in order to obtain additional capacity equals the economic value of that added capacity.

For older hydropower installations it is possible to upgrade the output with 15 to 40 % (Hydropower refurbishment, Alstom, 2006) .This can be realized by the replacement of the damaged or worn out parts, or by the replacement of the whole turbine or generator.

The general life cycle of turbines and generators is visualized in **Illustration 1**.

Illustration 1: Visualization of the life cycle of turbines and generators



For the generator, the refurbishment or upgrading consists of the following steps:

- replacement of stator core and windings and sometimes stator frame;
- new pole windings and sometimes poles replacement and/or reconstruction of bearings;
- reconstruction of the cooling system;
- replacement of the complete generator.

For the turbines the replacement of the runners is the most common refurbishment.

The upgrading of generators and turbines must be performed simultaneously to ensure a good result. This may result in:

- increased reliability;
- reduced production costs;
- increased power and generation of electric energy;
- increased static and dynamic stability;
- extended service life;
- increased efficiency.

The civil engineering of the hydropower plant (reservoir, dam, water supply and drainage facilities, power house, …) essentially remains the same, except in certain cases. Usually, only indispensable rehabilitations, adaptations or improvements are carried out.

1.4.2 Assessment op potential upgrading capacity

A number of calculations are made in order to assess the upgrading potential Only the upgrading of turbines and generators is considered. As mentioned above, the output could be upgraded with 15 to 40 % (based on Hydropower Refurbishment, Alstom, 2006) for older installations.

By upgrading the class 1 installations (the oldest hydropower installations), it is assumed that the maximum capacity can be increased with at least 15 %, representing 173 MW_e. Being more optimistic an increase of 27 % is considered (the average percentage of 15 and 40 %) which results in an increased maximum capacity with 311 MW_e.

For the class 2 hydropower installations, worst case scenario is that the capacity can not be increased. However, as best case scenario a capacity increase of 15% is assumed to be feasible. This means that the maximum capacity could be increased with 242 $MW_{e.}$

Following the above approach, it should be possible to realize an increase in total maximum capacity ranging between 173 MW_e and 553 MW_e.

This calculated capacity increase is rather small in comparison to the planned projects. As presented in **Table 1**, the future capacity of existing installations is even double of the presently installed capacity. Assuming that the projects mentioned were selected as being the most suitable for upgrading, and as we do not know if optimizations or refurbishments were already realized in the past, we would not assume a higher capacity increase.

1.5 Conclusion

Through upgrading, there is a potential to increase capacity but it is difficult to exactly quantify this potential increase.

In the evaluation a number of issues were not considered, such as

- the potential use of existing dams for energy production (more than 50 dams have now other uses);
- adaptations of existing installations to pumped storage hydropower installations;
- the potential of new technologies;
- the impact of climate change (and especially water resources);
- possible upgrading and refurbishment of the existing installations;
- the assumption that the selection of the projects under construction and in study are the ones which were best suitable to be adapted or upgraded;
- lack of information regarding former refurbishments and upgrading.

By turbine and generator upgrading a capacity increase between 173 and 553 MW_e should be possible to realize.

At least it should be noted that detailed analysis and study of all the other hydropower installations, especially those belonging to class 1, could result in a substantial increase of hydropower capacity.

2 Task 3b: To what extent the definition of factors to be considered in the SEA and the options chosen influence the outcome of the SEA? To what extent the outcome of the SEA is at all influenced by the assessment of the impacts on the water environment?

2.1 Introduction

On the basis of the information provided by the PNBEPH an expert assessment was made of the critical factors used in the SEA and the possible influence on the outcome of the analysis, considering in more detail the impacts on the water environment. It has been tested how the selection of options and factors may deliver different results.

This chapter is structured as follows:

- Section 2.2: Methodology and outcome of the SEA: short description of the method used
- Section 2.3: Critical factors: identification, assessment, outcome
- Section 2.4: Strategic options: identification, assessment, outcome
- Section 2.5: Influence of the assessment of the impacts on the water environment on the outcome: semi-qualitative test of selection of options and factors may deliver different results
- Section 2.6: SEA water-related parameters: considered impacts in line with the WFD
- Section 2.7 : Conclusions

2.2 Methodology and outcome of the SEA

The Strategic Environmental Assessment of the PNBEPH needed to be carried out according to the Portuguese law (*Decreto-Lei n.º 232/2007 of 15/06/2007, which is the transposition of the SEA directive 2001/42/CE*). The results of this assessment are presented in the documents *Relatorio Ambiental PNBEPH and Memoria PNBEPH*[1].

The Strategic Environmental Assessment considered **4 strategic options** for the selection of the best hydropower projects out of 25 potential hydropower sites with high hydrological potential identified in a national inventory, and assessed those strategic options against **6 critical factors** through a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis using the results of the multicriteria analysis. The advantages and disadvantages of each option regarding each critical factor were identified, and guidelines were established for further research.

As a **first step** *(Section 2.3)*, the 25 potential hydropower projects were assessed against 6 critical factors[2]:

- climate change;
- biodiversity;

[1] Available at: http://www.inag.pt/images/diversos/temporario/Seguranca_de_barragens/PNBEPH_RA_Memoria.pdf (version November 2007)

[2] Relatório Ambiental PNBEPH – annex IV

- natural and cultural resources;
- natural and technological risks;
- human development;
- competitiveness.

This multi criteria analysis compared the dams, ranked them and classified them into 3 classes (more favourable, intermediate and less favourable) for each critical factor and associated key criteria.

In a **second step** *(Section 2.4)*, 4 strategic options were identified:

- option A: Optimization of the hydroelectric potential and energy production;
- option B: Optimization of the hydro potential within the river basin;
- option C: Environmental conflicts and constraints;
- option D: Energetic, socio-economic and environmental balance.

The strategic options were identified based on a number of parameters representative for the target of each option, and led to a selection of the best dams for each option.

In a **third step** *(Section 2.4.3)*, a SWOT analysis was carried out for each strategic option, considering the 6 critical factors. The results of the multi criteria analysis (step 1) were consolidated in the selection of dams corresponding to each strategic option.

The **outcome** of the SEA is a ranking of the 4 strategic options, based on the multi-criteria analysis for each option, resulting in option D as being the best option (**Illustration 2**).

Illustration 2: Outcome of the SEA for the 4 strategic options

QUADRO 5.25
Síntese da Avaliação Ambiental das Opções Estratégicas

FACTOR CRÍTICO	OPÇÃO A	OPÇÃO B	OPÇÃO C	OPÇÃO D
Alterações Climáticas	++	+	+	++
Biodiversidade	--	--	-	-
Recursos Naturais e Culturais	--	0	0	+
Riscos Naturais e Tecnológicos	-	--	0	-
Desenvolvimento Humano e Competitividade	+	+	++	++
Avaliação global:	--	-	+	++

According to the SEA, the PNBEPH is hence the result of the selection of the 10 best hydropower projects to meet the target of a power generation of 1150 MW; while following the strategic option D and hence meeting environmental and sustainability targets.

The selected dams are located in the river basins of the rivers Douro (6 hydropower projects) and Tejo (2 dams), the Mondego (1 project) and the Vouga (1 hydropower project).

2.3 Critical factors and multi criteria analysis

2.3.1 Identification of the critical factors

Six critical factors were identified for the Strategic Environmental Assessment:

- **Climate change:** the assessment considers the contribution of the program to the reduction of greenhouse gas emissions and to the fulfilment of the Kyoto Protocol goals by Portugal;
- **Biodiversity:** the assessment considers the contribution of the program to the maintenance of the integrity of the natural systems and the protection of the biodiversity, through the analysis of the risks and opportunities in the context of this critical factor;
- **Natural and cultural resources:** the assessment considers the contribution of the program to the maintenance or enhancement of the natural and cultural resources (e.g. cultural heritage, water resources, mineral resources, landscape), through the analysis of the risks and opportunities in the context of this critical factor;
- **Natural and technological risks:** the assessment considers the contribution of the program to the reduction and control of natural and technological risks (e.g. floods, droughts, fires, coastal erosion), through the analysis of all the risks related to the projects;
- **Human development:** the assessment considers the contribution of the program to the enhancement of the human potential, poverty reduction, and improvement of the global health conditions, through the development of an analysis in the context of this critical factor;
- **Competitiveness:** the assessment considers the contribution of the program to the regional development and reduction of energy dependency, through the development of an analysis in the context of this critical factor.

The critical factors are represented by a number of key criteria, as presented in **Table 3**.

Table 3: Critical factors and key criteria

Critical factor	Key criteria
CF1 - Climate change	- C1: Potential reduction of the national emission of greenhouse effect gases (reduction in CO_2 emissions compared to a situation where the electricity would be produced in a combined cycle power station) - C2: Contribution to better use of other renewable energy sources in which the resources availability cannot be programmed (reversibility)
CF2 - Biodiversity	- C1: effects of the projects on the protected areas (national network and Natura 2000 network) - C2: potential impact of each project on threatened species - C3: potential impact on habitats and species insufficiently covered by the Natura 2000 network - C4: degree of naturalness of the water bodies affected by the reservoirs.
CF3 - Natural and cultural resources	- C1: Heritage and environment - C2: Mineral resources - C3: Water resources

Critical factor	Key criteria
CF4 - Natural and technological risks	- C1: Effects of incidents: accidental pollution, seismic risk, floods, extreme droughts and fire risks. - C2: Effects caused by the dam: coastal erosion and dam rupture risks.
CF5 - Human development	- C1: Economic profit index, Education index, Longevity index, Health and welfare indexes
CF6 - competitiveness	- Contribution to the use of resources (considering water and energy)

In **Table 4** the selected critical factors are compared to the environmental factors that according to national legislation on SEA (Decree 232/2007) should be considered in the Environmental Assessment.

Table 4: Comparison critical factors and regulatory requirements

SEA Directive (annex 1)	Decree 232/2007	Environmental and sustainability factors	Critical factors
Climatic factors	Climatic factors	Climate change	Climate change / Competitiveness
Biodiversity / Fauna / flora	Biodiversity / fauna / flora	Biodiversity	Biodiversity / Competitiveness
Air / soil / water	Air / soil / water	Quality of the environment	Natural and cultural resources / Natural and technological risks / Competitiveness
Water / soil	Water / soil	Resource use	Natural and cultural resources / Competitiveness
Population / human health	Population / human health	Human development	Human development / competitiveness
Material assets	Material assets	Spatial planning and regional development	Natural and cultural resources / Competitiveness
Cultural heritage	Cultural heritage	Cultural heritage	Natural and cultural resources
Landscape	Landscape	Geological heritage	Natural and cultural resources
Landscape	Landscape	Landscape	Natural and cultural resources
	Air / soil / water / material assets	Natural and technological risks	Natural and technological risks / Competitiveness

The following criteria, used in the assessment, are related to impacts on the water environment:

- **CF2: Biodiversity:** 2 of the 4 criteria are related to the water environment (fish and WFD):
  - *C2: potential impact on threatened species dependent on the lotic system*: in this key criterion, the impact on species classified as vulnerable was assessed;
  - *C4: degree of naturalness*: in this criterion the existing human pressure on the water bodies (preliminary risk assessment of achieving the WFD objectives) and the existing fragmentation of the lotic system were assessed.
- **CF3: Natural and cultural resources:** 1 of the 3 criteria is related to the WFD:
  - *C3: water resources*: in this criterion, the analysis of the water bodies in the framework of the WFD is included according to the PNBEPH, however the exact criteria used and their quantification is not clear and questionable. Also the effects on eutrophication and classified fish waters were assessed under C3.

The critical factors were established taking into account the opinions expressed on a first proposal by several stakeholders and a public consultation from 01/10/2007 till 13/11/2007. The stakeholders consultation led to the Critical Factors Report (June 2007).

The analyses were made on a scale 1:250 000 except for some aspects that were considered on a more detailed scale (e.g. 1:100 000 for biodiversity issues).

2.3.2 Assessment methodology and result

The methodology applied for the environmental assessment is based on a comparative analysis of the 25 potential dams against 6 critical factors, with a number of key criteria representing each critical factor (**Table 3**), following the method "*PAH – Processo Analítico Hierárquico*". This method can be considered in line with the methods adequate for the environmental assessment of river basin management projects[3], provided that the details of the criteria itself are sufficient and complete.

A weight (1-9) was attributed to the different key criteria, taking into account their relative importance (**Table 5**).

Table 5: Preference scale of the criteria

Preference	Value
Both criteria have the same importance	1
One of the criteria is slightly more important than the other (weak preference)	3
There is a strong preference of one in relation to the other	5
One criterion is really more important than the other	7
One criterion is preferred, in absolute terms, or is definitely more important	9
Intermediate values	2, 4, 6, 8

The values presented in the above table were used to establish a "preference matrix" for the comparison of pairs of criteria, based on expert judgement.

[3] *Analysis of the possible methodology for using multicriteria-analysis for the preparation of river basin management plans.* University Ghent, Ecolas, WES.

The qualification of the criteria is an important step, as the relative weight attributed at each criterion will determine in a significant way the final classification and hierarchy of the hydropower projects.

The weight of each criterion is calculated by the radical n (n being the number of analysed criteria) of the product of the relative weights, divided by the sum of the radicals.

A performance matrix was set up in order to compare one hydropower project against the others. However, this matrix was not published.

The key criteria used in the assessment and their relative weights are presented in **Table 6**. The criteria related to water impact are highlighted in yellow.

Table 6: Environmental Assessment[4]

Critical factor (CF)	Key criteria	Parameters / Indices	Calculation of the value of the CF
CF1-Climate change	C1 : Reduction of national GHG emissions	Yearly **Hydro-electrical productivity**: score "more favourable, intermediate, less favourable" based on quantitative ranking	Score "more favourable", "intermediate", "less favourable" (Table p. 11) *(Observation: According to the report: weight of criterion C1 more important than C2.)* *(GAP: No explanation of how the general score was established, discrepancies were detected)*
	C2 : Contribution to the better use of other renewable energy sources	Capacity / possibility to pump up and store the water (**reversibility**): present or not present = score "more favourable" or "less favourable".	
CF2-Biodiversity	C1 : protected areas	1) **Overlap with classified areas** (Habitat and Birds Directive): depending on the type of classified area and cumulative overlaps, score = 0,7 till 1 2) **Degree of adverse effect** (*Observation: based on complex analysis by experts):* adverse effect – potential adverse effect – no adverse effect: score = 1 – 0,7 till 0,5 >> Index C1 = product of 1 and 2 >> Transposition in preference values and preference matrix (*GAP: matrix not published in report*) >> Result presented in qualitative table "more favourable", "intermediate", "less favourable" *(GAP: not possible to verify classification)*	Sum of the 4 key criteria, taking into account the relative weight factors: C1: 0,5 C2: 0,21 C3: 0,21 C4: 0,08 *Observation: relative weight of C4 (WFD) is very small: relative importance was considered inferior to the other criteria, because indirect evaluation of biodiversity and based on preliminary results.* Final ranking (p. 52): scores 0,007 - 0,083 (*GAP: not possible to verify calculations: only qualitative results available from the criteria, not the preferential values))* Transposition to qualitative table "more favourable", "intermediate" and "less favourable" (p. 56): Score > 0.055: More favourable

	C2: Threatened species	**Overlap with habitat areas of protected species** that are especially dependent on the running-water-system (classified at least as "vulnerable") (considered species: continental migrating species, fish, 2 amphibian, 1 reptile, 1 mammal, bat shelters)(not considered: birds (later in EIA)).
		(Observation: remark made that the degree of adverse effect will need to be assessed in further detail in the EIA).
		>> Table with C (presence confirmed), P (possible presence) or absence (C: recent registers found, P no recent register found but the distribution of the species includes the area of the dam)
		>> Species index = Probability of occurrence (1:confirmed presence - 0,3: possible presence – 0: absence) x conservation status (1: critically threatened – 0,9:endangered – 0,7:vulnerable)
		>> Index = sum of species indices
		>>> Preferential matrix *(GAP: not published in report)*
		>>> Result presented in qualitative table "more favourable", "intermediate", "less favourable" *(GAP: not possible to verify classification)*	

[4] Relatório ambiental PNBEPH – Annex IV

Critical factor (CF)	Key criteria	Parameters / Indices	Calculation of the value of the CF

	C3: species insufficiently covered by Natura 2000	**Overlap with habitat areas of species (**habitat directive) that are insufficiently covered by the Natura 2000 network (annex 2 of 2006/613/EC)
		(Observation: Remark made that the degree of adverse effect will need to be analysed further in detail in the EIA)
		>> Table with (Presence confirmed), P (possible presence) of absence (C: recent registers were found, P no recent register were found, but the distribution of the species includes the area of the dam)
		>> Species index = Probability of occurrence (1: confirmed presence – 0,3: possible presence – 0:absense)
		>> Index = sum of species indices
		>>> Preferential matrix (*GAP: not published in report*)
		>>> Result presented in qualitative table “more favourable”, “intermediate”, “less favourable” *(GAP: not possible to verify classification)*
			Score < 0.022: Less favourable

	C4: degree of naturalness	1) **Existing human pressure** on the water bodies (Implementation of the WFD: preliminary impact analysis of the human pressure from the INAG study in 2005): : value: “risk”, “in doubt”, “no risk” (p.76)
		>> weight factor 0,5 – 0,7 – 1 (p.49)
		2) **Existing fragmentation** of the lotic system (existing large dams in the subwater basins): value “limited”, “intermediate”, “high”. (p. 48)
		>> weight factor: 1 – 0,7- 0,5(p.49)
		
		>> Index C4 = product 2 weight factors (p.49)
		>>> Preferential matrix (*GAP: not published in report*)
		>>> Result presented in qualitative table “more favourable”, “intermediate”, “less favourable” *(GAP: not possible to verify classification)*	

CF3-Natural and cultural resources	C1: Heritage and environment	1) Geological heritage 2) Landscape: identity and rareness 3) Cultural heritage >> Values by presence of heritage “none”, “small”, “intermediate”, “moderate”, “big”. >> Index by the application of the weight factors for the 3 elements: p. 70	Sum of the 3 criteria, taking into account the relative weight factors: C1: 0,36 C2: 0,22 C3: 0,42 *Observation: C3 has the biggest weight attributed* *GAP: final ranking and calculations not available*
	C2: Mineral resources	Location of the dams in potential mining areas >> Index p. 72	
	C3.1.: Water resources surface water C3.2. Water resources ground water	**Surface water:** 1) Interference with existing infrastructure for water use 2) Probability of occurrence of eutrophication 2.1.) location in a zone sensitive for eutrophication “yes”, “no” 2.2.) location in an area in use for agriculture “large use”, “moderate use”, “limited use”. 3) Adverse effect on the characteristics of the classified fish waters: “included in the classified fish waters for salmonids” , “included in the classified waters for cyprinids” **Groundwater:** 5) Lithology / capitation/ vulnerability *(GAP: no table published of the above assessment results)* >> Index (p. 95) with weight factors : Surface waters: 0,6 1) 0,51	

Critical factor (CF)	Key criteria	Parameters / Indices	Calculation of the value of the CF
		2) 0,19 3) 0,06 4) analysis of the water bodies WFD: 0,24 (*GAP: not explained what is behind this parameter, nor what were the scores)* Groundwater: 0,4 *Observation: the analysis of the WFD were attributed an intermediate weight*	
CF4-Natural and technological risks	C1: Risk on incidents	1) Effects on the dam and the reservoir: accidental pollution, seismic risk, floods, extreme droughts and fire risks. 2) Effects caused by the dam: costal erosion and dam breakage risks.	
	C2: Induced risks		
CF5-Human development / competitiveness		human development, education, longevity, health and welfare	

2.3.3 Outcome

The outcome of the analysis of the 25 potential sites per critical factor (CF) is a matrix, classifying each dam into 3 classes (more favourable, intermediate, less favourable) for each critical factor, as presented in **Table 7**

It is not possible to verify the result of this outcome, since several **gaps** in the publishing of intermediary results were identified (**Table 6**):

- The used weighing method was explained (chapter 4.3.2.2.), however, the necessary preference matrixes were not published, hence it is not possible to verify which (quantified) results were obtained and how the hydropower projects were classified into “more favourable”, “intermediate” and “less favourable”.
- There are several lacks in information on the criteria quantification; regarding impact on water the following can be highlighted:
  - Biodiversity: for the calculation of the final ranking for the critical factor biodiversity, it is not possible to verify the calculations of the scores: only qualitative results are available form the 4 criteria.
  - Natural and cultural resources: no table is presented of the results of the assessments used for the index calculation

A number of **observations** can be made regarding the assessment of the impact on water and relating to

- the weights those criteria have in the outcome;
- the quality of the available data and identified gaps;
- the necessary research to be done in the EIA phase.
- the compliance with the Water Framework Directive (discussed in detail in Section 0).

Table 7: Outcome of the impact assessment for all critical factors

QUADRO 8.1

Resultados da avaliação ambiental desenvolvida para a totalidade dos factores críticos

FACTOR CRÍTICO		APROVEITAMENTOS																								
		Assureira	Atalaia	Sra. de Monforte	Pêro Martins	Sampaio	Mente	Rebordelo	Foz Tua	Castro Daire	Alvarenga	Castelo de Paiva	Padroselos	Alto Tâmega (Vidago)	Daivões	Fridão	Gouvães	Póvoa	Pinhosão	Asse-Dasse	Girabolhos	Midões	Almourol	Santarém	Erges	Alvito
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
BACIA HIDROGRÁFICA/ CENTRAL	Bacia hidrográfica	Lima	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Vouga	Vouga	Mondego	Mondego	Mondego	Tejo	Tejo	Tejo	Tejo
	Linha de água	Castro Laboreiro	Côa	Côa	Côa	Sabor	Mente	Rabaçal	Tua	Paiva	Paiva	Paiva	Beça / Tâmega	Tâmega	Tâmega	Tâmega	Louredo / Tâmega	Vouga	Vouga	Mondego	Mondego	Mondego	Tejo	Tejo	Erges	Ocreza
	Área da bacia hidrográfica (km²)	56	946	1.404	2.140	2.435	616	1.322	3.822	364	610	775	315	1.557	1.984	2.630	100	257	401	189	980	1.423	67.323	67.838	1.155	968
	Potência instalada (MW)	88	50	81	218	150	48	252	234	134	175	80	113	90	109	163	112	41	77	185	72	54	78	85	42	48
	Energia produzida (GWh/ano)	119	82	121	297	186	41	364	340	180	257	80	102	114	148	299	153	57	106	232	99	72	209	269	45	62
Alterações Climáticas		○	−	○	+	○	−	+	+	○	+	−	○	○	○	+	○	−	○	+	○	−	○	+	−	−
Biodiversidade		○	○	○	○	−	−	−	+	−	−	−	+	+	+	+	○	○	+	○	+	−	○	○	−	+
Recursos Naturais e Culturais		○	−	○	○	○	+	+	○	−	○	+	○	+	○	−	−	○	+	○	○	○	○	○	+	+
Riscos Naturais e Tecnológicos		+	+	+	−	−	+	○	−	+	+	+	+	○	○	○	+	+	○	+	○	○	−	−	+	+
Desenvolvimento Humano		○	−	−	○	−	−	−	○	+	+	+	+	−	○	+	○	−	−	−	−	−	−	−	○	○
Competitividade		−	+	+	+	○	○	+	○	−	+	−	+	○	−	○	−	−	−	○	○	○	−	−	−	−

+ mais favorável / menos desfavorável

○ avaliação intermédia

− menos favorável / mais desfavorável

Table 8: Result of the multi criteria analysis for the critical factor Biodiversity

QUADRO 4.18

Resultados da avaliação dos aproveitamentos para o factor crítico Biodiversidade

FACTOR CRÍTICO	CRITÉRIOS	APROVEITAMENTOS																								
		Assureira	Atalaia	Sra. de Monforte	Pêro Martins	Sampaio	Mente	Rebordelo	Foz Tua	Castro Daire	Alvarenga	Castelo de Paiva	Padroselos	Alto Tâmega (Vidago)	Daivões	Fridão	Gouvães	Póvoa	Pinhosão	Asse-Dasse	Girabolhos	Midões	Almourol	Santarém	Erges	Alvito
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Biodiversidade	Afectação de Áreas Classificadas	avaliação intermédia	avaliação intermédia	avaliação intermédia	avaliação intermédia	mais desfavorável	avaliação intermédia	avaliação intermédia	menos desfavorável	mais desfavorável	mais desfavorável	mais desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	avaliação intermédia	menos desfavorável	menos desfavorável	mais desfavorável	menos desfavorável	mais desfavorável	menos desfavorável	menos desfavorável	mais desfavorável	menos desfavorável
	Presença de espécies ameaçadas particularmente dependentes do ecossistema lótico	menos desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	avaliação intermédia	avaliação intermédia	avaliação intermédia	menos desfavorável	avaliação intermédia	avaliação intermédia	avaliação intermédia	menos desfavorável	menos desfavorável	menos desfavorável	avaliação intermédia	avaliação intermédia	mais desfavorável	avaliação intermédia	menos desfavorável	menos desfavorável	avaliação intermédia	mais desfavorável	mais desfavorável	avaliação intermédia	mais desfavorável
	Sobreposição com área de distribuição de espécies insuficientemente cobertas pela Rede Natura 2000	avaliação intermédia	menos desfavorável	menos desfavorável	menos desfavorável	mais desfavorável	mais desfavorável	mais desfavorável	avaliação intermédia	avaliação intermédia	avaliação intermédia	menos desfavorável	avaliação intermédia	avaliação intermédia	avaliação intermédia	menos desfavorável	avaliação intermédia	mais desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	mais desfavorável	mais desfavorável	mais desfavorável	avaliação intermédia	avaliação intermédia
	Grau de Naturalidade	avaliação intermédia	avaliação intermédia	avaliação intermédia	avaliação intermédia	mais desfavorável	mais desfavorável	mais desfavorável	menos desfavorável	mais desfavorável	mais desfavorável	mais desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	avaliação intermédia	menos desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	avaliação intermédia	avaliação intermédia	mais desfavorável	menos desfavorável
Avaliação Global		avaliação intermédia	avaliação intermédia	avaliação intermédia	avaliação intermédia	mais desfavorável	mais desfavorável	mais desfavorável	menos desfavorável	mais desfavorável	mais desfavorável	mais desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	menos desfavorável	avaliação intermédia	avaliação intermédia	menos desfavorável	avaliação intermédia	menos desfavorável	mais desfavorável	avaliação intermédia	avaliação intermédia	mais desfavorável	menos desfavorável

- menos desfavorável
- avaliação intermédia
- mais desfavorável

Critical factor Biodiversity (CF2)

In this critical factor, some WFD parameters are taken into account in the key criterion C4 – degree of naturalness, in which the existing human pressure on the water bodies and the existing fragmentation of the lotic system were assessed. Each hydropower project was subject of a WFD risk assessment and the water body was classified as "at risk" or "not at risk" for achieving the WFD objectives. However, the risk assessment was based on a preliminary study of INAG of 2005 and the criterion C4 is incomplete and not representing the required WFD criteria (See Section 0).

Besides the fact that C4 is incomplete, the relative weight of C4 in CF2 is very limited: 8%. The relative importance was considered inferior to the other criteria (overlap with classified areas and habitats of protected species) by the PNBEPH because the criterion C4 merely provides an indirect evaluation of the biodiversity since it expresses human pressure and not the value of nature that is to be protected. The minor weight also reflects the fact that the pressure analyses were merely a preliminary version of an unfinished process.

However, when evaluating the results of the assessment for CF2, the general result would not be influenced significantly when increasing the relative weight of C4. Only 3 of the 25 dams would have a different result: Gouvães, Asse-Dasse and Midões would be evaluated more favourable (**Table 8**).

In addition to criterion C4, criterion C2 of the critical factor biodiversity takes into account the potential impact on threatened species dependent on the lotic system. In this key criterion the species classified as vulnerable and dependent on the running-water-system were assessed. However, again the criterion is not complete: the degree of adverse effect was not taken into account. This criterion has a more important weight in the critical factor biodiversity, amounting up to 21 %.

Critical Factor Natural and cultural resources (CF3)

In criterion C3 (water resources) of the CF3, the analysis of the water bodies in the framework of the WFD is included. However, it is not clear how this was quantified.

The weight attributed to the analysis of the water bodies WFD however is 24 % of the criterion C3, hence representing 6 % (24 % x 60 % x 42 %) in the critical factor CF3. However, other than the reference to the same criterion used in CF2 – C4 (water bodies at risk) and a general note on the inherent negative impact of the dams on the running-water-system, no other classification criteria were described that could clarify the context behind this criterion.

In addition, criterion C3 takes into account the impact on the classified fish waters for salmonids and cyprinids; and the impact on eutrophication. The relative weight of the parameter classified fish waters is very limited, representing 1,5 % (6 % x 60 % x 42 %) of the critical factor CF3. The relative weight of the impact on eutrophication is more important, representing approx. 5 % (19 % x 60 % 42 %) of CF3.

In general, the critical factor CF3 reflects the impacts on water for approximately 12,5 %.

Conclusion

The implementation of the WFD is in some way taken into account in the critical factor CF2 - biodiversity for 8 % (although the result would not alter a lot if more weight was given to the WFD criterion C4 in CF2) and in the critical factor CF3 – natural and cultural resources for 6 % although only with preliminary data in CF2 and unclear data in CF3 and the compliance with the WFD is questionable and will be further evaluated in Section 0.

Taking into account also the impact on fish species and classified fish waters, the impacts on water are represented by CF2 for 2 9% and by CF3 for 12,5 %.

However, several gaps in the available data and knowledge at the time of the environmental assessment, have led to an insufficiently detailed and incomplete assessment of the criteria. The following shortcomings can be highlighted:

- CF2 – C2: Further assessment of the degree of adverse effects on the threatened species needs to be done.
- CF2 – C4: A proper assessment should be done regarding the criteria related to the WFD, such as effects on water quality downstream, flows and water level modification, temperature regulation, management plan for water discharge control, etc, which has now been neglected. Main impacts on aquatic communities that need to be considered were not analysed (this will be further discussed in Section 2.6.1). Also, cumulative impacts on biodiversity and in estuaries and coastal areas need to be assessed further.
- CF3 – C3: It is not clear exactly which parameters were taken into account to assess this criterion. The same remark on the WFD implementation results as for CF2 – C3 applies.

2.4 Strategic options

In this section, the 4 strategic options were assessed based on a number of parameters representative for the target of each option, which led to a set of dams representative for each option.

2.4.1 Identification of the strategic options

Four strategic options were identified:

- Option A: Optimization of the hydroelectric potential and energy production, representing the basic objective of the program and the technical and economical aspects;
- Option B: Optimization of the hydro potential within the river basin, representing the socio-economical aspects of the program that can increase the importance of the program by the usability for other goals than energy production and demonstrates the added value;
- Option C: Environmental conflicts and constraints, that can be significant for the implementation of the dams;
- Option D: Energetic, socio-economic and environmental balance that represents the general value of each dam by a quantitative assessment of the above elements.

For each option, a number of parameters were analysed for each of the 25 dams and converted into a factor. The scores for the factor led to a ranking of the dams and the best dams (those with highest scores in the analysis) that would allow an energy production up to 1100 MW were selected as being representative for each strategic option.

The parameters and factors leading to the ranking are presented in **Table 9**.

2.4.2 Assessment of the strategic options

The 4 lists of selected hydropower installations representing the strategic options (**Table 9**) are:

- **Option A:** 7 selected projects: Foz Tua, Fridao, Rebordelo, Alvarenga, Gouvaes, Assureira, Sampaio (total power: 1174 MW)
- **Option B:** 7 selected projects: Atalaia, Alvarenga, Alvito, Foz Tua, Pero Martins, Sampaio, Rebordelo (total power: 1127 MW)
- **Option C:** 10 selected projects: Padroselos, Vidago, Pinhosao, Alvito, Foz Tua, Daivoes, Povoa, Girabolhos, Fridao, Gouvaes (total power: 1059 MW)
- **Option D:** 10 selected projects: Foz Tua, Padroselos, Vidago, Daivoes, Fridao, Pinhosao, Girabolhos, Gouvaes, Alvito, Almourol (total power: 1096 MW).

Those lists were subsequently subject to an environmental assessment based on the outcome of the multi criteria analysis, which resulted in a classification of each dam, as presented in **Table 10**.

Table 9: Definition of the 4 strategic options[5]

Option	Parameters	Factor	Result = Ranking
A: Optimization of the hydroelectric potential and energy production	1. power (MW), 2. energy production (GWh/year), 3. economic profit (%) 4. reversibility.(FR) (FR=1 for non reversible installations and FR=1.2 for reversible installations)	Factor E = (MW x GWh/year)0,5 x % x FR Conversion to range E= 0 – 100%	Scores for each dam 0-100% (p.147) **Result:** 7 selected projects:: Foz Tua, Fridao, Rebordelo, Alvarenga, Gouvaes, Assureira, Sampaio (total power: 1174 MW)
B: Optimization of the water potential within the River basin	1. Optimization of the cascade (situated upstream from other dams with high installed capacity and small storage capacity) 2. Water supply for human consumption 3. Water supply for irrigation 4. Other uses (Higher storage capacity, better flood protection, navigation, fire fighting reservoir, recreational)	Factor Fs = sum of qualitative scores based on comparison for the 4 parameters: - 3 = more favourable - 2 = intermediate - 1 = less favourable Conversion to range: Fs = 1 – 1,5 (demonstrating the added value of a dam)	Qualitative scores 1 – 1,5 (p. 155) **Result:** 7 selected projects: Atalaia, Alvarenga, Alvito, Foz Tua, Pero Martins, Sampaio, Rebordelo (total power: 1127 MW
C. Environmental conflicts and constraints	1. Biodiversity constraints: CB 2. Effects on classified cultural heritage: CP 3. Other territorial constraints, e.g. situated in a classified area or in areas of high agricultural value: CT *(Observation: no parameters directly related to water impact, no information on indirectly related parameters that might have been included)*	Qualitative score based on comparison for the 3 parameters: - 3 = more favourable - 2 = intermediate - 1 = less unfavourable *(GAP: it is not explained how the scores were attributed)* If CB, CP of CT = 1: C = CB + CP + CT If CB = 1 : C = 0,4*CB + (CP/100 + CT/100) If CT = 1 : C = 0,9*CT + (CB/100 + CP/100) If CP = 1 : C = 2,9*CP + (CB/100 + CT/100) *(Observation: CB more important than CP, CP more important than CT)* Conversion to range Fa= 0 - 100% (demonstrating the aspects that can constrain the implementation of a dam)	Qualitative scores 0 – 100% (p. 157) **Result:** 10 selected projects: Padroselos, Vidago, Pinhosao, Alvito, Foz Tua, Daivoes, Povoa, Girabolhos, Fridao, Gouvaes (total power: 1059 MW) *(Observation: the 10 selected dams are the same as in option D except for Povoa which is not included in option D)*
D: Energetic, socio-economic and environmental balance	A, B en C	$V = ((E *Fs*Fa)/1,5)^{0,5}$) *(Observation: the parameters have different ranges: E and Fa range from 0 to 100 and Fs from 1 to 1,5. No clarification is given on how this formula was established.)*	Scores 3,4 – 90,3 % (p. 159) **Result:** 10 selected projects: Foz Tua, Padroselos, Vidago, Daivoes, Fridao, Pinhosao, Girabolhos, Gouvaes, Alvito, Almourol (total power: 1096 MW). *(Observation: the 10 selected dams are the same as in option C exept for Almourol)*

[5] Relatório Ambiental PNBEPH

Table 10: Outcome of the impact assessment for all critical factors

QUADRO 8.1

Resultados da avaliação ambiental desenvolvida para a totalidade dos factores críticos

FACTOR CRÍTICO		APROVEITAMENTOS 1 Assureira	2 Atalaia	3 Sra. de Monforte	4 Pêro Martins	5 Sampaio	6 Mente	7 Rebordelo	8 Foz Tua	9 Castro Daire	10 Alvarenga	11 Castelo de Paiva	12 Padroselos	13 Alto Tâmega (Vidago)
BACIA HIDROGRÁFICA/ CENTRAL	Bacia hidrográfica	Lima	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro	Douro
	Linha de água	Castro Laboreiro	Côa	Côa	Côa	Sabor	Mente	Rabaçal	Tua	Paiva	Paiva	Paiva	Beça / Tâmega	Tâmega
	Área da bacia hidrográfica (km²)	56	946	1.404	2.140	2.435	616	1.322	3.822	364	610	775	315	1.557
	Potência instalada (MW)	88	50	81	218	150	48	252	234	134	175	80	113	90
	Energia produzida (GWh/ano)	119	82	121	297	186	41	364	340	180	257	80	102	114
Alterações Climáticas														
Biodiversidade														
Recursos Naturais e Culturais														
Riscos Naturais e Tecnológicos														
Desenvolvimento Humano														
Competitividade														

FACTOR CRÍTICO		14 Daivões	15 Fridão	16 Gouvães	17 Pôvoa	18 Pinhosão	19 Asse-Dasse	20 Girabolhos	21 Midões	22 Almourol	23 Santarém	24 Erges	25 Alvito
BACIA HIDROGRÁFICA/ CENTRAL	Bacia hidrográfica	Douro	Douro	Douro	Vouga	Vouga	Mondego	Mondego	Mondego	Tejo	Tejo	Tejo	Tejo
	Linha de água	Tâmega	Tâmega	Louredo / Tâmega	Vouga	Vouga	Mondego	Mondego	Mondego	Tejo	Tejo	Erges	Ocreza
	Área da bacia hidrográfica (km²)	1.984	2.630	100	257	401	189	980	1.423	67.323	67.838	1.155	968
	Potência instalada (MW)	109	163	112	41	77	185	72	54	78	85	42	48
	Energia produzida (GWh/ano)	148	299	153	57	106	232	99	72	209	269	45	62
Alterações Climáticas													
Biodiversidade													
Recursos Naturais e Culturais													
Riscos Naturais e Tecnológicos													
Desenvolvimento Humano													
Competitividade													

mais favorável / menos desfavorável

avaliação intermédia

menos favorável / mais desfavorável

Table 11: Final outcome of the SEA

QUADRO 5.25

Síntese da Avaliação Ambiental das Opções Estratégicas

FACTOR CRÍTICO	OPÇÃO A	OPÇÃO B	OPÇÃO C	OPÇÃO D
Alterações Climáticas	+ +	+	+	+ +
Biodiversidade	- -	- -	-	-
Recursos Naturais e Culturais	- -	0	0	+
Riscos Naturais e Tecnológicos	-	- -	0	-
Desenvolvimento Humano e Competitividade	+	+	+ +	+ +
Avaliação global:	- -	-	+	+ +

The results of the multi criteria analysis were used to achieve the table presented in **Table 11**. However, it is not clear how the multi criteria analysis of the 25 projects is taken into account in the final environmental assessment of the 4 strategic options.

This means that there is no guarantee that the “best” projects were finally selected in relation to their potential environmental impacts. A qualitative assessment of this uncertainty is presented in section 2.5.

2.4.3 Outcome

The outcome of the above assessment method is a list of 10 selected best dams representing strategic option D: Foz Tua, Padroselos, Vidago, Daivoes, Fridao, Pinhosao, Girabolhos, Gouvaes, Alvito, Almourol.

It is not possible to verify the result of this outcome since, specifically in the case of environmental constraints, it is not explained why or how certain scores were attributed (**Table 9**).

Some observations can be made regarding the relative weight of the impact on water in the strategic options.

- The environmental assessment is carried out on the four strategic options defined in the elaboration of the PNBEPH, for which a selection of hydropower projects has already been done (from 25 projects initially considered). This means that the outcome of the SEA is strongly influenced by the definition of the options as also the resulting lists of hydropower projects. The parameters used to define the options are also similar but significantly more limited than the critical factors in the impact assessment.
- In the definition of option C (environmental constraints), no parameters were taken into account specifically relating to impact on water.

Table 12: Comparison option C and option D

ORDENAMENTO DOS APROVEITAMENTOS PELA OPÇÃO C			
Nº	APROVEITAMENTO	VALOR (%)	POTÊNCIA INSTALADA (MW)
1	Padroselos	100.0	113
1	Vidago	100.0	90
1	Pinhosão	100.0	77
1	Alvito	100.0	48
5	Foz Tua	88.9	234
5	Daivões	88.9	109
5	Póvoa	88.9	41
5	Girabolhos	88.9	72
9	Fridão	32.9	163
10	Gouvães	32.7	112
10	Almourol	32.7	78
12	Santarém	32.7	85
12	Asse-Dasse	10.4	185
12	Assureira	10.3	88
12	Atalaia	10.3	50
12	Sra. de Monforte	10.3	81
12	Pêro Martins	10.3	218
12	Alvarenga	5.0	175
12	Castelo de Paiva	5.0	80
12	Midões	5.0	54
21	Sampaio	4.9	150
21	Mente	4.9	48
21	Rebordelo	4.9	252
21	Castro Daire	4.9	134
21	Erges	4.9	42

ORDENAMENTO DOS APROVEITAMENTOS PELA OPÇÃO D			
Nº	APROVEITAMENTO	VALOR (%)	POTÊNCIA INSTALADA (MW)
1	Foz Tua	90.3	234
2	Padroselos	46.2	113
3	Vidago	41.6	90
4	Daivões	40.1	109
5	Fridão	39.2	163
6	Pinhosão	36.1	77
7	Girabolhos	31.8	72
8	Gouvães	31.4	112
9	Alvito	24.7	48
10	Almourol	24.6	78
11	Póvoa	24.1	41
12	Santarém	23.6	85
13	Assureira	15.6	88
14	Rebordelo	15.4	252
15	Pêro Martins	15.2	218
16	Alvarenga	15.1	175
17	Asse-Dasse	14.7	185
18	Sampaio	10.8	150
19	Castro Daire	9.2	134
20	Sra. de Monforte	8.8	81
21	Midões	6.9	54
22	Castelo de Paiva	6.6	80
23	Atalaia	4.8	50
24	Erges	4.7	42
25	Mente	3.4	48

- Analysing the outcome of option D in relation to option C (**Table 12**), the difference between the selected hydropower projects is very small. Option D includes exactly the same projects as option C, except for Almourol instead of Póvoa. The explanation for this result can be found in the fact that the dams with higher scores for option A (Rebordelo, Alvarenga, Sampaio) were attributed extremely low scores for option C (in the order of 5), hence being eliminated from the final result. The balance between the 3 factors in the result of option D is presented in **Table 12** and reveals a clear influence of factor Fa (representing option C) on the outcome.

- The ranking of Almourol in option C shows an equal environmental score as the last project included (Gouvães), but a less favourable score of 32.7 compared to 88.9 for the substituted project Gouvães. Compared to the total impact index for option C (821.2), this represents an added environmental impact of approx. 7 %.

The following observations can be made regarding the impact of the selected dams on the water environment:

- Impact of the selected hydropower projects on WFD objectives (CF2-C4): all 10 selected hydropower projects are located in areas at risk of not meeting the quality objectives.
- Impact of the selected hydropower projects on fragmentation of the lotic system (CF2-C4): One project (Almourol) is located in a system with reduced existing fragmentation (no dams downstream, but 2 upstream). Two selected projects (Girabolhos and Alvito) are located in a system with elevated fragmentation (the presence of existing dams has originated in a high isolation of the sub-basin). The remaining other 7 projects are located in a moderate fragmented system (at least one dam exists downstream).
- Impact of the selected hydropower projects on water resources (CF3-C3): 2 of the 10 selected hydropower projects are considered less favourable for the impact on water resources: Foz Tua and Fridão. These projects would have a negative impact on existing drinking water captations (representing the highest relative weight in the criterion) and Fridão is located in an area sensible to eutrophication. However, their impact on the WFD is not described.
- Impact of the selected hydropower projects on threatened species dependent on the lotic system (CF2-C2). Two projects of the selected hydro power projects (Almourol and Alvito) were assessed as a very negative score for this criterion (2 of the 3 worst projects out of the 25). Almourol has 6 threatened species with confirmed presence (of which 1 is critical: Lampetra Fluviatils), and 2 with probable presence. Alvito has 4 threatened species with confirmed presence and 3 with probable presence (of which 1 is critical).

However, the WFD compliance assessment of water-related impacts is done in Section 0 and will determine the final conclusion on this aspect.

Conclusion

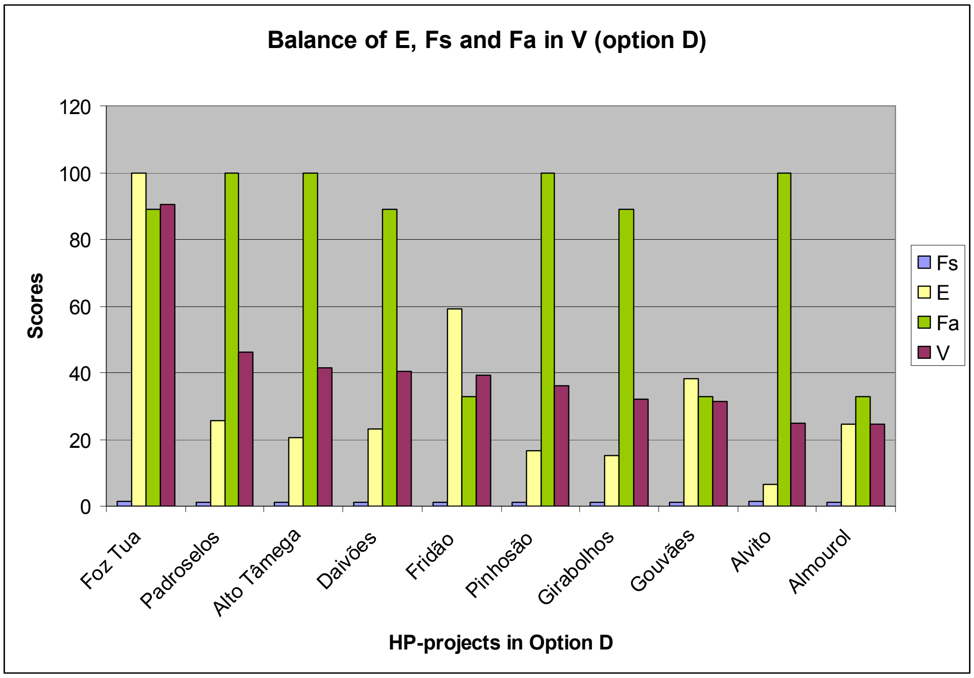
The definition of the strategic options has determined a list of selected hydropower projects representative for each strategic option and has a strong influence on the final outcome of the SEA. However, in the definition of the options, specific impacts on *water* environment were *not* taken into account.

The difference in the representative list of option C (environmental constraints) and option D (Energetic, socio-economic and environmental balance) is limited to 1 project.

The impact of the selected hydropower projects on the water environment is not assessed properly and in particular no assessment of the impacts WFD objectives is done.

The selected hydropower projects do not include major negative impacts on the water related parameters assessed, except for the impact on threatened species dependent on the lotic system, where 2 projects (Almourol and Alvito) have confirmed presence of vulnerable species.

Table 13: Balance of E, Fs and Fa in V (=option D)



	E	Fa	Fs	V
Foz Tua	100	88,9	1,38	90,4
Padroselos	25,7	100	1,25	46,3
Alto Tâmega	20,7	100	1,25	41,5
Daivões	22,9	88,9	1,19	40,2
Fridão	59	32,9	1,19	39,2
Pinhosão	16,5	100	1,19	36,2
Girabolhos	15,2	88,9	1,13	31,9
Gouvães	38,1	32,7	1,19	31,4
Alvito	6,4	100	1,44	24,8
Almourol	24,6	32,7	1,13	24,6
Póvoa	9,8	88,9	1	24,1
Santarém	22,7	32,7	1,13	23,6
Assureira	31,3	10,3	1,13	15,6
Rebordelo	58,1	4,9	1,25	15,4
Pêro Martins	25,7	10,3	1,31	15,2
Alvarenga	47,5	5	1,44	15,1
Asse-Dasse	26	10,4	1,19	14,6
Sampaio	28,4	4,9	1,25	10,8
Castro Daire	22	4,9	1,19	9,2
Sra. De Monforte	9	10,3	1,25	8,8
Midões	12,7	5	1,13	6,9
Castelo de Paiva	11	5	1,19	6,6
Atalaia	2,4	10,3	1,44	4,9
Erges	6,4	4,9	1,06	4,7
Mente	3,1	4,9	1,19	3,5

2.5 Influence of the assessment of the impacts on the water environment on the outcome

In this section, it has been tested how the selection of options and factors may deliver different results in the outcome of the SEA.

In order to perform a quantitative test, the following elements were critical for this task:

- Availability of the necessary information to carry out a multi criteria analysis and to apply a weighing methodology;
- Sufficient basic knowledge in the PNBEPH with respect to the effect criteria and their quantification.

In sections 2.3 and 2.4 it was described how numerous gaps in the published information made it impossible to verify the calculations that led to the multi criteria analysis results.

Moreover, it is not clear how the results of this multi criteria analysis were transposed into the qualitative scores -, 0, +, ++ for the combinations of dams in the strategic options.

However, a qualitative assessment of the outcome is possible by evaluating the outcome of the multi criteria analysis (as presented in **Table 10**) and comparing it with the final outcome.

For this evaluation, the results of the multi criteria analysis were transposed into the following scores:

- 1 : most favourable
- 0 : intermediate
- -1 : less favourable

In order to give a general score to each dam, a weight needs to be attributed to the critical factors. Taking into account the objective of assessing the influence of the assessment of the impact on water in the outcome, a higher weight can be attributed to the critical factors including impact on water environment. The water related critical factors were discussed in section 2.3.3, which concluded that the aspect water is represented by CF2 for 29 % and by CF3 for 20 %.

Hence, preference can be given by applying the formula for the general score

Score = CF1*0,05+CF2*0,4+CF3*0,4+CF4*0,05+CF5*0,05+CF6*0,05

The result is presented in **Table 14**.

Table 14: Evaluation multi criteria analysis results – general score for preference to the critical factors CF2 and CF3

Critical factor / general assessement	Formula	HP Projects																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		Assureira	Atalaia	Sra. De Monforte	Pêro Martins	Sampaio	Mente	Rebordelo	Foz Tua	Castro Daire	Alvarenga	Castelo de Paiva	Padroselos	Alto Tâmega	Daivões	Fridão	Gouvães	Póvoa	Pinhosão	Asse-Dasse	Girabolhos	Midões	Almourol	Santarém	Erges	Alvito
Capacity (MW)		88	50	81	218	150	48	252	234	134	175	80	113	90	109	163	112	41	77	185	72	54	78	85	42	48
Climate change (CF1)	"More favourable" = 1	0	-1	0	1	0	-1	1	1	0	1	-1	0	0	0	1	0	-1	0	1	0	-1	0	1	-1	-1
Biodiversity (CF2)	"Intermediate" = 0	0	0	0	0	-1	-1	-1	1	-1	-1	-1	1	1	1	1	0	0	1	0	1	-1	0	0	-1	1
Natural resources (CF3)	"Less favourable" = -1	0	-1	0	0	0	1	1	0	-1	0	1	0	1	0	-1	-1	0	1	0	0	0	0	0	1	1
Natural risks (CF4)		1	1	1	-1	-1	1	0	-1	1	1	1	1	0	0	0	1	1	0	1	0	0	-1	-1	1	1
Human development (CF5)		0	-1	-1	0	-1	-1	-1	0	1	1	1	1	-1	0	1	0	-1	-1	-1	-1	-1	-1	-1	0	0
Competitivenes (CF6)		-1	1	1	1	0	0	1	0	-1	1	-1	1	0	-1	0	-1	-1	-1	0	0	0	-1	-1	-1	-1
Strong preference CF2 Biodiversity and CF3 natural resources	=CF1*0,05+CF2*0,4+CF3*0,4+CF4*0,05+CF5*0,05+CF6*0,05	0	-0,4	0,05	0,05	-0,5	-0,05	0,05	0,4	-0,75	-0,2	0	0,55	0,75	0,35	0,1	-0,4	-0,1	0,7	0,05	0,35	-0,5	-0,15	-0,1	-0,05	0,75

This subsequently allows a ranking of the dams and the selection of the best dams to achieve about 1100 MW. This ranking is presented in **Table 15**.

Table 15: Evaluation multi criteria analysis results – selection for preference to the critical factors CF2 and CF3

Dam	MW	score
Alto Tâmega	90	0,75
Alvito	48	0,75
Pinhosão	77	0,7
Padroselos	113	0,55
Foz Tua	234	0,4
Daivões	109	0,35
Girabolhos	72	0,35
Fridão	163	0,1
Rebordelo	252	0,05
Pêro Martins	218	0,05
Asse-Dasse	185	0,05
Sra. De Monforte	81	0,05
Assureira	88	0
Castelo de Paiva	80	0
Mente	48	-0,05
Erges	42	-0,05
Santarém	85	-0,1
Póvoa	41	-0,1
Almourol	78	-0,15
Alvarenga	175	-0,2
Gouvães	112	-0,4
Atalaia	50	-0,4
Sampaio	150	-0,5
Midões	54	-0,5
Castro Daire	134	-0,75

The best dams achieving both the environmental objectives and the primary objective of approx. 1100 MW are highlighted in yellow in **Table 15** (total 1.158 MW). Comparing this list with the outcome of the SEA (list of Option D), no large differences are detected. In stead of Rebordelo, the outcome proposed Gouvães and Almourol. Analysing this difference more into detail:

- Rebordelo (not in outcome) has been assessed favourable for CF1, CF3 and CF6;
- Almourol (in outcome, but lower environmental score) has been assessed less favourable for CF4, CF5 and CF6 (not representing impacts on the water environment);
- Gouvães (in outcome, but quite environmental score) has been assessed less favourable for CF3 and CF6. The negative score for CF3 is mainly due to the heritage factor, and not due to the impact on water (criterion C3) which is assessed intermediate.

Hence, no major environmental constraints related to water are linked to Almourol or Gouvães. On the contrary, if more weight would be attributed to the implementation of the WFD in CF02, Gouvães would increase in the ranking of the multi criteria analysis.

The above shows that the outcome of the SEA can be evaluated as representative for a strong priority to the critical factors CF02 and CF03 in the assessment, being exactly the ones representing for about 20 % to 30 % the impact on water.

This was to be expected, since the list of option D is almost similar to the list of option C, which has been identified solely on the basis of the environmental constraints of biodiversity, overlap with classified areas (both included in CF2) and effects on cultural heritage (included in CF3-C3).

This can be verified by absolute preference to the respective critical factors in the multi criteria analysis (**Table 16** and **Table 17**).

Table 16: Evaluation multicriteria analysis results – selection for absolute preference to the critical factor CF2

Dam	MW	score
Foz Tua	234	1,00
Fridão	163	1,00
Padroselos	113	1,00
Daivões	109	1,00
Alto Tâmega	90	1,00
Pinhosão	77	1,00
Girabolhos	72	1,00
Alvito	48	1,00
Pêro Martins	218	0,00
Asse-Dasse	185	0,00
Gouvães	112	0,00
Assureira	88	0,00
Santarém	85	0,00
Sra. De Monforte	81	0,00
Almourol	78	0,00
Atalaia	50	0,00
Póvoa	41	0,00
Rebordelo	252	-1,00
Alvarenga	175	-1,00
Sampaio	150	-1,00
Castro Daire	134	-1,00
Castelo de Paiva	80	-1,00
Midões	54	-1,00
Mente	48	-1,00
Erges	42	-1,00

Table 17: Evaluation multicriteria analysis results – selection for absolute preference to the critical factor CF3

Dam	MW	score
Rebordelo	252	1
Alto Tâmega	90	1
Castelo de Paiva	80	1
Pinhosão	77	1
Mente	48	1
Alvito	48	1
Erges	42	1
Foz Tua	234	0
Pêro Martins	218	0
Asse-Dasse	185	0
Alvarenga	175	0
Sampaio	150	0
Padroselos	113	0
Daivões	109	0
Assureira	88	0
Santarém	85	0
Sra. De Monforte	81	0
Almourol	78	0
Girabolhos	72	0
Midões	54	0
Póvoa	41	0
Fridão	163	-1
Castro Daire	134	-1
Gouvães	112	-1
Atalaia	50	-1

Comparison of the selection based on absolute preference for CF2 with the outcome of the SEA (list of Option D), no large differences are detected. In stead of Pêro Martins, the outcome proposed Gouvães and Almourol. This is a similar result as discussed above. In addition, Almourol and Gouvães have the same score for CF2 than Pêro Martins (intermediate).

Comparison of the selection based on absolute preference for CF3 with the outcome of the SEA (list of Option D), more differences are detected, confirming the fact that option D/C has been identified mainly in line with CF2. In this case, 4 dams that score high on CF3 were not included in the outcome: Rebordelo, Castelo de Paiva, Mente and Erges. However, all 4 have a significant negative result for CF2, C4 (WFD implementation). It would hence not be recommended to include these dams in the outcome without considering CF3 on equal terms with CF2, as assessed in **Table 14** and **Table 15**.

2.6 SEA water-related parameters: considered impacts in line with the WFD

The way in which the impacts on aquatic ecosystem components will be assessed in an SEA for hydropower projects will depend on what one identifies as the main impacts. As part of the outcome of Task 2a and 2b, the following impacts on the aquatic ecosystem components were considered important for the Portuguese situation:

- The changed sediment patterns;
- The change in flow and habitat conditions;
- The barrier function;
- The changes in nutrient (and organic) conditions.

Furthermore, the assessment will also need to look at cumulative impacts (including newly planned and existing dams) as the selection of a number of hydropower locations in one specific river basin can have a significant impact on the complete river basin. The evaluation of the impacts that were assessed in the SEA is given in Section 2.6.1

The way this assessment should be done (especially in relation to the indicators used) is largely dictated by the European Directives relevant to the protection of water. Besides the European Directives related to eutrophication i.e. the Urban Wastewater Treatment Directive (91/271/EEC), the Nitrates Directive (91/676/EEC) and the Integrated Pollution Prevention and Control (IPPC) Directive (2008/1/EC), the Water Framework Directive dictates the main aspects that need to be considered in terms of impacts on the water ecosystem. This is explained further in Task 2 (requirements of SEA and WFD in accordance to the PNBEPH). The checking of inclusion of water impacts according to the WFD the SEA will be done in Section2.6.2..

2.6.1 Assessment of main impacts by SEA

In this chapter it is checked whehter the assessment of the main impacts as identified in Task 2b are also included in the SEA. The results of this evaluation are given in **Table 18**.

Table 18: Evaluation of the impacts described in the SEA according to the main impacts as identified as part of this study (Task 2b).

Impacts	SEA (Table 6: Environmental Assessment)	Evaluation
Changed sediment patterns	CF4 – Coastal erosion	**Specific effects on changed sedimentation patterns have not been assessed in the SEA**. Only the effect on coastal erosion has been described.
Changed flow and habitat conditions	(CF3 – C3.1 Adverse effects on the characteristics of the classified fish waters) (CF2 C2: Threatened species) (CF2-C3: Species insufficiently covered by Natura 2000)	**Specific effects on changed flow and habitat conditions have not been assessed in the SEA and will be assessed in the EIA.** (Indirect effects have been taken into account by giving lower scores to classified fish waters and by looking at threatened species and species depending on running waters insufficiently covered by Natura 2000).
Barrier function	(CF2 – C4: Existing fragmentation)	**The barrier function has not been assessed in the SEA.** (CF2-C4 has only used the parameter 'fragmentation' to favour fragmented river basins for possible hydropower location, but this ignores the longer-term objective of continuity of river systems and doesn't describe the possible barrier function of the planned hydropower installation itself.)
Changes in nutrient and organic conditions	CF3 – C3.1: Probability of occurrence of eutrophication CF3 - C3.2: Groundwater vulnerability	**Yes, changes in nutrient conditions have been assessed in the SEA but there is no transparency of the rules applied and no indicators based on biological elements have been used for the assessment.** Planned hydropower systems at locations in a zone sensitive for eutrophication and groundwater vulnerability do get a less favourable score.
Cumulative impacts		**No assessment of cumulative impacts has been done.** The SEA evaluated each of the hydropower installations individually and for the selection of favourable locations for hydropower installations, cumulative effects were not considered.

Conclusion

The assessment of the main impacts by the SEA is considered to be incomplete. The major impacts such as effects on the sedimentation process, the changed flow and habitat conditions and the barrier function are neglected and although the eutrophication aspects are included, the applied rules are not transparent and the assessment was not based on biological elements as required by the WFD.

The main arguments provided in the SEA with regard to the incomplete assessment state that further assessment should be carried out in the EIA of each project regarding some aspects related to the WFD, in particular on the following issues:

- eutrophication probability;
- potential effects on aquifers;
- effects on water quality caused by the reservoir in downstream water bodies;
- flows and water level modification cause by water releases - hydro peaking, in particular regarding erosion and deposition natural processes;
- temperature regulation in the discharged water downstream;
- management plan for water discharge control
- fish migration issues.

In the PNBEPH report, it is confirmed that the scale in which the SEA was undertaken and the lack of detailed information available at the time of this assessment on some particular aspects of biodiversity (e.g. information on species and habitats distribution where only assessed on a national scale) did not allow a proper assessment.

Cumulative impacts are not evaluated. This is an important gap in the analysis especially taking into account the number of dams already existing and proposed for some river basins and the number of dams planned in the Tâmega sub-basin (Douro River Basin).

The PNBEPH recommends that further analysis on the scale applied and the cumulative impacts should be carried out in the EIA of the projects. However, the EIA already carried out for the Foz Tua dam does not properly consider cumulative impacts in the Douro River Basin arguing that this is a subject that must be evaluated in the SEA.

2.6.2 WFD compliance

The WFD compliance analysis needs to start from the Directive itself, looking into what objectives need to be achieved and what parameters (indicators) are to be used to assess the possibility of not reaching the set objectives.

This is given in **Table 19**. In the first column, the objectives that need to be reached as well as the conditions under which one can obtain exemptions from these objectives are given. This has been discussed in Task 2 Table 28 (Objectives Water Framework Directive). The first three objectives i.e. good quality by 2015, no deterioration of status, and the objectives set for protected zones, do need to be assessed based on set indicators as listed in Annex V of the WFD, and these are given in the third column of **Table 19**. The relevant requirements in relation to these parameters are described in several sections of Annex V and references are given in column 2. In column 4 the SEA evaluation has been given with regard to what should have been used for a WFD compliance assessment.

In **Table 20**, the WFD compliance assessment of each of the individual parameters as used in the SEA of the PNBEPH has been described, but this does not result in a full gap analysis of the SEA (as is given in **Table 19**).

Table 19: SEA compliance assessment starting from the requirements as set by the Water Framework Directive (2000/60/EC)

Hydropower installations will have an effect on the following WFD objectives:	WFD Annex V relevant sections	Parameters to be used for the assessment	WFD Compliance assessment (see Table 6 for parameters SEA)
Art. 4.1.a.i no deterioration of status **Art. 4.1.a.ii** good quality by 2015	**Annex V.1.1** – quality elements for the classification of ecological status **Annex V.1.2** – normative definitions of ecological status classifications **Annex V.1.3.1** – Monitoring of ecological status and chemical status for surface waters – design of operational monitoring **Annex V.1.4.1** – Classification and presentation of ecological status **Annex V.1.4.3** – Chemical status	Selection of quality elements **(Annex V.1.3.2):** Operational monitoring - shall be undertaken in order to establish the status of those bodies identified as being at risk of failing to meet their environmental objectives - shall use parameters indicative of the biological quality element or elements most sensitive to the pressures to which the water bodies are subject (for WBs considered at risk – operational monitoring) - shall use parameters indicative of the hydromorphological quality element most sensitive to the pressure identified	For rivers the main elements to be used for estimating possible impacts by hydropower downstream of the installation are marophytes, macroinvertebrates and fish (concluded as part of Task 2b). The estimation of impact on the upstream water bodies will be assessed by looking to phytoplankton, macroinvertebrates and fish communities. The hydromorphological quality needs to be assessed for those water bodies at high ecological status. **These elements are not used for the analysis of impacts on the water environment.** **CF2 – C4: Degree of naturalness – Existing Human Pressure** No, there are 2 shortcomings when looking to WFD compliance: 1. WFD compliant assessments should have been used (i.e. status assessments by means of EQRs for the relevant biological elements) instead of risk assessments. 2. Violation of the WFD objectives (no deterioration of status, not reaching good quality by 2015) should have been analysed here. The rules applied (considering locations 'at risk' according to WFD risk assessment as being favourable for locating hydropower stations) are not compliant with the WFD objective of 'no deterioration' and 'good ecological status'. Some of the 'at risk locations' could suffer from pressures that are completely independent to the ones related to hydropower stations. **CF2 – C4: Degree of naturalness – Existing fragmentation** 1. Proper EQR status assessments are needed (based on fish) 2. Violation of the WFD objectives (no deterioration of status, not reaching good quality by 2015) should have been analysed here. The rules applied (considering locations 'fragmented' as being more favourable for locating hydropower stations than non-fragmented systems) are not compliant with the WFD objective of 'no deterioration' and 'good ecological status'. Some of the 'fragmented systems' could be caused by the absence or malfunctioning of fish traps which could be possibly solved in future. **CF3 – C3.1 – Analysis for the water bodies WFD** **?** (the parameter is called WFD but no clarification on the indicators used is given

Hydropower installations will have an effect on the following WFD objectives:	WFD Annex V relevant sections	Parameters to be used for the assessment	**WFD Compliance assessment** (see Table 6 for parameters SEA)
Art 4.1.c Protected Areas – compliance with standards and objectives by 2015 unless otherwise specified in the Community legislation under which the individual protected areas have been established – *objectives relevant are specified in Art. 4.1.a.*			**CF2 – C2: Threatened species** Yes, overlap with habitat areas of protected species that are especially depending on the running water system are looked at. This includes fish (WFD biological element). No, If fish EQR results would have been available, this would be in definition a full WFD compliant assessment as migrating fish would have been part of the overall classification system in the FAME index. However, status assessments are not available yet as classification tools haven't been finalised yet **CF3 – C.3.1 – Probability of occurrence of eutrophication (location in a zone sensitive for eutrophication, location in an area in use for agriculture)** Yes, this is linked to the protected zones (Nitrates Directive) (Annex IV of the WFD, nutrient-sensitive areas). We assume that the more vulnerable the less ideal for selection as a location of a hydropower station but these is no rule specified in the SEA. No, as no transparency on rules applied. **CF3 – C3.1 – Adverse effect on the characteristics of the classified fish waters** Yes, part of the compliance with regard to protected zones (Annex IV of the WFD, areas designated for the protection of economically significant aquatic species.) We assume that the more vulnerable the less ideal for selection as a location of a hydropower station but these is no rule specified in the SEA but this has not been explained in the SEA.
Art 4.7.a Mitigation measures **Art 4.7.b** reasons for modifying set out in RBMP **Art 4.7.c** (part of the scope of the SEA, not part of scope of this study) **Art 4.8** no exclusion or compromise of the achievement of the objectives of this Directive in other bodies of water within the same river basin district			No, the **possible mitigation measures have not been sufficiently covered in the SEA,** especially taking into account that derogation with Art 4.7 of the WFD is used for the PNBEPH. There is no information on mitigation of hydropeaking effects and minimum flow and mitigation of effects to do with sedimentation issues (reference is however made to the EIA). With regard to the mitigation option for the barrier function i.e. fish passes. One refers to the individual EIAs for the discussion on the need for fish passes (where in case of the EIA Foz Tua it is given that fish passes are not needed because of the already fragmented system and the consequent absence of migrating species. However, existing migration barriers could possibly be solved in future and as such need to be considered).

Table 20: WFD compliance assessment starting from the parameters used in the SEA of the PNBEPH

SEA 'Water Aspects' (see Table 6)	WFD conformity?	WFD compliance assessment
CF2 – C2: Threatened species	Yes, overlap with habitat areas of protected species that are especially depending on the running water system are looked at. This includes fish (WFD biological element)	If fish EQR results for the WFD biological elements would have been available, this would be in definition a full WFD compliant assessment as **migrating fish** would have been part of the overall classification system in the FAME index (proposed to be used for status assessments in Portugal). However, **status assessments are not used**.
CF2 – C4: Degree of naturalness – Existing Human Pressure	Yes, but scores are attributed in such a way that priority for a location is enhanced when the water body is 'at risk'. Preliminary risk assessment was in some occasions based on biological elements (mainly macroinvertebrates)	**Preliminary risk assessment results** have been used, There are **3 shortcomings** when looking to WFD compliance: 1. **WFD compliant stuatus assessments** should have been used (= status assessments by means of EQRs for the relevant biological elements) 2. **Violation of the WFD objectives** (no deterioration of status, not reaching good quality by 2015) should have been analysed here**. The rules applied** (considering locations 'at risk' according to WFD risk assessment as being favourable for locating hydropower stations) are **not compliant** with the WFD objective of 'no deterioration' and 'good ecological status'. Some of the 'at risk locations' could suffer from pressures that are completely independent to the ones related to hydropower stations (this is difficult to assess as the experts haven't received information on the risk assessment at the water body scale'). 3. The possible **mitigation measures** have not been sufficiently covered in the SEA, especially taking into account that derogation with Art 4.7 of the WFD is used for the PNBEPH. There is no information on mitigation of hydropeaking effects, minimum flow and on effects to do with changed sedimentation. (reference is made to the EIA).
CF2 – C4: Degree of naturalness – Existing fragmentation	Yes, but scores are attributed in such a way that priority for a location is enhanced when the water systems are already fragmented. The level of fragmentation does give an indirect evaluation for fish (assessment of continuity; part of hydro-morphological assessment according to WFD)	**3 shortcomings similar as above:** 1. P**roper EQR status assessments needed** (based on fish) 2. Violation of the WFD objectives (no deterioration of status, not reaching good quality by 2015) should have been analysed here. The rules applied (considering locations 'fragmented' as being more favourable for locating hydropower stations than non-fragmented systems) are not compliant with the WFD objective of 'no deterioration' and 'good ecological status'.

SEA 'Water Aspects' (see Table 6)	WFD conformity?	WFD compliance assessment
		Some of the 'fragmented systems' could be caused by the absence or malfunctioning of fish traps which could be possibly solved in future and as such need to be considered. 3. The **possible mitigation measures have not been sufficiently covered** in the SEA, especially taking into account that derogation with Art 4.7 of the WFD is used for the PNBEPH. One refers to the individual EIAs for the discussion on the need for fish passes (where in case of the EIA Foz Tua it is given that fish passes are not needed because of the already fragmented system and the consequent absence of migrating species. This is only considering the short-term situation as current migration barriers could be solved in future).
CF3 – C.3.1 – Probability of occurrence of eutrophication (location in a zone sensitive for eutrophication, location in an area in use for agriculture)	Yes, this is linked to the protected zones (Nitrates Directive) (Annex IV of the WFD, nutrient-sensitive areas). We assume that the more vulnerable the less ideal for selection as a location of a hydropower station but these is no rule specified in the SEA.	No transparency on rules applied.
CF3 – C3.1 – Adverse effect on the characteristics of the classified fish waters	Yes, part of the compliance with regard to protected zones (Annex IV of the WFD, areas designated for the protection of economically significant aquatic species. We assume that the more vulnerable the less ideal for selection as a location of a hydropower station but these is no rule specified in the SEA.	No transparency on rules applied.
CF3 – C3.1 – Analysis for the water bodies WFD	**?** (the parameter is called WFD but it is not said what is behind these parameter and scores were not given)	No information on what this 'WFD parameter' means, compliance cannot be assessed. No transparency on rules applied.
CF3 – C3.2 – Groundwater Lithology/capitation/vulnerablility	Yes but to double check content in SEA – Annex IV of the WFD areas designated for the abstraction of water intended for human consumption. We assume that the more vulnerable the less ideal for selection as a location of a hydropower station but these is no rule specified in the SEA.	No transparency on rules applied.

2.6.3 Conclusion on impacts considered and WFD compliance

The WFD compliance of the parameters used in the assessment is poor and incomplete as can be seen from the assessment given in **Table 19** and **Table 20**. The main issue here is that first of all a proper WFD status assessment (based on Ecological Quality Ratio results for the WFD biological elements) should have been used.

The rules applied for. the choice of locating hydropower installations at sites already affected by other impacts even not depending on the sort of impact, is not generally accepted by all parties and is seriously questioned as this is in theory in conflict with the objectives set by the Water Framework Directive and especially with the objective of reaching good quality by 2015. This issue has been discussed at the WFD & Hydropower Berlin workshop (2008), but in a different and less strong way and it only refers to locations that are impacted by a similar pressure: *Bearing the non-deterioration clause of the WFD in mind, "go" areas for new HP facilities could be water stretches or basins, which are already used for hydropower or are physically altered due to transverse structures for other uses (e.g. for navigation, drinking water supply or flood protection) or in those cases where the requirements of Art. 4 (7) are met. "No-go" areas for hydropower schemes could be unregulated rivers in areas of high ecological value or rivers with very limited number of hydropower stations, where the intention is to protect or restore the population of migratory species.*

The possible mitigation measures have not been sufficiently covered in the environmental assessment, especially taking into account that a derogation in accordance with art. 4.7 of the WFD has been applied for the PNBEPH. The SEA only mentions the type of measures that should be designed in the EIA for each project, e.g. minimum flows and fish passes. Nevertheless it is also assumed in the SEA that in some cases, these measures (in particular fish passes) will probably not be efficient for the type of dams envisaged and therefore could not be implemented.

Hence, the EIA of the projects included in the PNBEPH should carry out more detailed studies on the following issues, as confirmed in the PNBEPH. Some guidelines are provided in the PNBEPH in relation to:

- River continuum, in particular when migratory species are present; nevertheless, the report considers that there is limited knowledge about the possible mitigation measures for fish species of Mediterranean ecosystems, as most of them are designed for salmons, which will be inefficient in most cases, and therefore admits that in some cases it might be considered not applying such measures
- Ecological flows should be designed in the EIA of each project, according to best practice available for Mediterranean ecosystems. These aspects shall be particularly considered in the basins where several projects will be carried out and the mitigation measures should take into account the cumulative effects on the rivers and the estuaries affected. Ideally the water for ecological flows should be taken from independent hydraulic circuits to those used for bottom discharge so as to avoid the release of water with inappropriate temperature and quality conditions.
- Compensation measures shall be defined for unavoidable impacts in accordance with detailed studies to be carried out in the EIA for each dam.

An ecological assessment following the requirements as set by the WFD has been performed in Task 2b. Comparing the impacts assessed, the indicators used and the scale of the assessment, one could conclude that the SEA of the PNBEPH has serious gaps and can be considered as being non-compliant with the Water Framework Directive's requirements.

2.7 Conclusion

With regard to the definition of factors considered in the SEA and the options chosen, the following can be concluded:

1. The **outcome of the SEA** is mainly influenced by the critical factor biodiversity, including for approx. 29 % impacts on water (mainly focussing on overlap with habitat areas of threatened species dependent on the lotic system). The critical factor water resources, including impacts on water for approx. 12.5 % (mainly focussing on interference with existing infrastructure for water use and groundwater) is less reflected in the outcome. Explicit impact of WFD objectives is limited to 8 % in the critical factor biodiversity and 10 % in the critical factor water resources. However, the parameters used to assess the WFD objectives are considered as being not compliant.
2. The **definition of the strategic options** has determined a list of selected hydropower projects representative for each strategic option and has a strong influence on the final outcome of the SEA. However, in the definition of the options, specific impacts on *water* environment were *not* taken into account. The difference in the representative list of option C (environmental constraints) and option D (Energetic, socio-economic and environmental balance) is limited to 1 project.

Regarding the assessment of impacts on the water environment and its compliance with the WFD, the following can be concluded:

The main shortcomings in the SEA are related to (1) the incompleteness of the considered impacts (changes in sediment patterns, flow and habitat quality and the barrier function of the hydropower station are not looked at); (2) the incompleteness of the data to assess the impacts of hydropower stations and the (3) non-compliance of the data and rules applied following the criteria of the Water Framework Directive.

An ecological assessment following the requirements as set by the WFD has been performed in Task 2b in this study. Comparing the impacts assessed, the indicators used and the scale of the assessment, one could conclude that the SEA of the PNBEPH has serious gaps and can be considered as being non-compliant with the Water Framework Directive’s requirements. Impacts in relation to the water environment based on the WFD requirements should have been included in a prominent and transparent way. From the conclusions obtained in Task 2b, one could see it is certainly possible to estimate the magnitude and scale of impact (ecological and hydro-morphological) on the water environment at the planning stage, and this has not been done in the SEA of the PNBEPH.

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Task 3: Assessment of alternative options

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Upgrading of Hydropower plants, Technical information at http://www.ieahydro.org

ANNEXES

Task 1: Assessment of benefits of the PNBEPH

Annex 1: Summary with relevant information concerning the 10 planned hydropower installations

Name	River	Tributary of	River Basin	Municipalities (district)	Aim	Dam description (material, type, height, width)	Nominal flow	Nominal water fall	Power station	Hydraulic circuit	Reservoir	River flow
Foz Tua	Tua	Douro	Douro	Alijó (Vila Real) and Carrazeda de Ansiaes (Bragança)	Hydroelectric production, floods control	Concrete, vaulted, 135 m, 325 m	220 m3/sec	118 m	Underground, 234 MW	Tunnel of 600m from Foz Tua lagoon to Régua lagoon (Duero).	310 hm3, 51 km, 1100 ha	1207 hm3/yr
Padroselos	Beça	Tâmega	Douro	Cabeceiras de Basto (Braga) and Ribeira de Pena (Vila Real)	Hydroelectric production, floods control	Concrete, vaulted, 92 m, 550 m	60 m3/sec	208 m	Underground, 113 MW	Tunnel of 3,5 km from Padroselos lagoon to Daivões lagoon (project)	147 hm3, 10 km, 510 ha	203 hm3/yr
Alto Tâmega (Vidago)	Tâmega	Douro	Douro	Vila Pouca de Aguiar and Botivas (Vila Real)	Hydroelectric production, floods control	Concrete, vaulted, 82 m, 370 m	130 m3/sec	77 m	Underground, 90 MW	Tunnel of 1,7 km from Vidago lagoon to Daivões lagoon (project)	96 hm3, 28 km, 350 ha	664 hm3/yr
Daivões	Tâmega	Douro	Douro	Cabeceiras de Basto (Braga) and Ribeira de Pena (Vila Real)	Hydroelectric production, floods control	Concrete, gravity, 70 m, 300 m	180 m3/sec	67 m	Underground, 109 MW	Tunnel of 3,3 km from Daivões lagoon to Fridão lagoon	66 hm3, 19 km, 370 ha	1090 hm3/yr
Fridão	Tâmega	Douro	Douro	Celorico de Basto (Braga) and Amarante (Porto)	Hydroelectric production, floods control	Concrete, vaulted, 90 m, 440 m	240 m3/sec	76 m	At the foot of the dam, 163 MW	No tunnel, just a pipe from Fridão lagoon to the station.	195 hm3, 40 km, 800 ha	1790 hm3/yr

Name	River	Tributary of	River Basin	Municipalities (district)	Aim	Dam description (material, type, height, width)	Nominal flow	Nominal water fall	Power station	Hydraulic circuit	Reservoir	River flow
Gouvães	Torno	Tâmega	Douro	Vila Pouca de Aguiar (Vila Real)	Hydroelectric production, irrigation	Concrete, vaulted, 24 m, 160 m	20 m3/sec	620 m	Underground, 112 MW	Tunnel of 7,2 km from Gouvães lagoon to Daivões lagoon	12,7 hm3, 3,7 km, 160 ha	101 hm3/yr*
Pinhosão	Vouga	x	Vouga	Viseu and S. Pedro do Sul (Viseu)	Hydroelectric production	Embankment dam, 73 m, 300 m	50 m3/sec	171 m	Underground, 77 MW	Tunnel of 13 km from Pinhosão lagoon to Ribeiradio lagoon	68 hm3, 8 km, 250 ha	257 hm3/yr
Girabolhos	Mondego	x	Mondego	Gouveia (guarda) and Mangualde (Viseu)	Hydroelectric production	Concrete, vaulted, 87 m, 460 m	70 m3/sec	114 m	Underground, 72 MW	Tunnel of 5,8 km from Girabolhos lagoon to Midoes lagoon	143 hm3, 21 km, 520 ha	372 hm3/yr
Almourol	Tejo	x	Tejo	Vila Nova da Barquinha and Chamusca (Santarém)	Hydroelectric production	Concrete, gravity (mobile dam), 24 m, 320 m	720 m3/sec	12 m	At the foot of the dam, 78 MW	No tunnel, just a pipe from Almourol lagoon to Tejo river	20 hm3, 36 km, 1340 ha	11300 hm3/yr
Alvito	Ocreza	Tejo	Tejo	Vila Velha de Ródão and Proença-a-Nova (Castelo Branco)	Hydroelectric production, floods control, strategic water reserve creation, industrial and touristic developement	Concrete, vaulted, 76 m, 290 m	65 m3/sec	82 m	Underground, 48 MW	Tunnel of 1,7 km from Alvito lagoon to Pracana lagoon	209 hm3, 38 km, 1100 ha	318 hm3/yr

Annex 2: Other methods and recommendations for minimum flows

SPAIN

Table 3. Criteria established in the different Hydrological Basin Plans and in certain Autonomous Communities, together with the denomination given to the environmental flows in each case. *Criterios establecidos en los distintos Planes Hidrológicos de Cuenca y en algunas Comunidades Autónomas, junto con la denominación que en cada caso reciben los caudales ambientales.*

WATER AUTHORITY	CRITERIA
Norte I, II y III. *Minimum flow*	10 % of annual average flow, with 50 l/s as minimum.
Duero	Without specifications.
Tajo. *Environmental demand*	The volume corresponding to 50 % of natural summer average flow.
Guadiana I y II. *Minimum volume*	1 % of natural incoming for each reservoir.
Guadalquivir y Guadalete-Barbate *Environmental demand*	50 l/s as maximum in addition to the admitted uses of water.
Sur. *Ecological flow*	10 % of annual average flow.
Ebro. *Minimum flow*	10 % of annual average flow.
Júcar. *Maximum stock*	1 % of total water resources.
Segura. *Minimum flow*	10 % of annual average flow.
Cuencas Internas de Cataluña. *Maintenance flow*	QBM method (Palau & Alcázar, 1996).
Galicia-Costa. *Minimum flow*	10 % of annual average flow.
AUTONOMOUS COMMUNITY	**CRITERIA**
Galicia. *Ecological flow*	Any well verified method.
Asturias. *Minimum ecological flow*	20 % of the annual average flow.
Navarra. *Minimum flow*	10 % of the annual average flow for "cyprinid rivers" and Q_{330} for "salmonid rivers".
Aragón. *Ecological flow*	Without specifications.
Cataluña. *Maintenance flow*	QBM method.
Castilla y León. *Ecological flow*	20 % of the annual average flow.
Castilla-La Mancha. *Minimum ecological flow*	10 % of the annual average flow.
Extremadura. *Minimum flow*	Without specifications.

RECOMMENDED FLOWS TO PROTECT AQUATIC HABITAT IN GEORGIA STREAMS

James W. Evans[1] and Russell H. England[2]

Table 1. Recommended Instantaneous Flows to Protect Aquatic Life in Georgia Streams

Category/ sub-category	Season	Recommended Flow
Unregulated Streams		
Warm water streams	All	30% AAD[1]
Trout streams	All	Sept Median
Regulated Streams	July-Nov	30% AAD
	Jan-April	60% AAD
	May, June, Dec	40% AAD
Special Case Streams		
Field studies to determine flow requirements		
Peaking Hydropower Projects		
Site-specific IFIM studies		

[1]Average Annual Discharge

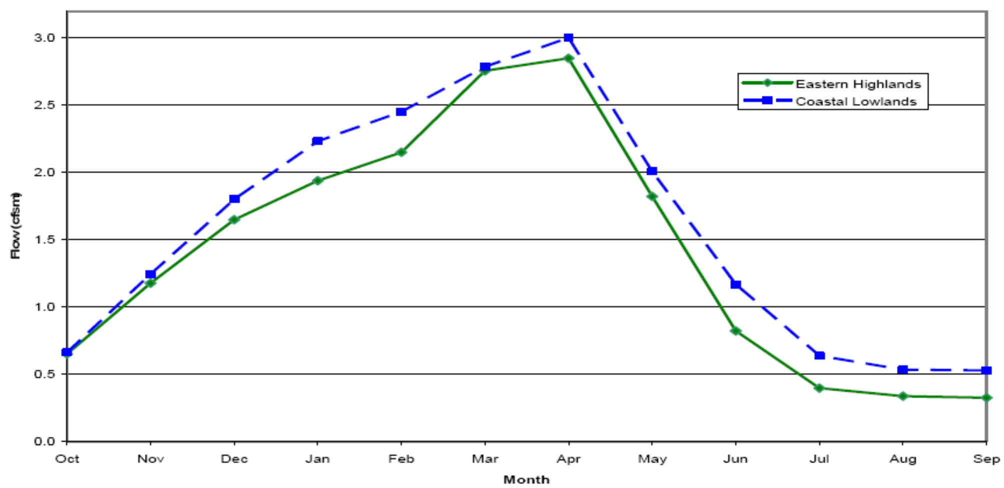
REFERENCE: Proceedings of the 1997 Georgia Water Resources Conference, held March 20-22, 1997, at the University of Georgia, Kathryn J. Hatcher, Editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

The Rhode Island modified ABF (RI-ABF) monthly instream flow values are presented in Figure 5.1. The standard consists of monthly medians of unregulated streams organized by physiographic regions.

Table 5.1 – RI-ABF Monthly Instream Flow Values

Monthly instream flow values in cubic feet per square mile of drainage (cfsm)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Eastern Highlands	0.65	1.18	1.65	1.94	2.15	2.76	2.85	1.82	0.82	0.4	0.34	0.32
Coastal Lowlands	0.66	1.24	1.8	2.23	2.45	2.79	3	2	1.17	0.64	0.54	0.53



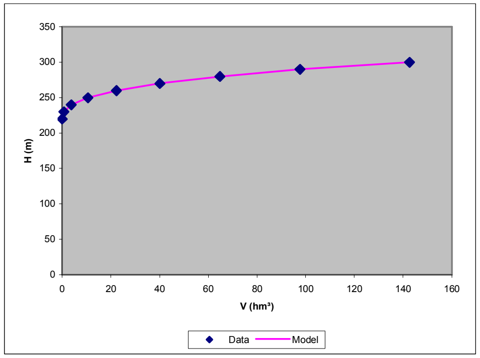
Annex 3::Calculation sheet energy production (Girabolgos)

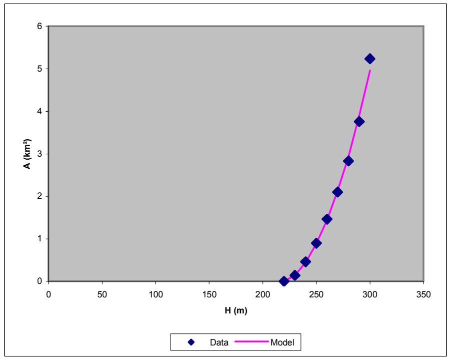
Reservoir relationships

a	0,003426	0,003426	11,773668
b	1,606305	1,606305	0,3960602
c	0,003004	0,003004	-0,00034

To be estimated using solver once Z / A / V data for reservoir are entered

Z m	A km²	V hm³	A calc km²	V calc hm³	H calc m			
220	0	0	0	0	220	0	0	0
230	0,14	0,71	0,142589	0,142589	230,27771	0,001343	22,83425	5,82E-06
240	0,46	3,74	0,44738	0,44738	239,82671	0,003096	67,90024	2,09E-06
250	0,9	10,56	0,884256	0,884256	249,83896	0,001246	140,6242	1,66E-06
260	1,46	22,34	1,446481	1,446481	259,98787	0,000346	236,5332	8,7E-09
270	2,1	40,14	2,133165	2,133165	270,12942	0,000982	352,0863	9,19E-07
280	2,83	64,8	2,946176	2,946176	280,09354	0,006478	481,765	4,46E-07
290	3,76	97,7	3,889024	3,889024	289,91829	0,004555	629,1158	3,18E-07
300	5,24	142,67	4,96636	4,96636	299,9967	0,011518	823,2575	4,84E-10
						0,029564	2754,117	1,13E-05





System specific properties

NPA max	300	m	NPA albufeira
NPA min	180	m	From transsectional drawings
Gross head	120	m	Queda bruta nominal
Net head	114	m	Queda util nominal
Head loss	6	m	
Minimum head	40	m	To be derived from drawings, difference between NPA max and height
Environmental flow	0,44	m^3/s	Estimate at 90 percentile flow, unless other data are provided
Electrical efficiency	90	%	

Power generation calculation

	Inflow m^3/month	Evaporation mm	Evaporation m^3/month	Environmental flow m^3/month	Buffer volume hm^3	Height buffer m	Surface buffer km^2	V turbi m^3/month	V turbi m^3/s	Power GWh			Power range LL	Power range UL	avg prop	Range C guia LL	Range C guia UL	C guia
Sep	1.945.000	40,8	112.383	930.598	39,3	269,7	2,11	41.439.457	15,99									
Oct	7.781.000	54,6	76.129	930.598	7,1	245,6	0,68	38.955.305	15,03	6,84	10,88		4,64	13,91	0,10	0,05	0,15	0,05
Nov	23.598.000	40,1	13.543	930.598	0,0	220,1	0,00	29.787.347	11,49	3,42	8,32		3,42	10,26	0,00	0,00	0,05	0,00
Dec	48.211.000	32,8	11.078	930.598	7,1	245,6	0,68	40.135.837	15,48	4,61	11,21		1,71	5,13	0,10	0,05	0,15	0,05
Jan	63.943.000	34,6	53.390	930.598	47,8	273,6	2,41	22.258.369	8,59	4,01	6,22		2,30	6,91	0,40	0,20	0,60	0,34
Feb	73.585.000	40,9	126.990	930.598	94,6	289,1	3,80	25.766.686	9,94	6,02	7,20		2,01	6,02	0,65	0,33	0,98	0,66
Mar	62.674.000	67,1	277.561	930.598	121,4	295,6	4,47	34.653.292	13,37	9,03	9,68		3,01	9,03	0,90	0,45	1,00	0,85
Apr	38.400.000	90,6	404.098	930.598	120,3	295,3	4,45	38.217.039	14,74	10,25	10,67		4,51	13,54	1,00	0,50	1,00	0,84
Mai	27.658.000	111,1	494.511	930.598	120,6	295,4	4,46	25.848.407	9,97	6,93	7,22		5,12	15,37	0,85	0,43	1,00	0,85
Jun	14.379.000	78,3	349.050	930.598	120,8	295,5	4,46	12.916.768	4,98	3,46	3,61		3,46	10,39	0,70	0,35	1,00	0,85
Jul	6.936.000	22,2	95.257	930.598	107,1	292,3	4,12	19.657.816	7,58	5,19	5,49		1,73	5,19	0,55	0,28	0,83	0,75
Aug	3.129.000	14	52.622	930.598	79,9	284,9	3,40	29.368.895	11,33	7,38	8,20		2,60	7,79	0,40	0,20	0,60	0,56
Sep	1.945.000	40,8	112.383	930.598	39,3	269,7	2,11	41.439.457	15,99	9,27	11,57		3,69	11,07	0,25	0,13	0,38	0,28
mean	31.019.917			3,00%						76,42	100,27	99						
											101%							

Annex 4: Hydrometric stations and data available for the calculations of minimum flows (data obtained from SNIRH on 13/04/2009)

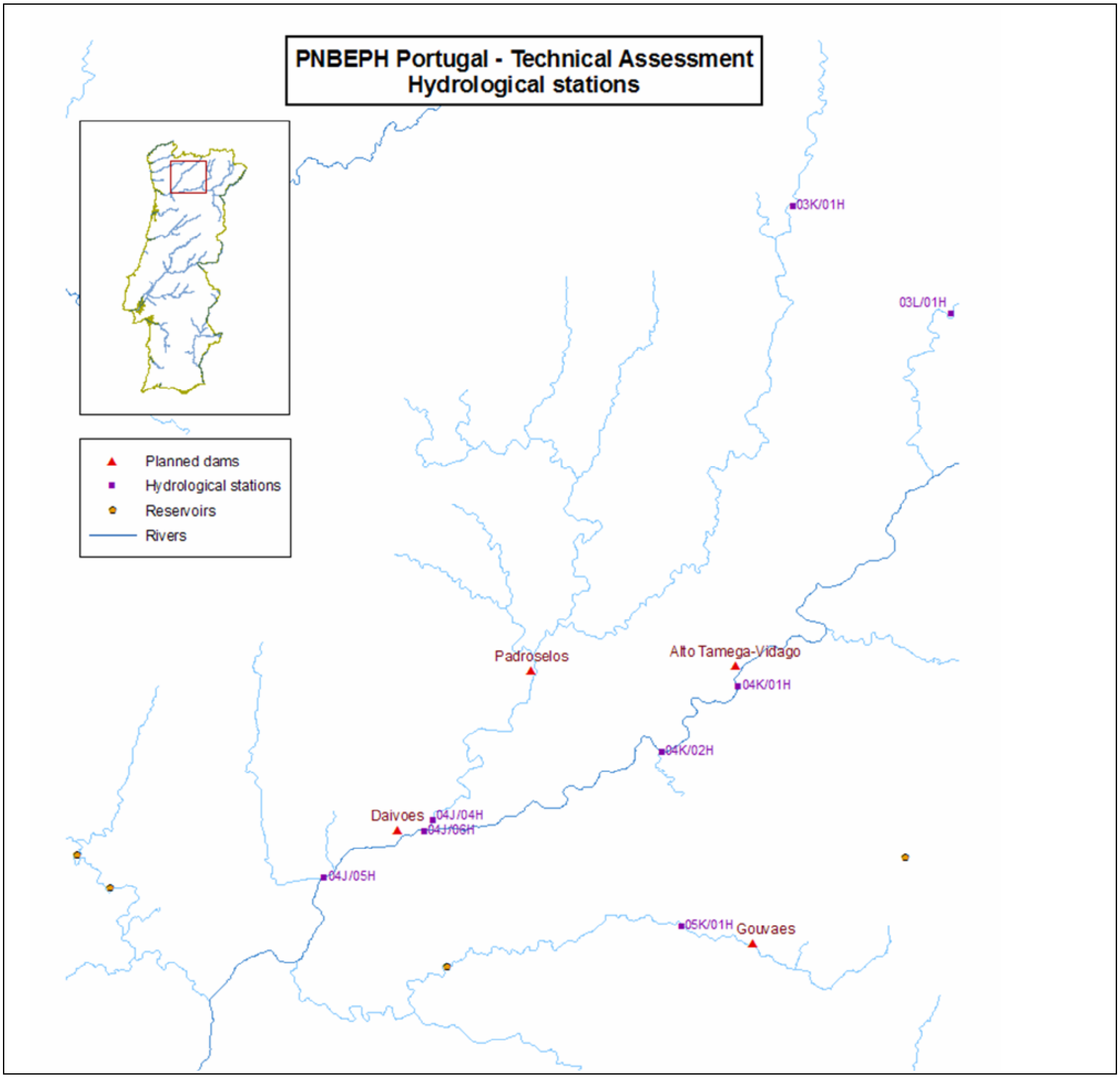
Dam (river)	Station	Location	Info availabe	Unit	Number of values	Data Start	Data End
Padroselos (Tamega)	CUNHAS (04J/04H)	About 6km downstream from the dam (Map 1, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	55	05/02/1950	15/11/2003
			Caudal médio diário	m³/s	20819	01/10/1949	30/09/2006
			Escoamento Anual	dam³	57	01/10/1949	01/10/2005
			Escoamento mensal	dam³	684	01/10/1949	01/09/2006
			Nível instantâneo máximo anual	m	12	30/12/1978	21/12/1989
			Nível médio diário	m	4383	01/10/1978	30/09/1990
Alto Tamega-Vidago (Tamega)	PARADA MONTEIROS (04K/01H)	Close to planned dam, downstream (Map 1, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	8	20/12/1983	13/03/1991
			Caudal médio diário	m³/s	2922	01/10/1983	30/09/1991
			Escoamento Anual	dam³	8	01/10/1983	01/10/1990
			Escoamento mensal	dam³	96	01/10/1983	01/09/1991
			Nível médio diário	m	1827	01/10/1983	30/09/1990
Daivões (Tamega)	PONTE CAVEZ (04J/05H)	Downstream planned dam (Map 1, **Annex 5**)	Caudal médio diário	m³/s	17897	01/10/1957	30/09/2006
			Escoamento Anual	dam³		01/10/1957	01/10/2005
			Escoamento mensal	dam³	588	01/10/1957	30/09/2006
	MOINHO DA CASINHA (04J/06H)	Upstream planned dam (Map 1, **Annex 5**)	Inactive station; no data on the website. Operating from 01/12/1979 to 28/01/1991.				
Gouvães (Louredo)	SANTA MARTA DO ALVÃO (05K/01H)	About 2km downstream planned dam (Map 1, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	36	15/12/1955	21/12/1989
			Caudal médio diário	m³/s	18628	01/10/1955	30/09/2006
			Escoamento Anual	dam³	51	01/10/1955	01/10/2005
			Escoamento mensal	dam³	612	01/10/1955	01/09/2006
			Nível instantâneo máximo anual	m	12	07/02/1979	21/12/1989
			Nível médio diário	m	4383	01/10/1978	30/09/1990

Dam (river)	Station	Location	Info availabe	Unit	Number of values	Data Start	Data End
Fridão (Tame-ga)	FRIDÃO (06I/03H)	Next to planned dam (Map 2, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	15	25/12/1985	27/10/2004
			Caudal médio diário	m³/s	7670	01/10/1985	30/09/2006
			Escoamento Anual	dam³	21	01/10/1985	01/10/2005
			Escoamento mensal	dam³	252	01/10/1985	01/09/2006
			Nível hidrométrico Instantâneo	m	365	01/10/2004	30/09/2005
			Nível instantâneo máximo anual	m	1	20/10/2004	20/10/2004
			Nível médio diário	m	1461	01/10/1985	30/09/1990
Foz Tua (Beça)	CASTANHEIRO (06M/01H)	Upstream dam (Map 2, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	32	24/01/1971	01/12/2003
			Caudal médio diário	m³/s	17532	01/10/1958	30/09/2006
			Escoamento Anual	dam³	48	01/10/1958	01/10/2005
			Escoamento mensal	dam³	576	01/10/1958	01/09/2006
			Nível instantâneo máximo anual	m	13	26/01/1977	21/12/1989
			Nível médio diário	m	4383	01/10/1978	30/09/1990
	CASTANHEIRO (05M/01H)	Upstream dam (Map 2, **Annex 5**)	Caudal instantâneo	m³/s	16616	28/08/2006	27/10/2008
			Caudal médio diário	m³/s	683	29/08/2006	24/10/2008
			Escoamento mensal	dam³	18	01/09/2006	01/09/2008
			Nível hidrométrico Instantâneo	m	16616	28/08/2006	27/10/2008
			Nível médio diário	m	594	29/08/2006	27/07/2008
	FOZ DO TUA (06M/02H)	About 2,5 km downstream dam (Map 2, **Annex 5**)	Inactive station; no data on the website. Operating from 01/10/1934 to 30/09/1942				
Pinhosão (Vou-ga)	CABRIA (09I/05H)	Downstream planned dam (Map 3, **Annex 5**)	Caudal médio diário	m³/s	365	01/10/2004	30/09/2005
			Escoamento Anual	dam³	1	01/10/2004	01/10/2004
			Escoamento mensal	dam³	12	01/10/2004	01/09/2005
	RIBAFEITA (09J/02H)	Upstream dam (Map 3, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	4	16/05/1983	29/01/1988
			Caudal médio diário	m³/s	2891	01/10/1981	30/09/1989
			Escoamento Anual	dam³	5	01/10/1981	01/10/1987
			Escoamento mensal	dam³	92	01/10/1981	01/09/1989
			Nível médio diário	m	2174	01/10/1982	30/09/1988

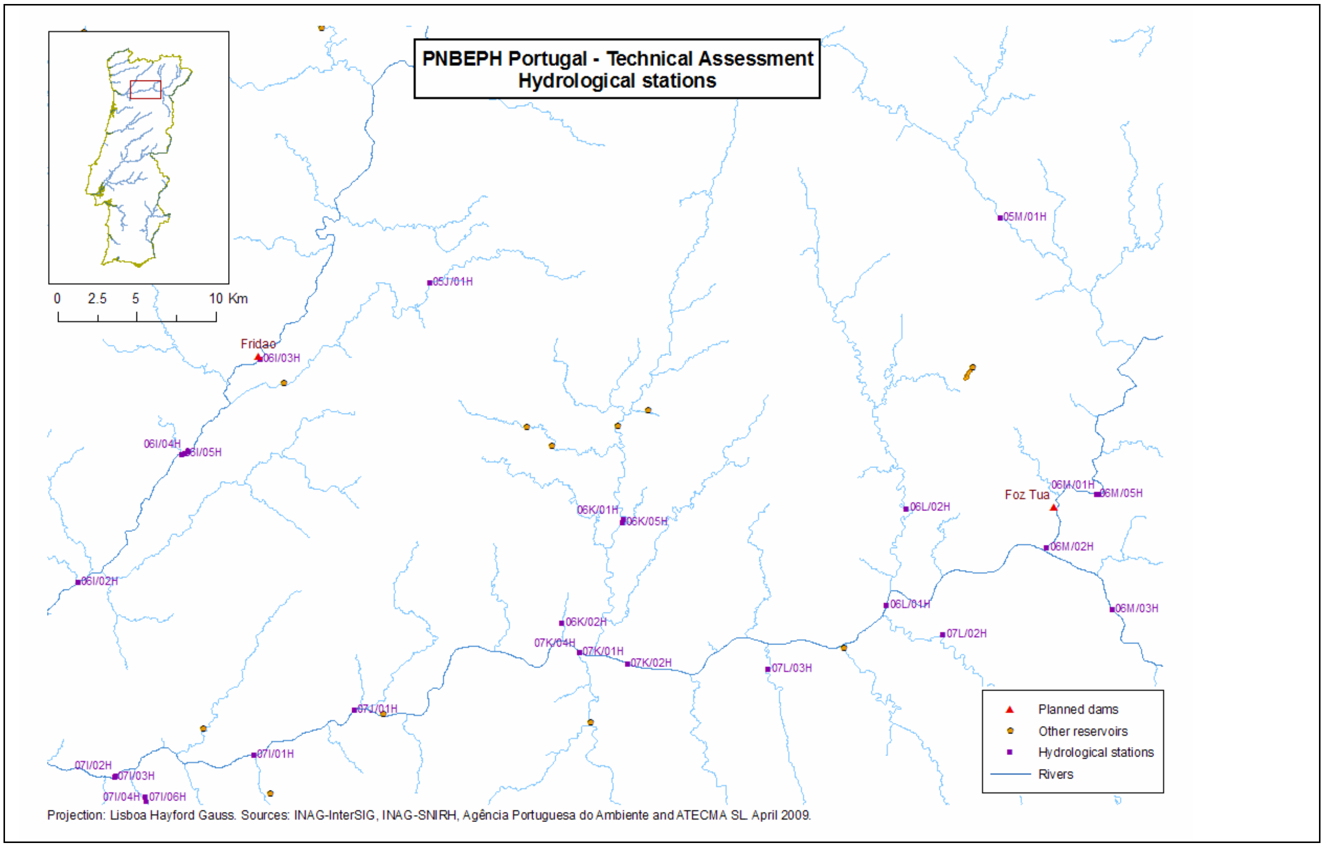
Dam (river)	Station	Location	Info availabe	Unit	Number of values	Data Start	Data End
Girabolhos (Mondego)	NELAS (INAG) (10K/08H)	About 7,5 km downstream dam (Map 3, **Annex 5**)	Nível hidrométrico Instantâneo	m	57467	10/12/2001	03/07/2008
			Nível instantâneo máximo anual	m	3	02/01/2003	04/11/2004
	NELAS (10K/03H)	About 7,5 km downstream dam (Map 3, **Annex 5**)	Caudal instantâneo máximo anual	m³/s	23	10/03/1975	31/10/2003
			Caudal médio diário	m³/s	10956	01/10/1974	30/09/2004
			Escoamento Anual	dam³	30	01/10/1974	01/10/2003
			Escoamento mensal	dam³	360	01/10/1974	01/09/2004
			Nível médio diário	m	2920	01/10/1982	30/09/1990
Alvito (Tejo)	FOZ DO COBRÃO (15K/02H)	About 1,5 km downstream dam (Map 4, **Annex 5**)	Caudal médio diário	m³/s	365	01/10/2004	30/09/2005
			Escoamento Anual	dam³	1	01/10/2004	01/10/2004
			Escoamento mensal	dam³	12	01/10/2004	01/09/2005
	ALMOURÃO (15K/01H)	About 0,8 km up-stream dam (Map 4, **Annex 5**)	Caudal médio diário	m³/s	8784	01/10/1941	30/09/1967
			Escoamento Anual	dam³	23	01/10/1941	01/10/1966
			Escoamento mensal	dam³	289	01/10/1941	01/09/1967
			Nível hidrométrico Instantâneo	m	2156	23/01/2002	23/04/2002
Almourol (Tejo)	ALMOUROL (17G/02H)	About 0,7 km up-stream dam (Map 4, **Annex 5**)	Caudal instantâneo	m³/s	222083	01/06/2001	05/04/2009
			Caudal instantâneo máximo anual	m³/s	27	05/03/1975	10/12/2003
			Caudal médio diário	m³/s	12560	02/10/1973	05/04/2009
			Escoamento Anual	dam³	27	01/10/1974	01/10/2007
			Escoamento mensal	dam³	400	01/10/1973	01/03/2009
			Nível hidrométrico Instantâneo	m	235042	01/06/2001	05/04/2009
			Nível instantâneo máximo anual	m	22	05/03/1975	10/12/2003
			Nível médio diário	m	8229	01/10/1978	31/05/2008
	TANCOS (17G/04H)	Downstream (Map 4, **Annex 5**)	Inactive station; no data on the website. Operating from 01/10/1911 to 30/09/1979				

Annex 5: Maps – Location of Hydrometric stations and hydropower installations

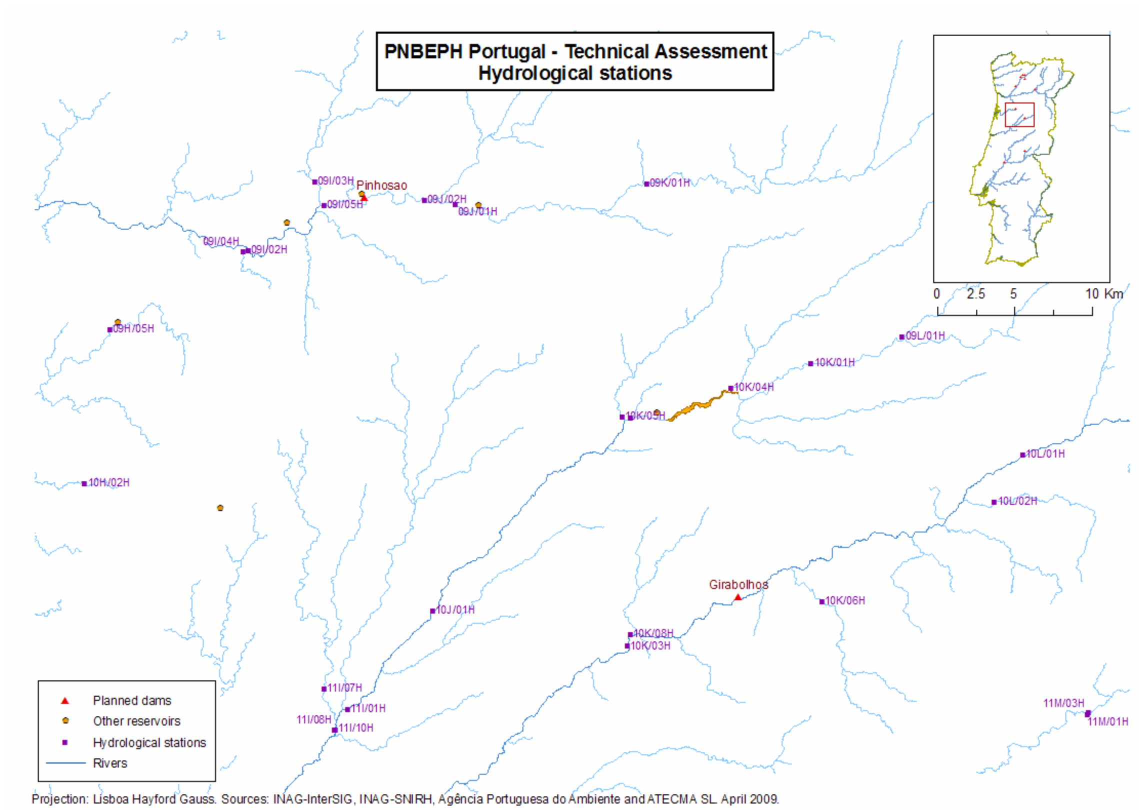
Map 1



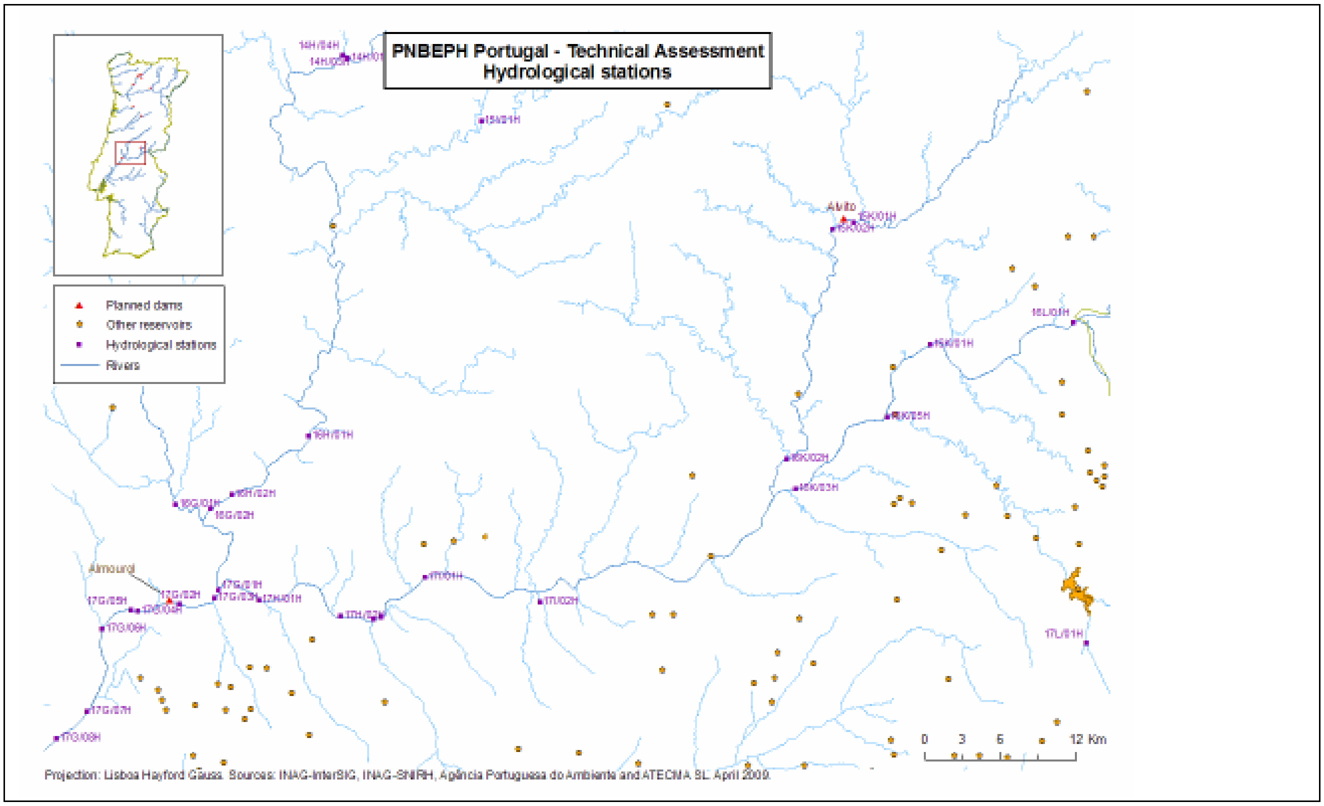
Map 2: Hydrometric stations and dams



Map 3: Hydrometric stations and dams



Map 4: Hydrometric stations and dams



Annex 6: Flow data used to estimate energy production for the Pinhosão hydro-power installation

SNIRH - SISTEMA NACIONAL DE INFORMAÇÃO DE RECURSOS HÍDRICOS

Relatório do parâmetro Escoamento mensal (dam3) em Vouzela

Ano Hid.	OUT	NOV	DEZ	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	N. Valores
1917/18	5398	5162	4740	23041	5357	5956	38143	7182	3407	3790	3244	4723	12
1918/19	3939	22057	13040	58737					4376	3408	3313	3975	8
1919/20	5282	14729	16629	43926	11016	26965	67892	22806	9933	4436	3719	3945	12
1920/21	15148	15411	31025	31042	30825	7385	4123	5123	2952	3296	2309	3148	12
1921/22	5014	6126	13059	96531	40008	63400	78034	14632	8713	3221	3853	4990	12
1922/23	21520	32064	43288	34661	91932	54322	49021	18748	5367	4152	3453	3745	12
1923/24	8114	38892	28924	62716	116647	142366	60790	19599	6078	3390	3368	6619	12
1924/25	4152	18160	64732	39694	49711	42796	37094	20717	14799	9655	1940	2315	12
1925/26	6402	40011	223918	66480	189994	59461	65342	24311	5474	2245	2421	3273	12
1926/27	8730	105853	27779	44492	72547	104229	33467	30935	5576	3259	3534	3993	12
1927/28	6087	8117	61373	40339				52215	26624	3967	3381	4076	9
1928/29	5067	6426	9948	8455	59927	34107	7136	5812	4071	4241	3167	3858	12
1929/30	5432	26874	108810	89952	81969	81586	81192	25114	6968	2844	2470	3217	12
1930/31	14518	4201	8921	68182	7265	67999	30377	21946	12222	2830	4840	4524	12
1931/32	7690	51888	6521	24284	6031	13147	12812	14060	5150	3406	4071	15293	12
1932/33	7176	7374	72955	57713	23400	87398	16588	11089	3712	4912	3288	3700	12
1933/34	5480	5685	12563	27396	5371	79688	62220	15451	4345	4296	4938	4609	12
1934/35	5429	5678		23243	31450	40261	7839	7022	4456	1983	2994	2514	11
1935/36	2598	28216	155314	269643	190727	166747	120164	26803	6769	4450	3803	3300	12
1936/37	5011	4978	6750	112096	135328	194028	81034	24462	5132	3884	3803	5282	12
1937/38	11164	56776	132093	53279	12764	7539	4349	7534		2986	3803	3681	11
1938/39	4985	10698	51386	234656	86747	45690	88093	41062	19246	3996	4003	9541	12
1939/40	58088	45201	40480	141445	166656	124905	55105	54385	24756	5920	3803	3681	12
1940/41	13732	88673	30943	205208	245546	192478	89204	103962	40980	12519	6672	6195	12
1941/42	6401	48173	34818	24949	36776	141617	113334	125984	98160	18517	3803	3689	12
1942/43	7671	24730	60712	184940	92098	43182	50941	22994	5508	4917	3806	13364	12
1943/44	57651	21206	71227	23686	11688	23664	29859	9755	4749	3980	14011	6362	12
1944/45	5301	7236	32485	21896	22409	11220	4723	5603	3963	2711	2116	1749	12
1945/46	3179	11083	100425	27281	23101	60634	59597	66525	44637	8383	3980	4549	12
1946/47	7389	14926	38419	45486	197408	167460	92191	35332	8876	2758	3165	4050	12
1947/48	3930	4433	27237	175249	50678	26910	20205	20691	7918	2597	2012	1764	12
1948/49	4355	3690	18287	18687	5250	4793	3664	3593	2949	3105	1305	1833	12
1949/50	3491	8921	9730	5835	49458	27104	9859	16991	9495	3986	2149	2048	12
1950/51	4586	11394	11338	34205	115805	207305	28549	24007	14850	4540	2609	4361	12
1951/52	5402	57286	16800	16650	10335	28293	38677	50022	9732	5027	4453	4454	12
1952/53	5042	26085	73137	29700	14698	9006	9977	7862	3889	3099	1366	2551	12
1953/54	8948	13163	26718	8541	23977	83494	29534	32847		4759	3235	2333	11
1954/55	3952	18413	41593				34746						4
1955/56												8330	1
1956/57	9859	6195	11661	22461	65229	49091	25980	28502	10136	5784	3014	2278	12
1957/58	2862	12423	18518	30838	63984	79465	109192	19292	17052	7590	4393	3209	12
1958/59	13722	4586	88672	79834	29627	76124	93246	49404	17004	4670	3803	13425	12
1959/60	8310	74371	242971	128197	265280	259104	63603	52786	31770	4227	4794	6771	12
1960/61	135042	224875	94433	92119	61602	47820	44867	34501	12873	10430	3844	3504	12
1961/62	3938	17360	58114	146659	38645	91687	69967	19271	5365	1942	1259	1168	12
1962/63	1278	1322	1381	64140	248682	110580	77509	28247	31638	6076	4550	5138	12
1963/64	5809	180450	125889	40602	116262	145515	56157	21247	24348	7725	4692	4602	12
1964/65	7296	6013	6161	23438	27658	75551	23633	12652	6255	3808	2888	10470	12
1965/66	21993	108437	103637	206750	257152	69237	126994	38987	20068	5709	3753	4327	12
1966/67	55574	40752	36187	52190	86945	61749	29012	40219	13801	5562	4723	3790	12
1967/68	5590	13003	7821	7332	71061	38981	47479	56655	12379	5067	3905	5514	12
1968/69	6206	52920	89646	107595	110964	191761	53864	64085	30473	7423	4518	6612	12
1969/70	7046	17906	19142	201861	64498	25782	13000	29699	13097	3880	4318	4032	12
1970/71	3790	10397	10492	65030	34658	40733	48239	45074	52376	20517	7916	5333	12
1971/72	5573	5521	6324	31831	144651	61910	24218	16813	7847	5721	3045	4533	12
1972/73	7246	18204	53804	102171	34981	20072	11120	52633	20433	6941	4596	4728	12
1973/74	9121	11489	17374	129844	113988	38690	22799	26103	35041	20793	6210	4487	12
1974/75	4601	23026	13043	28452		87746	26342	18103	8226	3997	2691	2821	11
1975/76	6591	7198	9825	8531	18220	14408	9056	6312	3706	2852	1903	3192	12
1976/77	32190	66925	78710	138574	207723	84727	51131	24410	16446	5981	4056	2431	12
1977/78	10108	10978	101557	59681	180138	120886	47062	57686	18875	5198	2239	1469	12
1978/79	2119	3779	151786	103234	269932	109058	96269	31525	14988	5738	2023	1446	12
1979/80						41078			10300	3635	1836	1827	5
1980/81	2945	8308	7130	6091	6547	13724	27279	31400	9520	2616	1267	1170	12
1981/82	7507	2844	78832	68974	26660	18458	12413	7546	4801	2160	1285	1817	12
1982/83	4959	13614	28739	16307	29777	15924	50446	91027	25249	6231	4482	1905	12
1983/84	4037	16496	70219	45313	35110	40112	53421	35903	28298	-	-	2508	10
1984/85	11755	91804	76213	85399	136867	56973	59265	22249	21820	5952	2905	2892	12
1985/86	3289	8885	40674	68990	105720	63736	33132	23161	6826	3043	2112	3269	12
1986/87	2645	4623			46139	25207	43410	10702	4737	1728	1106	3364	10
1987/88	41068	29195	68319	106900	95283	28507	30977	52543	30607	40629	6071	4257	12
1988/89	6571	7972	7311	6393	15924	21348	28229	13022	6578	1599	547	1527	12
1989/90	2309	36411			71773	26551	17440	11299	4257	2103	1056	791	10
1990/91	15093	26222	22155	69538	57984	133350	31889	13074	6134	2618	1219	1505	12
1991/92	3073	12717	12011	19453	8419	7349	29376	6168	5906	1961	975	1373	12
1992/93	4109	8117	38661	20121	12755	9098	15052	28188	21074	5265	1782	7481	12
1993/94	-	51497	40338	131014	64405	51423	31672	75112	31626	6172	1906	1585	11
1994/95	4245	22564	19718	66844	100392	34805	10331	8048	3708	1822	543	1901	12
1995/96	2998	14501	123454		85431	45117	48278	45785	12049	4332	2193	3370	11
1996/97	4810	13006	73530	94998	33984	16947	10311	12619	21610	6009	2868	2456	12
1997/98	9333	109169	155462	105057	39822	18246	78003	36489	38890	7855	3097	5614	12
1998/99	7839	9490	8831	-	11629	21419	-	-	-	-	-	-	5
1999/00	33675	-	49166	-	18362	15190	84135	55490	10937	2429	658	445	10
2000/01	780	32576	227725	289659	-	233398	55501	20808	2450	1502	1340	1229	11
2001/02	4062	-	986	7389	5866	16074	3142	2267	1093	321	88	385	11
2002/03	5147	49056	-	-	34373	36934	16999	5400	1204	-	-	-	7
2003/04	-	-	-	10189	11980	5217	3669	1954	469	105	149	-	8
2004/05	13668	4461	3439	1428	-	-	2921	1305	245	-	-	37	8
2005/06	737	1389	8264	3063	8279	37016	15499	2460	675	212	93	227	12
2006/07	26128	-	-	6392	46269	24659	4371	2816	2370	614	188	-	9
2007/08	-	-	286	3586	1277	890	47867	4104	1662	-	-	-	7

Data (dam³) derived for the site of the hydropower installation

Ano Hid.	OUT	NOV	DEZ	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	N. Valores	Min.	Máx.	Soma Anual	Média Anual
																	31536000
41/42	3.959	29.795	21.535	15.431	22.746	87.591	70.098	77.922	60.712	11.453	2.352	2.282	12	2282	87591	405876	33823
42/43	4.745	15.296	37.551	114.386	56.963	26.708	31.507	14.222	3.407	3.041	2.354	8.266	12	2354	114386	318446	26537
43/44	35.657	13.116	44.054	14.650	7.229	14.636	18.468	6.034	2.937	2.462	8.666	3.935	12	2462	44054	171844	14320
44/45	3.279	4.476	20.092	13.543	13.860	6.940	2.921	3.465	2.451	1.677	1.309	1.082	12	1082	20092	75095	6258
45/46	1.966	6.855	62.113	16.873	14.288	37.502	36.861	41.146	27.608	5.185	2.462	2.814	12	1966	62113	255673	21306
46/47	4.570	9.232	23.762	28.133	122.098	103.575	57.021	21.853	5.490	1.706	1.958	2.505	12	1706	122098	381903	31825
47/48	2.431	2.742	16.846	108.392	31.345	16.644	12.497	12.797	4.897	1.606	1.244	1.091	12	1091	108392	212532	17711
48/49	2.694	2.282	11.311	11.558	3.247	2.964	2.266	2.222	1.824	1.920	807	1.134	12	807	11558	44229	3686
49/50	2.159	5.518	6.018	3.609	30.590	16.764	6.098	10.509	5.873	2.465	1.329	1.267	12	1267	30590	92199	7683
50/51	2.836	7.047	7.013	21.156	71.626	128.219	17.658	14.848	9.185	2.808	1.614	2.697	12	1614	128219	286707	23892
51/52	3.341	35.432	10.391	10.298	6.392	17.499	23.922	30.939	6.019	3.109	2.754	2.755	12	2754	35432	152851	12738
52/53	3.119	16.134	45.236	18.370	9.091	5.570	6.171	4.863	2.405	1.917	845	1.578	12	845	45236	115299	9608
53/54	5.534	8.141	16.525	5.283	14.830	51.641	18.267	20.316	4.607	2.943	2.001	1.443	12	1443	51641	151531	12628
54/55	2.444	11.389	25.725	94.114	69.905	29.652	21.491	19.849	5.487	3.419	2.401	2.796	12	2401	94114	288672	24056
55/56	660	10.337	45.956	37.793	15.337	67.271	46.248	23.491	11.849	3.596	2.269	5.152	12	660	67271	269959	22497
56/57	6.098	3.832	7.212	13.892	40.344	30.363	16.069	17.629	6.269	3.577	1.864	1.409	12	1409	40344	148558	12380
57/58	1.770	7.684	11.453	19.073	39.574	49.150	67.536	11.932	10.547	4.694	2.717	1.985	12	1770	67536	228115	19010
58/59	8.487	2.836	54.844	49.378	18.324	47.083	57.673	30.557	10.517	2.888	2.352	8.303	12	2352	57673	293242	24437
59/60	5.140	45.999	150.279	79.291	164.077	160.257	39.339	32.648	19.650	2.614	2.965	4.188	12	2614	164077	706447	58871
60/61	83.524	139.086	58.407	56.976	38.101	29.577	27.750	21.339	7.962	6.451	2.378	2.167	12	2167	139086	473718	39477
61/62	2.436	10.737	35.944	90.709	23.902	56.709	43.275	11.919	3.318	1.201	779	722	12	722	90709	281651	23471
62/63	790	818	854	39.671	153.811	68.394	47.940	17.471	19.568	3.758	2.814	3.178	12	790	153811	359067	29922
63/64	3.593	111.609	77.863	25.113	71.909	90.002	34.733	13.141	15.059	4.778	2.902	2.846	12	2846	111609	453548	37796
64/65	4.513	3.719	3.811	14.497	17.107	46.729	14.617	7.825	3.869	2.355	1.786	6.476	12	1786	46729	127304	10609
65/66	13.603	67.069	64.100	127.876	159.050	42.823	78.546	24.114	12.412	3.531	2.321	2.676	12	2321	159050	598121	49843
66/67	34.373	25.205	22.382	32.280	53.776	38.192	17.944	24.876	8.536	3.440	2.921	2.344	12	2344	53776	266269	22189
67/68	3.457	8.042	4.837	4.535	43.952	24.110	29.366	35.041	7.656	3.134	2.415	3.410	12	2415	43952	169955	14163
68/69	3.838	32.731	55.447	66.548	68.632	118.605	33.315	39.637	18.848	4.591	2.794	4.090	12	2794	118605	449076	37423
69/70	4.358	11.075	11.839	124.852	39.892	15.946	8.041	18.369	8.101	2.400	2.671	2.494	12	2400	124852	250038	20837
70/71	2.344	6.431	6.489	40.221	21.436	25.194	29.836	27.879	32.395	12.690	4.896	3.298	12	2344	40221	213109	17759
71/72	3.447	3.415	3.911	19.688	89.467	38.292	14.979	10.399	4.853	3.538	1.883	2.804	12	1883	89467	196676	16390
72/73	4.482	11.259	33.278	63.193	21.636	12.415	6.878	32.554	12.638	4.293	2.843	2.924	12	2843	63193	208393	17366
73/74	5.641	7.106	10.746	80.309	70.502	23.930	14.101	16.145	21.673	12.861	3.841	2.775	12	2775	80309	269630	22469
74/75	2.846	14.242	8.067	17.598	37.873	54.271	16.293	11.197	5.088	2.472	1.664	1.745	12	1664	54271	173356	14446
75/76	4.077	4.452	6.077	5.276	11.269	8.911	5.601	3.904	2.292	1.764	1.177	1.974	12	1177	11269	56774	4731
76/77	19.910	41.393	48.683	85.709	128.478	52.404	31.625	15.098	10.172	3.699	2.509	1.504	12	1504	128478	441184	36765
77/78	6.252	6.790	62.814	36.913	111.416	74.769	29.108	35.679	11.674	3.215	1.385	909	12	909	111416	380924	31744
78/79	1.311	2.337	93.880	63.851	166.954	67.453	59.543	19.498	9.270	3.549	1.251	894	12	894	166954	489791	40816
79/80	15.858	19.120	29.183	36.065	32.162	25.407	21.501	25.511	6.371	2.248	1.136	1.130	12	1130	36065	215692	17974
80/81	1.821	5.139	4.410	3.767	4.049	8.488	16.872	19.421	5.888	1.618	784	724	12	724	19421	72981	6082
81/82	4.643	1.759	48.758	42.661	16.489	11.416	7.678	4.667	2.969	1.336	795	1.124	12	795	48758	144295	12025
82/83	3.067	8.420	17.775	10.086	18.417	9.849	31.201	56.301	15.617	3.854	2.772	1.178	12	1178	56301	178537	14878
83/84	2.497	10.203	43.431	28.026	21.716	24.809	33.041	22.206	17.502	2.021	331	1.551	12	331	43431	207334	17278
84/85	7.271	56.781	47.138	52.820	84.653	35.238	36.656	13.761	13.496	3.681	1.797	1.789	12	1789	84653	355081	29590
85/86	2.034	5.495	25.157	42.671	65.388	39.421	20.492	14.325	4.222	1.882	1.306	2.022	12	1306	65388	224415	18701
86/87	1.636	2.859	6.611	9.822	28.537	15.591	26.849	6.619	2.930	1.069	684	2.081	12	684	28537	105288	8774
87/88	25.401	18.057	42.256	66.118	58.933	17.632	19.159	32.498	18.931	25.129	3.755	2.633	12	2633	66118	330502	27542
88/89	4.064	4.931	4.522	3.954	9.849	13.204	17.460	8.054	4.069	989	338	944	12	338	17460	72378	6032
89/90	1.428	22.520	77.555	24.844	44.392	16.422	10.787	6.988	2.633	1.301	653	489	12	489	77555	210012	17501
90/91	9.570	16.195	31.441	43.089	36.111	82.708	19.732	8.055	3.864	1.681	794	1.110	12			254350	21196
1991/92	1.897	7.850	7.414	12.008	5.197	4.536	18.133	3.807	3.646	1.210	602	848	12			67149	5596
1992/93	2.536	5.010	23.865	12.420	7.873	5.616	9.291	17.400	13.009	3.250	1.100	4.618	12			105990	8832
1993/94		31.788	24.900	80.873	39.756	31.743	19.551	46.365	19.522	3.810	1.177	978	11				27315
1994/95	2.620	13.928	12.172	41.262	61.970	21.485	6.377	4.968	2.289	1.125	335	1.173	12			169704	14142
1995/96	1.851	8.951	76.206	0	52.735	27.850	29.801	28.262	7.438	2.674	1.354	2.080	12			239202	19934
1996/97	2.969	8.028	45.389	58.641	20.978	10.461	6.365	7.790	13.340	3.709	1.770	1.516	12			180956	15080
1997/98	5.761	67.388	95.964	64.850	24.581	11.263	48.150	22.524	24.006	4.849	1.912	3.465	12			374714	31226
1998/99	4.839	5.858	5.451		7.178	13.222							5				7310
1999/00	20.787		30.349		11.335	9.377	51.935	34.253	6.751	1.499	406	275	10				16697
2000/01	481	20.109	140.571	178.802		144.073	34.260	12.844	1.512	927	827	759	11				48651
2001/02	2.507		609	4.561	3.621	9.922	1.940	1.399	675	198	54	238	11				2339
2002/03	3.177	30.281			21.218	22.799	10.493	3.333	743				7				13149
2003/04				6.290	7.395	3.220	2.265	1.206	290	65	92		8				2603
2004/05	8.437	2.754	2.123	881			1.803	806	151			23	8				2122
2005/06	455	857	5.101	1.891	5.110	22.849	9.567	1.519	417	131	57	140	12			48095	4008
2006/07	16.128			3.946	28.561	15.222	2.698	1.738	1.463	379	116		9				7806
2007/08			177	2.214	788	549	29.548	2.533	1.026				7				

Annex 7: Conclusions from SIAM project – Executive Summary

(Santos et al 2002)

Impacts of climate change on water resources

The main impacts of climate in water resources are as follows (Figure 5):

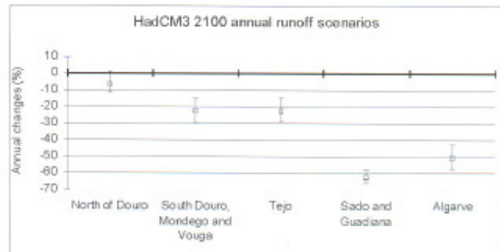
- The present simulations indicate a progressive reduction in river runoff during the 21st century. This reduction may be small in the northern region but becomes increasingly severe in more southerly latitudes. Furthermore, there seems to be a systematic trend towards a concentration of the river runoff in winter induced by a similar pattern of change in the monthly precipitation distribution.

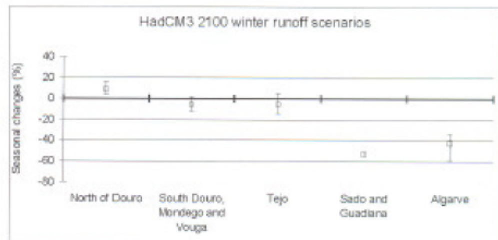
- The comparison of the simulations using the HadRM2 and HadCM3 climate scenarios shows that the former leads to a wider range of runoff change predictions due to larger anomalies in precipitation and temperature, namely a strong increase in winter precipitation and a strong decrease in the rest of the year.

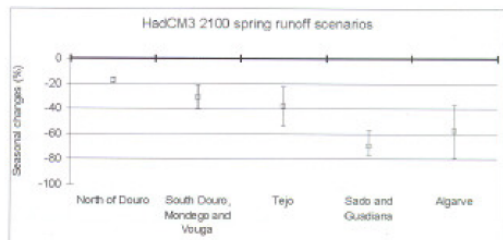
- By 2100, the annual mean runoff north of river Douro is estimated to change between +5% and –10% according to the HadCM3 model and increase about 10% according to the HadRM2 model.

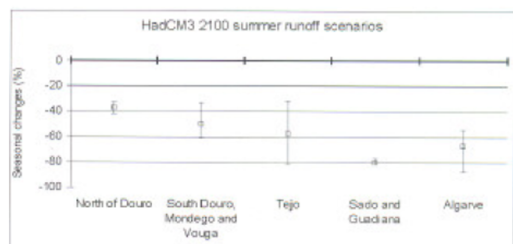
- By 2100, the annual mean runoff in the Vouga and Mondego basins may be reduced by 15% to 30% according to HadCM3. HadRM2 estimates are uncertain about the direction of change.

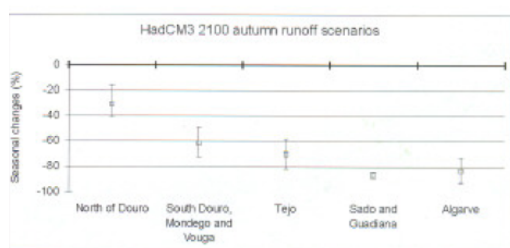
- By 2100, the annual mean runoff reduction in the Tejo river basins is estimated to be 10% to 30%, according to the HadCM3 climate scenario. Such reductions imply long periods with low river flows, which are likely to have a strong impact in water availability, particularly for irrigation activities. HadRM2 estimates predict an increase in annual runoff due to a strong increase in winter precipitation.











Annex 8: Calculated energy production for the different scenarios

GWh/year		1941-1991 Minimum flow			1981(82)-2006 (07) Minimum flow			2050 Minimum flow		
	PNBEPH	3%	good	fair	3%	good	fair	3%	good	fair
Foz Tua (Douro)	340	335	221	277	301	200	249	240	160	199
Padroselos (Douro)	102	98	65	81	81	53	67	64	42	53
Alto Tamega (Douro)	114	110	73	91	98	64	81	77	51	64
Daivoes (Douro)	148	143	94	118	127	83	105	101	66	83
Fridao (Douro)	299	290	191	239	256	168	211	203	134	168
Gouvaes (Doruo)	153	147	96	121	136	89	112	108	71	89
Pinhosao (Vougo-Mondego)	106	104	69	86	78	52	64	62	41	51
Girabolhos (Vougo-Mondego)	99	100	68	83	69	46	57	55	37	59
Almourol (Tejo)	209	194	133	163	181	126	152	145	101	122
Alvito (Tejo)	62	58	39	48	54	37	45	43	30	36
	1632	1579	1050	1308	1380	919	1143	1098	734	925
		97%	64%	80%	85%	56%	70%	67%	45%	57%

		1941-1991 Minimum flow			1981(82)-2006 (07) Minimum flow			2050 Minimum flow		
	PNBEPH	3%	good	fair	3%	good	fair	3%	good	fair
Foz Tua (Douro)		99%	65%	81%	89%	59%	73%	71%	47%	59%
Padroselos (Douro)		96%	64%	79%	79%	52%	66%	63%	41%	52%
Alto Tamega (Douro)										
Daivoes (Douro)										
Fridao (Douro)										
Gouvaes (Doruo)		96%	63%	79%	89%	58%	73%	71%	46%	58%
Pinhosao (Vougo-Mondego)		98%	65%	81%	74%	49%	60%	58%	39%	48%
Girabolhos (Vougo-Mondego)		101%	69%	84%	70%	46%	58%	56%	37%	60%
Almourol (Tejo)		93%	64%	78%	87%	60%	73%	69%	48%	58%
Alvito (Tejo)										
	mean Douro	97%	64%	80%	86%	56%	71%	68%	45%	56%
	mean VM	98%	65%	81%	70%	46%	58%	56%	37%	48%
	Tejo (Almour	93%	64%	78%	87%	60%	73%	69%	48%	58%
	mean	97%	65%	80%	81%	54%	67%	65%	43%	56%

Annex 9: Tool to define the Internal Rate of Return

Inputdata

Investment costs (M €)		
	Equipment	30,7
	Civil engineering work	71,2
	Total	101,9
One-off maintenance cost (M €)		5,3
Yearly operational costs (M €/year)		1,02
Yearly revenues (M €/year)		9,44
Discount rate		6%

year	GWh	ontvangsten (eruo)	Euro/GWH
		1000000	
Girabolhos	99	9,44	0,0954
	99		

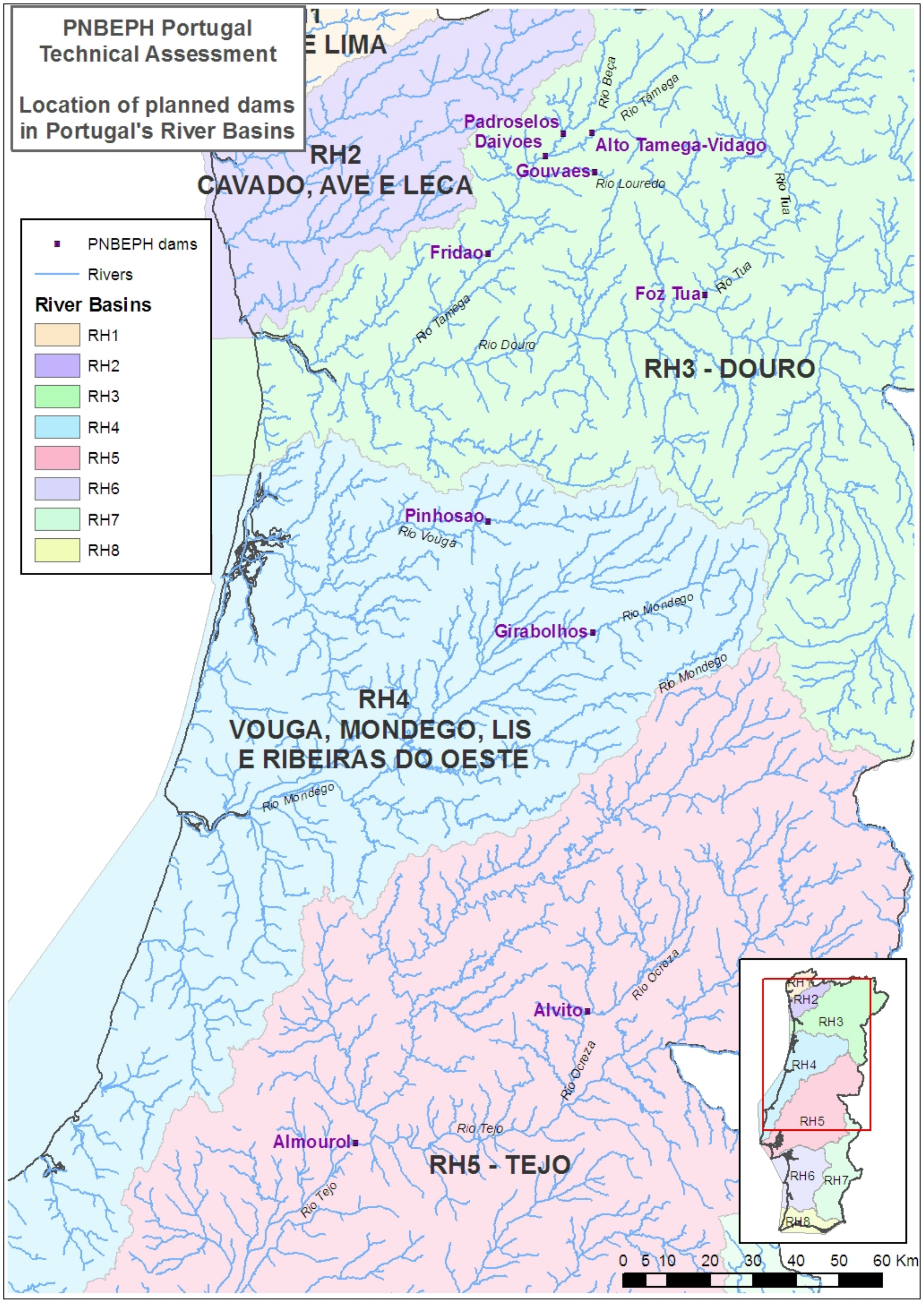
Year	1	2	3	4	5	6	7	8	9	10	23	24	40	41	42	43
Cash Flows																
Investment costs (M €)	20,38	30,57	30,57	20,38												
One-off maintenance cost (M €)											5,3					
Residual value investment at the end of the project horizon (M €)																35,6
Yearly operational costs (M €/year)				0,51	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02	1,02
Yearly revenues (M €/year)				4,72	9,44	9,44	9,44	9,44	9,44	9,44	9,44	9,44	9,44	9,44	9,44	9,44
Net Cash Flow (M €)	-20,38	-30,57	-30,57	-16,17	8,42	8,42	8,42	8,42	8,42	8,42	3,12	8,42	8,42	8,42	8,42	44,02
Discount rate	1	1,06	1,1236	1,191016	1,262477	1,338226	1,418519	1,50363	1,593848	1,689479	3,603537	3,81975	9,703507	10,28572	10,90286	11,55703
Net Present Value per year (M €)	-20,38	-28,8396	-27,2072	-13,5766	6,669429	6,291914	5,935768	5,599781	5,282812	4,983785	0,865816	2,204333	0,867727	0,818611	0,772274	3,808936

Results

Net Present Value (M €)	17,29
IRR (%)	7,27%

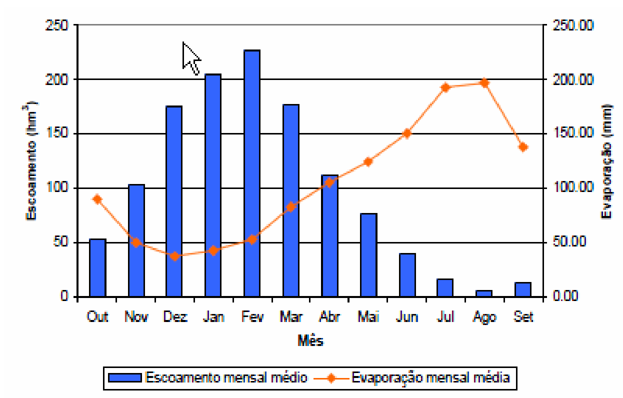
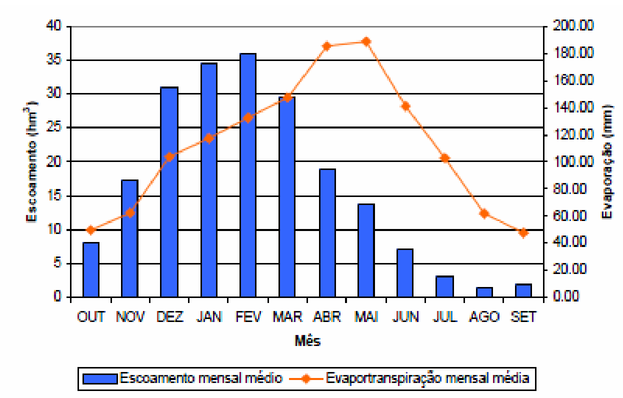
Task 2: Assessment of impacts of the PNBEPH

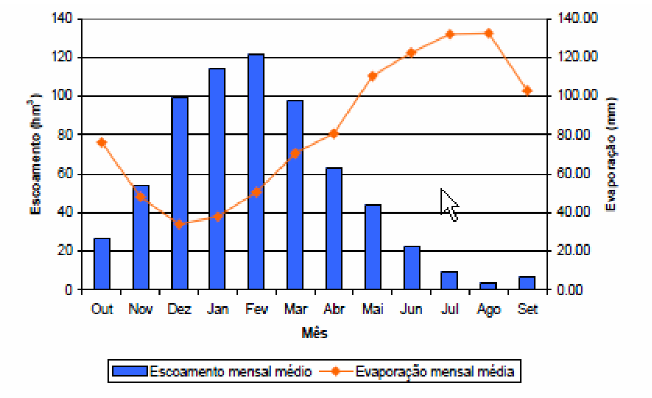
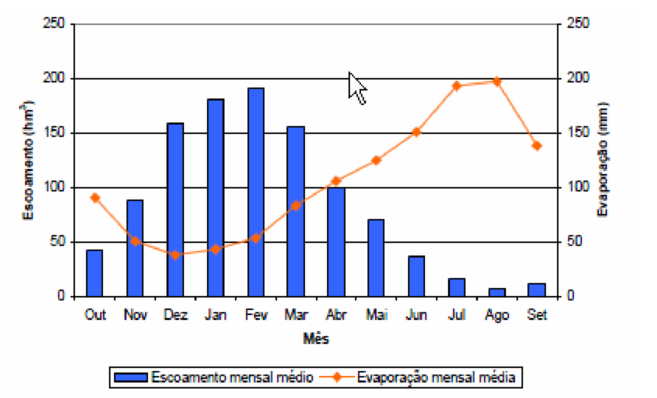
Annex 10: Location of planned dams in portugal's river basins

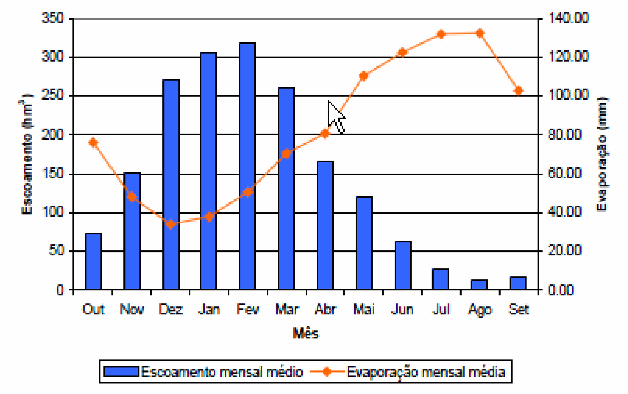
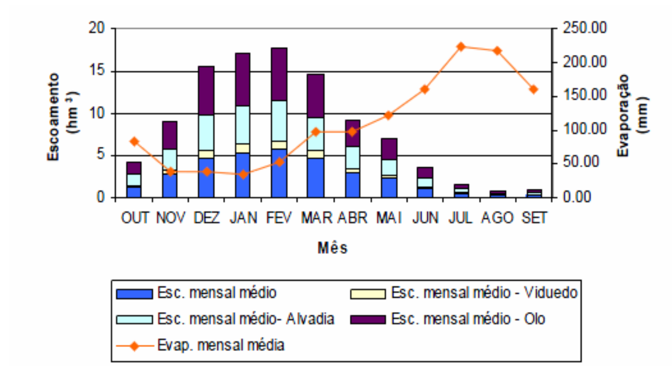


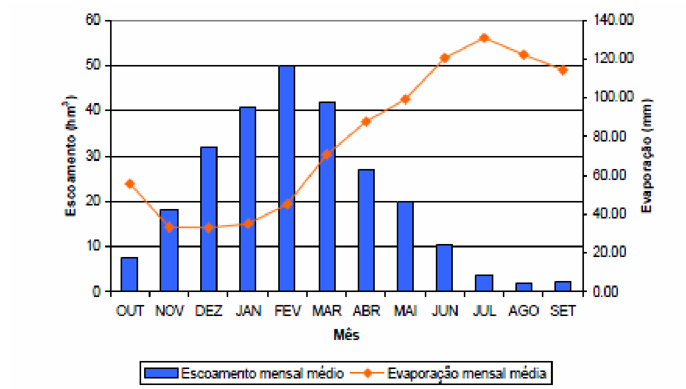
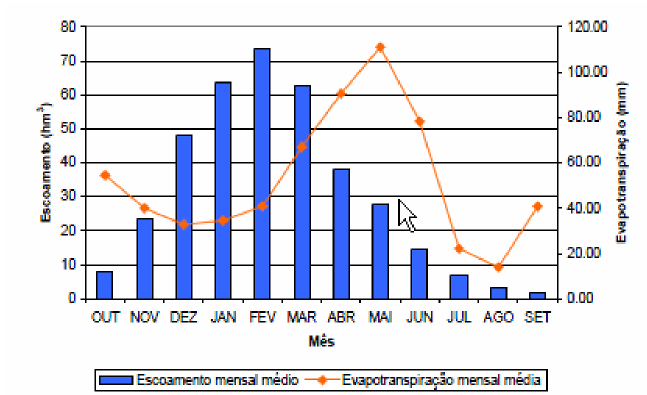
shp files: ART13_MDRENA_PTCONT_4_445, ART13_REGHID_PTCONT_0_282. Sources: INAG-InterSIG and ATECMA SL. July 2009.

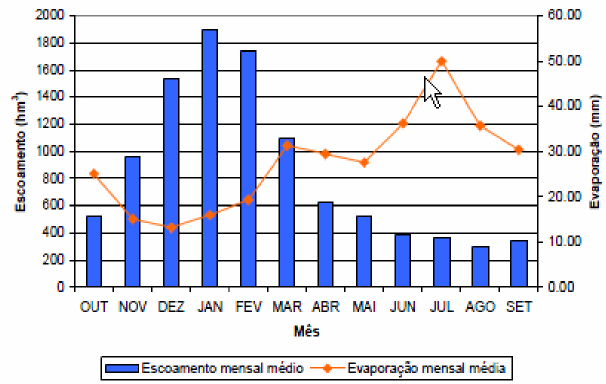
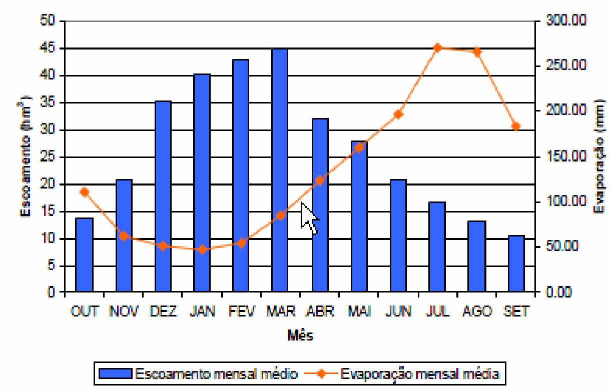
Annex 11: Planned dams PNBEPH

Name of dam	River	Tribu-tary of	River Ba-sin	River flow	River stretch-length, Reservoir area	Capacity of the lenght - curve flow	Nominal flow	Power station
Foz Tua	Tua	Douro	Douro river	1207 hm3/yr	310 hm3, **51 km**, 1100 ha		220 m3/sec	Underground, 234 MW
Padroselos	Beça / Tâmega (according to WFD reports)	Tâmega	Douro river	203 hm3/yr	147 hm3, **10 km**, 510 ha		60 m3/sec	Underground, 113 MW

Name of dam	River	Tributary of	River Basin	River flow	River stretch-length, Reservoir area	Capacity of the lenght - curve flow	Nominal flow	Power station
Alto Tâmega (Vidago)	Tâmega	Douro	Douro river	664 hm3/yr	96 hm3, **28 km**, 350 ha		130 m3/sec	Underground, 90 MW
Daivões	Tâmega	Douro	Douro river	1090 hm3/yr	66 hm3, **19 km**, 370 ha		180 m3/sec	Underground, 109 MW

Name of dam	River	Tribu-tary of	River Ba-sin	River flow	River stretch-length, Reservoir area	Capacity of the lenght - curve flow	Nominal flow	Power station
Fridão	Tâmega	Douro	Douro river	1790 hm3/yr	195 hm3, **40 km**, 800 ha		240 m3/sec	At the foot of the dam, 163 MW
Gouvães	Torno	Tâmega	Douro river	101 hm3/yr*	12,7 hm3, **3,7 km**, 160 ha		20 m3/sec	Underground, 112 MW

Name of dam	River	Tribu-tary of	River Ba-sin	River flow	River stretch-length, Reservoir area	Capacity of the lenght - curve flow	Nominal flow	Power station
Pinhosão	Vouga	x	Vouga-Mondego	257 hm3/yr	68 hm3, **8 km**, 250 ha		50 m3/sec	Underground, 77 MW
Girabolhos	Mondego	x	Vouga-Mondego	372 hm3/yr	143 hm3, **21 km**, 520 ha		70 m3/sec	Underground, 72 MW

Name of dam	River	Tributary of	River Basin	River flow	River stretch-length, Reservoir area	Capacity of the lenght - curve flow	Nominal flow	Power station
Almourol	Tejo	x	Tejo river	11300 hm3/yr	20 hm3, **36 km**, 1340 ha		720 m3/sec	At the foot of the dam, 78 MW
Alvito	Ocreza	Tejo	Tejo river	318 hm3/yr	209 hm3, **38 km**, 1100 ha		65 m3/sec	Underground, 48 MW

Annex 12: Monitoring stations for which data were requested from the Portuguese authorities

ID	DIST_CD	EU_CD	WB_LOCATIO	SURVEIL	OPERAT	CATEGORY
38674	PTRH3	PT02M50	PT03DOU0152	N	Y	RW
38676	PTRH3	PT02P02	PT03DOU0180	Y	N	RW
38677	PTRH3	PT02P50	PT03DOU0148	Y	N	RW
38679	PTRH3	PT03K50	PT03DOU0184	N	Y	RW
38680	PTRH3	PT03L50	PT03DOU0185	N	Y	RW
38681	PTRH3	PT03M05H	PT03DOU0159	N	Y	RW
38682	PTRH3	PT03N50	PT03DOU0202	Y	N	RW
38683	PTRH3	PT03O50	PT03DOU0181	Y	N	RW
38684	PTRH3	PT03O51	PT03DOU0187	Y	N	RW
38685	PTRH3	PT03O53	PT03DOU0180	Y	N	RW
38686	PTRH3	PT03O54	PT03DOU0189	Y	N	RW
38689	PTRH3	PT04I54	PT03DOU0238	N	Y	RW
38690	PTRH3	PT04J09	PT03DOU0300	N	Y	RW
38691	PTRH3	PT04J51	PT03DOU0242	N	Y	RW
38692	PTRH3	PT04K50	PT03DOU0204	N	Y	RW
38693	PTRH3	PT04L01	PT03DOU0211	N	Y	RW
38694	PTRH3	PT04L02	PT03DOU0226	N	Y	RW
38695	PTRH3	PT04L03	PT03DOU0197	N	Y	RW
38696	PTRH3	PT04L50	PT03DOU0198	N	Y	RW
38697	PTRH3	PT04M51	PT03DOU0253	Y	N	RW
38698	PTRH3	PT04N01	PT03DOU0244	Y	N	RW
38699	PTRH3	PT04O50	PT03DOU0239	N	Y	RW
38708	PTRH3	PT05K52	PT03DOU0255	N	Y	RW
38711	PTRH3	PT05M50	PT03DOU0260	Y	N	RW
38712	PTRH3	PT05M51	PT03DOU0277	Y	N	RW
38713	PTRH3	PT05M53	PT03DOU0293	Y	N	RW
38714	PTRH3	PT05N03	PT03DOU0331	N	Y	RW
38722	PTRH3	PT06H01	PT03DOU0393	N	Y	LW
38725	PTRH3	PT06I06	PT03DOU0319	N	Y	RW
38726	PTRH3	PT06I51	PT03DOU0341	N	Y	RW
38729	PTRH3	PT06L50	PT03DOU0352	Y	N	RW
38731	PTRH3	PT06N50	PT03DOU0288	Y	N	RW
38739	PTRH3	PT07F06	PT03DOU0384	N	Y	RW
38740	PTRH3	PT07F07	PT03DOU0367	N	Y	RW
38741	PTRH3	PT07F08	PT03DOU0362	Y	N	RW
38742	PTRH3	PT07G04	PT03DOU0407	N	Y	LW
38743	PTRH3	PT07G09	PT03DOU0408	Y	N	RW
38745	PTRH3	PT07G52	PT03DOU0420	Y	N	RW
38746	PTRH3	PT07G53	PT03DOU0424	Y	N	RW
38748	PTRH3	PT07H06	PT03DOU0407	N	Y	LW
38749	PTRH3	PT07H50	PT03DOU0409	Y	N	RW
38752	PTRH3	PT07J04	PT03DOU0383	N	Y	RW
38755	PTRH3	PT07K01	PT03DOU0359	N	Y	RW
38756	PTRH3	PT07K04	PT03DOU0401	N	Y	LW
38760	PTRH3	PT07K11	PT03DOU0365	Y	N	LW
38764	PTRH3	PT07L50	PT03DOU0355	Y	N	RW
38766	PTRH3	PT07L52	PT03DOU0348	Y	N	RW
38769	PTRH3	PT07M10	PT03DOU0353	Y	N	LW
38821	PTRH4	PT08G03	PT04VOU0506	N	Y	RW
38824	PTRH4	PT09F29	PT04VOU0543	N	Y	RW
38827	PTRH4	PT09G01	PT04VOU0553	N	Y	RW
38828	PTRH4	PT09G03	PT04VOU0546	Y	N	RW
38829	PTRH4	PT09G04	PT04VOU0544	Y	N	RW
38830	PTRH4	PT09G51	PT04VOU0523	Y	N	RW
38831	PTRH4	PT09G55	PT04VOU0541	Y	N	RW
38834	PTRH4	PT09I02	PT04VOU0530	N	Y	RW

ID	DIST_CD	EU_CD	WB_LOCATIO	SURVEIL	OPERAT	CATEGORY
38835	PTRH4	PT09I03	PT04VOU0530	N	Y	RW
38836	PTRH4	PT09I05	PT04VOU0529	N	Y	RW
38837	PTRH4	PT09I06	PT04VOU0526	Y	N	RW
38838	PTRH4	PT09I50	PT04VOU0534	Y	N	RW
38839	PTRH4	PT09J03	PT04VOU0519	Y	N	RW
38840	PTRH4	PT09K01	PT04VOU0520	Y	N	RW
38842	PTRH4	PT09K51	PT04VOU0516	Y	N	RW
38844	PTRH4	PT09M01H	PT04MON0576	N	Y	RW
38847	PTRH4	PT10F04	PT04VOU0543	N	Y	RW
38855	PTRH4	PT10K03	PT04MON0618	N	Y	RW
38859	PTRH4	PT10L01	PT04MON0618	N	Y	RW
38860	PTRH4	PT10L02	PT04MON0589	N	Y	RW
38861	PTRH4	PT10M08	PT04MON0618	N	Y	RW
38862	PTRH4	PT10N01	PT04MON0618	N	Y	RW
38863	PTRH4	PT10N02	PT04MON0597	Y	N	LW
38870	PTRH4	PT11H05	PT04MON0633	N	Y	LW
38875	PTRH4	PT11I10	PT04MON0633	N	Y	LW
38881	PTRH4	PT11K02	PT04MON0626	N	Y	RW
38882	PTRH4	PT11K03	PT04MON0658	Y	N	RW
38883	PTRH4	PT11L50	PT04MON0619	Y	N	RW
38884	PTRH4	PT11M01	PT04MON0606	N	Y	RW
38886	PTRH4	PT12F04	PT04MON0674	N	Y	RW
38893	PTRH4	PT12G09	PT04MON0661	Y	N	LW
38894	PTRH4	PT12G25	PT04MON0675	N	Y	RW
38898	PTRH4	PT12H02	PT04MON0666	N	Y	RW
38899	PTRH4	PT12H03	PT04MON0639	N	Y	RW
38900	PTRH4	PT12H05	PT04MON0635	Y	N	LW
38902	PTRH4	PT12I03	PT04MON0654	Y	N	LW
38903	PTRH4	PT12I04	PT04MON0658	Y	N	RW
38905	PTRH4	PT12K01	PT04MON0658	Y	N	RW
38906	PTRH4	PT12K50	PT04MON0640	Y	N	RW
38907	PTRH4	PT12K52	PT04MON0634	N	Y	RW
38992	PTRH5	PT13L01	PT05TEJ0826	N	Y	RW
38993	PTRH5	PT13L50	PT05TEJ0806	N	Y	RW
39014	PTRH5	PT14L50	PT05TEJ0836	N	Y	RW
39015	PTRH5	PT14L51	PT05TEJ0852	N	Y	RW
39016	PTRH5	PT14M01	PT05TEJ0816	N	Y	LW
39017	PTRH5	PT14M50	PT05TEJ0828	N	Y	RW
39025	PTRH5	PT15G50	PT05TEJ0898	Y	N	RW
39026	PTRH5	PT15H02	PT05TEJ0914	Y	N	LW
39031	PTRH5	PT15K01	PT05TEJ0885	N	Y	RW
39032	PTRH5	PT15K50	PT05TEJ0886	N	Y	RW
39033	PTRH5	PT15L50	PT05TEJ0859	N	Y	RW
39039	PTRH5	PT16G01	PT05TEJ0923	N	Y	RW
39040	PTRH5	PT16G52	PT05TEJ0917	Y	N	RW
39041	PTRH5	PT16H03	PT05TEJ0914	Y	N	LW
39042	PTRH5	PT16I02	PT05TEJ0942	N	Y	RW
39043	PTRH5	PT16I51	PT05TEJ0948	Y	N	RW
39044	PTRH5	PT16J01	PT05TEJ0936	N	Y	LW
39045	PTRH5	PT16J50	PT05TEJ0906	N	Y	RW
39046	PTRH5	PT16K10	PT05TEJ0910	N	Y	LW
39047	PTRH5	PT16K50	PT05TEJ0912	Y	N	RW
39048	PTRH5	PT16K51	PT05TEJ0916	N	Y	RW
39059	PTRH5	PT17G02	PT05TEJ1023	N	Y	RW
39060	PTRH5	PT17G54	PT05TEJ0952	Y	N	RW
39061	PTRH5	PT17H50	PT05TEJ0958	Y	N	RW
39062	PTRH5	PT17I50	PT05TEJ0947	Y	N	RW
39063	PTRH5	PT17J50	PT05TEJ0933	Y	N	RW
39084	PTRH5	PT19E02	PT05TEJ1023	N	Y	RW
39085	PTRH5	PT19E50	PT05TEJ0998	N	Y	RW
38962	PTRH4	PTTRANAVO1	PT04VOU0552	Y	N	TW

ID	DIST_CD	EU_CD	WB_LOCATIO	SURVEIL	OPERAT	CATEGORY
38959	PTRH4	PTTRANAVO11	PT04VOU0550	Y	N	TW
38960	PTRH4	PTTRANAVO14	PT04VOU0547	Y	N	TW
38816	PTRH3	PTTRANDOU2	PT03DOU0366	Y	N	TW
38817	PTRH3	PTTRANDOU3	PT03DOU0364	Y	N	TW
38818	PTRH3	PTTRANDOU5	PT03DOU0370	Y	N	TW
38965	PTRH4	PTTRANMON3	PT04MON0681	Y	N	TW
38966	PTRH4	PTTRANMON4	PT04MON0685	Y	N	TW
39145	PTRH5	PTTRANTEJ11	PT05TEJ1139	Y	N	TW
39146	PTRH5	PTTRANTEJ32	PT05TEJ1100	Y	N	TW
39147	PTRH5	PTTRANTEJ34	PT05TEJ1116	Y	N	TW
39148	PTRH5	PTTRANTEJ44	PT05TEJ1075	Y	N	TW

Annex 13: Extract of list of existing dams in Douro, Vouga-Mondego and Tejo river basins in Portugal (provided by INAG)

DIST_CD	EU_CD	NAME	Bacia Hidrográfica Principal	Linha de água	M	P	Ano entrada em funcionamento	Energia	Potência total instalada (MW)	Capacidade máxima de descarga (m3/s)	Dispositivo de passagem para peixes
PTRH3	PT03DOU0223	Albufeira Azibo	Douro	Azibo	303944	510483	1982	Não	N.A.	N.D.	Não
PTRH3	PT03DOU0245	Albufeira Miranda	Douro	Douro	354647	503464	1960	Sim	369	11460	
PTRH3	PT03DOU0275	Albufeira Picote	Douro	Douro	347024	492382	1958	Sim	195	11000	
PTRH3	PT03DOU0295	Albufeira Bemposta	Douro	Douro	339081	482479	1964	Sim	240	11500	
PTRH3	PT03DOU0328	Albufeira Aldeadavila	Douro	Douro	321407	472415	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH3	PT03DOU0353	Albufeira Valeira	Douro	Douro	263404	466834	1976	Sim	240	18280	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0365	Albufeira Regua	Douro	Douro	235589	463950	1973	Sim	180	22100	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0371	Albufeira Pocinho	Douro	Douro	286011	463899	1983	Sim	186	15310	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0386	Albufeira Varosa	Douro	Varosa	229978	461329	1934	Sim	25	1200	Não
PTRH3	PT03DOU0393	Albufeira Torrao	Douro	Tâmega	189103	458967	1988	Sim	turbinamento 140, bombagem 140	4750	
PTRH3	PT03DOU0401	Albufeira Carrapatelo	Douro	Douro	200533	457802	1971	Sim	201	22480	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0407	Albufeira Crestuma	Douro	Douro	170037	456350	1986	Sim	117	26000	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0415	Albufeira Saucelhe	Douro	Douro	311750	453985	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH3	PT03DOU0436	Albufeira Vilar - Tabuaco	Douro	Távora	249970	447270	1965	Sim	58	540	Não
PTRH3	PT03DOU0464	Albufeira Santa Maria de Aguiar	Douro	ribeira de Aguiar	305033	433567	1981	Não	N.A.	N.D.	Não
PTRH3	PT03DOU0480	Albufeira Vascoveiro	Douro	ribeira da Pega	288829	418130	2000	Não	N.A.	N.D.	
PTRH3	PT03DOU0503	Albufeira Sabugal	Douro	Côa	288462	374488	2000	Sim		210,3	Não
PTRH4	PT04MON0583	Albufeira Fagilde	Mondego	Dão	228758	407257	1984	Não	N.A.	N.D.	Não
PTRH4	PT04MON0597	Albufeira Caldeirao (Mondego)	Mondego	ribeira do Caldeirão	267222	396621	1994	Sim	40	266	
PTRH4	PT04MON0620	Albufeira Vale do Rossim	Mondego	ribeira da Fervença	246231	381362	1956	Sim	produção em Sabugueiro II	66	
PTRH4	PT04MON0629	Albufeira Lagoa Comprida	Mondego	ribeira da Lagoa	241083	377350	1966	Sim	0,6	92	Não
PTRH4	PT04MON0633	Albufeira Aguieira	Mondego	Mondego	193969	375087	1981	Sim	turbinamento 336, bombagem 276	2260	Não
PTRH4	PT04MON0654	Albufeira Fronhas	Mondego	Alva	197837	363816	1985	Sim	produção na Aguieira	500	Não
PTRH4	PT04MON0661	Acude Ponte Coimbra	Mondego	Mondego	173863	360821	1981	Não	N.A.	2000	Sim

DIST_CD	EU_CD	NAME	Bacia Hidrográfica Principal	Linha de água	M	P	Ano entrada em funcionamento	Energia	Potência total instalada (MW)	Capacidade máxima de descarga (m3/s)	Dispositivo de passagem para peixes
PTRH4	PT04RDW1172	Albufeira S. Domingos	Ribeiras do Oeste	São Domingos	97864	263588	1993	Não	N.A.	208	Não
PTRH5	PT04MON0635	Albufeira Raiva	Mondego	Mondego	189880	371308	1982	Sim	24	2047	Não
PTRH5	PT05TEJ0753	Albufeira Meimoa	Tejo	Meimoa	284268	366208	1985	Não	N.A.	N.D.	Não
PTRH5	PT05TEJ0783	Albufeira Santa Luzia	Tejo	Unhais	223471	346855	1942	Sim	25,6	230	Não
PTRH5	PT05TEJ0816	Albufeira Marateca - Sta. Agueda	Tejo	Ocreza	255722	333612	1991	Não	N.A.	N.D.	
PTRH5	PT05TEJ0818	Albufeira Marechal Carmona - Idanha	Tejo	Ponsul	279672	331132	1947	Sim	2,00	800	
PTRH5	PT05TEJ0824	Albufeira Cabril	Tejo	Zêzere	200418	329084	1954	Sim	108	2400	
PTRH5	PT05TEJ0842	Albufeira Toulica	Tejo	ribeira da Toulica	290509	323336	1979	Não	N.A.	18	Não
PTRH5	PT05TEJ0850	Albufeira Bouca	Tejo	Zêzere	192132	321042	1955	Sim	44	2400	
PTRH5	PT05TEJ0894	Albufeira Monte Fidalgo (Cedillo)	Tejo	Tejo	292400	325937	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH5	PT05TEJ0910	Albufeira Pracana	Tejo	Ocreza	227163	289171	1950	Sim	41	2612	
PTRH5	PT05TEJ0913	Albufeira Fratel	Tejo	Tejo	227929	286443	1974	Sim	132	16500	Sim
PTRH5	PT05TEJ0914	Albufeira Castelo de Bode	Tejo	Zêzere	183550	286500	1951	Sim	159	4500	Não
PTRH5	PT05TEJ0924	Albufeira Poio	Tejo	ribeira de Nisa	247412	283184	1932	Sim	1,5	110	Não
PTRH5	PT05TEJ0936	Albufeira Belver	Tejo	Tejo	211637	279050	1951	Sim	80,7	18000	
PTRH5	PT05TEJ0939	Albufeira Nisa - Povoa	Tejo	Nisa	249641	278877	1928	Sim	0,74	110	Não
PTRH5	PT05TEJ0964	Albufeira Apartadura	Tejo	Sever	264565	264930	1993	Não	N.A.	45	Não
PTRH5	PT05TEJ0971	Albufeira Jorge Bastos	Tejo	ribeira de Cojancas	231150	257370		Não	N.A.	N.D.	
PTRH5	PT05TEJ1015	Albufeira Montargil	Tejo	Sôr	196259	231809	1958	Sim	3,2	765	Não
PTRH5	PT05TEJ1030	Albufeira Maranhao	Tejo	ribeira da Seda	213620	227720	1957	Sim	6	1600	Não
PTRH5	PT05TEJ1033	Albufeira Magos	Tejo	Magos	151751	225358	1938	Não	N.A.	N.D.	Não
PTRH5	PT05TEJ1069	Acude Vale de Pocos	Tejo	ribeira do Vale de Poços	151725	225360		Não	N.A.	N.D.	Não
PTRH5	PT05TEJ1117	Albufeira Carrasqueira	Tejo	Cabido	220023	196469		Não	N.A.	N.D.	Não
PTRH5	PT05TEJ1128	Albufeira Divor	Tejo	Divor	218003	192543	1965	Não	N.A.	N.D.	Não
PTRH5	PT05TEJ1129	Albufeira Venda Velha	Tejo	Amieira	138833	191498	1945	Não	N.A.	N.D.	Não
PTRH5	PT05TEJ1142	Albufeira Minutos	Tejo	Almonsor	203116	187892	2003	Não	N.A.	N.D.	Não

N.A. = Não se aplica	N.D. = Não disponível

Annex 14: Description of the indicess used in the assessment of Portuguese rivers developed by by a team of researchers from Portuguese Universities to evaluate the ecologic and hydromorphological quality of water bodies within the scope of the WFD (Cortes et al. 2008; ADISA, 2008).

Hydromorphological elements

HQA - Habitat Quality

This index measures the richness, rarity and diversity of riparian habitats. It aggregates 10 sub-indexes concerning different aspects of the habitat quality such as: flow type, substrate, canal features, bank features, structure of bank vegetation, sedimentation, aquatic vegetation, riparian vegetation, land use, special characteristics and global habitat quality. For each one of these sub-indexes a score is assigned and the final score of HQA is obtained by adding them.

For the different river types described for Portugal the reference conditions for this HQA index (and for all the indexes described in this document) were defined (see Table 1) which enable us to know the current status of the water body at the selected point.

Table 1: Reference HQA values for the different river types (Cortes, 2008b).

HQA

Tipos	Mediana das Referências	Exc./Bom	Bom/Raz.	Raz./Med.	Med./Mau
M	41,5	42	32	22	12
N1	47,0	46	35	24	13
N2	45,0	42	32	22	12
N3	45,5	44	33	22	11
N4	45,5	44	33	22	11
L	39,0	36	27	18	9
S1	45,0	-	-	-	-
S2	45,0	-	-	-	-
S3	54,5	50	38	26	14
S4	-	-	-	-	-
Nacional	46,0	44	33	22	11

River connectivity

This element was measured in situ as well as considering the information available (maps, studies, etc.) for a study carried out in the framework of the WFD. The river connectivity evaluates the impacts of artificial barriers on migration (to sea and up to the sampling point for diadromous species). The scores assigned range from from 1 to 5 (increasing barrier effect) and are shown in Table 2.

Table 2: Score values for river connectivity element.

Quadro 2 – Classes para a variável *Conectividade do rio*.

Classes de impacto	Descrição
5	Barreira artificial perfeitamente definida
4	Passagem ocasional de uma única espécie
3	Passagem para determinadas espécies ou determinados anos
2	Passagem para a maior parte das espécies na maior parte dos anos
1	Não existem barreiras ou existência de um dispositivo tipo "bypass"

Source: INAG - Directiva Quadro da Água. Qualidade Ecológica das Águas Interiores Superficiais – Categoria Rios. Documento de Trabalho Nº1. Versão 60. 30 de Janeiro de 2004.

Biological elements assessment

Indexes used for the assessment of buiological eleknts are described below. The results for macro-invertebrates, macrophytes and fish are expressed in EQRs (Ecological Quality Ratios), which are classified in accordance with the requirements of the WFD (high, good, moderate, poor and bad)

Macro-invertebrates

The indexes used for this element are based on the work developed in the framework of the Working Group 2.3 – REFCOND, of the Common Implementation Strategy for the Water Framework Directive and the Geographic Intercalibration Groups (GIG's). Two indexes were used, one for Northern rivers (IptIN) and another one for Southern rivers (IPtIS), which evaluate the impacts of overall degradation on the invertebrates..

Macrophytes

The index used was the Mean Trophic Rank adapted to Portugal (MTRp). It is based on the presence and abundance of aquatic indicator species to which a score is assigned according to its response to eutrophication.

Fish

The Portuguese Fish Index (PoFI) was used. It ranks between 0 (bad ecological state) and 100 (high ecological status).

IVR - Riparian Vegetation Index

This index was developed based on the Iberian Multimetric Index (IMPI). It integrates specific elements of plant communities reflecting ecological processes and structural functions of ecosystems.

Annex 15: Habitat preferences and main threats for fish species in the PNBEPH area

Species	Distribution & migratory behaviour	Habitats requirements*	Population trend	Main threats
Alosa alosa	Autochtonous, migratory, anadromous, pelagic species	Lives in the sea until it reaches the adult phase, in deep waters. It enters large rivers with moderate current to reproduce, reaching further distance for spawning than its relative *A. fallax*. Reproduction takes place in freshawter, in middle and upper reaches of medium and large rivers. Spawning is carried out during night on sand and gravel, in low depths (less than 1.5 m). Juveniles stay for a variable period in the estuarine environment and then migrate to the sea, to plancton rich areas, where they grow up.	Decreasing (Eionet). Significant regression (PSRN2000)	Dam construction is the most serious threat; sand and gravel extraction; water pollution, over-exploitation of hydric resources, regulation of hydrologic systems; reduction of reproduction and spawning areas, destruction of riparian vegetation, overfishing, introduction of species.
Alosa fallax	Autochtonous, migratory, anadromous, pelagic species	Reproduction takes place in freshwater (middle sections of large rivers) and sometimes in the upper part of estuaries. Spawning occurs at night on over gravel, mud or sand, at a depth between 2,5 m and 9,5 m. Juveniles stay for a variable period in the estuarine area. Growing phase takes place in the sea, mainly in coastal areas. It enters the rivers from March to June, reproduction occurs in May and July. Spawns in freshwater over reaches still under the influence of the sea. Adults return immediately to the sea and the juveniles saty in freshwater during summer, and go to the estuary in Autumn.	Decreasing (Eionet). Regressive (PSRN2000)	More tolerant to habitat degradation than Alosa alosa. Dam construction is the most serious threat; sand and gravel extraction, over-exploitation od hydric resources, water pollution, regulation of hydrologic systems; reduction of reproduction and spawning areas, destruction of riparian vegetation, overfishing, introduction of species.

Species	Distribution & migratory behaviour	Habitats requirements*	Population trend	Main threats
Barbus bocagei	Iberian endemism, potamodromous	Large diversity of habitats. Middle and lower reaches of rivers. Frequently found in reservoirs. Tollerant to pollution. This species is an active swimmer with a high capacity of movement. It carries out reproductive migrations to upstream shallow areas with sand, gravel and cobble substrates, with swift current and high DO concentrations. Prefers areas with low or moderate current speed (exept during the reproduction), permanent rivers with high riparian vegetation cover, with marked lotic features and reduced hydric instability. It selects the deepest zones, well oxigenated and with fine susbstrate. The juveniles occupy zones with some depth, close to the margins of the river and without current, avoiding habitats with important tree cover.	Decreasing (Eionet).	Sand and gravel extraction; water pollution; modifying structures of inland water courses; management of water levels; introduction of disease; antagonism arising from introduction of species.
Barbus comizo	Iberian endemism, potamodromous	Inhabit middle and lower reaches, deeper areas than other Iberian barbels, especiallly the big individuals. Also present in reservoirs. Seasonal migrations. Spawning in areas with sand and gravel substrate without shading and with certain current speed.	Decreasing (Eionet). Regressive (PSRN2000).	Pollution, over-exploitation of hydric resources, regulation of hydric systems, sand and gravel extraction, destruction of riparian vegetation, introduction or expansion of allocthonous species. Dams construction is a threat not so seroious as for other species.
Achondrostoma arcasii	Iberian endemism	Low order streams. Shallow areas with gravel and cobble. Low macrophyte density. It occurs in mountain lakes and also in reservoirs. Its prefered habitat varies along the lyfe cycle. The species is generally more abundant in small streams with rapid current, clean waters and coarse substrate. The juveniles are found in areas with little current while the adults are found in deeper areas.	Decreasing (Eionet)	This species is particularly vulnerable owing to its very local distribution and the possible hybridation with species of the same genus. Pollution, sand and gravel extraction, introduction of allochtonous species, regulation of hydrological systems, destruction of riparian vegetation. Also found in reservoirs in Northern and Central Portugal.

Species	Distribution & migratory behaviour	Habitats requirements*	Population trend	Main threats
Pseudochondrostoma duriensis	Iberian endemism, potamodromous	The species inhabits medium reaches in areas with current, occurs mainly in affluents of low altitude and substrate of intermediate granulometry. The juveniles prefer areas with lime and sand, they select deeper zones in Summer-Autumn and less deep areas in Spring-Winter. Also found in reservoirs.	Decreasing (Eionet).	Pollution, sand and gravel extraction, introduction or expansion of allocthonous species, over-exploitation and/or regulation of hydric systems, destruction of riparian vegetation, introduction of species. Dams construction is a serious threat as for other species.
Iberochondrostoma lemmingii	Iberian endemism	Diverse lotic habitats. From low order stream to large rivers, both in permanent and intermittent rivers and streams. No occurence in reservoirs has been recorded.	Decreasing (Eionet). Marked regression: 30-50% (PSRN2000)	Introduction or expansion of allochtonous species, over-exploitation and/or regulation of hydrological resources; water pollution, dams construction (Guadiana river basin), sand and gravel extraction, destruction of riparian vegetation, introduction of species.
Iberochondrostoma lusitanicum	Portuguese enedmism	Small to medium streams with current and macrophytic cover. No occurence in reservoirs has been recorded.	Decreasing (Eionet). Strong reduction (up to 80%) in the last years (PSRN2000)	High fragmentation of the populations. Pollution, sand and gravel extraction, introduction or expansion of allochtonous species, over-exploitation and/or regulation of hydrological resources, dams construction, antagonism arising from introduction of species.
Pseudochondrostoma polylepis	Iberian endemism, potamodromous.	Permanent or intermittent rivers, also recorded in reservoirs. It is found in medium reaches with swift current. Large diversity of habitats with a notorious preference by habitats with current. Reproductive migrations to upstream shallow areas with sand, gravel and cobble and high DO.	Decreasing (Eionet). Decline (PSRN2000).	Pollution, sand and gravel extraction, introduction or expansion of allochtonous species, over-exploitation and/or regulation of hydrological resources, destruction of riparian vegetation. Dams construction is a serious threat as for other species.
Lampetra fluviatilis	Autochtonous, anadromous	Big rivers with clean water and estuaries. No record of occurrence in reservoirs. Reproduction habitat: well oxygenated water, shallow areas (no more than 30 cm depth) with sand and gravel substrate. Larval distribution is strongly dependent on sediment, especially particle size composition.	Decreasing (Eionet). Serious decline (PSRN2000).	Dams construction, sand and gavel extraction and water pollution are the main threats. Also over-exploitation and regulation of hydrological systems and destruction of riparian vegetation.

Species	Distribution & migratory behaviour	Habitats requirements*	Population trend	Main threats
Petromyzon marinus	Autochtonous, anadromous	Permanent rivers ar the principal habitat of the larval stages, and are also used by adults during the reproductive migration, as well as estuaries, and later by the juveniles during thier yhrphic migration. The sea constitutes the selected habitat in the growing phase. During the migratory period individuals seek resting places on rocky substrates. Spawning occurs on coarse substrates. Larvae are strongly dependent upon sediment, especially particle size composition. Smaller individuals (20 mm < TL ≤ 60 mm) are commonly found on silty and sand bottoms. Ammocoetes with a total length of 60 mm to 140 mm prefer a more heterogeneous substrate, where gravel and silt seem to make an identical contribution to sediment composition (gravel-silty-sand).	Decreasing (Eionet).	Dams construction, sand and gavel extraction, water pollution and overfishing are the main threats for this species.
Squalius alburnoides	Iberian endemism	Permanent and intermittent streams. Narrow and shallow streams (0,3 a 0,7m depth) with current and macrophytes cover. Also found in reservoirs. Not found in degraded rivers, selects unpolluted waters. (Different forms: diploids 2n = 50 triploids 3n = 75 and tetratploids 4n= 100. Some of these forms have non sexuated reproduction).	Decreasing in Mediterranean region (Eionet). Reduction of the population up to 50% in the last decade (PSRN2000).	Pollution, sand and gravel extraction, introduction of allochtonous species, over-exploitation and/or regulation of hydrological resources, dams and weir construction.
Achondrostoma oligolepis	Portuguese endemism, potamodramous	Large variety of habitats with a notorious preference by small to medium streams with slow current. Inhabits shallow waters and is resistent to lack of oxygen. Anusual in reservoirs. Reproductive migrations.	Unknown (Eionet).	Water pollution, sand and gravel extraction, introduction of allochtonous species, over-exploitation and/or regulation of hydrological resources, dams and weir construction.

Species	Distribution & migratory behaviour	Habitats requirements*	Population trend	Main threats
Anguilla anguilla	Catadromous (landlocked populations: cannot complete their life cycle).	Inhabits bottom of rivers and reservoirs, in an large diversity of habitats with slow currents. Tollerant to pollution. Reproduction in the Sargaço sea. Larvae migrate passively throughout ocean for 1 to 3 years. Then they suffer a metamorphosis (glass eel). Is in this phase that young eels enter into rivers where they will stay for 3 to 15 years. The Eel occurs in rivers with current and wel oxigenated waters, with substrate where it can excavate (sand or mud) or with dense vegetation. Males are predominant in estuaries and females in the upper parts of rivers.	Redution of the population in the upper cources of the river basins with dams	The construction of dams without a fish pass has caused the disappearance of the eel in the upper courses. Over-exploitation is also present. The population of the Mondego river had experienced a reduction in number of large-sized individuals. Pollution of the rivers (CPN)
Atherina boyeri	Short spawning migrations into estuaries in some populations	Present in coastal littoral, estuaries, coastal lagoons and freshwater.	No data	Habitat loss and degradation, mainly due to dams construction and water pollution.
Cobitis calderoni	Iberian endemism	This benthonic species inhabitats middle and upstream sections of rivers with high DO concentration, gravel cobble and rocky bottom substrate and swift current.	Population reduction over 30% in the last decade.	In intermedia trivers with shallow and well-oxygenated fluvial zones, with aquatic vegetation and shadow.
Cobitis paludica	Iberian endemism	It lives in the middle to lower parts of rivers with slow to moderate current, lime and sand or gravel and cobble substrate, with aquatic vegetation.	Decreasing	Main threat is habitat degradation due to dams and canals construction, and sand and gravel extraction. Introduction of exotic fish species.
Gasterosteus gymnurus	Both anadromous and resident populations	Permanent rivers are the main habitat of the freshwater populations. Anadromous populations use coastal littoral close to estuaries and freshwater environments.	No data	Main threats are related to habitat loss due to dams and weir construction, sand and gravel extraction, water pollution and introduction of non native species.

Species	Distribution & migratory behaviour	Habitats requirements*	Population trend	Main threats
Salmo trutta	Anadromous (but resident in river basins considered in this study)	Upper streams with low temperatures and high DO concentration. Swift and strong current. Reproductive migrations to shallow and well oxygenated waters with coarse substrates. When habitat degradation occurs, trout is replaced by cyprinid species. Currently, in Portugal only the populations of MInho and Lima rivers are migratory.	The number of mature individuals is extremely low and the migratory from is under continuous decline.	Main threats are the construction of dams which causes alteration of spawning areas or prevent their acces to those areas, and water pollution.
Squalius carolitertii	Iberian endemism	Common in medium size reaches although it can be found in a wide variety of habitats both upstream and downstream. During summer drought this species is well adapted to live in marginal pools with low level of dissolved oxygen. Large diversity of habitats with preference by small and medium dimension streams with macrophytic cover and small current.	Unknown	Main threat is the construction of dams which causes alteration of natural flow regime.
Squalius pyrenaicus	Iberian endemism	Permanent and intermittent rivers. Also in reservoirs. Large diversity of habitats with preference by small and medium dimension streams with macrophytic cover and small current. Shallow and well oxygenated waters.	Reduction below 30% in the last 20 years.	Main threats are habitat loss owing to the construction of dams, alteration of natural flow regime, water abstraction, sand and gravel extraction, water quality degradation, and introduction of non-native species.

Annex 16: Habitat preferences for some fish species (Spain and Portugal)

Martínez Capel, F. & D. García de Jalón (1999): Desarrollo de curvas de preferencia de microhábitat para *Leuciscus pyrenaicus* y *Barbus bocagei* por buceo en el río Jarama (Cuenca del Tajo). Limnetica 17: 71-83.

Oliveira JM., Ferreira, MT., Pinheiro NA. &J. Bochechas (2004) A simple method for assessing minimum flows in regulated rivers: the case of sea lamprey reproduction. Aquatic Conser*v*: Mar. Freshw. Ecosyst. 14: 481–489.

	Water velocity (cm/s-1)	Depth (cm)	Substrate	Authors/River
Barbus bocagei Adults Juveniles YOY*	 5 20 25	 121 56 51	 Bedrock Sand cobbles	Capel & Garcia de Jálon 1999 R Jarama (Tejo)
Leuciscus pyrenaicus Adults Juveniles YOY*	 30 40 15	 126 41 121	 Gravel Gravel Gravel	Capel & Garcia de Jálon 1999 R Jarama (Tejo)
Petromyzon marinus (spawning habitat)	0.5-1.5	≥10	Sand/gravel/pebbles	Oliveira et al. 2004 (Tejo)

Santos JM, Godinho FN, Ferreira MT (2004). Microhabitat use by Iberian nase Chondrostoma polylepis and Iberian chub *Squalius carolitertii* in three small streams, north-west Portugal. Ecology of Freshwater Fish: 13: 223–230.

This study was performed in the Lima River Basin. Results are presented below.

Table 1. Microhabitat availability and use by different species size classes in Adrão R., Froufe R. and Vez R., Lima basin.

Season		Water temperature (°C)	Depth (cm)	Water velocity (cm s^{-1})	Dominant substrate (class)	Cover (class)	*N*
Winter	*Availability*	8–10	63 (4.2)	49 (4.0)	5 (1–6)	2 (1–4)	69
	Nase						
	6–12 cm		52 (3.2)	19 (3.5)	5 (3–6)	2 (2–3)	25
	>12 cm		90 (4.4)	33 (2.4)	5 (3–6)	2 (2–3)	32
	Chub						
	5–9 cm		64 (3.9)	12 (2.9)	5 (1–6)	3 (1–4)	36
	>9 cm		81 (4.5)	23 (3.9)	5 (3–6)	3 (2–4)	35
Spring	*Availability*	10–12	69 (4.0)	49 (5.1)	5 (1–6)	2 (2–4)	44
	Nase						
	6–12 cm						4
	>12 cm		65 (6.4)	54 (8.6)	5 (4–6)	2 (2–3)	11
	Chub						
	5–9 cm		72 (6.5)	14 (3.9)	5 (2–5)	3 (2–3)	10
	>9 cm		73 (3.6)	25 (3.6)	5 (2–6)	2 (2–3)	42
Summer	*Availability*	17–20	52 (3.4)	6 (1.2)	5 (1–6)	2 (1–4)	50
	Nase						
	6–12 cm		48 (4.9)	3 (0.8)	5 (3–6)	2 (2–3)	13
	>12 cm		60 (3.0)	9 (1.0)	5 (2–6)	2 (2–4)	84
	Chub						
	5–9 cm		54 (3.6)	3 (0.9)	5 (2–6)	3 (2–3)	14
	>9 cm		60 (3.8)	4 (0.6)	5 (2–6)	3 (2–3)	61
Autumn	*Availability*	14–16	56 (4.9)	30 (5.3)	4 (1–6)	2 (1–4)	40
	Nase						
	6–12 cm						8
	>12 cm		74 (5.9)	30 (6.1)	5 (2–6)	2 (2–3)	33
	Chub						
	5–9 cm		53 (6.4)	7 (3.7)	5 (3–6)	3 (2–4)	10
	>9 cm		66 (6.2)	9 (1.9)	5 (2–6)	3 (2–4)	40

Mean values are given for depth and water velocity followed by standard error (in parentheses), while median values (with range given in parentheses) are given for dominant substrate size (1, silt; 2, <0.2 cm; 3, 0.2–2.5 cm; 4, 2.5–30 cm; 5, >30 cm and 6, bedrock) and cover (1, <25%; 2, 25–50%; 3, 50–75% and 4, >75%). Statistics are only given for sample sizes ≥10.

Gomes Lopes, LF.; Antunes Do Carmo, JS.; Cortes; RM. & Oliveira, D (2004) Hydrodynamics and water quality modelling in a regulated riversegment: application on the instream flow definition. Ecological Modelling 173: 197–218.

The study was performed in R. Lima Basin. The results concerning habitat preferences for each species are presented below.

Habitat suitability criteria (velocity and depth function) for the three target-species. (A) Adult brown trout (*Salmo trutta*),; (B) juvenile brown trout; (C) adult Iberian nase (*Chondrostoma polylepis*; (D) juvenile Iberian nase; (E) adult chub (*Leuciscus carolitertii*) ;(F) juvenile chub.

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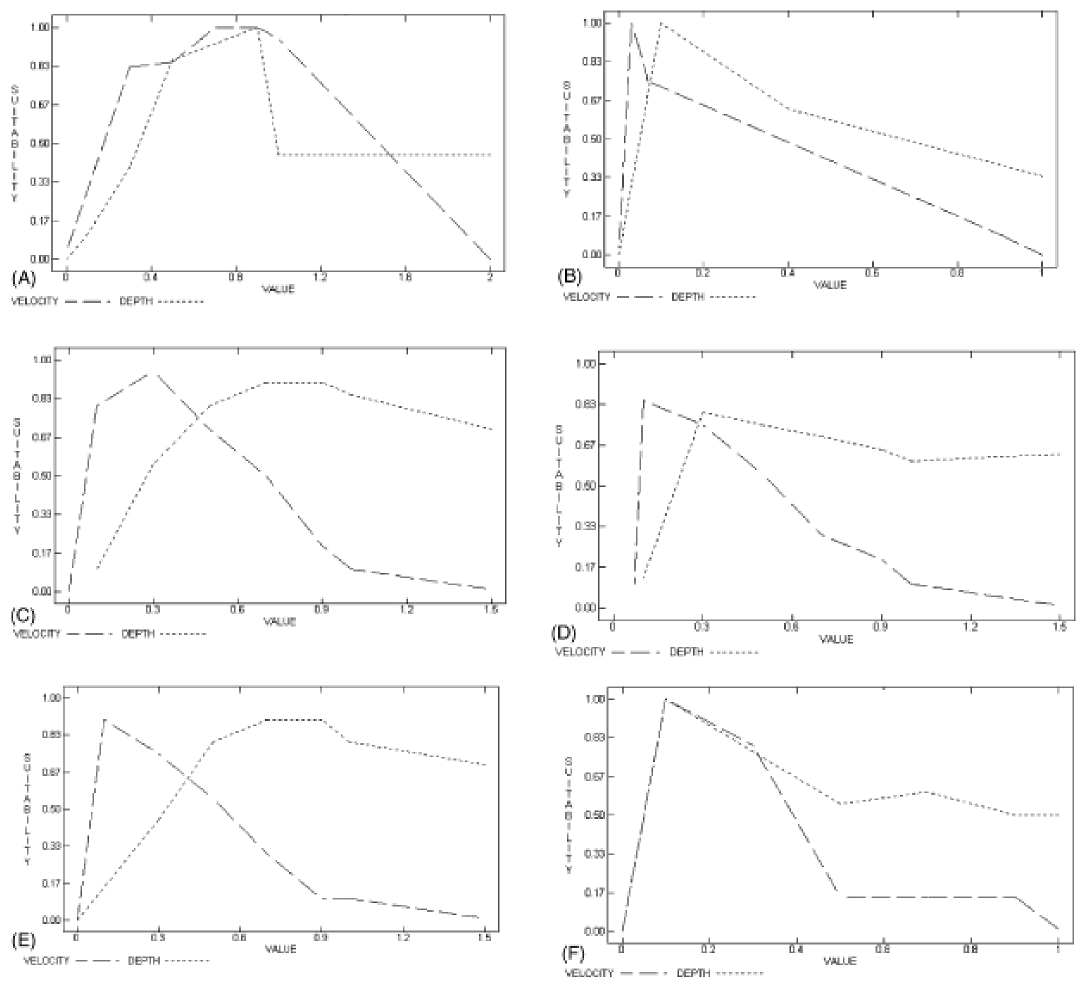

Fig. 7. Habitat suitability criteria (velocity and depth function) for the three target-species. (A) Adult brown trout; (B) juvenile brown trout; (C) adult Iberian nase; (D) juvenile Iberian nase; (E) adult chub; (F) juvenile chub.

Martínez Capel, F.; García de Jalón D. & M. Rodilla-Alamá (2004) On the estimation of nose velocities and their influence on the physical habitat simulation for Barbus bocagei Hydroécol. Appl. 14: 139-159.

This study was performed in the Tejo River Basin. Results are presented below. .

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Table 5. – Habitat suitability criteria for *Barbus bocagei* calculated from 81 records from the rivers Ambroz, Guadiela, Jarama and Sorbe, which have been used in the physical habitat simulation. The variables implemented are total depth (m), average velocity (m/s) and focal velocity (m/s).

	Interval	Depth	Average Velocity	Focal Velocity
Large Barbel (N=81)	Suitable	0.6-2.23	0.01-0.541	0.005-0.215
	Optimal	1.09-1.52	0.069-0.194	0.032-0.097

Martínez Capel, F.; García de Jalón D.; Werenitzky, D.; Baeza, D. & M. Rodilla-Alamá (2009) Microhabitat use by three endemic Iberian cyprinids in Mediterranean rivers (Tejo River Basin, Spain) Fisheries Management and Ecology, 16: 52–60

Table 3. Habitat suitability criteria for depth (D), focal height (F_h, distance from the bottom in percentage to depth), mean water column velocity (V_m), focal velocity (V), water velocity at the focal height of the fish), distance to shore (D_{ist}, in percentage to the mean river width), and substrate (S) for the nine fish groups. The optimal range [Opt] represents the central window of 50% in the data distribution, and suitable [Suit] is the central 95%

		D(m)	F_h (%)	V_m (m s^{-1})	V_f (m s^{-1})	D_{ist} (%)	S*
Barbel-small (*n* = 27)	Opt	0.31–0.54	4.0–10.0	0.066–0.397	0.026–0.236	10.7–23.7	3–5
	Suit	0.11–1.12	2.3–40.0	0.007–0.668	0.003–0.482	3.2–43.0	1–8
Barbel-medium (*n* = 180)	Opt	0.42–1.09	4.2–20.0	0.069–0.196	0.024–0.134	15.4–32.3	4–5
	Suit	0.22–1.95	1.5–50.0	0.004–0.466	0.000–0.302	3.1–53.8	1–8
Barbel-large (*n* = 103)	Opt	0.96–1.45	2.8–15.6	0.074–0.200	0.034–0.129	17.2–25.9	3–6
	Suit	0.55–2.24	0.4–44.0	0.005–0.591	0.000–0.401	1.5–49.5	1–8
Nase-small (*n* = 97)	Opt	0.34–0.61	5.0–40.0	0.039–0.303	0.039–0.234	5.8–21.5	1–4
	Suit	0.18–1.09	3.0–53.1	0.001–0.659	0.001–0.525	1.8–41.0	1–8
Nase-medium (*n* = 144)	Opt	0.42–0.96	4.0–30.0	0.08–0.284	0.045–0.213	12.9–32.3	3–5
	Suit	0.22–1.63	1.8–53.8	0.003–0.699	0.001–0.576	3.2–53.8	1–8
Nase-large (*n* = 144)	Opt	0.79–1.32	3.8–24.1	0.096–0.348	0.060–0.239	20.7–32.3	4–5
	Suit	0.31–1.94	1.9–63.8	0.004–0.770	0.007–0.531	6.1–59.2	1–8
Chub-small (*n* = 62)	Opt	0.26–0.51	9.8–38.4	0.016–0.190	0.010–0.157	10.7–32.3	4–5
	Suit	0.13–1.36	2.5–80.0	0.001–0.402	0.000–0.345	1.7–65.1	1–8
Chub-medium (*n* = 88)	Opt	0.30–0.50	8.8–23.5	0.089–0.211	0.054–0.156	16.1–32.3	4–5
	Suit	0.20–0.91	3.4–50.8	0.002–0.372	0.001–0.303	3.5–53.8	1–8
Chub-large (*n* = 25)	Opt	0.49–1.40	11.3–50.0	0.011–0.156	0.014–0.151	19.0–29.4	4–5
	Suit	0.23–1.68	2.9–70.0	0.004–0.288	0.005–0.203	0.0–58.8	1–8

*S, substrate types: 8 - bedrock; 7 - large boulders (∅ > 1024 mm); 6 - boulders (256–1024 mm); 5 - cobbles (64–256 mm); 4 - gravel (8–64 mm); 3 - fine gravel (2–8 mm); 2 - sand (62 μm–2 mm); 1 - silt (< 62 μm).

Teixeira, A. & Cortes, RM. (2007) PIT telemetry as a method to study the habitat requirements of fish populations: application to native and stocked trout movements Hydrobiologia 582:171–185

This study was performed in Douro Basin (R. Baceiro and Sabor). Big native are individuals with 20 or more cm length and small native trout are animals with less 20 cm length. Results are given below. .

Table 1 Mean (±1 S.E.) total depth (cm), distance to nearest stream bank (cm), distance to riffle (cm) surface velocity (m s^{-1}), water column velocity (m s^{-1}) and bottom velocity (m s^{-1}) from the 40 antennae positions of small native, big native and stocked trout in the Baceiro and Sabor streams

Microhabitat variables	Baceiro stream			Sabor stream		
	Small native (n = 178)	Big native (n = 185)	Stocked (n = 527)	Small native (n = 18)	Big native (n = 142)	Stocked (n = 585)
Total depth	56.0 ± 1.16	59.2 ± 1.75	65.9 ± 0.98	34.6 ± 2.88	34.3 ± 1.22	62.3 ± 1.19
Distance to stream bank	93.0 ± 9.51	100.7 ± 5.51	117.8 ± 4.40	58.4 ± 12.12	83.6 ± 8.53	211.7 ± 6.05
Distance to riffle	1393.6 ± 64.23	314.2 ± 10.28	445.5 ± 18.59	1477.2 ± 142.9	648.9 ± 46.98	1236.1 ± 32.94
Surface velocity	0.017 ± 0.003	0.073 ± 0.004	0.065 ± 0.003	0.055 ± 0.030	0.223 ± 0.02	0.123 ± 0.01
Water column velocity	0.014 ± 0.003	0.077 ± 0.004	0.057 ± 0.003	0.044 ± 0.024	0.165 ± 0.01	0.083 ± 0.01
Bottom velocity	0.014 ± 0.003	0.088 ± 0.006	0.056 ± 0.003	0.034 ± 0.020	0.134 ± 0.01	0.057 ± 0.01
Dominant substrate						
Organic detritus	21.5	4.9	18.0	0.0	0.0	0.0
Silt and sand	0.6	0.0	10.2	0.0	0.0	0.0
Gravel	28.1	9.2	6.3	33.3	2.8	23.6
Pebble	5.6	31.4	19.7	38.8	3.5	2.1
Cobble	21.2	43.2	27.8	5.6	41.5	13.2
Boulder	9.0	11.3	17.3	16.7	41.5	53.3
Bedrock	14.0	0.0	0.8	5.6	10.7	7.8
Aquatic cover						
Substrate particles (>15 cm)	60.7	64.3	35.1	11.1	45.8	28.4
Overhanging vegetation	7.3	3.2	5.3	44.4	12.0	13.2
Roots, undercut banks, woody debris	10.7	0.5	0.4	38.9	12.7	0.7
Surface turbulence	2.8	17.8	16.7	0.0	3.5	6.0
No cover	18.5	14.1	42.5	5.6	26.1	51.8

Cover and dominant substrate type used by fishes are shown as relative frequency (%). Numbers of observations (n) are presented in parentheses and correspond to non-repeated frequency data for each trout class

Annex 17: List of habitat types and species, for which the Commission cannot conclude that the network is complete for Portugal (Decision 2006/613/EC-annex2)

QUADRO 4.9

Habitats e espécies insuficientemente cobertos pela rede de SIC em Portugal

CÓDIGO	HABITAT/ESPÉCIE
1130	Estuários
1330	Prados salgados atlânticos (*Glauco-Puccinellietalia maritimae*)
2170	Dunas com *Salix repens* ssp. *argentea* (*Salicion arenariae*)
2260	Dunas com vegetação esclerófila da *Cisto-Lavanduletalia*
3120	Águas oligotróficas muito pouco mineralizadas em solos geralmente arenosos do oeste mediterrânico com *Isoetes* spp.
1024	*Geomalacus maculosus*
1029	*Margaritifera margaritifera*
1032	*Unio crassus*
1037	*Ophiogomphus cecilia*
1041	*Oxygastra curtisii*
1044	*Coenagrion mercuriale*
1088	*Cerambyx cerdo*
1095	*Petromyzon marinus*
1096	*Lampetra planeri*
1099	*Lampetra fluviatilis*
1102	*Alosa alosa*
1103	*Alosa fallax*
1133	*Anaecypris hispanica*
1142	*Barbus comizo*
1324	*Myotis myotis*
1352	**Canis lupus*
1362	**Lynx pardinus*
1388	**Bryoerythrophyllum campylocarpum*
1549	**Ononis hackelii*
1595	* *Tuberaria major*
1726	*Linaria algarviana*
1742	*Plantago algarbiensis*
1788	*Leuzea longifolia*
1862	*Narcissus cyclamineus*
1892	*Holcus setiglumis duriensis*

Task 3: Assessment of alternative options

Annex 18: Dataset INAG (May 2009)

DIST_CD	EU_CD	NAME	Gestão	Bacia Hidrográfica Principal	Linha de água	M	P	Ano entrada em funcionamento	Energia	Abastecimento	Rega	Navegação Marítimo-Turística	Volume abastecimento (hm3)	Volume rega (hm3)	Potência total instalada (MW)	N.º de grupos	Tipo de turbina	Queda bruta (m)	Média da Produção 1993/2008 (GWh)	Capacidade máxima de descarga (m3/s) (2)	"actual efficiency" (3)	"mean actual discharge" (4)	"oirgnially aimed electricity production" (5)	Dispositivo de passagem para peixes
PTRH1	PT01LIM0028	Albufeira Alto Lindoso	PT	Lima	Lima	194246	544770	1992	Sim	Não	Não	Sim	N.A.	N.A.	630	2	Francis eixo vertical	288	797	250	95,81	37,46	910	não
PTRH1	PT01LIM0036	Albufeira Touvedo	PT	Lima	Lima	181675	538149	1993	Sim	Sim	Não	Sim	13.53 (garantia interanual 28)	N.A.	22	1	Kaplan eixo vertical	25	63	100	97,23	35,55	61	elevador para transposição de peixes
PTRH2	PT02CAV0072	Albufeira Alto Rabagao	PT	Cávado	Rabagão	223258	529889	1964	Sim	Sim	Não	Sim	4.97 (garantia interanual 11)	N.A.	68	2	Francis eixo vertical	180	102	49	91,9	8,32	155	não
PTRH2	PT02CAV0086	Albufeira Canicada	PT	Cávado	Cávado	191865	520399	1955	Sim	Não	Não	Sim	N.A.	N.A.	62	2	Francis eixo vertical	121	302	68	95,14	37,51	340	não
PTRH2	PT02AVE0107	Albufeira Ermal	PT	Ave	Ave	199655	512935	1939	Sim	Não	Não	Sim	N.A.	N.A.	10,8	2	Francis eixo vertical	82	22	17,3	N.D.	2,06	29	N.D.
PTRH2	PT02CAV0068	Albufeira Paradela	PT	Cávado	Cávado	215195	533280	1956	Sim	Não	Não	Não	N.A.	N.A.	54	1	Francis eixo vertical	460	232	16,4	96,98	7,61	255	não
PTRH2	PT02CAV0080	Albufeira Salamonde	PT	Cávado	Cávado	203494	524731	1953	Sim	Não	Não	Não	N.A.	N.A.	42	2	Francis eixo vertical	125	222	43,2	95,06	26,82	240	não
PTRH2	PT02CAV0083	Albufeira Venda Nova	PT	Cávado	Rabagão	212566	523336	1951	Sim	Sim	Não	Não	0.917 (garantia interanual 2)	N.A.	281	3+2	3Pelton (H)+2 Francis (V)	414	376	81	95,64	13,16	610	não
PTRH2	PT02CAV0069	Albufeira Vilarinho das Furnas	PT	Cávado	Homem	193712	532692	1972	Sim	Não	Não	Não	N.A.	N.A.	125	2	1 Francis+1 Francis reversível, verticais	425	178	37,5	93,32	6,06	184	não
PTRH3	PT03DOU0328	Albufeira Aldeadavila	ES	Douro	Douro	321407	472415	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH3	PT03DOU0223	Albufeira Azibo	PT	Douro	Azibo	303944	510483	1982	Não	Sim	Sim	Não	1,663	5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH3	PT03DOU0295	Albufeira Bemposta	PT	Douro	Douro	339081	482479	1964	Sim	Sim	Não	Não	0.6 (garantia interanual 2)	N.A.	240	3	Francis eixo vertical	69,0	901	456	95,56	184,08	1100	Não
PTRH3	PT03DOU0401	Albufeira Carrapatelo	PT	Douro	Douro	200533	457802	1971	Sim	Sim	Não	Sim	0.826 (garantia interanual 2)	N.A.	201	3	Kaplan eixo vertical	33,3	760	792	94,81	296,99	1000	tipo Borland localizado no muro barragem-central

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PTRH3	PT03DOU0407	Albufeira Crestuma	PT	Douro	Douro	170037	456350	1986	Sim	Sim	Não	Sim	110 (garantia interanual 264)	N.A.	117	3 grupos tipo bolbo	Kaplan eixo horizontal	12,6	327	1320	90,8	387,58	399	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0245	Albufeira Miranda	PT	Douro	Douro	354647	503464	1960	Sim	Sim	Não	Não	0.42 (garantia interanual 1)	N.A.	369	4	Francis eixo vertical	57,0	836	770	95,47	200,68	890	não
PTRH3	PT03DOU0275	Albufeira Picote	PT	Douro	Douro	347024	492382	1958	Sim	Sim	Não		0.353 (garantia interanual 2)	N.A.	195	3	Francis eixo vertical	69,0	811	336	95,4	167,23	1045	não
PTRH3	PT03DOU0371	Albufeira Pocinho	PT	Douro	Douro	286011	463899	1983	Sim	Sim	Não	Sim	0.5 (garantia interanual 0.5)	N.A.	186	3	Kaplan eixo vertical	22,0	407	1142	94,69	274,33	525	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0365	Albufeira Regua	PT	Douro	Douro	235589	463950	1973	Sim	Sim	Não	Sim	0.27 (garantia interanual 1)	N.A.	180	3	Kaplan eixo vertical	28,5	576	948	93,18	298,13	743	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0503	Albufeira Sabugal	PT	Douro	Côa	288462	374488	2000	Sim	Sim	Sim	Não	0,106	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Não
PTRH3	PT03DOU0464	Albufeira Santa Maria de Aguiar	PT	Douro	Ribeira de Aguiar	305033	433567	1981	Não	Sim	Não	Não	0,011	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH3	PT03DOU0415	Albufeira Saucelhe	ES	Douro	Douro	311750	453985	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH3	PT03DOU0393	Albufeira Torrao	PT	Douro	Tâmega	189103	458967	1988	Sim	Sim	Não		7.29 (garantia interanual 15)	N.A.	turbinamento 140, bombagem 140	2 reversíveis	Francis de eixo vertical	52,0	252	320	95,71	71,43	233	não
PTRH3	PT03DOU0353	Albufeira Valeira	PT	Douro	Douro	263404	466834	1976	Sim	Não	Não	Sim	N.A.	N.A.	240	3	Kaplan eixo vertical	33,0	629	1068	94,4	277,43	600	tipo Borland localizado no muro barragem-central
PTRH3	PT03DOU0386	Albufeira Varosa	PT	Douro	Varosa	229978	461329	1934	Sim	Não	Não	Não	N.A.	N.A.	25	3	Francis de eixo horizontal	199,9	52	15,8	N.D.	3,39	60	Não
PTRH3	PT03DOU0480	Albufeira Vascoveiro	PT	Douro	Ribeira da Pega	288829	418130	2000	Não	Sim	Não	Não	0,026	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.	N.A.	N.A.	N.A.	N.D.
PTRH3	PT03DOU0436	Albufeira Vilar - Tabuaco	PT	Douro	Távora	249970	447270	1965	Sim	Sim	Não	Não	1.8 (garantia interanual 4)	N.A.	58	2	Pelton eixo vertical	461,0	118	16	94,93	3,61	155	Não

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PTRH4	PT04MON0661	Acude Ponte Coimbra	PT	Mondego	Mondego	173863	360821	1981	Não	Sim	Sim	Sim	9,866	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Sim
PTRH4	PT04MON0633	Albufeira Aguieira	PT	Mondego	Mondego	193969	375087	1981	Sim	Sim	Sim	Sim	1.96 (garantia interanual 5)	160 (inclui abastecimento público a jusante)	turbinamento 336, bombagem 276	3 reversíveis	Francis de eixo vertical	63,2	388	525	93,92	86,31	260	Não
PTRH4	PT04MON0597	Albufeira Caldeirao (Mondego)	PT	Mondego	Ribeira do Caldeirão	267222	396621	1994	Sim	Sim	Não	Não	4.3 (garantia interanual 11)	N.A.	40	1	Francis de eixo vertical	193,0	40	26	97,36	3,12	44	Não
PTRH4	PT04MON0583	Albufeira Fagilde	PT	Mondego	Dão	228758	407257	1984	Não	Sim	Não	Não	0,560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH4	PT04MON0654	Albufeira Fronhas	PT	Mondego	Alva	197837	363816	1985	Sim	Sim	Não	Não	0.394 (garantia interanual 1)	N.A.	produção na Aguieira	produção na Aguieira	produção na Aguieira	produção na Aguieira	produção na Aguieira	N.A.	N.A.	N.A.	N.A.	Não
PTRH4	PT04MON0629	Albufeira Lagoa Comprida	PT	Mondego	Ribeira da Lagoa	241083	377350	1966	Sim	Não	Não	Não	N.A.	N.A.	0,6	1	Francis de eixo horizontal	28,5	1,0	2,6	N.D.	0.58	1,7	Não
PTRH4	PT04MON0635	Albufeira Raiva	PT	Mondego	Mondego	189880	371308	1982	Sim	Não	Sim	Sim	N.A.	160 (inclui abastecimento a jusante)	24	2 de eixo horizontal	Bolbo de eixo horizontal (kaplan)	18,2	43	160	95,93	36,9	50	Não
PTRH4	PT04RDW1172	Albufeira S. Domingos	PT	Ribeiras do Oeste	São Domingos	97864	263588	1993	Não	Sim	Não	Sim	1,677	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH4	PT04MON0620	Albufeira Vale do Rossim	PT	Mondego	Ribeira da Fervença	246231	381362	1956	Sim	Não	Não	Não	N.A.	N.A.	produção em Sabugueiro II	produção em Sabugueiro II	produção em Sabugueiro II	produção em Sabugueiro II	produção em Sabugueiro II	66	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ1069	Acude Vale de Pocos	PT	Tejo	Ribeira do Vale de Poços	151725	225360		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ0964	Albufeira Apartadura	PT	Tejo	Sever	264565	264930	1993	Não	Sim	Sim	Não	2,480	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ0936	Albufeira Belver	PT	Tejo	Tejo	211637	279050	1951	Sim	Não	Não	Sim	N.A.	N.A.	80,7	6	Kaplan de eixo vertical e grupo 6 eixo horizontal	15,2	154	798	N.D.	143,35	220	N.D.

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PTRH5	PT05TEJ0850	Albufeira Bouca	PT	Tejo	Zêzere	192132	321042	1955	Sim	Não	Não	Sim	N.A.	N.A.	44	2	Francis de eixo vertical	53,5	138	100	94,01	35,79	162	N.A.
PTRH5	PT05TEJ0824	Albufeira Cabril	PT	Tejo	Zêzere	200418	329084	1954	Sim	Sim	Não	Sim	5.2 (garantia interanual 12)	N.A.	108	3	Francis de eixo vertical	121,0	270	108	92,02	33,97	310	Não
PTRH5	PT05TEJ1117	Albufeira Carrasqueira	PT	Tejo	Cabido	220023	196469		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ0914	Albufeira Castelo de Bode	PT	Tejo	Zêzere	183550	286500	1951	Sim	Sim	Não	Sim	240 (garantia interanual 480)	N.A.	159	5	Francis de eixo vertical	96,0	335	24	90,72	49,2	390	Não
PTRH5	PT05TEJ1128	Albufeira Divor	PT	Tejo	Divor	218003	192543	1965	Não	Não	Sim	Não	N.A.	4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ0913	Albufeira Fratel	PT	Tejo	Tejo	227929	286443	1974	Sim	Não	Não	Sim	N.A.	N.A.	132	3	Kaplan de eixo vertical	29,0	256	150	90,7	145,74	430	Sim
PTRH5	PT05TEJ0971	Albufeira Jorge Bastos	PT	Tejo	Ribeira de Cojancas	231150	257370		Não	Não	Sim	Não	N.D.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ1033	Albufeira Magos	PT	Tejo	Magos	151751	225358	1938	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ1030	Albufeira Maranhao	PT	Tejo	Ribeira da Seda	213620	227720	1957	Sim	Não	Sim	Sim	N.A.	N.D.	6	1	Francis	38,6	N.D.	N.D.	N.D.	N.D.	N.D.	Não
PTRH5	PT05TEJ0816	Albufeira Marateca - Sta. Agueda	PT	Tejo	Ocreza	255722	333612	1991	Não	Sim	Não	Não	4,423	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ0818	Albufeira Marechal Carmona - Idanha	PT	Tejo	Ponsul	279672	331132	1947	Sim	Não	Sim	Não	N.A.	30	2,00	1	Francis	27	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH5	PT05TEJ0753	Albufeira Meimoa	PT	Tejo	Meimoa	284268	366208	1985	Não	Sim	Sim	Não	0,269	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ1142	Albufeira Minutos	PT	Tejo	Almonsor	203116	187892	2003	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ1015	Albufeira Montargil	PT	Tejo	Sôr	196259	231809	1958	Sim	Não	Sim	Sim	N.A.	N.D.	3,2	1	Francis	26,6	N.D.	N.D.	N.D.	N.D.	N.D.	Não
PTRH5	PT05TEJ0894	Albufeira Monte Fidalgo (Cedillo)	ES	Tejo	Tejo	292400	325937	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH5	PT05TEJ0939	Albufeira Nisa - Povoa	PT	Tejo	Nisa	249641	278877	1928	Sim	Sim	Não	Sim	0,148	N.A.	0,74	2	Francis	27,0	1,14	3	N.D.	0,6	21	Não
PTRH5	PT05TEJ0924	Albufeira Poio	PT	Tejo	Ribeira de Nisa	247412	283184	1932	Sim	Não	Não	Não	N.A.	N.A.	1,5	2	Francis	65	N.D.	N.D.	N.D.			Não
PTRH5	PT05TEJ0910	Albufeira Pracana	PT	Tejo	Ocreza	227163	289171	1950	Sim	Não	Não	Não	N.A.	N.A.	41	3	Francis de eixo ver-	57,0	49	88	95,19	13,19	58	Não

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																	tical							
PTRH5	PT05TEJ0783	Albufeira Santa Luzia	PT	Tejo	Unhais	223471	346855	1942	Sim	Sim	Sim	Sim	0,274	N.D.	25,6	4	Pelton de eixo hori-zontal	316,0	45	10	N.D.	1,98	67	Não
PTRH5	PT05TEJ0842	Albufeira Toulica	PT	Tejo	Ribeira da Touli-ca	290509	323336	1979	Não	Sim	Não	Não	0,032	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ1129	Albufeira Venda Velha	PT	Tejo	Amieira	138833	191498	1945	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH5	PT05TEJ0777	Beságueda	PT	Tejo	Rio Besá-gueda	289464	352949		Não	Sim	Sim	Não	0,120	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ0860	Corgas	PT	Tejo	ribeira de cor-gas	219621	316544		Não	Sim	Sim	Não	0,775	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ1035	Furadouro	PT	Tejo	Raia	193434	222397	1958	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ0961	Gáfete	PT	Tejo	ribeira Vale do Castelo	241203	269690		Não	Sim	Sim	Não	0,023	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH5	PT05TEJ1035	Gameiro	PT	Tejo	Raia	201989	220759	1960	Sim	Não	Sim	Não	N.A.	N.D.	1,2	1	Francis	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PTRH6	PT06SAD1268	Acude Vale Coelheiros	PT	Sado	Viscosa	151116	147836		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1193	Acude Vale das Bicas	PT	Sado	Marate-ca	157740	180078		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1273	Albufeira Alvito	PT	Sado	Odivelas	219360	145916	1977	Não	Não	Sim	Sim	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1345	Albufeira Campilhas	PT	Sado	Campil-has	157137	97384	1954	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1335	Albufeira Daroeira	PT	Sado	Daroeira	183211	104347	1953	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1340	Albufeira Fonte Ser-ne	PT	Sado	Benate-lar	167910	101768	1977	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1250	Albufeira Herdade de Vale da Lameira	PT	Sado	Algalé	192853	154344		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1361	Albufeira Monte da Rocha	PT	Sado	Sado	186115	84566	1972	Não	Sim	Sim	Não	0,62	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SUL1645	Albufeira Morgavel	PT	Mor-gavel	Morga-vel	144798	103654	1980	Não	Sim	Sim	Não	24,45	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1290	Albufeira Odivelas	PT	Sado	Odivelas	201604	135355	1972	Não	Sim	Sim	Não	N.A.	50	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1235	Albufeira Pego do Altar	PT	Sado	Alcáço-vas	177407	161249	1948	Não	Sim	Sim	Sim	1	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1265	Albufeira Rasquinha	PT	Sado	Afl. Odi-velas	229966	148026		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.

DIST_CD	EU_CD	NAME	Gestão	Bacia Hidrográfica Principal	Linha de água	M	P	Ano entrada em funcionamento	Energia	Abastecimento	Rega	Navegação Maríti-mo-Turística	Volume abasteci-mento (hm3)	Volume rega (hm3)	Potência total insta-lada (MW)	N.º de grupos	Tipo de turbina	Queda bruta (m)	Média da Produção 1993/2008 (GWh)	Capacidade máxima de descarga (m3/s) (2)	"actual efficiency" (3)	"mean actual discharge" (4)	"oirginally aimed electricity producti-on" (5)	Dispositivo de pas-sagem para peixes
PTRH6	PT06SAD1331	Albufeira Roxo	PT	Sado	Roxo	204586	107257	1967	Não	Sim	Sim	Não	3,38	15	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1252	Albufeira S.Brissos 1	PT	Sado	Xarrama	198298	151327		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06MIR1392	Albufeira Santa Clara	PT	Mira	Mira	172673	60927	1968	Não	Sim	Sim	Não	1,795	27,54	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1209	Albufeira Tourega	PT	Sado	Valverde	208651	170308	1953	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1276	Albufeira Trigo de Morais - Vale do Gaio	PT	Sado	Xarrama	185842	142315	1949	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH6	PT06SAD1249	Albufeira Vale da Arca 2	PT	Sado	Algalé	186474	155147	1974	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH6	PT06SAD1203	Albufeira Venda Nova (Sa-do)	PT	Sado	Afl. S. Martinho	163062	172303		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1407	Albufeira Abrilongo	PT	Guadi-ana	Xévora	287494	237022	2000	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1487	Albufeira Alqueva	PT	Guadi-ana	Guadia-na	255877	136709	2002	Sim	Sim	Sim	Sim	30	590 (valor máximo previsto quando todas as obras estive-rem con-cluídas)	260	2	Francis reversíve-is	76	204	203,2	87,91	41,6	400	Não
PTRH7	PT07GUA1624	Albufeira Beliche	PT	Guadi-ana	Beliche	255283	34757	1986	Não	Sim	Sim		34,469	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH7	PT07GUA1422	Albufeira Caia	PT	Guadi-ana	Caia	285503	226220	1967	Sim	Sim	Sim	Sim	2,759	35	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH7	PT07GUA1591	Albufeira Chança	ES	Guadi-ana	Guadia-na-Espanha	254109	65963		N.D.	N.D.	N.D.	Não	ND	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1522	Albufeira Enxoe	PT	Guadi-ana	Enxoé	258804	114405	1998	Não	Sim	Sim	Não	1,161	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH7	PT07GUA1441	Albufeira Lucefecit	PT	Guadi-ana	Lucefécit	263268	185644	1982	Não	Não	Sim	Não	N.A.	3	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH7	PT07GUA1541	Albufeira Monte dos Grous	PT	Guadi-ana	Afl. Ter-ges	216243	101466	1965	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1458	Albufeira Monte	PT	Guadi-ana	Degebe	236870	171641	1982	Não	Sim	Não	Não	4,227	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não

DIST_CD	EU_CD	NAME	Gestão	Bacia Hidrográfica Principal	Linha de água	M	P	Ano entrada em funcionamento	Energia	Abastecimento	Rega	Navegação Marítimo-Turística	Volume abastecimento (hm3)	Volume rega (hm3)	Potência total instalada (MW)	N.º de grupos	Tipo de turbina	Queda bruta (m)	Média da Produção 1993/2008 (GWh)	Capacidade máxima de descarga (m3/s) (2)	"actual efficiency" (3)	"mean actual discharge" (4)	"oirgnially aimed electricity production" (5)	Dispositivo de passagem para peixes
PTRH7	PT07GUA1476	Novo Albufeira Mourao	PT	Guadiana	Mourão	269644	159413	1955	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1618	Albufeira Odeleite	PT	Guadiana	Odeleite	257317	40330	1996	Não	Sim	Sim	Não	Ligação à Alb. Beliche através de um túnel	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH7	PT07GUA1513	Albufeira Pedrogao	PT	Guadiana	Guadiana	244162	127206	2005	Não	Não	Sim	Sim	N.A.	N.D.	10	2	Tubulares de eixo vertical	25	36	24,9	99,97	22,3	45	Do tipo elevador
PTRH7	PT07GUA1577	Albufeira Tapada Grande	PT	Guadiana	Tapada Grande	255230	78286	1882	Não	Não	Sim	Sim	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1461	Albufeira Torres	PT	Guadiana	Azambuja	223892	170624		Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1455	Albufeira Vigia	PT	Guadiana	Vale Vasco	245856	174702	1981	Não	Sim	Sim	Não	1,371	4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH7	PT07GUA1537	Albufeiras Herdade do Facho I e II	PT	Guadiana	Afl. Cobres	259953	104688	1954	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1604	Alcoutim	PT	Guadiana	Afl. Cadavais	256719	56173		Não	Sim	Sim	Não	0,016	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1571	Boavista	PT	Guadiana	Afl. Terges	203750	59636		Não	Sim	Não	Não	0,175	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH7	PT07GUA1490	Bufo	PT	Guadiana	Murtega	299498	132827		Não	Sim	Não	Não	0,149	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.D.
PTRH8	PT08RDA1669	Albufeira Arade	PT	Arade	Arade	178542	30440	1956	Não	Não	Sim	Não	N.A.	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH8	PT08RDA1666	Albufeira Funcho	PT	Arade	Arade	177862	33031	1993	Não	Sim	Sim	Não	30,489	N.D.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não
PTRH8	PT08RDA1679	Albufeira Odiaxere - Bravura	PT	Ribeiras do Barlavento	Odiáxere	149814	26388	1958	Sim	Sim	Sim	Não	5,164	5,319	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	Não

N.A. = Não se aplica **N.D. = Não disponível**

(1) Produtibilidade média para a série hidrológica 1966/2005

(2) Caudal máximo turbinável

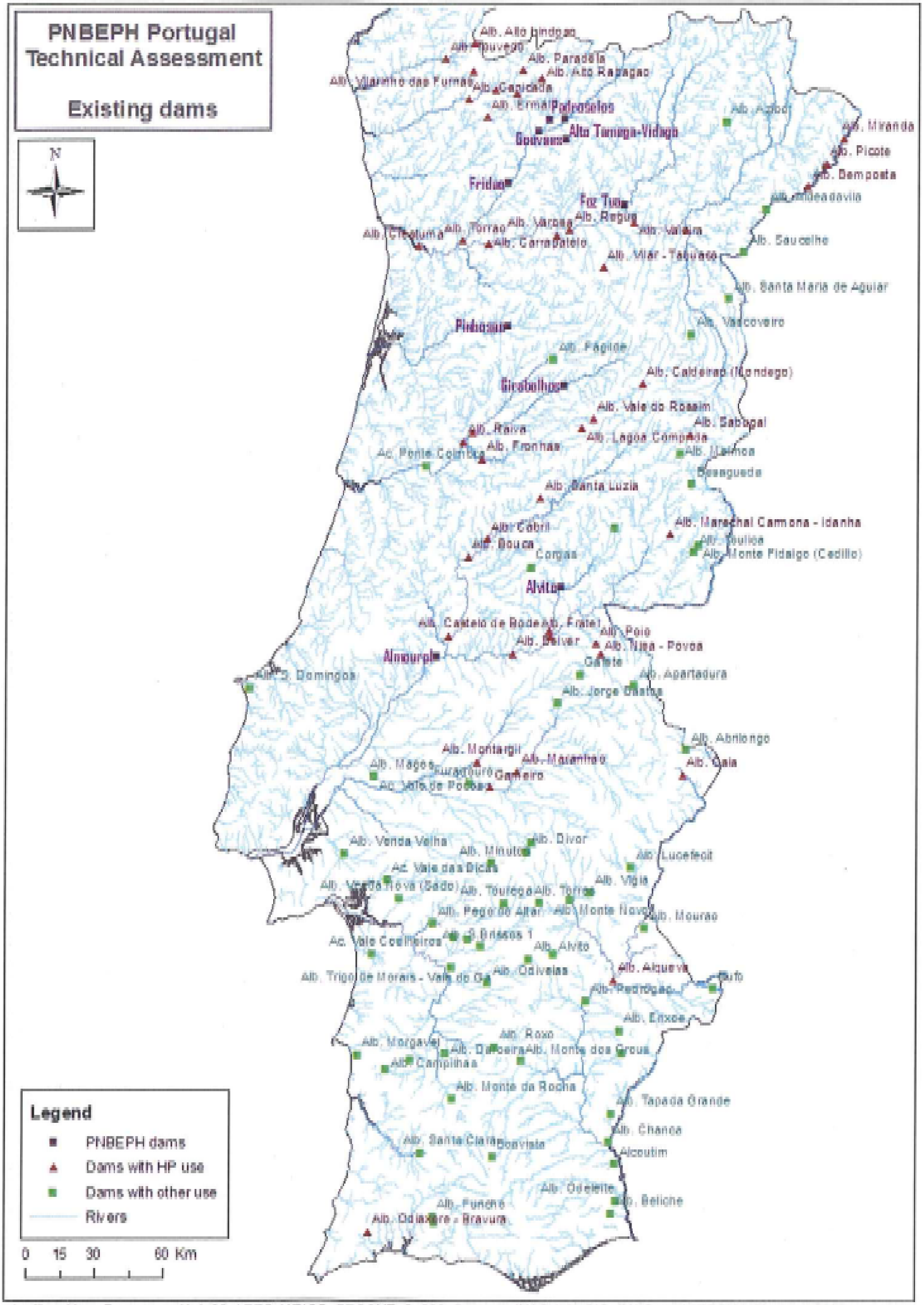
(3) Corresponde à Taxa Disponibilidade - Média 1993/2008 (%)

(4) Caudal Médio Turbinado 1993/2008 (m3/s)

105 dammen

Annex 19: Overview of hydropower installations (INAG, May 2009)

Name	Hydrological basin	River	Start of exploitation	Maximum capacity P (MW)	Actual efficiency	Desgined electricity production (GWh)	Average electricity production 1993/2008 (GWh)	Relationship average to designed electricity production
Albufeira Nisa - Povoa	Tejo	Nisa	1928	0,74		21	1,14	5%
Albufeira Poio	Tejo	Ribeira de Nisa	1932	1,5				
Albufeira Varosa	Douro	Varosa	1934	25		60	52	87%
Albufeira Ermal	Ave	Ave	1939	10,8		29	22	76%
Albufeira Santa Luzia	Tejo	Unhais	1942	25,6		67	45	67%
Albufeira Marechal Carmona - Idanha	Tejo	Ponsul	1947	2,00				
Albufeira Pracana	Tejo	Ocreza	1950	41	95,19	58	49	84%
Albufeira Venda Nova	Cávado	Rabagão	1951	281	95,64	610	376	62%
Albufeira Belver	Tejo	Tejo	1951	80,7		220	154	70%
Albufeira Castelo de Bode	Tejo	Zêzere	1951	159	90,72	390	335	86%
Albufeira Salamonde	Cávado	Cávado	1953	42	95,06	240	222	93%
Albufeira Cabril	Tejo	Zêzere	1954	108	92,02	310	270	87%
Albufeira Canicada	Cávado	Cávado	1955	62	95,14	340	302	89%
Albufeira Bouca	Tejo	Zêzere	1955	44	94,01	162	138	85%
Albufeira Paradela	Cávado	Cávado	1956	54	96,98	255	232	91%
Albufeira Vale do Rossim	Mondego	Ribeira da Fervença	1956	10				
Albufeira Maranhao	Tejo	Ribeira da Seda	1957	6				
Albufeira Picote	Douro	Douro	1958	195	95,4	1045	811	78%
Albufeira Montargil	Tejo	Sôr	1958	3,2				
Albufeira Odiaxere - Bravura	Ribeiras do Barlavento	Odiáxere	1958					
Albufeira Miranda	Douro	Douro	1960	369	95,47	890	836	94%
Gameiro	Tejo	Raia	1960	1,2				
Albufeira Alto Rabagao	Cávado	Rabagão	1964	68	91,9	155	102	66%
Albufeira Bemposta	Douro	Douro	1964	240	95,56	1100	901	82%
Albufeira Vilar - Tabuaco	Douro	Távora	1965	58	94,93	155	118	76%
Albufeira Lagoa Comprida	Mondego	Ribeira da Lagoa	1966	0,6		1,7	1,0	58%
Albufeira Caia	Guadiana	Caia	1967					
Albufeira Carrapatelo	Douro	Douro	1971	201	94,81	1000	760	76%
Albufeira Vilarinho das Furnas	Cávado	Homem	1972	125	93,32	184	178	97%
Albufeira Regua	Douro	Douro	1973	180	93,18	743	576	78%
Albufeira Fratel	Tejo	Tejo	1974	132	90,7	430	256	60%
Albufeira Valeira	Douro	Douro	1976	240	94,4	600	629	105%
Albufeira Aguieira	Mondego	Mondego	1981	276	93,92	260	388	149%
Albufeira Raiva	Mondego	Mondego	1982	24	95,93	50	43	86%
Albufeira Pocinho	Douro	Douro	1983	186	94,69	525	407	78%
Albufeira Fronhas	Mondego	Alva	1985					
Albufeira Crestuma	Douro	Douro	1986	117	90,8	399	327	82%
Albufeira Torrao	Douro	Tâmega	1988	140	95,71	233	252	108%
Albufeira Alto Lindoso	Lima	Lima	1992	630	95,81	910	797	88%
Albufeira Touvedo	Lima	Lima	1993	22	97,23	61	63	103%
Albufeira Caldeirao (Mondego)	Mondego	Ribeira do Caldeirão	1994	40	97,36	44	40	91%
Albufeira Sabugal	Douro	Côa	2000					
Albufeira Alqueva	Guadiana	Guadiana	2002	260	87,91	400	204	51%



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