TWINBAS

Twinning European and third countries rivers basins for development of integrated water resources management methods

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Work Package 6

Classification of Water Bodies
Volume I: Characterisation (D6.2)

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1. Introduction

Environmental objectives are set to protect users and uses of water from the effects of pollution and to protect the water environment itself from especially dangerous substances. The Water Framework Directive (WFD, probably the most important directive on environmental management that has been promulgated in the EU over the last decade, introduces new broader ecological objectives designed to protect, and where necessary restore, the structure and function of aquatic ecosystems.

The basic management unit for setting environmental objectives is the water body. A water body is a distinct, significant and relatively homogenous element of water. Water bodies can be grouped in different categories, such as rivers, lakes, wetlands, coastal waters, transitional waters (estuaries) and groundwaters. The WFD requires characterisation of both surface water and groundwater water bodies, and identification of the specific pressures on each water body. Identification and spatial delineation of individual water bodies within each category, by differentiating the various types on the basis of their natural characteristics, enables their environmental status to be accurately described. The WFD also requires registers of areas requiring special attention to protect their surface waters or groundwaters, or to conserve habitats and species that depend on those waters. The environmental objectives that need to be achieved under the WFD are summarised in Table 1.1:

Table 1.1 WFD environmental objectives for surface and groundwater water bodies (from Defra, 2005a)

	Environmental objective
Surface waters	Achievement of good ecological status and good surface water chemical status by 2015
	Achievement of good ecological potential and good surface water chemical status for HMWBs* and AWBs*
	Prevention of deterioration from one status class to another
	Achievement of water-related objectives and standards for protected areas
Groundwaters	Achievement of good groundwater quantitative and chemical status by 2015
	Prevention of deterioration from one status class to another
	Reversal of any significant and sustained upward trends in pollutant concentrations and prevent or limit input of pollutants to groundwater
	Achievemnt of water-related objectives and standards for protected areas

*HMWB – heavily modified water body; AWB – artificial water body

The status of each water body is determined by comparison with desired reference conditions, usually specified as the ecological status of a water body free from anthropogenic influences. Therefore, within each category, water bodies are grouped according to their physical, chemical, biological, morphological and hydrological characteristics, and type-specific reference conditions are established. Based on the reference conditions, each water body is classified as having a high, good, moderate, poor or bad ecological status. Once actual or potential environmental problems have been identified, in terms of the risk of not achieving good status by 2015, cost-effective protection and improvements measures can be designed and implemented, as a component of successful river basin planning. Risk assessments, and river basin management plans, should be updated periodically as knowledge of the risks to the status of the water environment improves through modelling and targeted monitoring.

The conceptual adaptation and application of the WFD approach to water body classification is more advanced in some of the TWINBAS basins than others:

- The analysis has largely been completed in the UK, and the information presented here for the Thames River Basin is summarised from the report for the Thames River Basin District (Defra, 2005a) and supporting maps (Defra, 2005b). Selected maps are reproduced in Volume II of this deliverable with written permission of the Environment Agency for England and Wales.

- In Kazakhstan, for the first time, water bodies of the Nura River Basin have been classified according to the WFD methodology, and protected areas and recreational sites have been documented.

- In Chile, where available resources and baseline information are limited, emphasis was put on the establishment of a water body typology for the rivers of the Biobío River Basin, and other surface water categories may be addressed in future research efforts.

- In Sweden, neither a classification of ecological status nor a risk categorisation for the Norrström River Basin was made under the framework of the TWINBAS project, in order to avoid confusion with the on-going work of the District Water Authority.

- In Southern Africa, classification work was focussed on the Okavango Delta wetland. Wetlands are a category not explicitly included in the WFD natural surface water body classification, and so the WFD has not been adopted.

After this introduction, Section 2 sets out the key components of the water body classification, defining, in general terms, the different types of water body, the pressures and impacts on them, reference conditions for water bodies, and the overall risk assessment. Section 3 summarises the environmental and economic characteristics of the five river basins, to set the scene for the water body classification in Section 4 and the risk categorisation in Section 5. Section 6 presents some concluding remarks for each basin. This document should be read in conjunction with the supporting maps volume (WP6, 2007b).

2. Approach to water body classification

The WFD gives guidance on how to identify individual water bodies and organise them according to category, and how to establish a typology for each category of water body. Although there are general recommendations, standards and objectives for all European water bodies, local adaptations to the general framework may be required. This is also the case when WFD concepts and methodologies are applied to non-European river basins, such as those in TWINBAS, where both the regional natural conditions and the national legal and institutional frameworks need to be taken into consideration.

2.1 Defining and identifying water bodies

2.1.1 Natural surface water bodies

In the WFD, natural surface water bodies are split into rivers, lakes, and transitional (estuarine) and coastal (sea) waters:

- ***Rivers*** - The WFD baseline threshold for river water bodies is a catchment area of at least 10 km^2. Under WFD system A[1], used in the UK, river types are defined according to a system that uses altitude, catchment size and geology to create 48 possible river types. However, in Sweden, system B is used with threshold of river stretches greater than 15 km or river stretches downstream of a lake larger than 1 km^2, as system A is not representative of Swedish biology (Swedish EPA, 2005).

- ***Lakes*** - The WFD baseline threshold for lakes is a surface area of at least 0.5 km^2. In Sweden, this threshold is increased to 1 km^2 using the 1:250K Swedish land survey base maps. Under WFD system B[1], lake types are defined according to a system that gives priority to those factors that have the greatest bearing on the lake's ecological condition, such as the geology of the catchment, expressed as the base status (alkalinity) of the lake, and the depth of the lake, expressed as the mean depth. The system also uses altitude, latitude, longitude and size, as necessary.

- ***Transitional and coastal waters*** - Transitional (estuarine) and coastal (sea) waters contain a diverse range of habitats. Under WFD system B[1], water bodies of these types are defined according to a system that uses latitude, longitude, tidal range and salinity, as well as mixing characteristics, mean substratum composition and wave exposure which are important in determining ecology.

2.1.2 Artificial and heavily modified surface water bodies

AWBs and HMWBs fit into different classification schemes to natural surface water bodies as, firstly, it is recognised that their modified state is socially and/or economically beneficial and should be retained and, secondly, they do not have undisturbed or relatively undisturbed states against which to set reference conditions. However, it is useful to provisionally classify them into types until work on an appropriate classification schemes (e.g. Swedish EPA, 2005) are finalised as some measures may be required to retain the benefits of the use whilst, where possible, mitigating any adverse effects of the modification:

[1] System A prescribes how water bodies are characterised spatially and with respect to specific altitude, size and lake depth intervals, whilst System B uses the same obligatory factors but lacks this prescription and also permits the use of additional factors where necessary. Most EU Members States use System B.

- ***Artificial water bodies*** **-** AWBs are bodies of surface water created by human activity, usually for specific uses which provide valuable social and economic benefits e.g. lriver AWBs include canals and surface water transfers whilst lake AWBs include man-made reservoirs and gravel pits. Many AWBs are important for water supply reasons and it is important to manage their water quality and hydrology for the purposes of satisfying the WFD. However, many AWBs have secondary uses other than for the reason they were designed and may support aquatic ecosystems (e.g. artificial reservoirs are often used for recreational activities), which requires the water quality, ecological or water quantity to be managed appropriately. Some AWBs may have a significant impact on non-AWBs and it is beneficial to manage them to protect the non-AWBs.

- **Heavily modified water bodies –** HMWBs are natural bodies of surface water which have been substantially physically altered for specific purposes such as navigation, water storage, flood defence and land drainage.

2.1.3 Groundwaters

Groundwater water bodies are identified according to, firstly, hydrostratigraphic boundaries and then, secondly, catchment hydrological boundaries. Where available, information on groundwater catchment divides is also used. Aquifers are then grouped into categories based on how groundwater flows within them and how much water is available for abstraction. The main groundwater water body types are Primary, Secondary, Significant Drift and Unproductive Strata.

In addition to groundwater bodies themselves, it is also necessary to consider ecosystems and water bodies dependent on groundwater quantity and quality, known as groundwater dependent terrestrial ecosystems (GWDTEs).

2.1.4 Protected areas

The WFD requires that a register of protected areas be established, which will help to ensure that areas are managed to protect the surface water or groundwater bodies within them, and to assess whether they are likely to reach their objectives, designated by the appropriate directive, by 2015. In the EC, areas benefiting from or requiring protection include:

- Waters used for the abstraction of drinking water – protected areas for drinking water supplies are identified as water bodies that supply a daily average of more than $10m^3$ water for drinking or supply more than 50 people, and must be identified under the WFD.

- Areas designated for the protection of economically significant species – these areas are designated for the protection of shellfish and freshwater fish, and of the economic activities that depend on them.

- Recreational waters – these areas are designated bathing waters.

- Nutrient sensitive areas – these areas comprise designated nitrate vulnerable zones and designated as sensitive eutrophic or nitrate areas.

- Areas designated for the protection of habitats or species – these areas are designated for the protection of habitats or species where maintaining or improving the status of water is important for their protection.

2.1.5 Wetlands

The WFD does not set environmental objectives for wetlands in the same way that it does for other surface water bodies. However, wetlands form an important component of two of the TWINBAS river basins, the Nura and the Okavango which both terminate in inland wetlands, and so are considered in this report.

The Ramsar Convention defines a wetland as: "*An area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres and may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands.*" Furthermore, a wetland is deemed to be of international importance if it is of: "*International significance in terms of ecology, botany, zoology, limnology or hydrology*" and that "*in the first instance, wetlands of international importance to waterfowl at any season should be included.*"

The Ramsar Convention identifies six wetland categories:

- Marine – open ocean and continental shelf not influenced by river flows (e.g. coastal lagoons, rocky shores, and coral reefs)
- Estuarine - where rivers meet the sea, influenced by diurnal tidal cycles (e.g. deltas, tidal marshes, and mangrove swamps)
- Lacustrine - areas of permanent water with little flow and vegetation (e.g. lakes)
- Riverine - land periodically inundated by river overflow (e.g. wetlands along rivers and streams)
- Palustrine - more or less permanent water with significant vegetation cover (e.g. marshes, swamps, and bogs)
- Artificial - wetlands created or radically modified by humans (e.g. fish ponds, gravel pits, temporary storage areas, artificial salt pans)

The natural features which characterise wetlands are water, soil and vegetation. Surface and ground water are interlinked as surface water infiltrates to ground water, and rising ground water may exfiltrate in surface channels and depressions. Soils are typically alluvial and characterised by permanent and frequent saturation. Vegetation ranges from aquatic plants growing in standing water and saturated soils (reeds and sedges) to terrestrial plants (grasses, shrubs and trees) dependent on groundwater recharged from the surface.

Wetlands are of particular importance to the classification of water bodies because there is a recognised interaction between wetlands and other water bodies (EA, 2002a):

- The effects of groundwater pollution or over-abstraction on terrestrial ecosystems that depend on groundwater, such as wetlands, must be controlled to achieve good groundwater status. This will entail development of a technical understanding of the water needs of these ecosystems and the establishment of criteria for defining what constitutes significant damage to them.

- The ecological quality of surface water bodies depends to some extent on the structure and condition of the land immediately surrounding them. Wetlands adjacent to other surface water bodies must be protected and restored in so far as is necessary to achieve the ecological and chemical status objectives for those water bodies.

- Wetlands can provide an effective means of trapping and breaking down pollutants that would otherwise end up in surface water bodies. Wetlands may, therefore, be an important and cost-effective means of controlling pressures such as urban and agricultural diffuse pollution.

- The WFD establishes a planning mechanism designed in part to help achieve the objectives of protected areas, including areas designated for the protection of wetland habitats and species where the maintenance or improvement of the status of water is an important factor in their protection.

Hence, the protection of wetlands and understanding of how wetlands interaction with surface and groundwater water bodies is key to achieving environmental objectives in those water bodies. WFD supplementary guidance states that wetlands should be treated as appropriate surface water bodies or groundwater dependent terrestrial ecosystems (GWDTEs). It also states that wetlands may be accounted for as ‘protected areas’ such that they have defined special hydro-ecological requirements.

2.2 Pressures on water bodies

One of the main parts of water body classification and risk assessment is the analysis of pressures on water bodies and impacts of those pressures. This work was largely covered in WP5 (2007), which focused on pollution pressures. Pressures on water bodies can be summarised as:

- ***Point sources*** – A water body is at risk if the environmental quality standards for any of the 33 priority substances identified by the EU (on the basis of their toxicity, persistence and liability to bioaccumulate), plus radioactive substances, are exceeded. Point source pressures are often linked to economic activities, and so particularly aimed at sewage works and industry who typically have to have a licence to discharge these substances that can damage the ecology of receiving waters.

- ***Diffuse sources*** – A water body is at risk if it fails the WFD objectives due to pollution from nutrients, sediment, pesticides and sheep dip, urban land use, acidification, mines and minewater. These pollution activities have an individually minor, but collectively significant, environmental impact. Links between economic activities and diffuse pollution sources are more difficult to determine, though population and urban growth (runoff from hard surfaces) and agricultural production (use of fertilisers and pesticides) are identified important drivers.

- ***Abstraction and flow regulation pressures*** – Water is abstracted from surface and ground water bodies to provide water for domestic, agricultural and industrial activities. Abstraction of too much water can damage aquatic ecology, particularly during dry periods when the environment may already be under pressure. Abstraction and flow regulation are clearly linked to economic activities, as household and industrial growth will affect the level of water demand. Integrated river basin planning aims to balance socio-economic and environmental demands.

- ***Morphological pressures*** – Physical alterations to a water body can cause damage to habitats that might result in the decline or loss of species. These could be activities such as land reclamation, construction of flood defences, weirs, dams, etc, dredging, commercial fishing, transport and recreation. Some morphological changes can be lined to economic activities, but others are more difficult, often lined to historical activities. AWBs and HMWBs are particularly subject to such pressures.

- ***Other pressures*** – An increasingly important issue highlighted here is that of deliberately or accidentally introduced alien species, which are non-native organisms that establish themselves in, and may disrupt, native ecosystems i.e. flora and fauna. They can result in loss of biodiversity and may have economic impacts. This issue has gained prominence in South Africa in recent years, with their well-established "Working for Water" campaign which aims to remove non-indigenous plants and trees to improve land and water management.

It is difficult to predict all the likely changes in pressures that may take place between now and 2015 when the WFD's environmental objectives must be achieved, or to assess the likely effects of (for example) current, proposed or future regulatory activity. Therefore, the general assumption that, if a water body is at risk of not meeting the environmental objectives of the WFD by 2015 due to pressures operating now, the same level of pressure will still exist in 2015, is not unreasonable. Of course, in reality the pressures on those water bodies may decrease or increase during the period up to 2015. Trends may be factored into the risk assessments when there are readily available trend data, or where planned investment is already funded. For instance, in the Thames Basin, trends incorporated into risk assessments are water industry investment plans for the period 2005-2010, Agency Water Resource Strategies, and preliminary assessment of nitrate trends in groundwater (considered in diffuse source assessments for groundwater).

2.3 Reference conditions

Good status is defined differently for surface waters and groundwaters. For surface water bodies, it comprises good "ecological" status and good "chemical" status (WWF/EEB, 2004). Ecological status measures the quality of the structure and functioning of aquatic ecosystems associated with surface waters, which result from a combination of biological elements (e.g. organisms, diversity), physico-chemical elements (e.g. temperature, oxygen) and hydromorphological elements (e.g. flow). Good ecological status means a slight biological deviation from what would be expected under natural or undisturbed reference conditions i.e. no chemical contamination, water abstraction or physical changes like dams or embankments). Table 2.1 lists the requirements for different ecological status classes (EA, 2002a). Good chemical status is achieved when all EU environmental quality standards are met, including the Directive on the discharges of dangerous substances to surface waters and the list of priority substances under WFD article 16.

Reference conditions for natural surface water body types describe the biological (flora and fauna i.e. plants, macroinvertebrates, fish) and the chemical, physical and hydromorphological conditions expected to occur in undisturbed or relatively undisturbed states. The exercise to establish reference conditions for water body types will directly inform future monitoring, modelling and research programmes since it reveals where there remain significant gaps in knowledge of the pressures and impacts on some water bodies. For example, in the UK, there are currently no suitable or widely available datasets for identifying the impacts of hydromorphological pressures on ecological status (e.g. on macroinvertebrate communities).

Table 2.1 Ecological status classes (from EA, 2002a)

Ecological status class	Definition
High	Each of the relevant biological, physico-chemical and hydromorphological quality elements match their reference conditions
Good	The relevant biological quality elements are only slightly changed from their reference conditions as a result of human activities. Environmental quality standards are achieved for the relevant physico-chemical quality elements.
Moderate	The relevant biological quality elements are moderately changed from their reference conditions as a result of human activities.
Poor	The relevant biological quality elements show major changes from their reference conditions as a result of human activities (i.e. there are substantial changes to the reference biological communities).
Bad	The relevant biological quality elements are severely changed from their reference conditions as a result of human activities (i.e. large portions of the reference biological communities are absent).

The WFD recognises that some water bodies have been changed or created as a result of human activity to such an extent that it is not possible to achieve good ecological status. The restoration of these water bodies to reference conditions may not be practical or feasible without leading to significant adverse effects on the purpose for which they were modified. These HMWBs or AWBs have separate classification schemes using classes of ecological potential as opposed to ecological status, though they still have to achieve good chemical status.

Good groundwater status comprises good "chemical" status and good "quantitative" status. Good chemical status is achieved if no salt or other intrusions occur, if relevant EU standards are met, and if surface waters and terrestrial ecosystems, like wetlands, are not negatively impacted. Good quantitative status means that less water is abstracted than is recharged in the long-term, and that there is enough flow to maintain all the ecological functions of associated surface waters and terrestrial ecosystems.

In addition to the designation of water bodies for environmental reasons, the WFD also requires surface and groundwater water bodies to be designated as drinking water protected areas if they provide more than 10 m^3/day or serve more then 50 people per day, or are intended to do so in the future.

WFD Annex V establishes the definition of good status and lists the quality elements and criteria to achieve it. These are reproduced in the relevant CIS guidance document (WFD CIS No 10; EC, 2003) which also describes methods, principles and criteria for establishing reference conditions and quality class boundaries, including determining the roles of the biological, physico-chemical and hydromorphological elements in the overall ecological status. Figure 5.1 indicates the relative roles of biological, physico-chemical and hydromorphological quality elements in ecological status classification (WWF/EEB, 2004). The WFD requires that ecological status classifications should be based on the "one out – all out" principle which means that ecological status is based on whichever of the values for the biological and physico-chemical assessment for the relevant quality elements is lower.

As mentioned earlier, reference conditions are equivalent to the biological quality elements at high status that are found at existing sites in suitably undisturbed states. However, if there are no undisturbed sites of a particular water body type, reference conditions can be derived from analysing historical information, from modelling, or by using expert judgement (WWF/EEB, 2004).

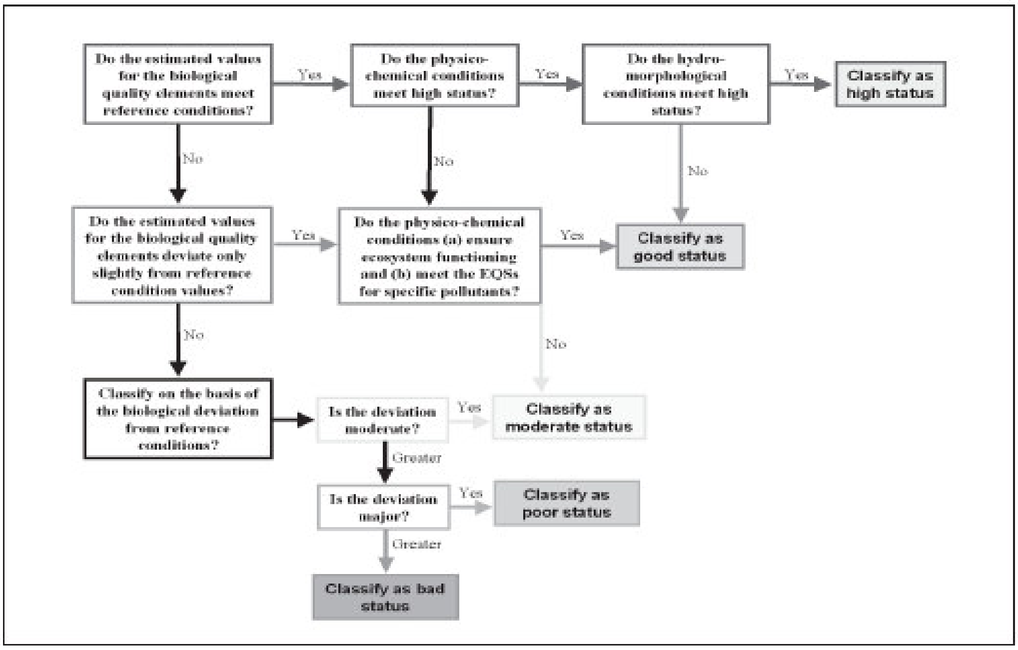


Figure 2.1 Relative roles of biological, physico-chemical and hydromorphological quality elements in ecological status classification (from WWF/EEB, 2004)

2.4 Assessing and categorising risk

The principal objective of the WFD is for member states to aim to achieve good status for their water bodies, and to comply with protected area standards and objectives, by 2015. Good status refers to good ecological status and good chemical status for surface water, and good quantitative status and good chemical status for groundwater. The WFD requires water bodies to be reported as either at risk or not at risk of failing their objectives by 2015, to help shape monitoring programmes, provide a starting point for identifying risk reduction measures (through a programme of measures) and the basis for river basin management planning.

Table 2.2 shows risk reporting categories and subsequent actions proposed for the UK. It is reasonable to assume that if a water body is at risk now, it will also be at risk in 2015, except where there are accurate trend data to suggest otherwise and/or where programmes of measures are already funded in place. The risk categories help target future work, including monitoring programmes, to improve the reliability of assessments.

Table 2.2 Reporting categories and subsequent actions in the UK (from Defra, 2005a)

WFD risk category	UK risk category Risk of failing WFD objective	Action
At risk	Water bodies at significant risk	Consideration of appropriate measures can start as soon as practicable
	Water bodies probably at significant risk, but for which more information is required	Focus on more detailed risk assessments to determine whether water bodies in this category are at significant risk (by 2007)
Not at risk	Water bodies probably not at significant risk	Focus on improving quality of information (by 2013)
	Water bodies not at significant risk	Review by 2013 to identify any significant changes in the situation

3. Environmental and economic characteristics of river basins

3.1 Biobío

3.1.1 Environmental characteristics

The Biobío River Basin spreads out over Chile's VIIIth and IXth Administrative Regions, two of Chile's more heavily populated regions. The basin covers a total surface area of approximately 25,000 km^2. The location of the Biobío River Basin with respect to other important hydrographic basins of South-Central Chile, is given in Figure 3.1.

With a mean annual flow of 954 m^{3}s^{-1} at its mouth, the Biobío River has the second highest mean flow of all Chilean rivers. Precipitation fluctuates between 1200 and 2000 mm annually across the basin, falling mainly between May and August (winter). Snowfall occurs during winter in the uppermost parts of the Andes, and occasionally at the highest elevations in the coastal mountains. The flow regime is pluvial, with maximum and minimum monthly means of 1823 and 279 m^{3}s^{-1} during July and February (summer), respectively.

The Biobío River, the main course of the river network of this basin, is the most important source of drinking water for most of the human population located along its run. It is also an important provider of hydroelectric power, with a number of natural and artificial reservoirs located in the Andes, some of which have a big influence on the flow regime of the Biobío River, both at the daily, seasonal and inter-annual level. The Biobío River further also acts as a receiving body for an important amount of both industrial and urban effluents. Water abstraction for agriculture from both Biobío and tributaries is very important during summer, especially in the central part of the basin.

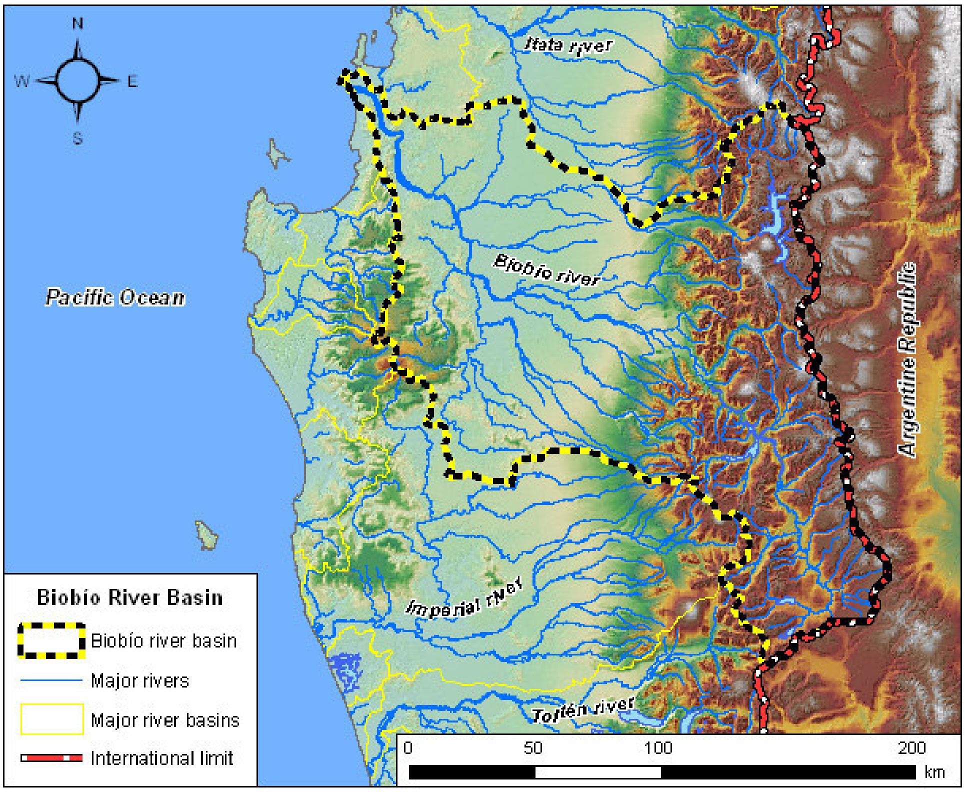


Figure 3.1 Hydrographic context of the Biobío River Basin, Central Chile

This concentration of human activities in the Biobío River Basin generates considerable pressure on the water resources, and causes the existence of a series of environmental problems, especially along the middle and lower reaches of the Basin where the major urban centres are located (e.g. Concepción, capital of the VIIIth Administrative Region). These problems constitute serious risks for the protection and conservation of both the natural and human environments in the Basin. Some of the human activities with a potentially strong impact are the modifications of the natural flow regime due to hydropower generation and water abstraction for irrigation purposes, the deforestation of hillslopes and the consequent loss of the top soil layer (accelerated erosion), the non-authorised sand and gravel extractions and modifications of river morphology, and the discharge of contaminants from the different economic activities in the basin (point and non-point sources).

In order to counteract the negative effects of human activities in the basin, several initiatives have been undertaken in recent years. Special mention can be given to the sanitation plans developed by the regional water company as well as by several of the most important industrial polluters in the basin (e.g. implementation of cleaner technologies and secondary treatment of waste waters). Another important aspect that can be mentioned is the current development of a secondary (i.e. in-river) Water Quality Standard for the Biobío River Basin. This new water quality standard will take into consideration the currently known spatial variability of water quality conditions in the basin which will be used as a reference condition for preventing further deterioration of the surface water quality. The results from the present work package, once confirmed by ongoing research, may then be incorporated in the future revisions of this new standard, which are planned to take place every five years.

3.1.2 Economic characteristics

The Biobío River Basin constitutes a hotspot for economic development, and concentrates an important amount of commercial, industrial and political activities. Most importantly, the Biobío River, the main course of the river network of this basin, is an important provider of hydroelectric power, generated by the hydropower plants of Pangue and Ralco. In a similar way, the Laja River, one of the main tributaries to the Biobío, constitutes one of the most important sources of hydropower at the national level, generated by a series of plants such as Abanico, El Toro, Antuco and Rucúe. A number of natural and artificial reservoirs are located in the Andes and some of these have a big influence on the flow regime of the Biobío River. Figure 3.2 shows the most important urban settlements in the basin, located mainly in the central and lower parts. Also shown are the major Andean lakes (Laja in the north-east and Galletue and Icalma in the south-east), and the Pangue and Ralco artificial reservoirs on the main river.

Other uses of the basin's water include paper mills and other industries, agriculture and forestry activities, and water abstraction for domestic, agricultural and industrial supply, all of which have the potential to cause pollution in the Basin. The most important pollution pressures in the Basin are the point-source discharges from industry and households, non-point contamination from agriculture and forestry activities, and flow regulations due to dam operation and extraction of river water for irrigation. Considering the amount of industrial discharges and municipal effluents, the Biobío River is one of the Chilean water bodies most heavily loaded with contaminants. Negative impacts from these point-sources have increasingly been addressed over the last years, but regional topography and a pronounced seasonality of rainfall also generate a high potential for contamination from diffuse sources. It is expected that non-point source contamination will gradually receive more attention over the next few years.

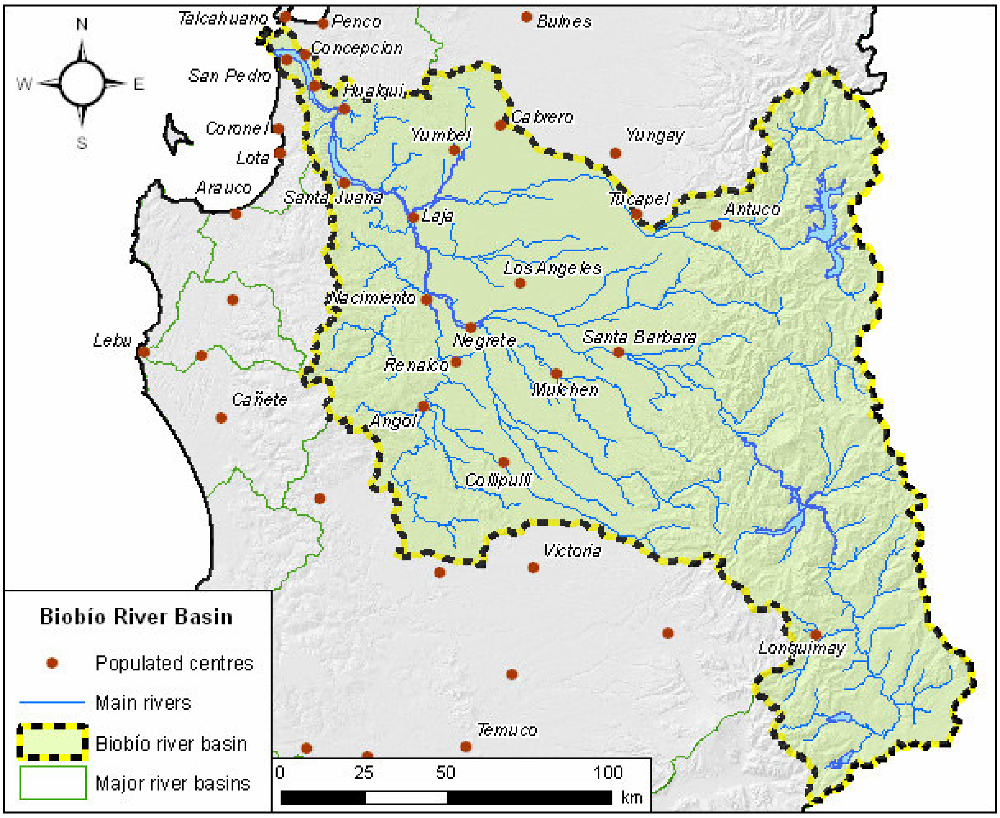


Figure 3.2 River network, major lakes and urban settlements of the Biobío River Basin

Harvesting, land use conversion and forest fires have severely fragmented and degraded the surface area still covered by intact, native vegetation. The effects of human activities on aquatic biodiversity remain largely unknown. The assessment and remediation of the potential negative impacts of climate change and future development scenarios on the local water balance, water quality and aquatic ecosystem health are major challenges that urgently need to be addressed.

3.2 Norrström

3.2.1 Environmental characteristics

The Norrström river basin (Figure 3.3) covers an area of 22,600 km^2 and includes two of Sweden's largest lakes: Lake Mälaren and Lake Hjälmaren. The basin has its outlet in the central Stockholm. Forests and mires dominate the area and cover about 70%. There are also large agriculture areas, covering approximately 20%, while lakes cover around 10 % of the area (Wallin *et al.,* 2000). Apart from Stockholm, three of the ten largest cities in Sweden are situated in the Norrström basin: Örebro, Uppsala and Västerås.

The Norrström river basin receives an average of 640 mm rainfall per year which is in close proximity to the national average of 690 mm (based on an average of the years of 1995-1999). Lake Mälaren, the largest lake, has an average depth of 12.8 m, though in more than 20 % of the lake the average depth is only 3.0 m. During the last 30 years, the flow at Norrström has averaged 164 m^{3}s^{-1}. Mälaren provides about 1.5 million people with drinking water and is, at the same time, the recipient from surrounding cities and industries. Continuous water quality monitoring and sewage treatment is of great importance. The largest water quality problem in Mälaren is eutrophication (WP1 report, 2004).

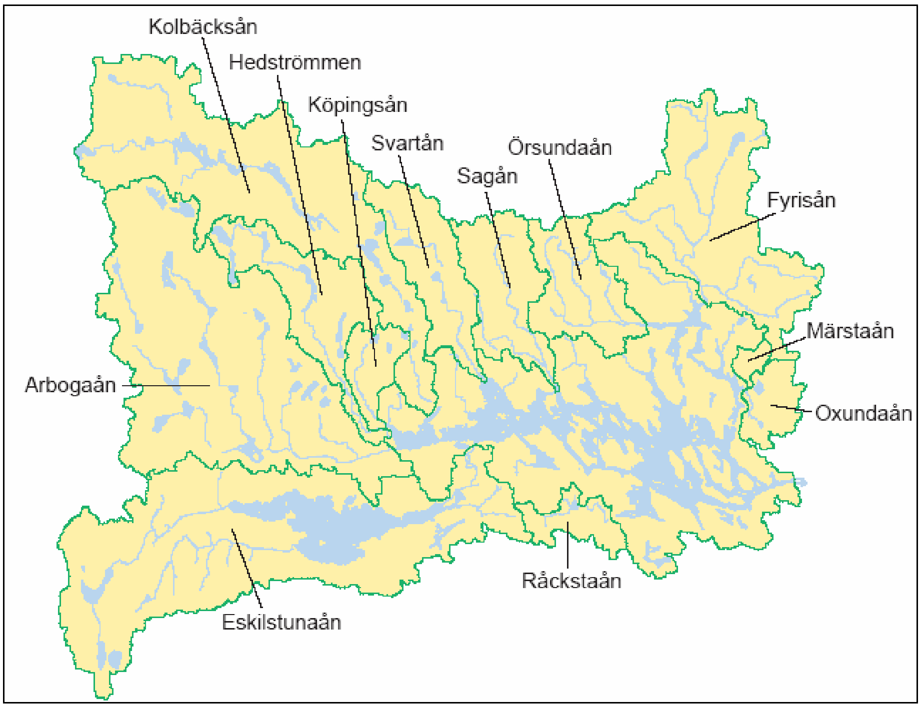


Figure 3.3 River network and main tributaries of the Norrström River Basin, Central Sweden (from Wallin et al., 2000)

In the late 1960s and early 1970s, the chemical and biological status in Lake Mälaren improved significantly. This was mainly due to improvements in techniques of sewage treatment plants which caused a reduction of phosphorous of 60 % of the total input to Mälaren (WP1, 2004). Today, source distribution calculations indicate that agriculture accounts for the largest impact of nutrients to Lake Mälaren (WP5, 2007).

3.2.2 Economic characteristics

The Norrström river basin covers an area of about 5 % of Sweden and has a population of approximately 1.7 million (reference date 2002). Sweden is divided into five water districts. The Norrström river basin is a part of the North Baltic Water District, and constitutes the main part of that district. In 2004, Statistics Swedish made an investigation of the basic economic conditions in the water districts to give an economic view of the water use.

The North Baltic Water District has the highest gross regional product of all the districts. It has also the largest number of households and the highest income per household. The industries using most water nationally are pulp mills, chemical manufacturers, steel/metal industries and electricity/heat suppliers, and account for almost 85 % of the national water abstraction. In the North Baltic Water District, these industries contribute however only 5 % of the gross regional product and are not very significant for the regional economy. The most expense for environmental protection is paid by the heating companies. Households, as in the other water districts, pay most in terms of environmental taxes. In the North Baltic Water District, the households pay about 50 % of the taxes.

The largest water out-take is by the municipalities' water treatment plants. This out-take is mostly used by the households. The municipal water treatment plants accounts for the largest pollution discharges, and the largest releases of cleaned water. Of the water intensive industries, the pulp mills are responsible for the largest discharges.

3.3 Nura

3.3.1 Environmental characteristics

The Nura basin covers an area of 53,147 km^2 and is the most water deficient river basin in Kazakhstan (Figure 3.4). The 978 km long River Nura is the main river of the central Kazakhstan region. It rises in the Karkaralinsk mountains in the east of the country and flows westward through the heavily industrialised Karaganda region before entering the terminal lakes and wetlands of the internationally important Kurgaldzhino nature reserve. The predominant land form in the basin is semi-arid steppe, characterised by low undulating hills and sparse grassland drained by seasonal rivers. The climate is sharply continental, with cold winters, hot summers and little precipitation. The average January temperature is -15°C, rising to an average +20°C in July, and annual precipitation ranges from 250-300 mm. The river freezes on average for a period of 140-150 days, and a stable ice cover is generally established by the end of November. Because of the climate of the region, the majority of surface flow of the Nura occurs as snowmelt in the spring. The size of the spring flood is extremely variable, however, and peak flow can range from 40 to 980 m^{3}s^{-1}. Estimated annual naturalised flow is 5.9 m^{3}s^{-1} at Karaganda, and 19.6 m^{3}s^{-1} near Astana. The average annual discharge from the river Nura to the Tengiz-Kurgaldzhinsky lakes is approximately 1.1 km^3.

The main water users in the basin are industry, municipal economy and agriculture. The region's water resources are supplied by a complex and interconnected system of hydro-engineering structures and mainly depend on surface water. Groundwater resources are generally scarce and are mainly exploited for drinking water supply. A significant proportion of the industrial water demand used to be supplied by the 458 km long Irtysh-Karaganda Canal which transfers water from the River Irtysh in the north-east of the country to the Nura just upstream of Karaganda, via 14 dams and 22 pumping stations. However, it is uncertain whether the canal is a viable option for the long-term water supply of the Karaganda-Temirtau region

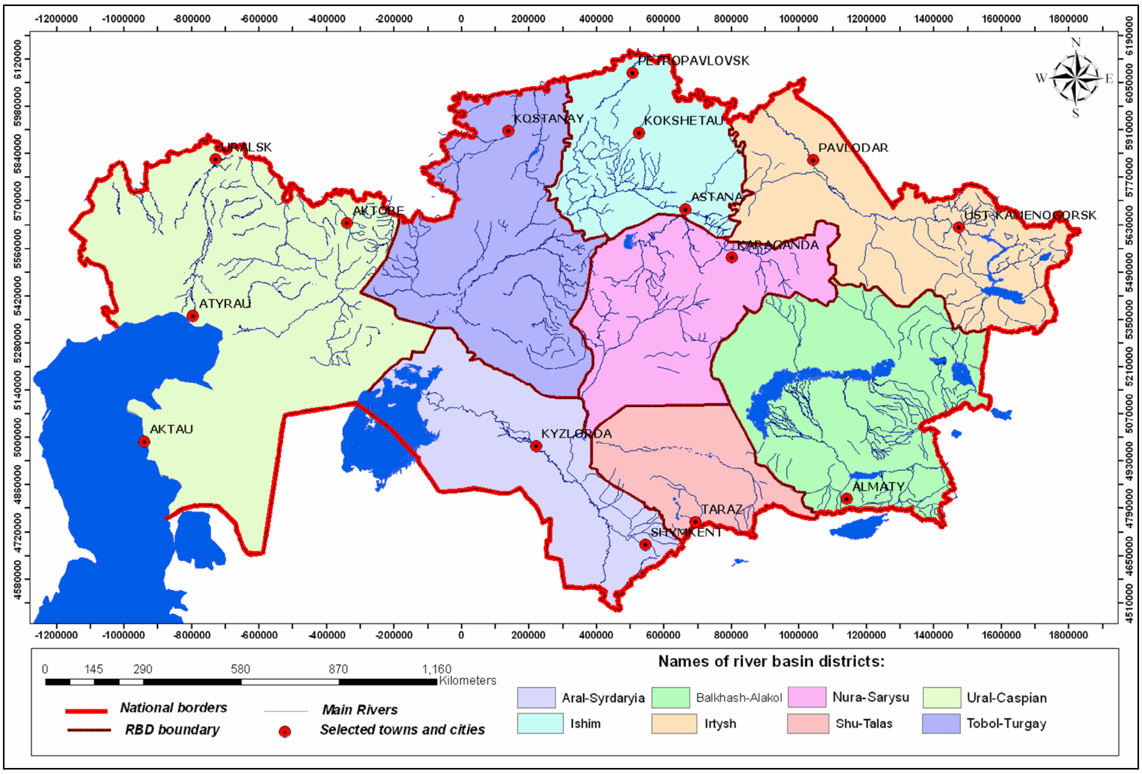


Figure 3.4 River basin districts in the Republic of Kazakhstan

and the water security of the new capital city Astana, situated 300 km downstream of Temirtau on the River Ishim which has an average annual flow three times smaller than the Nura. A 25 km link canal between the Nura and the Ishim is intended to supply additional water from the Nura to Astana. There is widespread concern however over the impact of changes in the river abstraction regime and upstream water quality on the wetlands 150 km downstream of Astana.

Downstream of the densely populated and industrialised Karaganda region, the Nura suffers from a high level of pollution by heavy metals, oil products, and other chemicals. The principal pollutant of concern is mercury. Mercury wastes have entered the river for many years with effluents from a chemical plant in Temirtau as a result of accidents and outdated technological processes. Water quality is generally a serious problem: 31% of water samples do not meet minimum chemical composition standards. As there is no organised sewage/wastewater disposal from cattle-breeding or agricultural fields, diffuse pollution occurs especially during snowmelt and during rains. A project to clean up the most polluted section of the Nura river downstream of Temirtau has recently been initiated by the World Bank. Remediation work is scheduled to start in spring 2008 and must be finished by August 2010.

3.3.2 Economic characteristics

In administrative terms, the Nura basin belongs to the Nura-Sarysu river basin district, one of eight major river basin divisions in Kazakhstan (Figure 3.4). The Sarysu River is located in the arid south of the region and only has surface flow in spring. The two river systems are connected via the non-operational Nura-Sarysu canal. The Nura catchment alone (Figure 3.5) covers almost 55,000 km^2, excluding the area of Lake Tengiz in the terminal wetlands. Major population centres are also shown, though Astana is not indicated as it lies just outside the Nura basin and formally belongs to the Ishim river basin.

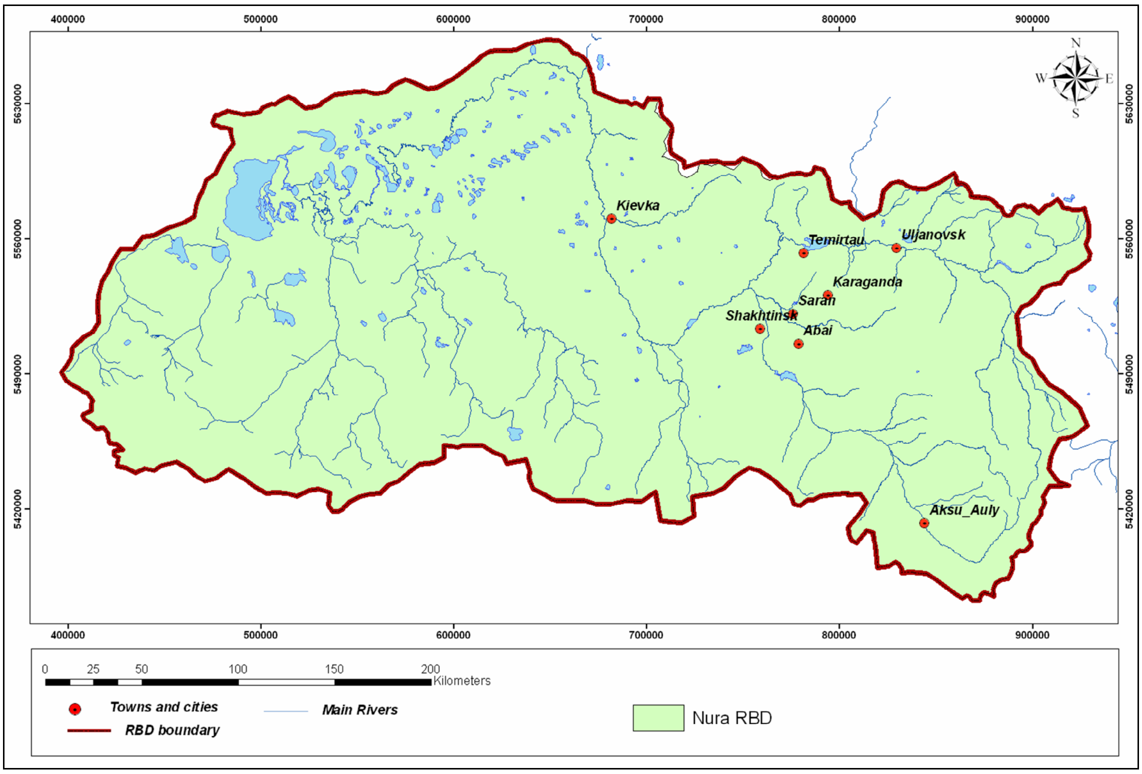


Figure 3.5 River network, major lakes and urban settlements of the Nura River Basin

The Nura basin covers the southern part of the Akmola oblast (administrative region) and the northern part of the Karaganda oblast. Near the Nura lie many of the cities and large population centres of central Kazakhstan, such as Karaganda, Astana, Temirtau, Shakhtinsk, Abay, and Saran. The largest cities – Karaganda and Temirtau – grew in response to the industrial development associated with coal and iron deposits and steel making. Although the urban population has declined considerably over the past 15 years due to a general decline in industrial activities, Karaganda is still the second largest city in Kazakhstan. The new capital of Kazakhstan Astana, whilst on the River Irtysh, is close to the Nura and its rapid on-going growth is an important consideration for the Nura basin. The population of Astana is expected to increase significantly over the next decades, and the Nura is considered the most likely future source of water for the city.

Apart from the urban areas, the population density in the Nura basin is generally low. To the south of the river it is less than 2-3 persons per km^2. To the north, it is 10-20 persons per km^2, with higher densities in the areas around Karaganda, Temirtau, and Astana. The population of these oblasts and Astana is 17% of the population of Kazakhstan. From 1999 to 2005, the population of Astana has increased from 326,000 to 529,000. This offsets an almost equal reduction in the population of the Akmola and Karaganda oblasts from 2,240,000 to 2,078,000.

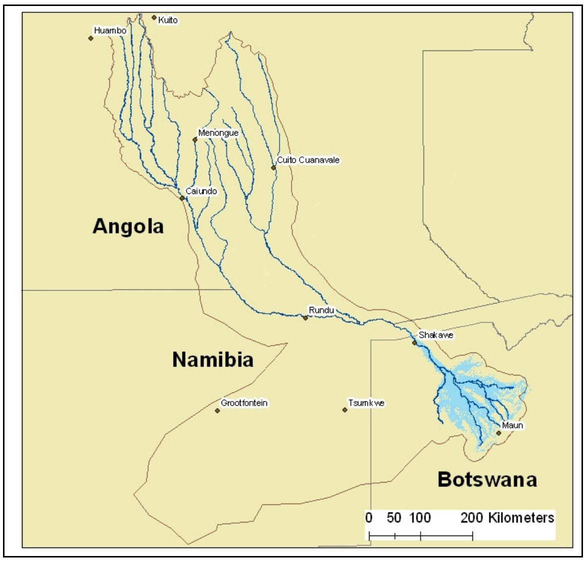
In Soviet times, the area was developed for metallurgy and wheat production, the latter being heavily reliant on subsidy and irrigation. Construction of the Irtysh-Karaganda-Canal in 1976 led to intensive industrial growth in the Karaganda – Temirtau region and a noticeable increase in water consumption. Since the collapse of the Soviet Union, the basin has first experienced serious economic decline due to the loss of subsidy and of traditional markets and end users in the Russian Federation, but now growth is restoring economic conditions. As a share of the GDP of the country as a whole, GDP for the two oblasts and Astana has declined from 20% to 18.7%, with an even larger decline if Astana is excluded. For Akmola and Karaganda oblasts share of GDP declined from 15.7% to 12.2% between 1999 and 2004. In this period, GVA in real terms increased by 36%, GVA in industry by 70%. The most remarkable change is, however, for other services which includes governmental administration where Astana shows an increase in real terms of 370% in that period.

The main freshwater consumers are ferrous metallurgy, the electric power industry, and the fuel industry. Some recycled water is used by the electric power industry and ferrous metallurgy. The current estimated water demand in the Nura basin, not considering the demand of Astana, is in excess of 220 Mm^3y^{-1}. A World Bank Study reports that 90% of projected Astana water demand could possibly be met from diverting water from the River Nura. The World Bank study reports that the cost of water in Astana coming from the Nura is \$0.07 per m^3 compared to a cheapest alternative of \$0.17 per m^3. However, if environmental costs are included in both prices, then it is highly likely that this ordering would be reversed.

3.4 Okavango

3.4.1 Environmental characteristics

The Okavango River Basin and Delta comprise a phenomenon virtually unique in the world. (Figure 3.6). The basin covers an area of 429,394 km^2, 1% of the total surface area of Africa, or 16.1% of the surface areas of Angola, 18.6% of Namibia and 13.0% of Botswana. The main river, the Cubango or Okavango, rises in the Angolan highlands and flows in a south easterly direction. The river forms the border between Namibia and Angola for some 415 km before it crosses the Caprivi Strip and enters north western Botswana, some 1400 km from its source.



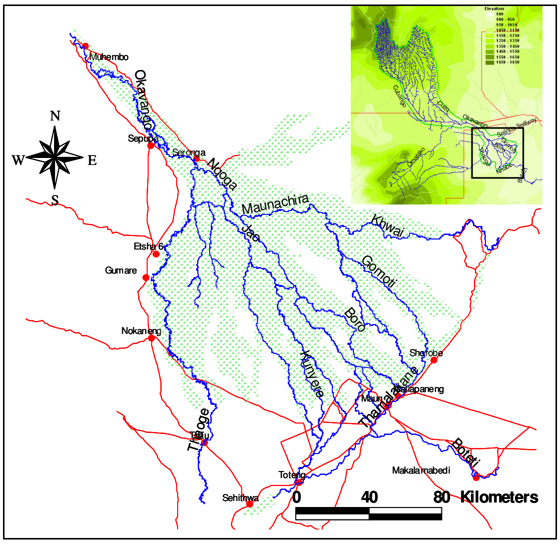


Figure 3.6 Location and plan of the Okavango River Basin and Delta, Southern Africa

The river, with an average annual inflow of 7500 Mm^3 per annum, terminates in the semi-arid Kalahari in a delta with an area of 30,000 km^2. Virtually the entire inflow evaporates and transpires from the perennial and seasonal swamps, while a small percentage infiltrates to ground water. The delta is in a state of dynamic equilibrium. The channels flow over an alluvial fan, running up to a fault line downstream. The detailed topography includes relics of dunes and channels, reflecting the climatic extremes experienced in past eras. Considerable variations in the flows and flooded areas have been recorded, since David Livingstone first saw Lake Ngami in the south west of the delta in 1849.

In 1997, Botswana acceded to the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention). The Okavango Delta was listed as a Ramsar site. Contracting countries are obliged to formulate a management plan for Ramsar sites and to ensure the maintenance of the ecological characters of the site. To this end, the Botswana government initiated the Okavango Delta Management Plan, which will be completed by October 2006.

The Okavango Delta is significant not only as the largest Ramsar site, but also for possessing a remarkable biodiversity. There are 208 aquatic and semi-aquatic plant species, 675 herbs and grasses and 195 woody species. One endemic species has been identified, the ground orchid (*habenaria pasmithii*). A number of other plant species have been identified as rare or endangered in the ecological zoning study carried out in 1990 (Map OK1). The predominant vegetation types are *Brachystegia* and *Burkea* woodlands, savannah and the permanent and seasonal wetlands within the delta. The fauna of the Okavango Delta are also numerous in respect of their variety and rarity (Map OK2). A total of 650 terrestrial and water fowl species has been identified. Two resident species, the wattled crane (*burgeranus caruncalatus*) and the slaty egret (*egretta vinaceiqula*) are globally threatened. The density of large mammal species is high, particularly elephant (*loxodonta africana*). It is also the habitat of one of the largest remaining populations of the African wild dog (*lycaon pictus*), and is a stronghold for the sitatunga antelope (*tragelaphus spekii*) and the Nile crocodile (*crocodilus niloticus*).

In an arid country, water is precious and the delta and its abundant water, vegetation, and wildlife resource have always attracted people. Signs of human habitation in the delta and its periphery have been found that date back around 100,000 years. Natural factors such as climatic changes, the changes in the flow pattern, outbreaks of epidemic diseases and the spread of tsetse fly have affected settlement and land use. Many ethnic groups, the BaYei, the BaTawana, the HaMbukushu, the OvaHerero and the River San, with different perceptions of land and natural resource utilisation, are presently living mainly along the fringes of the delta. Large parts of the population in and around the delta still depend directly on the utilisation of natural resources of the delta for subsistence. Fishing, hunting, livestock grazing, flood plain cultivation and collection of raw materials for building, fuel, and the production of handicrafts are important elements of the local economy. Arable agriculture is practised in Ngamiland mainly at subsistence level as soils and climate are generally not well suited for crop production. Along the fringes of the delta there is small scale flood recession farming. The grazing resources are generally good in the dry land areas. The availability of water and the occurrence of tsetse fly close to the delta have restricted the development of the livestock sector. The inner Okavango Delta is a livestock free zone. Following an outbreak of cattle lung disease 320,000 cattle were culled in Ngamiland in 1996. By now livestock numbers in the planning area have recovered to well over 100,000.

Abstractions are taken from both the surface and ground water of the delta. Surface water abstractions are taken for domestic water supply, livestock and small-scale irrigation. Based on permits issued by the Department of Water Affairs, surface water abstraction totals 17 Mm^3 per annum, around 0.2% of the average annual inflow to the delta. Present ground water abstraction, mainly from ephemeral river valleys in the downstream delta to supply the town of Maun, is around 6 Mm^3, or 0.1% of the delta inflow.

3.4.2 Economic characteristics

The population of the basin was estimated to be 1.1 million in 2000, nearly double that in 1990, although figures in Angola are not well known. The basin is still predominantly rural (Figure 3.7). However the population density in Angola is nearly six times that of Botswana and Namibia. The two largest urban centres, Rundu and Maun, have populations of more than 40,000. There are six other towns and over 250 settlements concentrated in north-west and along the riparian zone in Namibia. The future population remains uncertain, both in terms of the proportions of rural to urban populations and the basin population as whole. Key factors such as HIV/AIDS have reduced life expectancy and migration towards regional economic centres mean only a moderate change in rural population.

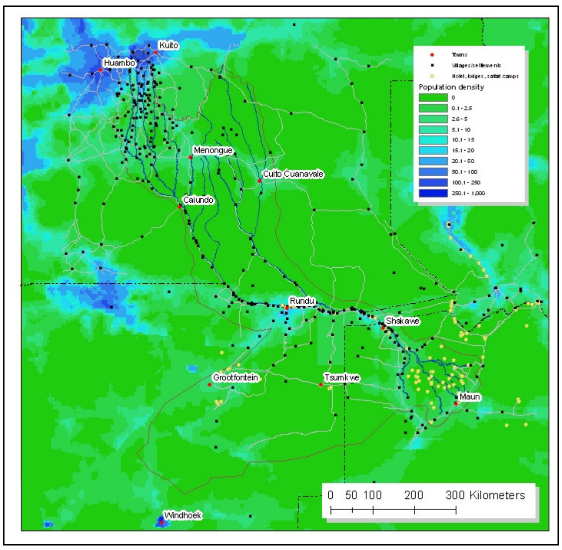


Figure 3.7 Locations of urban areas in the basin

The outstanding natural beauty and abundant wildlife resources of the Okavango Delta form the basis of a fast growing tourism industry, which is offering alternative employment opportunities to people in the rural communities of Ngamiland District. The main socio-economic activities in and around the delta are shown in Figure 3.8, and are described in some detail below.

The prime Moremi Game Reserve national park covers an area of 8000 km^2, and is open to limited numbers of visitors who may stay at up-market lodges or at open camp sites only accessible by 4WD vehicles and where they have to be totally self sufficient. There is no off-take of natural resources from the game reserve. In addition, Wildlife Management Areas cover an area of 13,000 km^2 of the delta. These are leased to community trusts and individual concessionaires for tourism, including controlled hunting. Settlements and agriculture are restricted. Community Based Natural Resource Management practices provide a conducive environment for the sustainable utilisation of the natural resources, linking socio-economic development with natural resource management. The people living closest to nature suffer most from its over-exploitation, and have the greatest incentive to engage in conservation.

Tourism in the delta is mainly based on viewing the wildlife in the wetland environment. Tourism is the main contributor to the local economy, with more than 50% of all formal employment. Nationally, tourism has overtaken livestock as the second largest contributor to GDP, after diamond mining, accounting for some 4%. While records are not kept of actual tourist numbers, in the period 2000 to 2005 the number of tourist operations doubled. Tourism is focussed on luxury lodges in the delta, most of which are accessed by light aircraft (Map OK3). The operations are mostly foreign owned, though the trend is towards increasing national ownership. Local people tend to occupy less skilled jobs. Training programmes should help redress the balance.

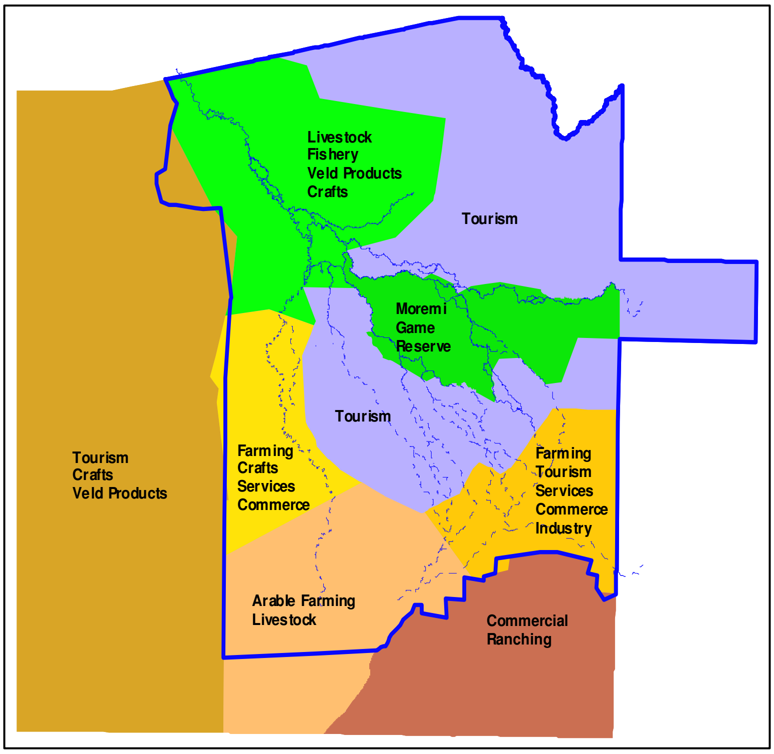


Figure 3.8 Socio-economic activities in the delta

Livestock are important in the local and national economy. Around the delta, livestock are concentrated near permanent and seasonal surface water sources, where both water and forage are present. The intensity is such that there is a danger of irreversible damage. Many livestock are in a poor condition, owing to the prevalence of parasites in the swamp areas. In 2001/02, aerial spraying eradicated tsetse fly from an area of 16,000 km^2. There is the constant threat of reintroduction from neighbouring countries (Namibia, Angola, Zambia). Further aerial spraying is planned for 2006. The environmental impact of the spraying is closely monitored. It seems the pesticide is highly species-specific, and has no more than a temporary effect on the delta ecology. The region also has extensive veterinary fences to prevent the free movement of livestock and control the transmission of communicable diseases. The Buffalo Fence rings the inner delta, separating cattle from wild buffalo, in which population foot and mouth disease is endemic.

Fisheries in the delta may be classified as subsistence (i.e. supplies the immediate food needs of villages in and around the delta), commercial (i.e. carried out from power boats with gill nets, and freezers, large bream having a particularly high value), or recreational (i.e. carried out with a rod and line with the return of small fish, bream and tigerfish being the favoured catch).

The natural vegetation of the delta wetland is a resource for crafts (weaving and woodcarving), wood for construction and firewood, and, most important, thatching grass. Fruits are also harvested for local consumption.

3.5 Thames

3.5.1 Environmental characteristics

The Thames River basin covers an area of 13,000 km^2 (Figure 3.9). The basin area represents some 4% of the area of the United Kingdom. The Thames flows for 330 km from its source in a remote Gloucestershire meadow to its confluence with the North Sea at Shoeburyness in Essex. The non-tidal Thames is 237 km long and has several major tributaries, including the Kennet, the Lee, the Mole and the Pang. There are 5330 km of main river and 896 km^2 of floodplain in the basin, which is rich in rivers, canals, lakes and flooded gravel pits, many of which are home to a range of wildlife. The western parts of the basin are predominantly rural, with towns concentrated along motorway corridors. In the northern and south-eastern parts, urban land uses tend to predominate, although considerable areas of rural land remain. The eastern part is dominated by Greater London which is heavily urbanised (Defra, 2005: map 23).

The Thames basin receives an average of 690 mm rainfall per year, compared with a national average of 897 mm. This makes the Thames basin one of the driest parts of the UK. The mean runoff is approximately 260 mm per year, with 85-90% occurring from October to March. The character of the subcatchment flow reflects the variability in the underlying geology. A band of permeable chalk runs south-west to north-east across the basin. To the north and west of this runs impermeable Oxford clay, and beyond this oolitic limestone. The south and east of the basin are underlain by London clay. The Thames itself runs over alluvial sands and gravels for much of its length. There are fast runoff-dominated responses in the tributaries from the clay parts of the basin, and slow baseflow-dominated responses in those from the chalk.

Approximately 55% of the runoff in the Thames basin is abstracted, although much of this is returned to the river at some point. Of this 85% is used for public supply and the remainder is abstracted directly by agriculture and industry. The level of water resource available to users locally depends both on the specific environmental sensitivity to abstraction and current levels of abstraction. During the summer months there is no additional water available for approximately 80% of the Thames. Indeed, during dry summer months, river flows can consist of over 90% treated sewage. During the winter months, there is currently a surplus. For groundwater sources, approximately 50% of the basin has no surplus, and overabstraction of groundwater is an important management issue in the upper reaches of the Thames and its tributaries.

Beginning with the Industrial Revolution, the Thames has had a history of pollution, particularly in the London area. Successive campaigns have been aimed at improving water quality: firstly gross organic pollution and latterly nutrient enrichment. However, whilst river water quality may be improving, groundwater pollution is an progressively more important issue with nitrate concentrations in groundwater across the Thames basin continuing to increase slowly. The tidal Thames is now cleaner and healthier than it has been for nearly 200 years and supports a wide variety of wildlife including 119 species of fish, though through and downstream of London it is still particularly contaminated with pollutants.

The Thames basin is rich in rivers, canals, lakes and flooded gravel pits, many of which are home to a range of wildlife. For example, the Kennet tributary is a renowned trout fishery and is particularly noted for the conservation value of its instream plants and floodplains. The Thames basin contains parts of five Areas of Outstanding Natural Beauty, parts of two Environmentally Sensitive Areas, and there are 146 Sites of Special Scientific Interest within 5 km of the banks of the Thames. The Environment Agency, who manages the river, plays a key role in enhancing biodiversity in the basin. It has drawn up action plans for 15 priority animal and bird species, and habitat action plans have been prepared for chalk rivers and salt marshes. Other recent activities include the construction of "fish passes" on weirs in the river, enabling adult salmon access to suitable spawning and nursery habitats.

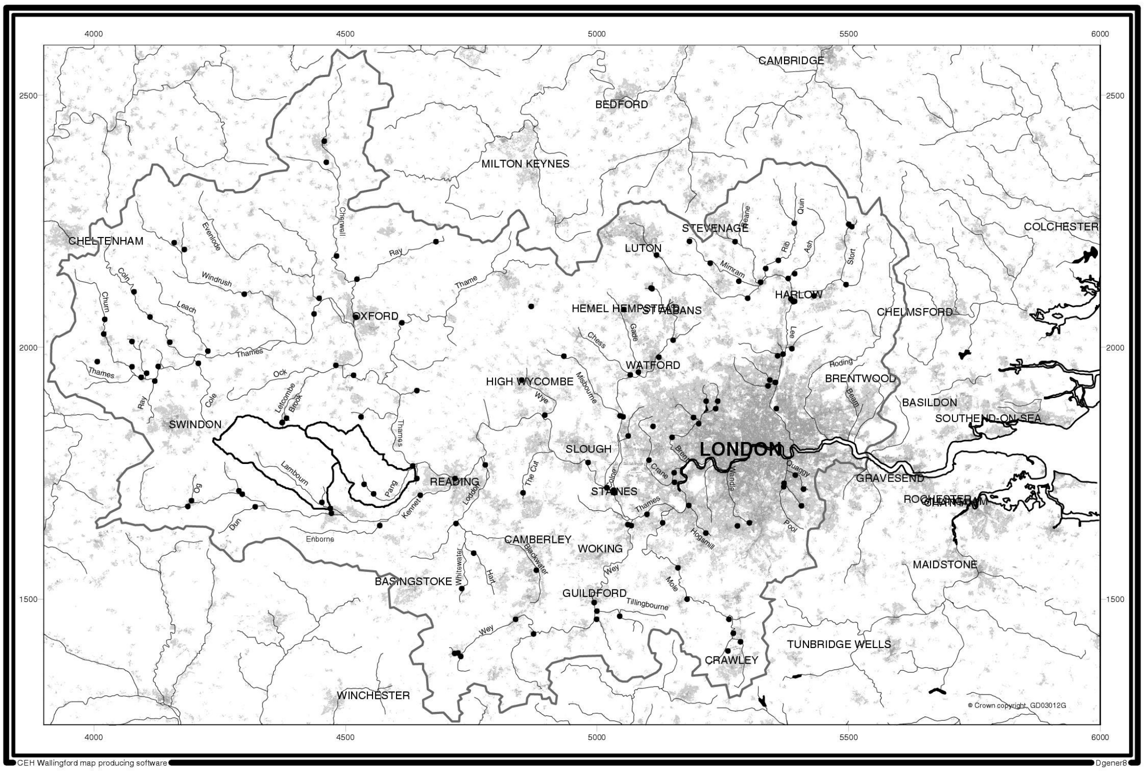


Figure 3.9 River network, gauging stations (•) and urban settlements of the Thames Basin, UK

3.5.2 Economic characteristics

The Thames basin area represents some 4% of the area of the United Kingdom. However, it houses a growing population of over 12 million people (one fifth of the UK's population), and generates more than a quarter of the Gross National Product. This creates intense pressure on the natural environment though the demand on land for homes, offices and other developments, stress on the basin's water resources and waste disposal. The population is estimated to increase by 800,000 by 2025.

Business services makes up almost one fifth of the economy of the Thames basin, with other key sectors being banking and insurance, and wholesale and distribution. The manufacturing sector is now a small part of the economy, as is the agricultural sector, with animal husbandry and vegetable growing the largest agricultural activities. The transport sector is also important, with the ports of London and Sheerness providing deepwater facilities for international marine traffic.

Between 1995 and 2002, output has increased by 3.8 percent per annum, with output in the service sector (business, retailing, health etc) showing the strongest growth, whilst there has been a sustained decline in the manufacturing sector and employment in this sector. Output from the service sector is forecast to rise up to 2015, with a corresponding increase in employment in this sector. Output forecasts from the manufacturing sector are mixed, with only paper and chemicals expected to increase, and therefore some reduction in employment in this sector.

4. Water body classification

4.1 Biobío

4.1.1 Natural surface water bodies

Within the framework of the TWINBAS project, emphasis was put on the establishment of a water body typology for the river category, whereas other categories may be addressed in future research efforts.

Rivers

The definition of individual water bodies within the Biobío river network requires the river network to be segmented, preferably in a logical and systematic way. The WFD puts forwards a criterion of a drainage area greater than 10 km^2 and a reach length greater than 1 km in order for a reach to be considered as an individual water body. After some initial testing, a modified criterion of a drainage area greater than 5 km^2 and a reach length greater than 2 km was applied to the Biobío Basin river network. This means that all headwaters and all river reaches contained between two confluences were considered as individual water bodies, as long as the above conditions were fulfilled.

The use of these threshold values resulted in the identification of 1100 river segments as individual water bodies within the Biobío basin. This number may be further modified in the future, if it is found to be excessively high for practical purposes (e.g. river basin planning, and/or the establishment and control of differential water quality standards). These 1100 river water bodies were divided into 14 different river types, depending upon their elevation, drainage area, drainage area with snowmelt contribution and soil type (Map BB1). A detailed description of the river water body classification exercise is given in Appendix 1.

Lakes

No specific research activities have been undertaken for water bodies belonging to the lakes category in the framework of TWINBAS. This is due mainly to logistical restrictions associated with the project budget and time frame, and to the higher priority given by local decision makers to the river category. Also, major efforts will be needed in order to obtain the basic information layers required for establishing a lake water body typology. However, this task should definitely be addressed in the future, as lakes and lagoon ecosystems play an important role in the river basin. Therefore, the definition of a lake water body typology and the establishment of lake reference conditions can be put down as future activities for the Biobío basin, to be inspired by the river classification work.

Transitional and coastal waters

No specific research activities have been undertaken for water bodies belonging to the transitional and coastal waters category in the framework of TWINBAS. This is due to the complexity involved in their characterisation process, and the completely different legal and institutional frameworks associated with the coastal waters/coastal zone management.

At the moment, one single water body has been identified and assigned to the transitional waters category. This water body corresponds to the segment of the Biobío River which reaches from approximately 11 km upstream of the Biobío mouth down to the mouth itself (Map BB2). This upper reach limit was set in the light of currently available analytical results (mainly conductivity), which indicate a slight marine influence at this point. In the future, a more precise limit may be set. A further subdivision of the reach in separate water bodies may also be considered, as more information becomes available. In the meantime, special attention should be given to the potential impacts of any future development options within this area due to its exceptionally high ecological value. This reach exhibits a high heterogeneity of both channel morphology and physical and chemical water quality conditions, which result in the presence of a high diversity of macrohabitat types, not typically encountered in other single water body reaches belonging to the river category. However, due to its downstream position within the Biobío river network, this reach receives cumulative effects from all human activities in the river basin.

4.1.2 Artificial and heavily modified water bodies

The artificial water bodies in the Biobío basin include a Central Valley network of irrigation canals, and artificial lakes and dams used in irrigation and in hydroelectric power generation (Map BB3). These water bodies were excluded from the current classification of river water bodies according to their typology, but should be considered due to their potential ecological value. Therefore, in future work, the maximum ecological potential that these artificial channels can achieve should be established, explicitly taking into account the economic function of these artificial water bodies. This ecological potential can then be further used as a reference condition for these water bodies.

4.1.3 Groundwaters

No specific research activities have been undertaken for water bodies belonging to the groundwater category in the framework of the current project. This is because of logistical restraints and, also, in the light of a priority setting process: currently, most problems in the basin are related to surface waters. However, it is clear that this aspect should be addressed in future studies.

4.1.4 Protected areas

Waters used for the abstraction of drinking water

No detailed up-to-date inventory is available for sites requiring protection in the Biobío basin. Within the framework of TWINBAS, an inventory has been established for the most important urban and industrial centres in the basin, their indicative drinking water sources and their mean abstracted volume (Map BB4). Most of these (at least 26) are located in the more downstream part of the basin. In the case of the more isolated human settlements, small water provision systems are typically in use, which in most cases correspond to wells located in the immediate vicinity of rivers and streams.

Areas designated for the protection of habitats or species

At the national level, Chile has a system of (terrestrial) sites and areas that are protected by law: the National System of State-Protected Natural Areas, or Sistema Nacional de Areas Silvestres Protegidas por el Estado (SNASPE). Within SNASPE, a differentiation can be made between National Reserves, National Parks and National Monuments. All of these are administered by the Chilean National Forestry Corporation or Corporación Nacional Forestal (CONAF). These (mainly) terrestrial systems, however, include within their limits an important number of surface water bodies. Table 4.1 lists 12 of these state-protected areas, which are completely or partially contained within the Biobío River Basin (Map BB5, which also shows basin land use), and almost exclusively located within the Andes.

Table 4.1 State-protected natural areas within the Biobío River Basin (SNASPE)

No	SNASPE site	Type	Surface area (ha)
1	Alto Biobío	National Reserve	35,000
2	China Muerta	National Reserve	9,887
3	Conguillio	National Park	60,833
4	Ñuble	National Reserve	75,078
5	Lago Galletué	National Reserve	105,449
6	Laguna del Laja	National Park	11,880
7	Malalcahuello	National Reserve	13,730
8	Malleco	National Reserve	16,625
9	Nahuelbuta	National Park	6,832
10	Nalcas	National Reserve	13,775
11	Ralco	National Reserve	12,492
12	Tolhuaca	National Park	6,474

4.2 Norrström

4.2.1 Natural surface water bodies

Rivers and lakes

The surface waters in the Norrström river basin are divided into 356 rivers with a total length of 2900 km, and 790 lakes with a total area of 2780 km^2 (Map NO1).

4.2.2 Artificial and heavily modified water bodies

One lake and the river down stream of this lake, in the tributary of Kolbäcksån, have been classified as a Preliminarily identified Heavily Modified Water Bodies (PHMWBs). The outlet of the Norrström river basin, in the central of Stockholm has also been identified as a PHMWB. The work to identify and categorise HMWBs is still in progress.

4.2.3 Groundwaters

The work to identify and categorise groundwaters is still in progress.

4.2.4 Protected areas

The work to identify and categorise the protected areas is not yet completed in Sweden. The estimated protected areas in all of Sweden include (Swedish EPA, 2004):

- >2000 water bodies identified as drinking water protected areas
- 42 areas designated for the protection of economically-significant species
- 774 recreational waters (EU directive)
- 7 nutrient sensitive areas
- 1000 areas designated for the protection of water habitat and species

Waters used for the abstraction of drinking water

The Swedish Geological Survey has investigated water bodies identified as drinking waters. A database (DGV) has been created for storing information on groundwater and drinking waters. This database contains details of all drinking water bodies providing more than $10 m^3$ per day. The municipalities are in the process of updating the database with local information (Lars-Ove Lång, SGU, personal comment, 2006).

Areas designated to protect economically significant species

According to the statues of the Swedish EPA (Naturvårdsverket förteckning över fiskvatten som ska skyddas enligt förordningen 2001:554 om miljökvalitetsnormer för fisk och musselvatten), there are no protected freshwater fish or shell fish areas in the Norrström river basin. The work on the subject of economically-significant species is not completed within the WFD-work in Sweden yet.

Recreational waters

There are in total 391 recreational waters in the Norrström river basin. For 100 of these, represented in the EU WFD (Map NO2), yearly samples of water quality are taken.

Nutrient-sensitive areas

The Lake Mälaren and Lake Hjälmaren basins are classified as nitrogen-sensitive areas (Map NO3). The whole of Sweden is classified as sensitive to discharges from phosphorous.

Areas designated for the protection of habitats or species

A register of all water-related Natura 2000 areas will be created in the 2005-2007 period, and will be updated regularly. During this period of time, a handbook regarding protected areas will also be provided (Swedish EPA, 2005). Five of the WFD's nature types related to waters, are found in Swedish Natura 2000 areas. In Sweden, waters can be protected as in nature reserves or national parks. Areas can also be of national interest regarding nature protection and outdoor life, for example. In addition to this, there is also a general protection of biotopes in the agricultural landscape. Water areas with high values have also been identified in the inventories of forest biotopes and in the national inventory of wetlands (Swedish EPA, 2005).

There are 335 Natura 2000 areas in the Norrström river basin covering an area of 518 km^2 (Map NO4). About 80 of these Natura 2000 areas (SPA) are water-related. Work concerning water related Natura 2000 areas (SCI) is still in progress. 259 areas are nature reserves and comprise a total an area of 1475 km^2 (Map NO5). There are also 195 areas of national interest for nature protection (1294 km^2) and 10 areas regarding outdoor life (220 km^2), several of which coincide (Map NO6). Six areas are protected as valuable biotopes at a total area of 6.2 km^2.

4.3 Nura

Water bodies pertaining to the Nura basin have, for the first time, been classified according to the methodology stipulated by the WFD, and protected areas and recreational sites have been documented.

4.3.1 Natural surface water bodies

Rivers

The Nura basin has about 200 rivers with a length of more than 10 km. The total length of all rivers is 8677 km, and the average density of watercourses is 0.15 km per km^2. The largest tributary of the Nura is the 281 km long Sherubainura, which itself drains an area of 15600 km^2. Classification of sub-catchment types by geology and altitude is outlined in Table 4.2 and Map NU1.

Table 4.2 Sub-catchment type classification, Nura basin

Altitude	Catchment size	Geology	No. in basin
High (>800 m)	Large (>1000 – 10000 km^2)	Calcareous	2
High (>800 m)	Medium (>100 – 1000 km^2)	Siliceous	5
Mid (400 – 800 m)	Large (>1000 – 10000 km^2)	Calcareous	21
Mid (400 – 800 m)	Medium (>100 – 1000 km^2)	Saline	32
Low (<400 m)	Large (>1000 – 10000 km^2)	Saline	8
Low (<400 m)	Medium (>100 – 1000 km^2)	Saline	21
Low (<400 m)	Small (>50 – 100 km^2)	Organic	7
Low (<400 m)	Extra small (<50 km^2)	Saline	3

Lakes

The basin's 115 lakes were classified into types according to their depth (very shallow / shallow / deep) and the degree of surface water mineralization (fresh / moderately saline / strongly saline). The classification matrix in Table 4.3 shows the criteria and numbers identified per category. The distribution of the different lake types across the basin is shown in Map NU3.

Table 4.3 Lake type classification, Nura basin

Depth Mineralisation	Very shallow <0.7 m	Shallow 0.7 – 2.0 m	Deep >2.0 m	Total
Fresh, <3 g/l	3	6	9	18
Moderately saline, 3 – 30 g/l	28	17	3	48
Strongly saline, >30 g/l	22	25	2	49
Total	53	48	14	115

Transitional and coastal waters

Similarly to the Okavango, the Nura is an endorrheic basin and drains into a large inland wetland area, therefore there are no transitional or coastal waters.

4.3.2 Artificial and heavily modified water bodies

There are two major reservoirs on the Nura: Samarkand reservoir in Temirtau, and the unfinished Intumak reservoir, located about 75 km further downstream. A third reservoir is located on the Sherubainura, the largest tributary to the Nura which joins the river about 60 km downstream of Temirtau. Together they have a total volume of more than 500 Mm^3. Apart from the large reservoirs, there are about twenty smaller reservoirs on the Nura and its tributaries with a total useable volume of 100 Mm^3, and more than two hundred ponds with a total capacity in excess of 50 Mm^3. The highest number of ponds are located downstream of the Sherubainura inflow. Ponds are filled during the spring flood and are used partly for irrigation of pastures (rivers Kulanutpes, Kon, Kirei) and mainly for regular irrigation. In total, 289 artificial lake water bodies were identified.

There are two canals that were constructed to transfer surface water between regions: one is the 458 km long Irtysh-Karaganda-Canal that links the Nura with the river Irtysh in the north, and the other is the 25 km long Nura-Ishim canal that is intended to supply additional water to Astana. Both canals are presently used below capacity, but are in principal fully operational. A third canal, the Nura-Sarysu canal, is non-operational and has therefore not been included in the classification. There are also a number of smaller canals in the basin, presumably for irrigation. Where information was available these have been included in the map.

Provisionally identified artificial water bodies, canals and water transfers are shown in Map NU3.

4.3.3 Groundwaters

Three types of groundwater bodies were identified in the basin: fresh (mineralization up to 1 g/l, up to 15 m in depth), low saline (mineralization up to 3 g/l, up to 30 m in depth), and saline (mineralization up to 10 g/l, up to 30 m in depth). Their geographical extent is illustrated in Map NU4. Groundwater dependent surface water bodies and terrestrial ecosystems are shown in Map NU5.

4.3.4 Protected areas

Protected areas in the Nura basin include:

- 19 water bodies identified as drinking water protected areas (Map NU6)
- 66 freshwater fish lakes and 15 km of river designated for the protection of economically-significant aquatic species (Map NU7)
- 27 recreational waters (Map NU8)
- 20 nutrient-sensitive areas (Map NU9)
- 8 areas designated for the protection of water habitat and species (Map NU10)

Waters used for the abstraction of drinking water

Altogether there are 19 groundwater bodies that are classified as productive (Map NU6). Four of the deposits are currently not exploited. Out of 25 established drinking water abstraction points, 20 are currently in operation.

Areas designated for the protection of habitats or species

The 8 areas designated for the protection of water habitat and species (Map NU10) comprise 6 Special Areas of Conservation and 2 Special Protection Areas, including one wetland area (Map NU11).

The largest and most significant protected area in the basin is the Tengiz-Kurgaldzhino Lake System. The area comprises the Kurgaldzhinsky group of lakes and the saline Lake Tengiz. Lake Kurgaldzhino is one of the most important fresh water bodies in Kazakhstan. It has a drainage area of 55000 km^2 and a surface area of 39600 ha. Lake Tengiz is the largest salt water reservoir in Northern Kazakhstan and is fed by the Nura and Kulanutpes rivers. The lake covers 156,000 ha and has a drainage area of 91,000 km^2. The water level in the Tengiz-Kurgaldzhino lakes fluctuates widely between seasons and between individual years and is largely dependent on the supply of water from the Nura, as is the degree of mineralization. The area constitutes one of the most important wetland sites in Central Asia and is of great importance as breeding, moulting and resting grounds for migratory waterfowl. Nearly 300 species of birds have been recorded at Lake Tengiz; many of them are endangered. Breeding species include the Greater Flamingo (*Phoenicopterus ruber*), Dalmatian Pelican (*Pelecanus crispus*) and White-headed Duck (*Oxyura leucocephala*). The site was added to the List of Wetlands of International Importance by the former Soviet Union in 1976 and was declared a Zapovednik (state nature reserve) about 10-15 years later. All activities other than research were prohibited, including tourism. Hunting was restricted and exploitation of natural resources was controlled in accordance with conservation of the wetland as a waterfowl habitat. In May 2007, the wetlands will officially become Kazakhstan's first designated Ramsar site. The area is also under consideration as a UNESCO World Heritage Site. The territory of the Ramsar site comprises the Nature Reserve itself around the lake shore area, roughly 259,000 hectares with about the same boundaries as the Soviet-era designation, plus a 2-km buffer zone around it, bringing the total area to 353,341 ha.

4.4 Okavango

The focus of water body classification in the Okavango basin has concerned the Okavango Delta wetland. In Section 4.4.4 and Appendix 2, this is classified according to the water, soil and vegetation criteria for categorising wetlands set out in Section 2.1.

4.4.1 Natural surface water bodies

Rivers

Approaches to the identification of river water bodies in large basins can be based on digital river networks, or on digital elevation models (DEM) of the basin (e.g. USGS Hydro1K) with a specification of the minimum threshold area at which rivers can be defined, thus enabling a consistent approach across the basin. Comparison of rivers from digital river networks and those generated from the DEM in the Okavango basin reveals that the DEM is in good agreement with digital river network, particularly in the upper parts of the basin, but there are problems in the low relief areas of the Okavango Delta. Using a DEM and a 50 km^2 threshold, 4244 river water bodies were defined (Map OK4). Using a 100 km^2 threshold, 2165 river water bodies were defined. Using the WFD baseline threshold of 10 km^2 would define considerably more water bodies, but would be unreliable in the low relief delta region.

In contrast to the method described above, Mendelsohn and Obied (2004) incorporate hydrological and geomorphological characteristics in their classification of river water bodies (Map OK5). It includes local topographical variations masked by the 1 km DEM, in particular the incised valleys of the upper north-west basin.

Transitional and coastal waters

Similarly to the Nura, the Okavango is an endorrheic basin and drains into a large inland wetland area, therefore there are no transitional or coastal waters.

4.4.2 Artificial and heavily modified water bodies

Almost no water-related development has taken place within the upper Okavango basin. Water for domestic supply is abstracted by small pumps or through chores performed at the water’s edge. Small-scale building of bunds to protect floodplain gardens and minor channel clearing and diversion activities have taken place in some riverine areas, but most development e.g.

commercial irrigation, has occurred along the river and, as such, has not required the construction of canals and other infrastructure to distribute water or for transportation. The largest development in the basin is the Omatako Dam, a water supply reservoir located in the upper reaches of the Omatako, Namibia. There are records of a small run-of-river hydropower scheme near to Mengongue, though it is not clear if it still operational and what modifications to the river channel have taken place.

4.4.3 Groundwaters

The Okavango basin is located on a large regional aquifer system, known generally as the Kalahari Aquifer, though local names apply e.g. in Namibia, it is called the Okavango–Epukiro groundwater system (Christeli and Struckmeier, 2001). The Kalahari Aquifer is unconfined, with recharge occurring directly by rainfall and indirectly by ephemeral runoff. Some recharge of the aquifer occurs from the Okavango when it is in flood, usually causing a temporary improvement in water quality. The sands form a moderate to high yielding porous aquifer.

4.4.4 Protected areas

The Okavango Delta, including the Moremi Game Reserve and the Okavango Delta Wildlife Management Area, is protected under the Ramsar Convention. However, this does require international cooperation and, at present, Botswana remains the only signatory to this. Other protected areas within the Okavango basin include various game parks and reserves: Popa Game Park, Khaudum Game Park, Mahango Reserve, Waterburg Plateau Game Park, and Mangetti Reserve, with a combined area totalling 472,053 ha.

Areas designated for the protection of habitats or species: Okavango Delta

For the purpose of water body classification in the Okavango Delta, the wetland area is taken as that of the alluvial fan, around 30,000km^2. Three wetland categories, as identified by the Ramsar Convention (section 2.1.3) are present, namely lacustrine, palustrine and riverine. Each of these wetland systems interfaces with the others, and with related habitats fringing the wetland proper. However, given the importance of a holistic approach to the investigation, understanding and management of the wetland, and of the continuum of environments at the land-water interface, in this classification, the Ramsar site is extended to include two additional fringing habitats:

- Terrestrial wetland – fringing the normally or frequently flooded areas, receiving flood water from overspill from an average seasonal upstream flood;
- Terrestrial dryland – occupying the remainder of the alluvial fan, but rarely flooded under the present climate and flow pattern, and generally only from local rainstorms which are slow to drain.

The area of the Ramsar site was determined through a process of consultation with stakeholders, including communities, fishermen, the tourism business and government departments, and rationalised in relation to ecological, geological, geographical, hydrological and socio-economic factors. The various areas are shown in Map OK6.

The wetland is classified by water, soil and vegetation types, and a detailed description of the Okavango Delta classification exercise summarised below is given in Appendix 2:

- ***Water*** - the delta is divided into five flood zones, the first being the Panhandle and the remaining four according to the probability of flooding (Map OK7). The four flooding zones with decreasing probability approximate to the lacustrine, palustrine, riverine and terrestrial Ramsar classes.

- ***Soil*** – almost all of Okavango River Basin is covered by Kalahari sands. The soils of the delta are correspondingly uniform, ranging from medium to fine sand, through sandy loam to clayey loam. The soil type distribution shows correspondence with the flood probability zones, and illustrates the process of sorting as the coarser particles are deposited in the Panhandle and the upstream delta, while the finer particles are transported by the slow moving flow to the downstream delta (Map OK8).

- ***Vegetation*** - there is a high diversity of vegetation in the Okavango Delta. A preliminary vegetation map based on remote sensing with limited ground truthing has been prepared by HOORC. This has a total of 70 classes of vegetation. This has been aggregated by ODMP to 10 classes (Map OK9) which show correspondence with the flood probability zones.

Considering the three defining features of the delta i.e. the surface and ground water, the soils and the vegetation, the soils may be taken to be determined by the surface water flooding. The vegetation is determined by the soils and by the climate, both rainfall and evapotranspiration, and surface and ground water, though the climate appears to have a greater influence. In arriving at a static areal classification of the delta, a combination of a simplified vegetation classification with the surface water flood zone pattern seems to represent the best single indicator. This has been used as a basis for the simulation of both evapotranspiration from the vegetation, and resistance to overland flow through the delta. The classification has six categories, as shown in Map OK10.

4.5 Thames

The identification and classification of water bodies in the Thames River Basin is summarised from the UK report for the Thames River Basin District (Defra, 2005a) and supporting maps (Defra, 2005b). Selected maps are reproduced in Volume II of this deliverable with written permission of the Environment Agency for England and Wales.

4.5.1 Natural surface water bodies

Rivers

The WFD baseline threshold for rivers is a catchment area of at least 10 km^2. However, in the UK, rivers with catchments smaller than 10 km^2, that are not part of a larger catchment and that have a river stretch greater than 1 km in length, have also been identified as water bodies. The surface waters in the Thames basin are divided into 449 river water bodies.

River types in England and Wales are defined according to system A of the WFD. This system uses altitude, catchment size and geology to define the types. This system creates 48 possible types of which 8 are found in the Thames River Basin (Map TH1).

Lakes

The WFD baseline threshold for lakes is a surface area of at least 0.5 km^2. However, in the UK, lakes and saline lagoon clusters with a surface area greater than 0.05 km^2, that are designated features under the Habitats or the Birds Directives or that are drinking water supplies, have also been identified as water bodies. The surface waters in the Thames basin are divided into 46 lake water bodies.

The approach adopted in England and Wales for defining lake types complies with system B of the WFD, and is based on the natural characteristics that have the greatest bearing on their ecological condition i.e. the geology of the catchment, expressed as the base status (alkalinity) of the lake, and the depth of the lake, expressed as the mean depth. This system creates 12 possible lake types of which 5 are found in the Thames River Basin (Map TH2).

Transitional and coastal waters

The surface waters in the Thames basin are divided into 7 transitional and 3 coastal water bodies. In the UK, WFD system B, based predominantly on latitude, longitude, tidal range and salinity, is used to divide transitional and coastal waters into types. This system results in 5 transitional and 7 coastal water types, of which 2 types of transitional water and 1 type of coastal water are represented in the Thames River Basin (Defra, 2005b: maps 5 and 6, respectively).

4.5.2 Artificial and heavily modified water bodies

Artificial water bodies

Several provisional artificial water bodies have been identified in the Thames River Basin (Map TH3) including man-made reservoirs, flooded gravel pits, canals and other 'linear' waters (open water transfers). A separate classification scheme will be developed for artificial water bodies that need to attain good ecological potential, as opposed to good ecological status.

Heavily modified water bodies

Several provisional HMWBs have been identified in the Thames River Basin as part of the characterisation work by Defra (2005a), and a separate classification scheme will be developed for HMWBs that need to attain good ecological potential, as opposed to good ecological status.

4.5.3 Groundwaters

Groundwater water bodies are identified according to, firstly, hydrostratigraphic boundaries and then, secondly, catchment hydrological boundaries. Where available, information on groundwater catchment divides is also used. Aquifers are then grouped into categories based on how groundwater flows within them and how much water is available for abstraction. The main groundwater water body types are Primary, Secondary, Significant Drift and Unproductive Strata. Of the 45 groundwater water bodies in the Thames River Basin, 5 cross the boundary with neighbouring river basin districts and, of these, three are allocated to the Thames and the remainder to the neighbouring South-East River Basin District (Map TH4). Terrestrial ecosystems and surface water bodies dependent on groundwater are shown in Defra (2005b) map 9.

4.5.4 Protected areas

The protected area register for England and Wales lists protected areas, their location and their originating Directive and is used to ensure that surface and groundwater water bodies are managed to achieve their protected area objectives.

The protected areas in the Thames River Basin include:

- 101 water bodies supplying more than 10 m^3 per day or more than 50 people per day and, therefore, identified as drinking water protected areas (Map TH5)
- 4 shellfish waters, 19 lakes and 2929 km of river designated for the protection of economically-significant species (Defra, 2005b: map 11),
- 17 recreational waters (Defra, 2005b: map 12)
- 10 nutrient-sensitive areas, with regard to nitrates and phosphates (Map TH6)
- 23 areas designated for the protection of habitat and species (Map TH7)

Table 4.2 Summary of water body classification for the five TWINBAS basins

	Bíobío	**Norrström**	**Nura**	**Okavango** (partial)	**Thames**
Natural surface water bodies					
Rivers	1100	356	44*	>4244	449
Lakes	n/a	790	144	n/a	46
Wetlands	n/a	n/a	n/a	>1	n/a
Transitional	1	0	0	0	7
Coastal	n/a	0	0	0	3
Artificial and heavily modified water bodies					
Canals	yes	2#	17	n/a	yes
Lakes	yes	1#	289	yes	yes
Transfers	n/a	n/a	2	n/a	yes
Groundwaters					
Aquifers	n/a	n/a	9	>1	45
Protected areas					
Drinking	>26	n/a	19	n/a	101
Shellfish	n/a	0	0	n/a	4
Lakes	n/a	n/a	66	n/a	19
River (km)	n/a	n/a	15	n/a	2929
Recreational	n/a	100	27	n/a	17
Nutrient	n/a	1	20	n/a	10
Protection	12	n/a	8	>7	23

Figures indicate numbers of water bodies, unless otherwise stated; n/a not available
Norrström Basin HMWBs: preliminary identification of HMWBs.
* Nura Basin rivers: 99 classified sub-catchments and more than 200 rivers > 10 km in length.

5. Risk categorisation

5.1 Biobío

As explained in Section 4.1, within the framework of the TWINBAS project, emphasis was put on the classification of river water bodies, whereas other categories may be addressed in future research efforts.

5.1.1 Establishment of reference conditions for river water bodies

In the Biobío River Basin, the establishment of reference conditions against which to assess the status of river water body types, and subsequently the risk of not achieving good status as defined by the WFD, would ideally involve the selection of a set of representative elements from each river water body type, for which it could be reasonably assumed that "natural" or "reference" conditions exist. The term "reference conditions" covers physical, chemical, biological and morphological characteristics of a given water body type, and may require validation in the field. Setting a standard for each water body type enables evaluation of the current status of sites that belong to each water body type.

However, adaptations to this approach have been made in the Biobío River Basin, in light of the limited available resources, and the limited baseline information available for the basin. Efforts have been directed towards an evaluation of the location of those river water bodies that currently present a high potential of being under reference conditions. For this evaluation, the following parameters were considered, based on their potential influence on aquatic ecosystem health (many additional parameters could be included; however, it is thought that many of these are correlated to the more general parameters included below):

- Naturality of the land cover in the reach-specific drainage area
- Naturality of the land cover in the total upstream drainage area for a given reach
- Local presence of irrigation channels
- Local population density
- Local and upstream presence of flow regulation

These parameters reflect some of the pressures on the water bodies of the Biobío River Basin identified in WP5 (2007). A quantitative indicator was assigned to each parameter, reflecting the level of human intervention. Through a combination of the estimated impacts of human activities, represented by these distinct GIS layers, a first approximation was obtained of the degree of "accumulative intervention" for each individual water body in the basin. This can be used both for the identification of reference sites (this Section), and for a preliminary analysis of those sites that are currently or potentially under risk of being severely impacted by human activities (next Section). This analysis can be expanded, incorporating more advanced analysis methods and tools, as more resources become available in the future.

Degree of naturality of the land cover per reach-specific drainage area

In order to identify those parts of the basin where land cover has not be significantly influenced by human activities, the National Inventory of Natural Vegetation Resources of Chile, commonly known as the "Catastro del Bosque Nativo" (CONAF, 1997) was used. Taking this GIS layer as a base, natural land cover conditions were grouped in order to separate those parts of the basin under human land use from those where natural conditions prevail (native forests, shrubs, Andean steppe, etc).

This was then combined with the river water bodies layer (Figure A1.1), and the percentage of each reach-specific drainage area under natural land cover conditions was determined. The results from this exercise are expressed in Map BB6, and reveal that most remaining areas with an significant natural land cover are located in the Andes Mountain Range, and to a slighter extent also in the southern Coastal Mountain Range or "Cordillera de Nahuelbuta".

Degree of naturality of the land cover in the total upstream drainage area

Due to the cumulative effects of the upstream drainage area on water body quality and ecological status, the process described above was repeated, taking into account the total upstream area for each reach. The results from this exercise are shown in Map BB7. Comparison of Maps BB6 and BB7 clearly shows how, in Map BB7, the "pristine" conditions in the upstream part of the basin "reach down" through the river network into the Central Valley, indicated by high percentages of natural land cover conditions for the river reaches which belong to the main river channels such as the Biobío and Laja river.

Irrigation channel density

Irrigation channels are considered to have an impact on the river ecosystem, through the modification of the natural flow regime (artificially low discharge rates during summer) and/or through the implementation of physical structures across the channel cross-section. The density of irrigation channels (length per surface area) within each reach-specific drainage area was analysed. Results are given in Map BB8, where the high density of irrigation channels associated with agricultural activities in the central part of the basin can be observed.

Demographic density

The population density in the vicinity of the different river reaches was analysed as an indicator of the potential multiple effects on water bodies derived from the human presence in the surrounding drainage area. Data from the 2002 Census were used, which are distributed by the National Institute for Statistics (Instituto Nacional de Estadística (INE), 2002). However, these data are not available separately for each locality. Rather, they are integrated at the district level. For this reason, total population of each district was distributed over the different human settlements located within its limits, taking into consideration the type of each human settlement, when assigning part of the total population to it. By this means, and using additional GIS spatial analysis functionality, it was possible to represent estimated population density within each reach-specific drainage area. Results from this process are shown in Map BB9.

River segments with flow regulation

The final GIS layer used in this analysis represents the location of the main points of modification of the hydrodynamic flow regime (hydropower and irrigation reservoirs), as well as of the downstream reaches affected by these modifications.

In the case of the hydropower plants, two grouped production complexes can be identified: the first one is located on the Upper Biobío River and the second one on the upper Laja River, near the outlet of the Laja Lake. River reaches (water bodies) downstream of these structures are identified and marked, as the hydrological regime in this reaches is expected to be considerably modified by the reservoir operation (e.g. hydropeaking is common practice in the basin).

With respect to the reservoirs used for irrigation purposes, no information is currently available on their modus of operandi, so it is unclear how big their effect on downstream reaches may be.

However, reaches in these areas are typically also affected by the presence of irrigation channels, so impacts in these areas certainly occur.

The results from this preliminary analysis on the spatial context of water bodies affected by flow regulation are given in Map BB10. This GIS layer may be further improved in the future, as more information becomes available.

Reference conditions for river water bodies

Using the principles of multi-criteria analysis, the previously generated GIS layers were mathematically combined by assigning a weight factor to each layer and then summing all individual contributions. The result of this operation is a quantitative index, which reflects the potential deviation of local river water body status from reference conditions. The index can thus be interpreted as reflecting the "degree of naturality" of the water body and its surrounding environment. In order to allow for a more qualitative interpretation, class limits can be established in order to identify the potential for each water body to be "under reference conditions" as "high", "good", "moderate", "poor" or "bad".

5.1.2 River water bodies at risk

A classification of all river water bodies belonging to the Biobío river network according to the above principles is shown in Map BB11. From this map it can be seen how river water bodies with a good potential for representing reference conditions are almost exclusively located in the Andes Mountain Range. The only exception is formed by the uppermost part of the Coastal Mountain Range where a cluster of water bodies can be found with high potential of representing reference conditions. Areas that most probably do not represent reference conditions are the Central Valley and the Lower Biobío Basin. This corresponds to an area where population density is high, and where most human activity takes place. The cumulative effect of the upstream drainage area is also reflected in the low "potential" assigned to the river water bodies which belong to the main stem and main tributaries of the Biobío river network.

The consequence of this unequal spatial distribution of reference sites over the Biobío River Basin is that, for many river water body types, it may currently be impossible to establish reference conditions by means of experimental monitoring at a representative set of reference sites. This becomes particularly clear when interpreting the results of the combination of river water body type (map BB1) with reference conditions potential (Map BB11), as expressed in Maps BB12 and BB13, and in Table 5.1 which indicates the number of river water bodies under reference conditions for each water body type.

The information contained in Maps BB11-13 and Table 5.1 can be used to select those sites to be included in future monitoring efforts. For such cases where good reference sites are absent, field observations, expert judgment and the results from model applications may need to be combined, if reference conditions are to be established for these river water body types.

In the absence of results from more advanced research, the currently obtained products can already be used as a first assessment of the spatial location of river water bodies which present a risk of not achieving environmental objectives (Table 5.3). The results from Map BB11 could, thus, also be interpreted as a preliminary status classification, indicating which river water bodies most urgently need attention.

The results from the pressure analyses (WP5, 2007) can also be combined with the information layers on protected areas, and on drinking water production sites. This shows that state-

Table 5.1 Biobío river water body types probably under reference conditions

River WB types	No of river WB potentially under reference conditions				
	Bad	Poor	Moderate	Good	High
1114	18	114	19	1	-
1122	9	58	14	-	-
1132	6	-	-	-	-
1146	17	7	-	-	-
1232	6	-	-	-	-
2112	2	19	3	-	-
2113	4	116	57	11	-
2123	3	28	34	19	6
2232	-	2	-	-	-
2233	8	-	1	-	-
3113	-	-	7	37	84
4213	-	-	2	57	193
4215	-	-	1	11	24
4223	-	6	15	13	68
Total	73	350	153	149	375

protected natural areas contain a considerable proportion of the total number of potential reference sites, but only contain a limited number of water body types; conditions in protected areas are typically not affected by upstream pressures, as most protected areas include (or are limited to) the headwaters of the corresponding river networks. Furthermore, many drinking water production sites are located in areas where considerable pressures exist; these potential risks need to be considered in the decision-making process, in order to safeguard water quality and health of the human population.

5.2 Norrström

In Autumn 2005, at meetings with the District Water Authority (DWA) and the County Board of Västmanland, it was requested that neither a classification of ecological status nor a risk categorisation for the Norrström River Basin was made under the framework of the TWINBAS project, in order to avoid confusion with the on-going work of the DWA. Therefore, in accordance with this request, these tasks have not been carried out for the Norrström or any of the tributaries to Lake Mälaren. This decision was ratified at a project board meeting in March 2006 and staff resources planned for these tasks have been reallocated to WP5 (2007). The following section instead discusses the general approach to the classification of ecological status in Sweden.

5.2.1 Implications of pressure-impact analysis on water body status

The WFD guidelines recommend assessment of ecological status of water bodies as a comparison between the water body and a reference water body, thus calculating an ecological quality ratio (EQR), in which the resultant value is 1 if the water body is in the same quality class as the reference water body, and 0 if the water body is in the lowest quality class. The actual boundaries of the different quality classes (high, good, moderate, poor and bad status) cover the physical, chemical, biological and morphological characteristics of a water body (Figure 5.1), and are being determined by each EU country individually. In Sweden, they have

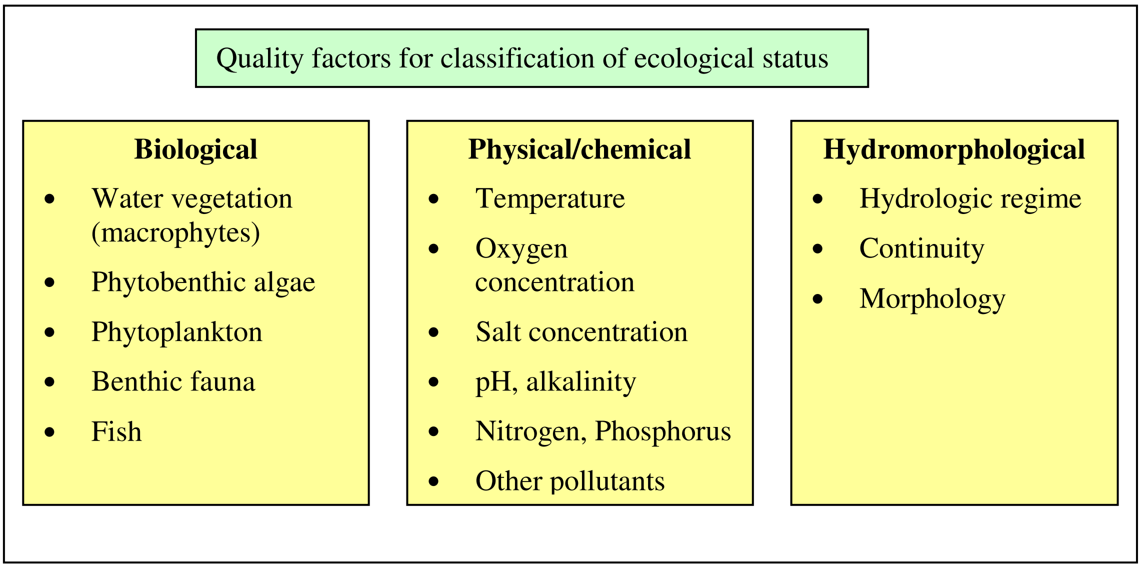


Figure 5.1 Examples of quality factors usable to assess ecological status in Sweden (the final factors assessed are yet to be determined)

been determined for high status and good status, but for moderate status they have been determined only for biological parameters. For poor status and bad status, no definitions have been produced. This is the situation for many countries.

Current discussions concern whether the "one out – all out" principle should be applied, which would mean that if just one of the physical, chemical, biological or morphological elements was assessed as 'poor', the final ecological status for the water body would also be 'poor', thus calling for actions to reach good status by 2015. It is most likely that this approach will prevail

The pressures on the water bodies in the Norrström River Basin are mainly hydromorphological alternations (small dams and wetland ditching) and discharge of nutrients from agriculture, rural households and a few point sources. Other chemical pressures are comparatively low (oxygen concentration, salinity, pH, alkalinity, heavy metals, persistent organic pollutants including biocides). The focus of pressure and impact analysis work in WP5 has, therefore, been on nutrient pressure.

The impact of high nutrient pressure on biological parameters such as benthic fauna average score/diversity or habitat survey is, however, not necessarily negative in the river itself. Tjernell and Axner (2005) shows by surveys of benthic fauna and fish habitats that the biological status of a specific river tributary is high in spite of the chemical nutrient concentrations of the individual river water bodies being poor or bad. This follows expectations, in that the biological status of river water bodies are not degraded by high nutrient transport. The biological effect is instead on downstream lakes, such as Lake Mälaren, where algae blooms and increased primary production causes oxygen deficit, as well as changed ecology in terms of changed habitat suitability for benthic flora (due to e.g. lower sight depth) and fish. When the impact of nutrient pressure is assessed, it is thus crucial to consider the effect on downstream lakes and the sea. In this case it is necessary to have a separate group of factors associated with "pressure" status.

Figure 5.2 illustrates how alternative approaches to final determination of ecological status will affect the classification in a case typical for the tributaries to Lake Mälaren. If only biological factors are considered, which actually lie closest to "ecological quality", the river would be classified as "high" in terms of ecological status, but if chemical status, or downstream pressure is determinant, the ecological status would be classified as “bad”, thus calling for measures to reach good status.

5.3 Nura

Routine monitoring of the impacts of pressures relevant to the risk analysis is almost non-existent in the Nura River Basin and where it is carried out is mostly restricted to the River Nura itself (WP5, 2007). The risk analysis is, therefore, preliminary and is based on the data and information that are currently available, and consultations with the RBO.

5.3.1 Pressures on water bodies

The main sources of pollution impacting on surface water quality in the Nura River Basin are municipal and industrial wastewaters from cities such as Karaganda, Temirtau, and Shakhtinsk. During low flow periods, wastewater accounts for over 80% of the flow in the river below Samarkand reservoir, and for almost 100% of the flow in the Karakengir river. Map NU12 shows the main areas of point source pressures by sewage treatment works discharges. The majority of the existing wastewater treatment stations have fallen into disrepair and are, therefore, working inefficiently. Tighter government control is required to regulate wastewater discharges, and more water recycling and local cleaning are also needed. Future human activity is likely to have a growing impact near the new capital city of Astana, and surface water abstraction will be a significant pressure if the Nura-Ishim Canal is used to supply water to Astana. This is likely to put the sustainability of the terminal wetlands at risk.

There are also morphological pressures, as the river banks tend to collapse in some areas at times of flood.

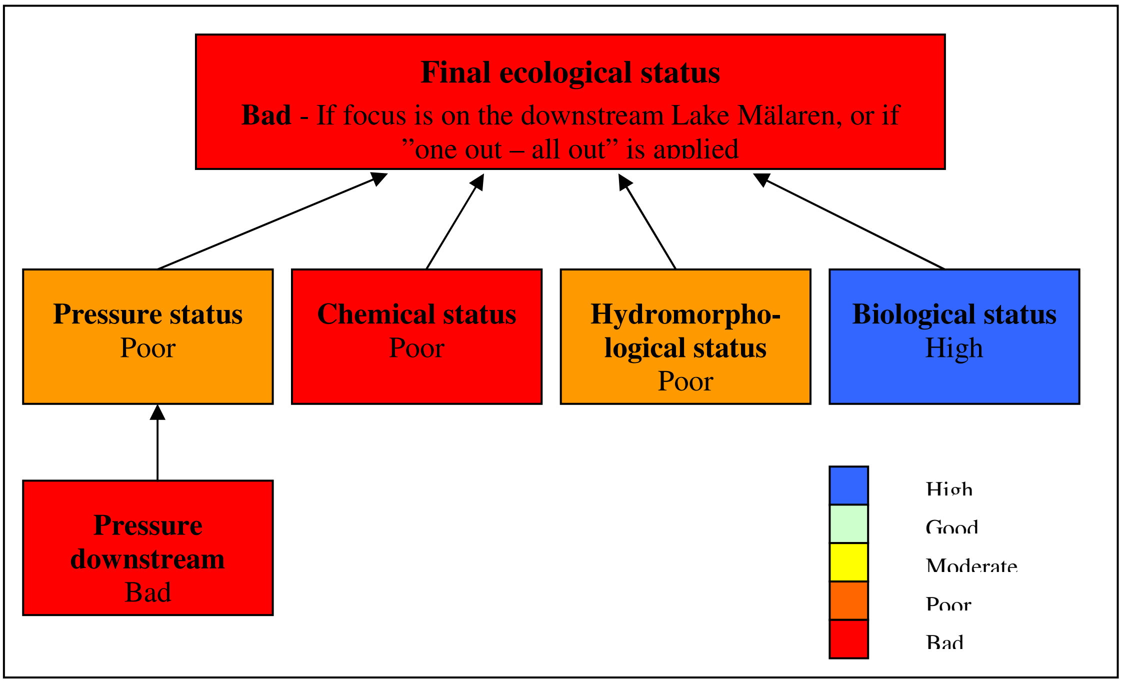


Figure 5.2 Example of how ecological status would be classified in Enköpingsån if the above approach is applied (Enköpingsån is one of the tributaries to Mälaren, and similar in character to e.g. Svartån and Sagån). Modified after Tjernell and Axner (2005).

5.3.2 Water bodies at risk

Out of a total of 44 classified river water bodies in the Nura River Basin, four are ‘at risk’ and one is ‘probably at risk’ (Table 5.3). The four river bodies designated as ‘at risk’ are the Nura, the Sherubainura, the Karakengir and the Sokur rivers. The Nura below Samarkand reservoir is heavily impacted by mercury and wastewater from industrial enterprises. The contaminant status of the Nura carries associated risks of polluting the alluvial aquifer (see below).

Twenty out of 144 lake water bodies in the Nura River Basin are ‘at risk’, and 16 are ‘probably at risk’ (Table 5.4). However, in terms of the lake surface area, this means that 70% of the area occupied by lake water bodies are in the ‘at risk’ or ‘probably at risk’ categories. The biggest pressures on lake water bodies are their drying up due to insufficient water supply and evaporation, with a corresponding increase in mineralisation, and nitrate pollution.

There are no transitional or coastal water bodies in the Nura River Basin.

The majority of the groundwater reserves in the Nura River Basin are deemed to be suitable for use. Nevertheless, of a total of 19 groundwater bodies, 7 were classified as ‘at risk’ (Table 5.5). Of these, the Haying, Saransk, Nurinsk and Rozhdestvenska reserves are most at risk, with maximum allowable concentrations (PDK values) being exceeded for mineralization up to 2-4 times, for mineral oil up to 3 times, for phenols up to 10 times, and for manganese, selenium and beryllium up to 15 times. In total, almost 50% of the groundwater bodies are in the ‘at risk’ or ‘probably at risk’ categories. Map NU13 shows the groundwater bodies that are at risk from diffuse source pollution pressures.

Risk assessments for the protected areas in the Nura River Basin are shown in Map NU14 (economically-significant aquatic species), Map NU15 (recreational waters), Map NU16 (water dependent conservation areas), and Maps NU17 and NU18 (wetlands and wetland source pollution, respectively).

5.4 Okavango

5.4.1 Pressures on water bodies

The Okavango River Basin is in a more or less natural and pristine state. Civil strife in Angola which has spilled over to Namibia has constrained development upstream. Recognition of the environmental importance of the delta has restrained development in Botswana. With peace settling on the region, population and development pressure threaten the extent and diversity of the Okavango Delta. The threats, which reflect some of the pressures on the water bodies of the Okavango River Basin identified in WP5 (2007), may be classified under hydrology, ecology and socio-economics, and are discussed in the following sections.

Hydrology

The extent of the Okavango Delta, and also the biodiversity since this is a function of the extent, are dependent on the amount and the pattern of the inflow from the upstream basin in Angola and Namibia, abstractions from the delta, the clearance of vegetation blockages and the climate over the basin and the delta:

- ***Upstream water resources*** - Water resource developments in the basin in Angola and Namibia comprise water supplies, hydropower and irrigation. While demands for domestic supplies will increase, and the feasibility of an interbasin transfer to the

Swakop River Basin to supply towns in Namibia has been studied, the major threats are from hydropower development and irrigation.

- ***Upstream hydropower*** - Present hydropower planning in Angola aims at meeting the immediate needs of the settlements along the river with several mini-hydro run-of-river schemes which will have no significant impact on the pattern of water and sediment flow downstream (10 possible schemes). In the longer term, larger dams may be constructed (6 possible schemes). While the large hydropower schemes would not consume water, they may alter the pattern of water flows and, significantly for the delta, the sediment discharge. Studies of a small-scale hydropower scheme at Popa Falls, upstream of the Botswana border in Namibia, have been suspended owing to concerns about the interruption of sediment flows to the delta.

- ***Upstream irrigation*** - Irrigation consumes water, especially when it is most needed in the dry season. Again to meet the immediate needs of the population in Angola, small scale irrigation schemes are planned, which would have limited impact on the delta. However, although the Kalahari sands covering most of the basin are not ideal for irrigated agriculture, both Angola and Namibia see a potential for increased food production from large scale irrigation. This would have a severe impact on the delta, particularly the area which remains flooded through the dry period would be considerably reduced. Map OK11 shows the simulated impact of irrigation of the permanently flooded area of the delta, reduced by about 30%.

- ***Abstraction from the delta*** - Both surface water and groundwater are abstracted from the delta for domestic supplies to local settlements and livestock. These are assessed at 0.3% of the total inflow and, while there may be some local impact, the effect on the delta as a whole is barely perceptible. Future projected abstractions would amount to 0.5% of the inflow, and are also minimally significant. The Okavango Delta is one of only two perennial surface water sources in Botswana, the other being the Linyanti-Chobe tributary of the Zambezi River in the far north east of the country. Plans laid in the late 1980s to channel water from the delta to the diamond mine at Orapa and supply settlements along the route were shelved owing to environmental considerations. As the Okavango Delta is now a gazetted Ramsar site, such plans are unlikely to be revived.

- ***Clearance of vegetation blockages*** - From the apex of the delta, the main Okavango River splits into smaller channels which convey flood water to the swamp areas, and drain the delta downstream. The formation of these channels through the swamp, and their closure by sedimentation and encroaching vegetation, is a continuous natural phenomenon. Clearance of vegetation from the channels has long been carried out in the delta, with the objective to maintain access to villages, fisheries, vegetation resources and tourist lodges, and to encourage the flow of water to settlements in the downstream part of the delta. Such clearances are carried out manually and are generally of a small scale. The vegetation usually reasserts itself within a year or two. Clearance by mechanical means could have a greater impact, resulting in decreased flooding and groundwater upstream, and with a corresponding increase downstream (Map OK12).

- ***Climate change*** - Results from the HadCM3 meteorological model have been applied to predict the possible impact of climate change on the Okavango Delta. Declining rainfall reduces the runoff from the upstream basin and the inflow to the delta, and also the direct rainfall input to the delta swamps and soils. Increasing temperature increases the rate of evapotranspiration from the water, soil and plants of the delta. The impact of such projected climate change would be severe, with a 50% decline in the permanently flooded area of the delta.

Ecology

There are numerous fauna in the delta which are classified as endemic, rare and noteworthy. Globally threatened species are the white and black rhinoceros, wild dog, cheetah and brown hyena, and several avian species. Both the flora and fauna of the delta are dependent on the spatial and temporal distribution of water, and are at risk from adverse changes to the hydrologic regime of the delta. Fish are also dependent on the inflows to the delta spreading over vast flood plains where they breed and find food.

Salvinia molesta or Kariba Weed is an alien invasive species found in the Okavango Delta. It is detrimental to the wetland, increasing eutrophication and causing a severe drop in fish populations. The Department of Water Affairs Aquatic Vegetation Control Unit conducts research into control of the weed, the favoured method being biological control with a host specific weevil *cyrtobagous salviniae*. Adult weevils feed on the leaves, and larvae tunnel the rhizomes. The photographs in Figure 5.3 show the impact of the biological control agent, before and after application in 2005.

(a)

(b)

Figure 5.3 Impact of biological control agent on Kariba Weed: (a) before, (b) after, application

Socio-economics

There are a number of threats to the Okavango Delta related to the use of the environment, the most significant of which are related to livestock farming. Owing to diseases to which cattle are prone being endemic in the wildlife, such as foot and mouth, veterinary fences are erected to prevent contact between cattle and wildlife. In 1997, the entire cattle population of 320,000 was slaughtered owing to CBPP (contagious bovine pleuro pneumonia) infection from water buffalo. The Buffalo Fence rings the inner delta, making it a cattle free zone (Map OK2). Cattle crossing the fence are shot by the wildlife department. Veterinary fences restrict wildlife migration routes, and given the number of elephants in the area, maintenance of the fence is a problem. Confinement leads to overgrazing and degradation within the fence.

Tsetse fly have been virtually eradicated by aerial spraying. While the direct environmental impact of the spraying appears to be minimal, it has, as intended, allowed humans and their livestock to encroach on the delta. Given the general water shortage outside the rainfall season, livestock are concentrated near wetland areas, where there is both water and forage, leading to degradation of these areas. Farmers start fires to encourage the growth of new grass. This also has a detrimental effect on the biodiversity. The condition of the cattle is also poor owing to parasitic infections from the swamps.

Another human related threat to the delta is the disposal of liquid and solid waste from the tourist lodges. The actual impact of the limited numbers of tourists is not known, but it may be significant where lodges are clustered in a particular area (Map OK3).

5.5 Thames

5.5.1 Establishment of reference conditions

The Agency is responsible for maintaining or improving the quality of fresh, marine, surface and underground water, with standards that are uniform across England and Wales. River water quality is assessed using a survey called the General Quality Assessment (GQA) scheme, which monitors quality at about 7000 sites representing 40,000 km of rivers and canals (EA, 2002b). Four aspects of quality are measured:

- ***Biology GQA*** - The biological GQA is based on macro-invertebrates, such as the larvae of insects (e.g. mayfly, caddis fly) and snails, shrimps and worms. Macro-invertebrates are used because they are found in virtually all rivers, they do not move far and they respond to water pollutants as well as to physical damage to their habitat. The survey measures the difference between the macro-invertebrates found in the river and those expected if the river was unpolluted and undamaged.

- ***Chemistry GQA*** - The chemical GQA looks at chemical water quality in terms of dissolved oxygen (DO), biochemical oxygen demand (BOD) and ammonia. DO is essential to aquatic life. BOD is an indicator of organic pollution from treated and untreated sewage, agriculture and industry. Ammonia is another indicator of organic pollution, mainly from sewage treatment works and farms, but is also poisonous to fish and other aquatic life.

- ***Nutrients*** - The nutrients scheme measures the average concentrations of phosphate and nitrate in rivers. These are the nutrients whose presence is most likely to be affected by human activities. Naturally, phosphate concentrations in rivers tend to be low and thus limit the amount of algae growth.

- ***Aesthetic quality*** - Perceptions of the quality of a river are usually based on sight and smell, and so the aesthetics scheme measures aspects such as litter on the banks and in the river, sewage-derived waste (cotton buds, sanitary towels, etc), the colour and smell of the water, oil, scum, foam, sewage fungus and ochreous deposits, and dog fouling.

Figures from the 2003 survey for the Thames basin are shown in Table 5.2 (EA, 2002b) and Map TH10 shows the latest GQA biology classification (Defra, 2005b).

In the WFD implementation, reference conditions for natural surface water body types in the Thames River Basin must describe the biological (flora and fauna i.e. plants, macroinvertebrates, fish) and the chemical, physical and and hydromorphological conditions expected to occur in undisturbed or relatively undisturbed states. The biology GQA classification system for rivers provides a partial assessment of the aquatic ecology in terms of macro-invertebrates and is the closest measure of status available for the biological quality element of the WFD's ecological status classification scheme.

Table 5.2 Results from 2003 GQA survey in Thames basin (from EA, 2002b)

	Percentage of river length					
	A*	**B**	**C**	**D**	**E**	**F**
Biology	36.7	33.6	18.1	7.8	3.6	0.1
Chemistry	22.0	42.3	20.2	10.1	5.0	0.4
Nitrate	0.6	3.7	15.5	26.1	36.7	17.4
Phosphate	2.7	10.0	10.2	13.5	49.0	14.5
Aesthetics†	n/a	47.3	n/a	25.5	9.1	18.2

*For **biology and chemistry**, A is very good, B is good, C is fairly good, D is fair, E is poor, F is bad. For **nutrients**, A is very low, B is low, C is moderately low, D is moderate, E is high, F is very high.
† For aesthetics, survey date is 2000; percentage is of sites surveyed, not river length; classes A and C not used.

The biology GQA approach is only a partial assessment of biological status because GQA tends to reflect the impact of only sanitary pollutants (oxygen-demanding susbstances and ammonia) on aquatic ecology, and not of all environmental pressures. Thus water bodies classified as A or B under the biology GQA may still be assessed as “at risk” overall (next section), reflecting both the wider parameters of the WFD standards compared with the current GQA classification, and that pressures in a surrounding catchment may cause deterioration in a high quality water body if no risk management measures are applied. Results from a recent lowland catchment study in the UK, involving the Pang and Lambourn catchments of the Thames River Basin (NERC, 2006), suggest that this conventional biological assessment of river ecological quality is inadequate and a new ecosystem-based approach is needed.

5.5.2 Water bodies at risk

In the Thames River Basin, point source pollution pressures (Map TH8) are significant for lakes and transitional waters, where more than 40% are at risk from discharges from, for instance, sewage works and industrial processes that can contain substances that damage the ecology of waters (see Defra, 2005a: maps 21 and 22). For lakes, the most significant point source pressure is considered to be phosphorus from treated sewage effluent.

Point source pollution sites within the Thames basin are licensed and closely monitored and controlled by the Agency as necessary. Therefore, the majority of point sources are already subject to controls and do not cause any damage to the water environment. However, there may be accidental discharges of harmful substances.

In contrast, diffuse pollution pressures on river water bodies account for around 90% of them being at risk of not achieving good status (Map TH11 for all surface water bodies). Diffuse pollution pressures are also significant for lakes, and groundwater bodies, accounting for around 90% of the latter being at risk of not achieving good status, and also account for around a third of coastal waters being at risk (Map TH12 for groundwater water bodies).

The Agency’s current surface water monitoring programme is designed mainly to assess the impacts from point source pressures. As a result, knowledge of diffuse source impacts at a national scale is less than that for point sources. Groundwater monitoring focuses mainly on nitrate and pesticides. Diffuse pollution is strongly lined to land use activity, with the agricultural sector a major, though declining, source of diffuse pollution.

Abstraction (Map TH9) is also a significant pressure, with approximately 40% of groundwater bodies at risk from over-abstraction for public water supply and for industry and agriculture, and so possibly not leaving enough water in the environment to conserve ecosystems (see Defra, 2005a: maps 27 and 28).

Abstraction and flow regulation pressures are clearly linked to economic activities e.g. household and economic growth will affect the level of water demand. The most important abstractors in the Thames basin are water companies, followed by the electricity industry. Abstraction in the Thames River Basin is controlled by a licensing system administered by the Agency.

Many of the surface water bodies at risk through morphological alterations are provisionally identified as being heavily modified (HMWBs). Morphological pressures are significant in nearly three quarters of river HMWBs, and cause all three coastal HMWBs and all seven transitional HMWBs to be at risk of not achieving good ecological potential (see Defra, 2005a: map 30).

Some morphological pressures can be linked to economic activities, but others are more difficult and further work linking morphological pressures to activities is necessary.

Defra (2005a: map 31) shows rivers, lakes, transitional and coastal water bodies that have known occurrence of alien species and so are at risk of not achieving WFD environmental objectives.

Risk assessments for the protected areas in the Thames basin are shown in Defra (2005): map 15 (economically-significant aquatic species), map 16 (recreational waters), maps 17 and 18 water-dependent conservation areas).

Maps TH13 and TH14 show surface and groundwater bodies, respectively, at risk from all pressures. Tables 5.3, 5.4 and 5.5 show the distribution of rivers, lakes and groundwaters in each risk assessment category, respectively. Of the river water bodies at risk, diffuse pollution pressures account for around 90% and morphological pressures around 70%. Both point and diffuse source pollution pressures are significant for lakes. Morphological pressures cause all three coastal waters and all seven transitional waters to be at risk. Point source pollution pressures are also significant in transitional waters, and diffuse source pollution pressures in coastal waters. Diffuse source pollution pressures and abstraction pressures are significant for groundwater bodies, accounting for around 90%, and 40%, respectively, being at risk of not achieving good status. More detail about how the risk assessments were done in the Thames River Basin is provide by Defra (2005a).

Table 5.3 River water bodies at risk

	Bíobío		Norrström		Nura		Okavango		Thames*	
	No.	Length (km)	No.	Length (km)	No.	Length (km)	No.	Length (km)	No.	Length (km)
Total	1100				44	4883			449	4474
At risk	423				4	876			403	4347
Probably at risk	153				1	44			40	114
Probably not at risk	149				3	123			6	12
Not at risk	375				36	3840			0	0
Total at risk	576				5	1043			443	4462
Total at risk (%)	52				11	19			98.7	99.7

*source of Thames figures: Defra (2005a)

Table 5.4 Lake water bodies at risk

	Bíobío		Norrström		Nura		Okavango		Thames*	
	No.	Area (km^2)	No.	Area (km^2)	No.	Area (km^2)	No.	Area (km^2)	No.	Area (km^2)
Total					144	2994			46	29
At risk					20	1979			21	14
Probably at risk					16	127			10	4
Probably not at risk					13	30			15	10
Not at risk					95	857			0	0
Total at risk					36	2106			31	19
Total at risk (%)					25	70			67.4	63.9

*source of Thames figures: Defra (2005a)

Table 5.5 Groundwater water bodies at risk

	Bíobío		Norrström		Nura		Okavango		Thames*	
	No.	Area (km^2)	No.	Area (km^2)	No.	Area (km^2)	No.	Area (km^2)	No.	Area (km^2)
Total					19	1122			45	10641
At risk					7	368			22	7018
Probably at risk					2	107			20	2810
Probably not at risk					3	120			3	813
Not at risk					7	527			0	0
Total at risk					9	475			42	9828
Total at risk (%)					47	42			93.3	92.4

*source of Thames figures: Defra (2005a)

6. Summary and concluding remarks

The water body classification and categorisation exercise in the TWINBAS basins represents a preliminary risk assessment. Knowledge of the risks to the status of the water environment will improve as future work is guided by this initial analysis, and thereby make future risk assessments more comprehensive and reliable. The results will steer further characterisation, including the development of a targeted and efficient monitoring system, and as a starting point for the development of measures ensuring a cost-effective approach to water protection.

Biobío

In the Biobío River Basin, a theoretical framework has been established for defining a typology for the river water bodies. This typology is based on an analysis of readily available GIS layers and guided by local expert judgment. The work done in the Biobío was inspired by the methodology developed in the framework of the EC WFD for the classification of water body ecological status, based on the prior definition of a water body typology and the establishment of reference conditions. The preliminary results and conclusions have a high potential for steering both future research, as well as practical decision-making, with respect to the management of the Biobío River Basin. Limitations inherent to the used approach should be taken into consideration when using the results for practical decision-making.

Results from this process have been preliminarily evaluated in the light of currently available information on the basins' aquatic ecosystems. Fourteen major river water body types were identified in the basin. For several of these, sites presenting reference conditions may no longer be available. From this point of view, field measurements may no longer be indicative of "optimum conditions" for ecosystem functioning in these water body types, and more advanced analytical techniques, based on a combination of expert judgment and modelling efforts may be needed. Most of these sites are located in the Central Valley and the Lower Biobío Basin. Alternatively, for water body types with a high presence in the Andes and Coastal Mountain Range, it may still be possible to establish reference conditions representative for optimal ecosystem functioning. Efforts for the establishment of these conditions and further validation of findings will have to be achieved through field measurements and observations, to be executed in the framework of post-TWINBAS projects.

Norrström

In Sweden, neither a classification of ecological water stsus nor a rosk categorisation for the Norrström River Basin was made under the framework of the TWINBAS project, in order to avoid confusion with the on-going work of the District Water Authority.

Nura

For ease of comparability between the basins, the maps supporting the summary report of the characterisation, impacts and economics analyses required by Article 5 Thames River Basin district (Defra, 2005b) were used as a blueprint for the preparation of the classification maps for the Nura. The water bodies in the Nura River Basin have, for the first time, been classified in this case according to the methodology stipulated by the WFD. Result reveal that upstream areas of the Nura are relatively pristine, but diffuse pollution due to unregulated agricultural runoff is significant in the whole basin. This is difficult to control. Point source pollution pressures are significant in the Karaganda region. The river currently fails in the section below Temirtau, but is expected to improve after clean-up which is scheduled to start in Spring 2008.

Regular surface water quality monitoring for mercury will be needed during and after these works.

The Nura maps were presented to all interested stakeholders at a seminar held in the capital of Kazakhstan, Astana, on 6 September 2006. At the end of the project, the maps will be given to the Ministry of Environmental Protection of the Republic of Kazakhstan. Adoption of the water body classification requirements of the WFD in the Nura River Basin has been a pioneering exercise that will inform future river basin management plans.

Okavango

In Southern Africa, classification work was focussed on the Okavango Delta wetland. Wetlands are a category not explicitly included in the WFD natural surface water body classification, and so the WFD approach was not adopted. However, the main pressures on the delta are likely to come from developments in the upper basin in Angola. A water body classification approach based on that in the WFD could be critical in developing future river basin management plans. In the Okavango River Basin, emphasis must be on international cooperation in the management of the whole basin, from the upper basin in Angola to the terminal delta in Botswana.

Thames

The water body classification requirements of the WFD will allow the Agency and stakeholders in the Thames River Basin to take a more holistic and integrated approach to water management and the improvement of aquatic environments in the future. The next steps include the design of targeted monitoring networks and a review of water bodies at risk of not meeting the WFD environmental objectives. However, current understanding of the relationship between pressures and activities is less well known for certain pressures e.g. diffuse pollution from non-agricultural activities or hydromorphology, and another future activity must be to strengthen the understanding of such links through further characterisation in order to develop the most cost-effective combinations of measures.

As a result of these refinements, the proportion of water bodies identified as being “at risk” may alter as further risk assessment work (including monitoring data) improves confidence in the risk to those waters. A greater certainty in the risk assessments should lead to a decrease in the proportion of water bodies in the ‘probably at significant risk’ and ‘probably not at significant risk’ categories, whilst those in the ‘at significant risk’ or ‘not at significant risk’ categories should increase.

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Appendix 1 Water body typology for the Biobío river network

Parameters used for establishing a typology for the Biobío rivers

As described in Section 4.1, a criterion of a drainage area greater than 5 km^2 and a reach length greater than 2 km was applied to the Biobío river network to define individual river water bodies. This resulted in the identification of 1100 river segments as individual water bodies (Figure A1.1). The next step is the selection of relevant parameters to be included in the establishment of the typology. For this purpose, it is important to take into consideration that it must be possible to express these parameters (and their spatial variability) by means of thematic GIS layers which cover the whole of the river basin. In the Biobío basin, the WFD System A classification scheme, which considers three basic parameters for the establishment of a river water body typology (elevation, geology and drainage area), was adapted to local conditions.

Based on local expert judgment, geology was eliminated as a parameter and replaced by soil type. This decision was based on the relative homogeneity of the geology in the basin (in terms of its ecological impact), and due to the fact that the local aquatic ecologists expect the dominant soil type of a water body's contributing area to have a more important impact on the aquatic ecosystem functioning. Additionally, the percentage of the contributing area above the mean annual snowline was incorporated as a fourth parameter in the classification process. Hence, in agreement with the specifications given in the WFD, and taking into consideration the recommendations of local experts, the following parameters were selected for use in the classification process:

- Mean elevation of the reach-specific drainage area
- Percentage of the total upstream drainage area with snowmelt contribution
- Total upstream drainage area
- Dominant soil type within the reach-specific drainage area

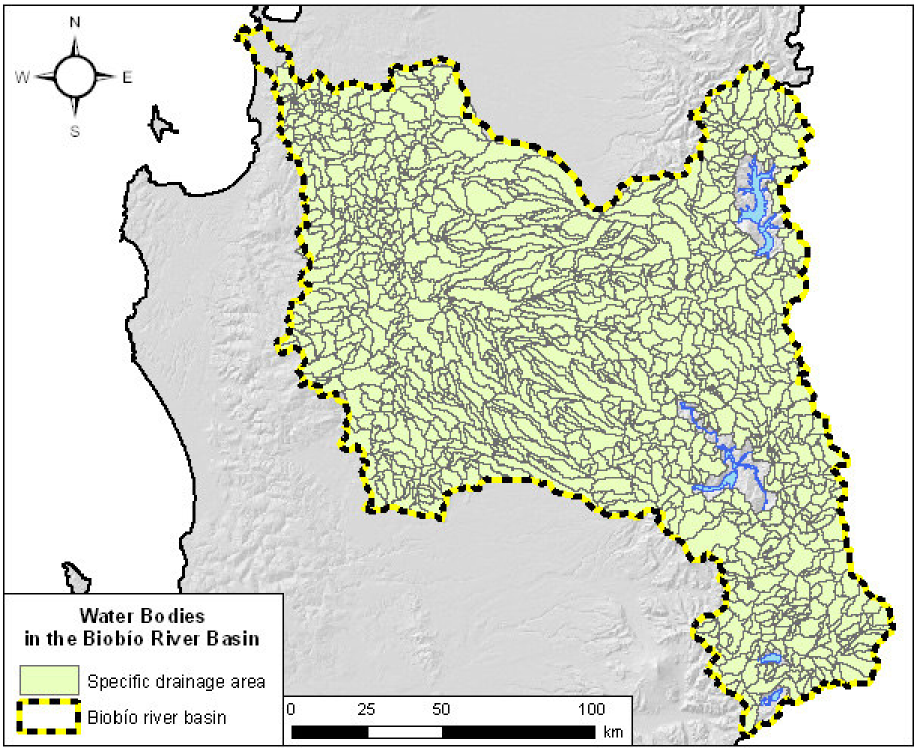

Figure A1.1 River water bodies in the Biobío River Basin

More details are given below on each one of the parameters used in the process for establishing the river water body typology for the Biobío rivers.

Mean reach-specific drainage area elevation

A "final version" 2005 Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) was used for characterising basin topography. GIS raster functionality was used for post-processing the DEM (filling of data gaps and elimination of outliers). The SRTM DEM was compared to digitised 50 m elevation contours from the Chilean Geographic Institute (Instituto Geográfico Militar, IGM). A very good correspondence was observed between both data sources.

The class criteria used for the mean elevation value of the water body's reach-specific drainage area are given in Table A1.1. These values are modifications of the original values contained in the WFD, and correspond to what local experts believe to be ecologically significant elevation ranges. Based on these criteria, each water body is assigned to one of the four elevation classes. The results of this classification process are illustrated in Figure A1.2.

Table A1.1 Class thresholds used for establishing the *elevation* type

Altitude thresholds (masl)	Type
< 200	1
200 - 800	2
800 – 1200	3
> 1200	4

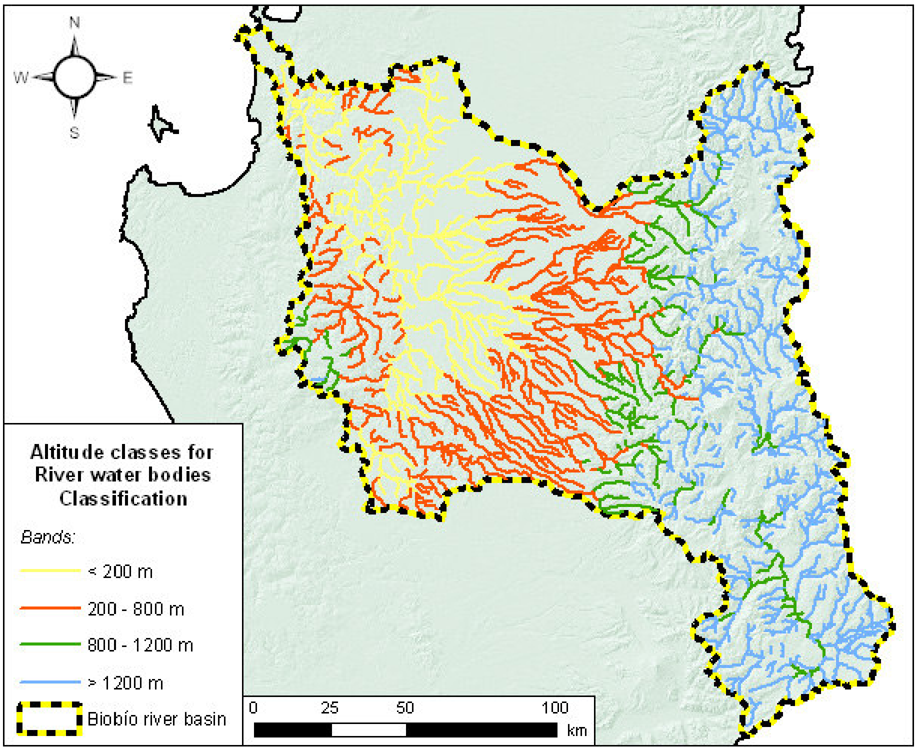

Figure A1.2 Codification of river water bodies according to Elevation Type

Percentage of the total upstream drainage area with snowmelt contribution

In the Biobío basin, certain river reaches are fed to a big extent by melt water coming down from the snow-covered higher mountain areas, while others correspond to rain-fed streams. For a given river reach (water body), the contributing area that is located above the snowline has an impact on the characteristics of the aquatic ecosystem, as snowmelt can heavily influence physical and chemical water conditions in a river. For this reason, a GIS layer that indicates, for each water body, the percentage of the total upstream drainage area that is located above the mean annual snowline (zero isotherm) is used as the second parameter in the establishment of the river water body typology.

As a first step in this process, the area of the basin where snowmelt contributions to runoff are prevalent is defined. For this purpose, the mean annual zero isotherm for the area is established at 1400 m.a.s.l., based on information from the Chilean General Water Directorate DGA. Using this subdivision of the basin, the percentage of the total accumulated drainage area above the snowline is calculated for each river water body. Two classes were established, using a threshold value of 40% (Table A1.2). Reaches having less than 40% of their drainage area above the snowline were defined as having a rainfall regime,; other reaches are considered to correspond to the mixed snow/rainfall regime. This classification may differ from "pure hydrological" classifications based on observed hydrograph data, but is considered to be an acceptable first approximation, in the absence of a dense cryological measuring network. However, interpretation of class names should not be done in a strict hydrological sense. Figure A1.3 shows the spatial distribution of river water bodies belonging to the two classes specified.

Table A1.2 River water body typology according to the parameter *hydro-regime*

Snow cover	Type
% with snow < 40%	1
% with snow > 40%	2

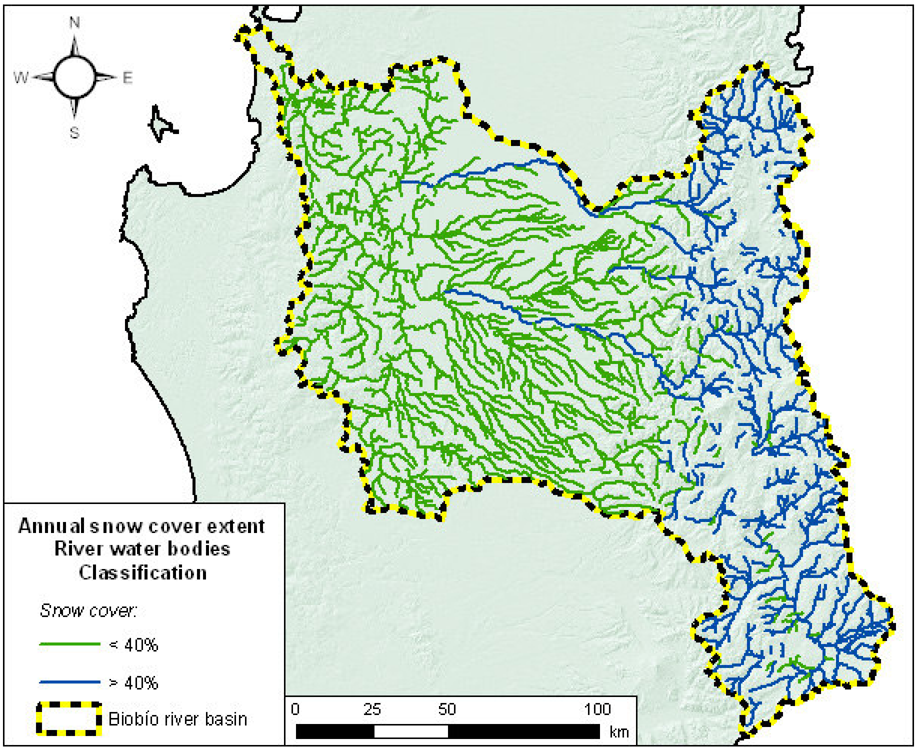

Figure A1.3 Codification of river water bodies according to Snowmelt Contribution Type

Total upstream drainage area

The third parameter considered in the establishment of a water body typology for the Biobío river network corresponds to the total upstream drainage area of each river reach. For this purpose, the class limits contained in the WFD were used without modification. Some testing took place replacing upstream drainage area by Strahler stream order, resulting in slightly to moderately different results. Finally, it was opted to use the drainage area-based approach. Figure A1.4 shows the classification of the Biobío river reaching according to their respective total upstream drainage area, using the class limits given in Table A1.3.

Table A1.3 Class limits used in the establishment of a typology based on total *drainage area*

Drainage area	Type
A < 100 km^2	1
100 < A < 1000 km^2	2
1000 < A < 10000 km^2	3
A > 10000 km^2	4

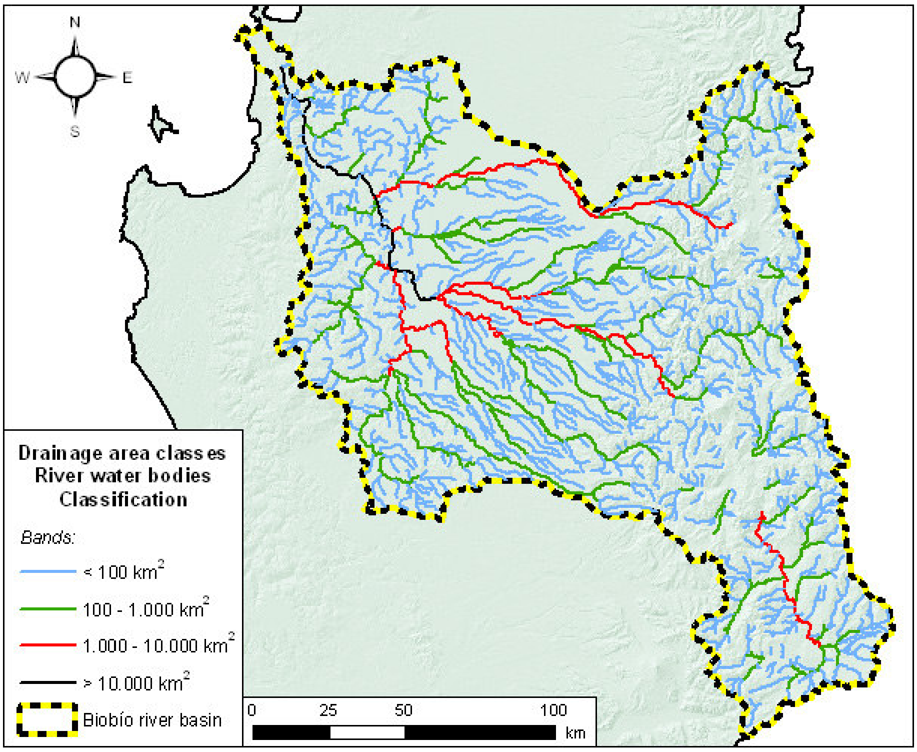

Figure A1.4 Codification of river water bodies according to Drainage Area Type

Dominant soil use within the reach-specific drainage area

The fourth and last parameter used for establishing a typology for the Biobío river network corresponds to the dominant soil type in the reach-specific drainage area. This parameter replaces the information on drainage area geology, contained in the original WFD classification scheme. The decision to replace geology by soil type information is based on the absence of important calcareous formations within the basin. This particular condition, as well as the field experience from local aquatic ecologists, in which soil type is established as a parameter having a major influence on aquatic ecosystem composition, justifies this replacement.

The soil types that were considered in this exercise are given in Table A1.4. Figure A1.5 shows a classification of water bodies according to the dominant soil type in their reach-specific drainage areas.

Table A1.4 *Soil* types considered in the water body typology definition process

Soil type classes	Type
Lacustrine deposits	1
Volcanic sands	2
Other volcanic soils	3
Granite	4
Rocky soil	5
Metamorphic	6
Clays	7

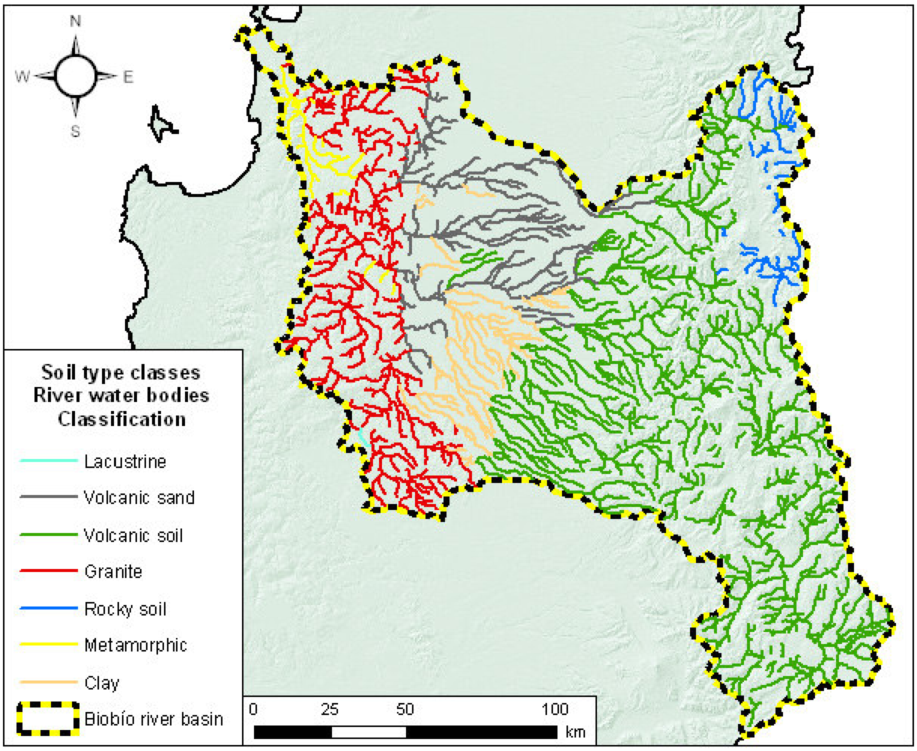

Figure A1.5 Predominant soil type classes per river water body

Biobío river water body types

Two water bodies belonging to the same class for the elevation parameter can still be substantially different, as they may belong to different classes for one or more of the remaining typology parameters. For this reason, the final typology is established by considering all previously generated GIS layers. Through an overlay operation in GIS, the four classification parameters can be combined in order to generate a new layer, in which each class represents a unique combination of all four parameter classes.

Through the combination of these information layers, a large number of river water body types are obtained. In practice, such a high degree of differentiation (high number of water body types) is unmanageable in the context of, for example, the establishment and control of a differential water quality standard (i.e. standards in function of spatially variable reference conditions). For this reason, it is necessary to implement a process that allows a reduction in the total number of water body types, by grouping similar classes into a single super-class. This process will preserve the most representative river water body types in the basin, and will absorb the less relevant ones (i.e. in terms of their presence in the basin; note, however, that underrepresented types may be ecologically highly relevant). The process implemented in the case of the Biobío basin consists of a cluster analysis in which different sub-types are grouped into a limited number of new, most-representative, river water body types. The cluster analysis implemented was supervised by means of a decision support mechanism, which allowed for the incorporation of local knowledge and expert judgment.

As a result of this exercise, a total of 14 final river water body types were obtained for the Biobío basin river network. This number may further be reduced in future efforts, if desired. A nomenclature for the 14 river body types of the Biobío basin is given in Table A1.5. Their spatial distribution over the basin is graphically represented in Map BB1.

It is important to indicate, however, that as a consequence of the grouping process, the river body type nomenclature should not be interpreted literally, as certain reaches may now have joined a water body type with different characteristics (class memberships) for one or several of the classification parameters. In this sense, type membership should now be interpreted in a broader sense i.e. as either having all specified characteristics for this type, or as belonging to a sub-type which is similar or identical in most, but not necessarily all, characteristics to the indicated (super-)type.

Table A1.5 Unique identifiers and class description (nomenclature) for the different river water body types in the Biobío River Basin

Type	*Elevation* class	*Hydro-regime* class	*Drainage area* class	*Soil* class
1114	Lower Altitude watersheds	Rainfall regime	"Head reaches"	Granitic
1122	Lower Altitude watersheds	Rainfall regime	Secondary reaches	Volcanic Sands
1146	Lower Altitude watersheds	Rainfall regime	Lower Biobío	Metamorphic
1132	Lower Altitude watersheds	Rainfall regime	Middle Biobío & main tributaries	Volcanic Sands
1232	Lower Altitude watersheds	Snow/rainfall regime	Middle Biobío & main tributaries	Volcanic Sands
2112	Middle Altitude watersheds	Rainfall regime	"Head reaches"	Volcanic Sands
2113	Middle Altitude watersheds	Rainfall regime	"Head reaches"	Volcanic Sands
2123	Middle Altitude watersheds	Rainfall regime	Secondary reaches	Volcanic Sands
2232	Middle Altitude watersheds	Snow/rainfall regime	Middle Biobío & main tributaries	Volcanic Sands
2233	Middle Altitude watersheds	Snow/rainfall regime	Middle Biobío & main tributaries	Volcanic Sands
3113	Foothills watersheds	Rainfall regime	"Head reaches"	Volcanic Sands
4213	Mountain watersheds	Snow/rainfall regime	"Head reaches"	Volcanic Sands
4215	Mountain watersheds	Snow/rainfall regime	"Head reaches"	Lithosols
4223	Mountain watersheds	Snow/rainfall regime	Secondary reaches	Volcanic Sands

Appendix 2 Classification for the Okavango Delta

Wetland components

Wetlands are typically characterised by water, soil and vegetation (Section 2.1). A further essential feature of the Okavango Delta wetland is the wildlife and other fauna (see Map OK3), which rely on the water to drink and, considering the lower food chain, the vegetation for food. The vegetation also expresses the biodiversity of the delta, in which lies its greatest ultimate value.

An important subcomponent of the water wetland characteristic is water quality (acidity and salinity). This is relevant to the Okavango Delta as, in a terminal river wetland system where evapotranspiration is the primary component of the water balance, even very low salt concentrations in the river inflows may be expected to accumulate over thousands of years.

In the Okavango Delta, trees grow on islands with a slightly higher elevation. Their deep roots draw the soil moisture towards the islands, and through the roots and stems to the leaves, where the moisture transpires to the atmosphere. The salt which is toxic to the plants accumulates in the soil, and builds up the level of the island. Eventually, the salinity of the island soil reaches a level where it kills the vegetation, starting from the inner core of the island (see Figure A2.1).

Thus, the surface water, and water recharging the groundwater, remain fresh with very low salt concentrations. The fate of the salt which has built up to a high level on the islands remains unclear. The area occupied by salt islands appears to remain constant i.e. there is no long-term accumulation of salt in the higher lands of the delta. It is presumed that the salt accumulated in the island soils is flushed to the groundwater by overland flow and rainwater, and owing to the higher density of saline water occupies deeper groundwater aquifers. This is supported by the fact that deep groundwater mined in the Kalahari is generally saline. Fresh water is only mined where there is relatively recent fluvial surface water recharge.

Surface water and groundwater

As in any hydrologic system, the occurrence of surface and ground water are inter-related. The inflow hydrograph from the upstream basin in Angola and Namibia is shown in Figure A2.2 for a 15-year period from 1987 to 2002, together with the mean rainfall over the delta. The entire basin lies in the summer rainfall area. The peak of the inflow hydrograph occurs towards the end of the rainy season in March, as the flood wave travels through the 350,000 km^2 upstream

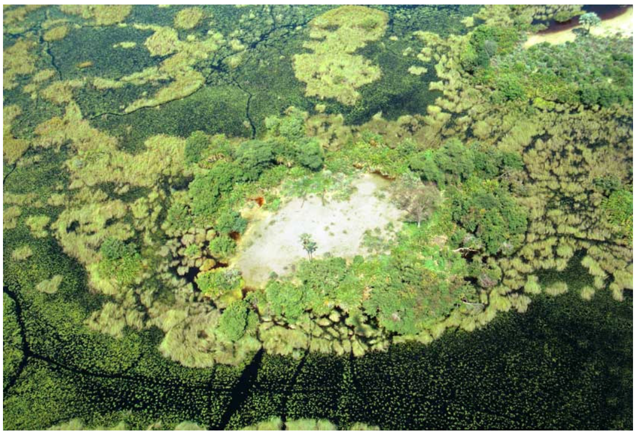

Figure A2.1 Impact of soil salinity on vegetation in the Okavango Delta basin. Of the inflowing water, less than 1% flows out of the delta, the remainder having mostly evaporated with some infiltration to groundwater. The outflow amounting to a few cubic metres per second is soon lost to further evaporation and infiltration in the Kalahari downstream. The water balance for a 5-year period, 1987 to 1992, as represented by the Integrated Hydrologic Model of the delta (WP4 report, 2006), is shown in Figure A2.3.

The flooded area of the delta within the period of hydrological observations over the past 70 years ranges from around 4000 km^2 in the dry period (October/November) to 15,000 km^2 at the peak of the upstream flood (July/August). When the rains start, the rain falls on a relatively dry delta, with a flooded area around 4000 km^2. The rainfall mostly falls on dry land, raising the soil moisture, which in turn evaporates and is transpired by the vegetation. The flood from the upstream basin firstly enters the Panhandle, flooding the adjacent swamps to a depth up to several metres and a width of 15 km. Around 100 km downstream, the flood wave enters the delta proper, and spreads through the swamps to flood an area up to 15,000 km^2. Map OK7 shows the five resulting flood zones, the first being the Panhandle and the remaining four according to the probability of flooding.

The surface water processes are illustrated in the time series of the average depth for each zone (Figure A2.4). The Panhandle is the first zone to be affected by the incoming flood wave, with the largest rise in water level, around 1.5 m. Then the flood wave propagates to the normally flooded areas, and on to the frequently, occasionally and rarely flooded areas, with a time lag of three to four months. The response of the groundwater is shown in Figure A2.4 for the same five zones. This closely follows the rainfall and surface water pattern. In the frequently flooded areas, the ground water is at the surface, and the plot reflects the surface water depth (as a negative value).

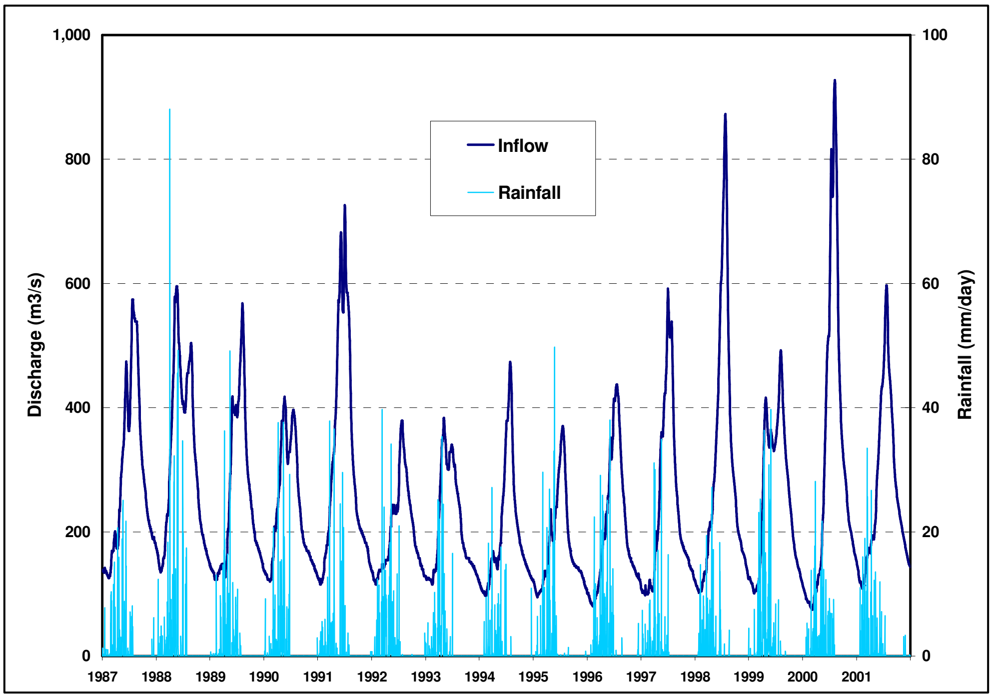

Figure A2.2 Okavango Delta inflow and rainfall

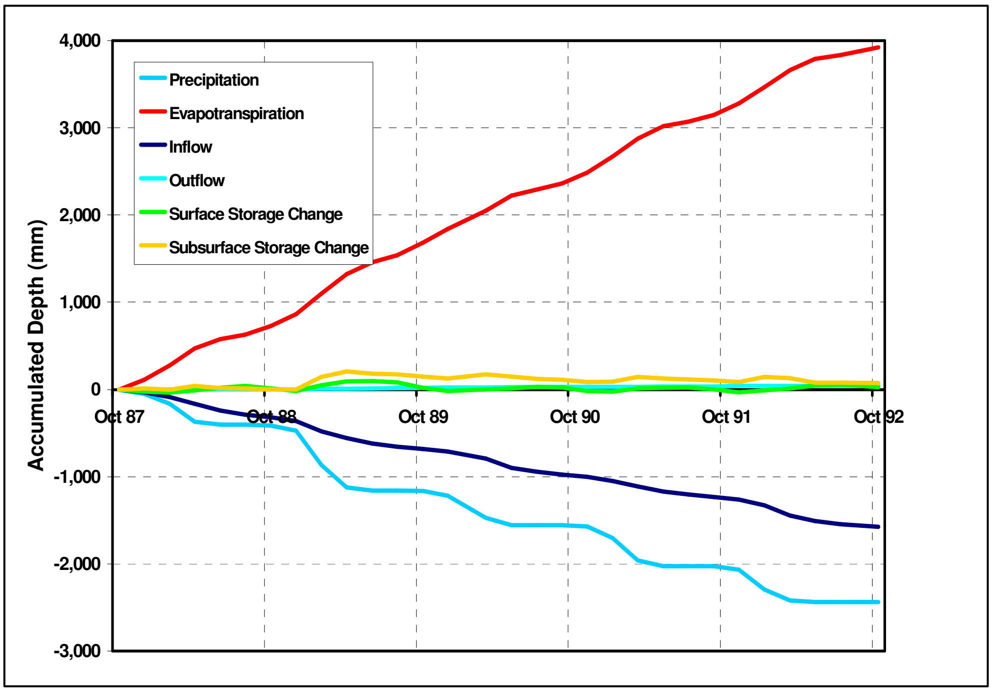

Figure A2.3 Okavango Delta 5-year water balance

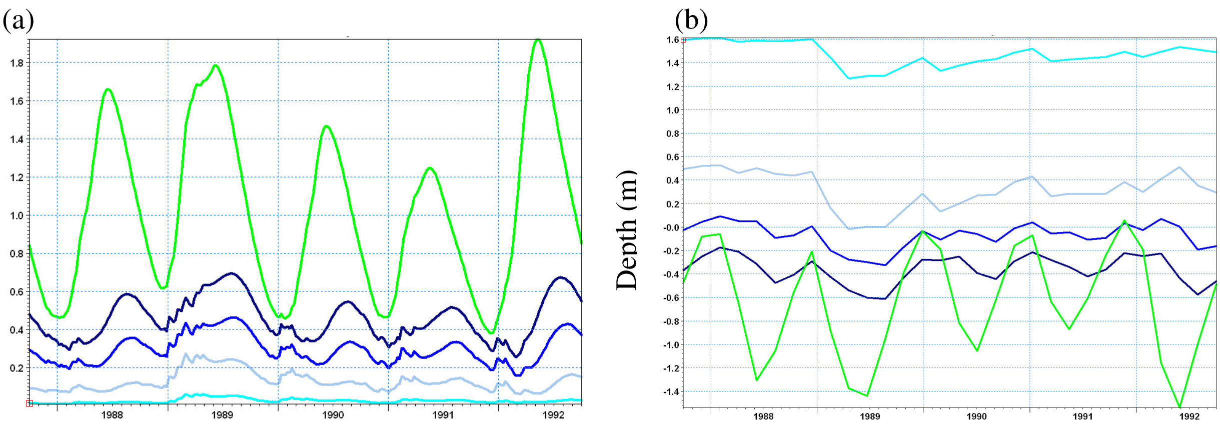

Figure A2.4 Average depth of (a) surface water and (b) groundwater by flood zone

Soils

Almost the entire Okavango River Basin is covered by Kalahari Sands. The soils of the delta are correspondingly uniform, ranging from medium to fine sand, through sandy loam to clayey loam (Map OK8). The distribution of the soils over the alluvial fan is determined by fluvial processes, and closely matches the probability distribution of flood water over the delta. Since the soils have been built up over thousands of years, this suggests that the overall pattern of flows in the delta has not changed greatly.

Vegetation

The vegetation of the wetland (Map OK9) is primarily dependent on the spatial and temporal variation in surface water, soil moisture and ground water, and is an essential component of the evapotranspiration process. This process comprises evaporation from open water, from vegetation and from the soil, and transpiration from the vegetation. The key dynamic parameter of the evaporation and transpiration is the leaf area. Other parameters assumed to be static are the root depth, the stomata resistance, the vegetation height and the extinction coefficient.

The leaf area index (LAI) is the ratio of the total area of all leaves on the plants to the area of ground covered, and is thus a measure of the vegetation density. The LAI can be assessed by remote sensing. A time series grid of the delta has been produced, with a temporal resolution of eight days (January 2000 to February 2004) and a spatial resolution of one kilometre. Figure A2.5 shows samples of the LAI for different seasons.

The variation of the LAI is shown in Figure A2.6 for the same five flood zones. This clearly demonstrates that the density of the vegetation varies primarily with the rainfall over the delta, and not with the incoming flood wave (Map OK9). Rainfall raises the soil moisture over the entire delta, with a corresponding growth spurt in the vegetation. The incoming flood also increases the amount of water available to the plants in the flooded areas, and immediately adjacent dry land. Thus, the index is maintained at a higher level, around 0.9, through the dry season, whereas in the drier areas the index drops to around 0.05.

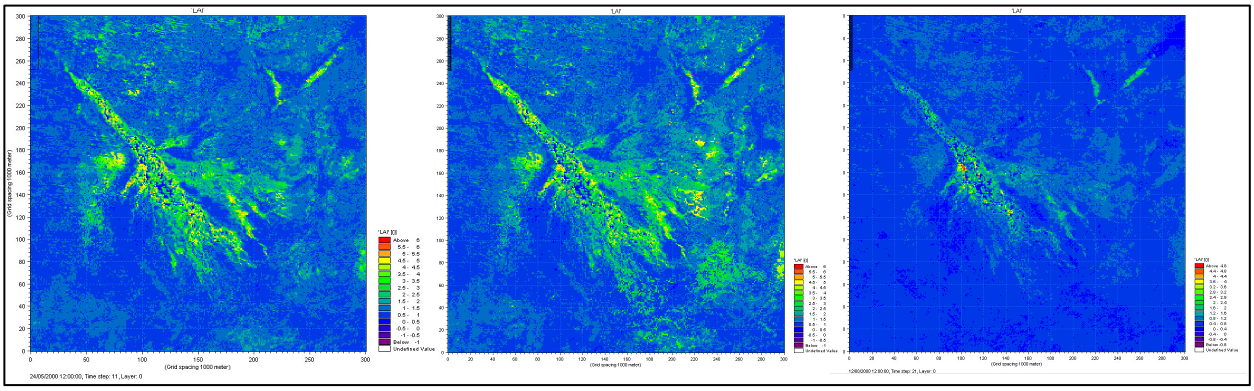

Figure A2.5 Sequence of satellite data showing vegetation density across the Okavango Delta

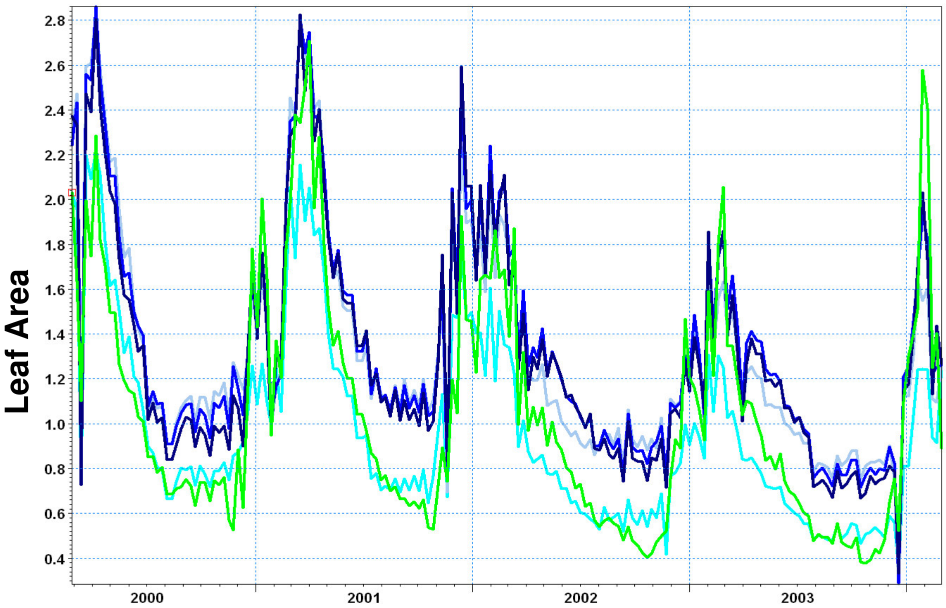

Figure A2.6 Variation in leaf area index by flood probability zones in the Okavango Delta