TWINBAS

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

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Work Package 9

Report on Action Efficiency Research (D9.1)

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1. Introduction

The WFD aims to establish a holistic approach to managing the water environment, based on river basins, and integrating water quantity with quality considerations, the latter based on an ecological classification system. In addition to contributing to sustainable management and development of the water environment to ensure a better quality of life, now and in the future, greater integration should help to avoid unnecessary duplication of effort, ensure that there are no contradictions between the objectives and the priorities shown in the different plans, achieve greater transparency of objectives and priorities among stakeholders, whilst ensuring that individual statutory obligations can still be met, and maximise cost-effective approaches to meeting multiple objectives (Defra, 2002).

River basin management plans (RBMPs), which set out specific objectives and the measures to achieve them, are the key planning documents to achieve this aim. The RBMPs must be in place by 2009 and must be reviewed and updated every 6 years after that. The RBMPs are informed by a programme of cost-effective actions or combinations of actions to achieve the WFD's environmental objectives by 2009, based on monitoring and analysis of the river basin's characteristics, and the identification for each water body of any discrepancy between its existing status and that required under the WFD. The programme of measures should consider:

- Proposals for modification of the current procedures for licensing abstractions and consenting discharges.

- Basic measures required to implement EU Directives to protect water bodies in the river basin district i.e. Bathing Water, Birds, Drinking Water, Major Accidents, Environmental Impact Assessment, Sewage Sludge, Urban Wastewater Treatment, Plant Protection Products, Nitrates, Habitats, Integrated Pollution Prevention and Control.

- Any pricing measures, or other economic/fiscal instruments, intended to provide incentives to encourage more sustainable and efficient use of water.

- Supplementary measures if the above are not sufficient to meet WFD requirements e.g. abstraction and emission controls, negotiated environmental agreements, codes of good practice, demand management measures, efficiency and re-use measures, artificial recharge of aquifers, re-creation and restoration of wetlands, construction projects, desalination plants, rehabilitation projects, education projects, research projects.

- In exceptional cases, additional measures may be needed e.g. for international river basins.

In all activities, a balance must be maintained between the three principles of sustainable development: environmental, economic and social (FWR, 2004). Indeed, economic analysis forms an important aspect of the development of the programme of measures and is used to evaluate the costs and effectiveness of potential measures, to support the designation of heavily modified water bodies, to construct a cost-effective programme of measures, to evaluate whether costs are disproportionate to the benefits gained, and to assess the financial implementation of the programme of measures.

These programmes of measures setting out the actions to be taken to secure WFD objectives must be in operation by 2012, and the environmental objectives achieved by 2015, by which time the RBMP for the next period will be in place (FWR, 2004). The reasons for taking a long-term view in this process are that the drivers for change are often of a long-term nature (e.g. climate change and land use), that there are many long-term impacts on the water environment (e.g. it takes many years to reverse pollution in groundwater and pollution from nutrients such as phosphates), that the substantial investment in the changes needed requires long time scales for both planning and execution, and that behavioural change is likely to take time to be fully achieved (e.g. by households to reduce water use, or by farmers to address diffuse pollution). Therefore, river basin management planning is necessarily an iterative process, with many of the activities repeated in the next cycle, though informed by the results of the last cycle.

This report considers the identification and assessment of possible actions or combinations of actions to achieve these environmental objectives in the five TWINBAS river basins. WP9 is a culmination of activities in all the previous TWINBAS work packages (Figure 1.1). WP1 (2003) started by reviewing the history and current knowledge in each basin, and reporting on stakeholder views, needs and problems, and gaps in knowledge and expertise. Stakeholder involvement was developed in WP3 (2007) together with process guidelines for identification of users and stakeholder water requirements transferable to other river basins. WP2 (2003) reviewed existing monitoring networks in the basins and identified needs for new monitoring under TWINBAS. Some of the data collected during the project have been used in hydrological modelling (WP4, 2006) in the Biobío, Norrström and Okavango River Basins, whilst other data have been used for water quality modelling (WP5, 2007) and the analysis of pollution pressures and impacts. WP7 (2007) assessed the effect of climate change, as well as rural and urban development scenarios, on the hydrological regime, water availability and water quality. Knowledge of the risks to the status of the water environment steered the water body categorisation and classification exercise in WP6 (2007) and provided a starting point for the development of programmes of measures and RBMPs (WP9, 2007), supported by the economic analyses in WP8 (2007) to ensure a cost-effective approach to water management. Because the TWINBAS RBMP contributions do not encompass all aspects or problems of water use in the case studies, due to budgetary limits, they are intended as examples, to be used by local or national planning authorities in their further work to produce authorised RBMPs.

After this introduction, Sections 2-6 report on the progress of the action efficiency research in each of the five TWINBAS river basins, including the scope of the problem(s) under consideration, the methods and tools for assessing action efficiency, the proposed actions, and stakeholder involvement in the process. Rather than integrating the approaches from each basin in separate topic chapters, this layout was chosen because the methodology in each river basin, and the progress made, are different. Some partners have chosen to focus on one or more issues in a small part of the basin, whilst others have chosen to address issues at the basin level. Section 7 presents some concluding remarks for each basin. The results contribute to the river basin management plans considered in the second WP9 report (2007).

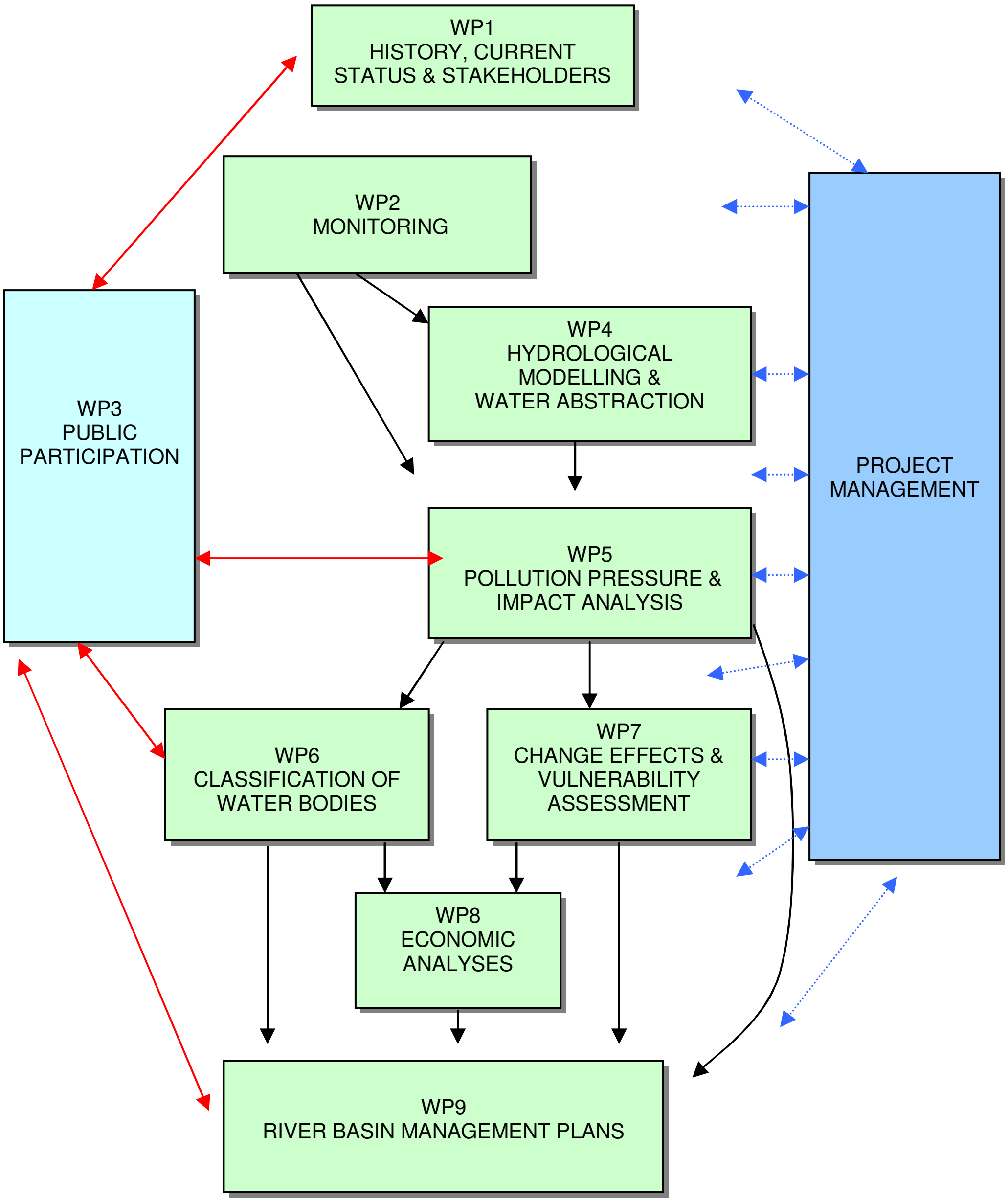

Figure 1.1 Links between TWINBAS Work Packages

2. Biobío

2.1 Scope of problem

The Biobío River Basin is Chile's third largest river basin and it occupies 3% of the country's continental territory. The basin has a high value in terms of biodiversity, characterised by a considerable number of endemic species. At the same time, the area constitutes the country's most important centre for forestry activities, contains a major portion of the Chilean agricultural soils, and plays a predominant role in the national energy supply. The basin has a total estimated population of 1.1 million. The lower part of the river currently suffers from pollution problems, with municipal effluents discharges from about 650,000 inhabitants, but the implementation of wastewater treatment technologies is likely to reduce the magnitude of this problem. Instead, attention may gradually shift towards contaminants from point-sources (pulp mills), not eliminated by the implemented technologies, and to the problems caused by non-point source contamination.

The Biobío river is considered one of the Chilean water bodies most polluted with chemicals. The pulp and paper industry produces about 50 % of its pulp with water from the Biobío river, abstracting 220,000 m^3/day (c.a. 2.5 m^3/s), and discharging 1,083,000 tonne/yr (ca. 3.500 tonne/day). These effluents have the potential for both inhibitory (e.g. toxicity) and stimulatory (e.g. nutrients) impacts on aquatic biota. It is common to find concentrations of polychlorobenzene biphenyls (PCBs), HC isomers and hexachlorobenzene (HCB) in the Biobío river. There are reaches of heavy chemical stress, especially at the mouth of the river.

Pollution, in terms of overloads with organic matter and inorganic nutrients, has potential ecologically important effects and could trigger or amplify eutrophication within the effluent receiving watercourses. Of particular concern are increases in temperature, pH and conductivity, the latter caused mainly by sodium salts arising from the degradation of wood products. Chemicals in the effluents contain a high concentration of suspended particulate material and dissolved and particulate organic matter, consisting among other things of cellulosic fibres and carbohydrates, which can negatively affect the oxygen budget of the water body and sediments. The excess of inorganic key nutrients (nitrogen and phosphorus) in the effluents can contribute to overload of the carrying capacity of the receiving aquatic ecosystems by supporting eutrophication processes, which can lead to anoxic conditions. Some important discharges in the Biobío river along of the basin are listed in Table 2.2.

An significant proportion of Chilean PIB is generated by activities associates with the Biobío River Basin, including hydropower generation, forestry, pulp mill, petrochemical industry, irrigated land, etc.

Table 2.2 Key point source pollution sites along the Biobío river

Industry	Municipalities
CMPC S.A. Laja (Pulp and Paper)	Laja
CMPC S.A. – Inforsa (Paper Mill)	Nacimiento
Norske Skog S.A. (Paper mill)	San Pedro de la Paz
Nestle Chile S.A. (Milk Plant))	Los Angeles
Soprole S.A. (Milk Plant)	Los Angeles
CMPC S.A. Pacífico (Pulp Mill)	Mininco (Angol)
ENAP S.A. (Petroleum Refinery)	Hualpén
Huachipato S.A.(Metallurgical Plant)	Talachuano

2.2 Tools for assessing action efficiency

Three types of tool were used to assess the effectiveness and cost–efficiency of the different actions proposed (Table 2.1).

Meetings

Meetings were a common tool used for two-way communication through the life of the TWINBAS project. Various meeting with basin stakeholders took place, including residents, users and industry representatives, and also meetings with different levels of Government organisation (i.e. local, regional and national).

At those meetings, contamination problems of the basin and future action to minimise the environmental impacts (e.g. investment in the industrial and sanitary sectors) were discussed. For each meeting, a report was made for the review of all stakeholders and government organisations, and each stakeholder was free to make comments or observations to the final report. The final version of the report is considered by all stakeholders as an agreed summary of the meeting and statement of outcomes.

Workshops

Workshops were attended by a wide range of people for general discussion and presentation of progress and proposals of TWINBAS project activities. Again, a report or paper for future review by all stakeholders was written.

Case studies

The Biobío partners required input from economics experts from local institutions in order to assess the effectiveness and cost–efficiency of the different actions proposed. The experts assisted in the economic aspects of the TWINBAS project and helped define future actions to develop or implement.

2.3 Stakeholder consultation on proposed actions

The discussions with stakeholders, referred to in Section 2.2, highlighted the important problems and management issues in the Biobío River Basin, which inform recommendations for future actions (Table 2.1).

Some reaches of the river are used for the discharge of effluents that have not always been adequately treated so, in particular, there is a requirement for more information about the water quality of the river basin including:

- Monitoring information generally, but with special consideration of biological parameters which may be impacted by pulp and paper industries.
- The seasonal variation of parameters like turbidity, suspended solids, conductivity and colour.
- Others parameters that provide regional environmental information like DQO, total nitrogen, total phosphorus, AOX, and pentachlorophenol.
- Review of past and present projects with an Environmental Qualification Resolution to help define the current status of water quality.

Stakeholders are interested in being actively involved in water resource management decisions, but the form of the participation could be better defined, including the roles of the different stakeholders and their responsibilities in the process. Institutional responsibilities, and budgets and financing arrangements, for water resources management also needs to be clearer, in particular the coordination and cooperation between various ministries and organizations.

Any action on the Biobío River Basin will have social and economic impacts for the population that requires potable water for drinking, for new industrials projects and for the State in relation to inspection and environmental monitoring. For this reason, it is very important to make social and economic studies to determinate the costs and benefits of the different actions proposed, remembering that any actions must include the natural phenomena of the basin like volcanic phenomena because, in this situation, the characteristics of the basin are totally different to normal status.

Table 2.1 Biobío River Basin - Proposed actions and impacts

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action	Constraints to efficiency
1	Biobío river basin	New discharges from industrial activities causes loss in quality for public water supply	Incorporate new criteria in the DS 90 mass contribution limits for each regulated pollutant	Recovery of water quality in all basin	Likely to be successful in terms of increasing water quality, but will not control growing industrial activities & new sources	Political discussion not conducive to necessary agreement for success of new legal proposal
2	Biobío river basin	New discharges from industrial activities breaches the water quality standard for different pollutants & reaches	Develop the Decree Law for the basin management according to the actual legislation	Recovery of water quality in all basin	Likely to be successful in terms of increasing water quality & is possible will control growing industrial activities and new sources	Political discussion not conducive to necessary agreement for success of new legal proposal. Bureaucratic process
3			Incorporate new criteria in DS 90 about relationship between points of abstraction of water & discharge of effluent	Recovery of water quality in all basin	Likely success in control of the effluent quality & efficiency of treatment, but will not prevent impact on aquatic life or caudal	Bureaucratic & legal process can be too long. Political discussion not conducive to necessary agreement
4			Improvement of the Continuous Monitoring Programme	Improvement of the efficiency & control of the actions	Likely success in control of the water quality	Financial & technical limitations.
5	Medium reaches of Biobío basin	Over-abstraction of groundwater for industrial & public supply causes depletion of low flows & drying of wells	Incorporate the calculation of water rights in the complete water balance	Minimise the impacts on the hydrological balance	Normally improve the management of the water resource	Not enough data to implement the new calculation mechanism
6			Establish the obligation to make a register of groundwater abstractions	Improvement of the efficiency over the use & availability	Likely to be successful when associated with other support measures	Requires the other complementary system to work well
7	Biobío river basin	Increase in the caudal of discharges causes loss in quality for public water supply, aquatic life & ecosystems	Incorporated new criteria in the DS 90 mass contribution limits for each regulated pollutant	Improve the degree of protection of water quality	Likely to be successful in terms of increasing water quality, but will not control growing industrial activities & new sources	Bureaucratic & legal process can be too long. Political discussion not conducive to necessary agreement

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action	Constraints to efficiency
8	Biobío river basin	Significant changes in discharge composition causes direct impact on the biota (positive or negative) by synergy effects	Incorporate biological monitoring	Improve knowledge about the ecosystems & the appropriate standards & actions	Likely to be successful when associated with other physico-chemical standards	Technical discussion not conducive to necessary agreement
9	Biobío river basin	Urban growth causes increase of micronutrients & BOD	Incorporate new criteria in the DS 90 mass contribution limits for each regulated pollutant	Improvement of the standard of water quality	In general urban growth does not have corresponding impact on water resources	Requires a political discussion, that is highly bureaucratic
10			Modification of mechanisms of control in DS 609 (industrial discharges in sewers system)	Better control over industrial discharges and better operation of municipal wastewater plants	Will help to reduce breaches of the limit established by the law	Requires a political discussion, that is highly bureaucratic
11			Promote education (for children & adults) about this watershed & about interrelationships of land use & human activities with public health, recreation, water quality, & fish & other aquatic life	Possible to obtain better results	Likely success in the long term with high social profit	Requires a strategy & continuing effort from government & private sector with high economic cost

3. Norrström

3.1 Scope of problem

The Norrström River Basin covers an area of 22,600 km^2, which corresponds to about 5% of the area of Sweden. The basin includes two of Sweden's largest lakes: Mälaren with an area of 1000 km^2, and Hjälmaren which is about 500 km^2 (Figure 3.1). The number of people living in the area is approximately 1.2 million. Forests and mines dominate the landscape and cover about 70% of the area. There are also large agriculture areas, covering approximately 20%, while lakes cover around 10 % of the area (Wallin et al., 2000). Mälaren and Hjälmaren are connected through river Eskilstunaån. The outlet of Lake Mälaren to the Baltic Sea is situated in central Stockholm.[1]

The most important water quality problem in the Norrström river basin is by far the eutrophication of Lake Mälaren, to which all the tributaries in the basin transport nutrients. TWINBAS has focused on this problem. The sources are agriculture, point sources and rural households. The contribution of point sources and rural households is fairly easily assessed and, therefore, the development tasks within the project have been concentrated on improving the dynamic modelling of nutrient leaching from agriculture. Application of the developed modelling technique has been carried out for five of the twelve main tributaries in TWINBAS, but analysis of action cost-effectiveness for agricultural management practice actions was for budget reasons limited to a sub-basin in the Sagån tributary, namely the Frögärdesbäcken catchment and parts of Lillån, but can be generalised to large parts of the Norrström basin. The measurements done in the Svartån and Sagån watersheds have shown that these basins have a substantial affect in terms of eutrophication on adjacent parts of Lake Mälaren due to their high transports of nitrogen (N) and phosphorus (P).

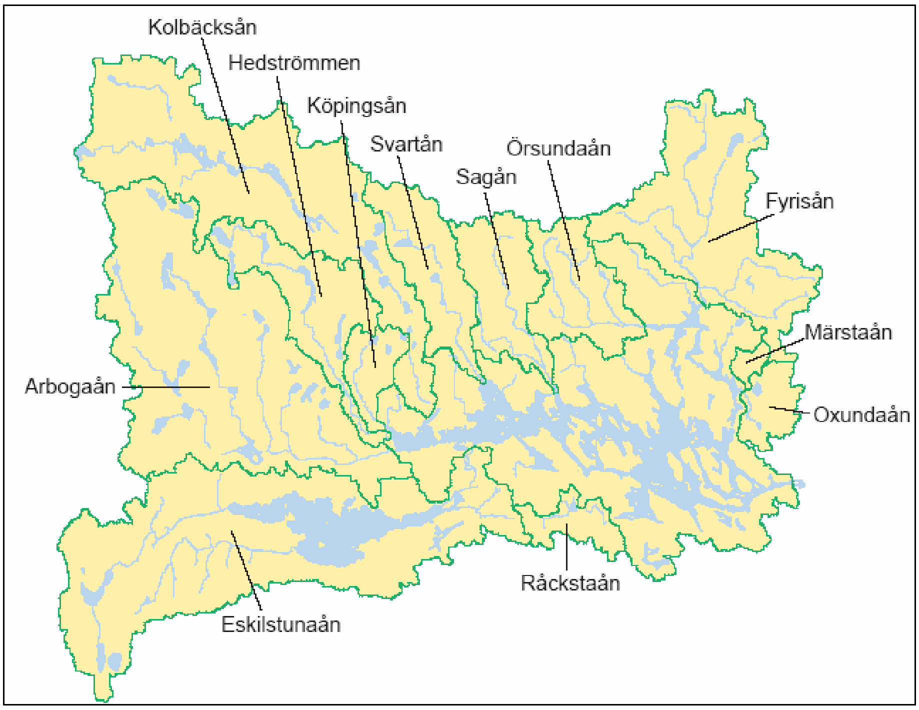

Figure 3.1 River network and main tributaries of the Norrström River Basin, Central Sweden (from Wallin et al., 2000)

[1] http://ivl.dataphone.se/twinbas/norrstrom.asp

In Sweden in general, and Västmanland as well as the related municipalities in particular, the sources of eutrophication are many. Table 3.2 depicts the average leaching of nitrogen and phosphorus using the SWAT model. As shown, the agriculture areas are the dominant source of leaching of the nutrients to Sagån during the years 1998-2004. Leaching of nitrogen and phosphorus from these areas is more than 78% and 80%, respectively. The other sources with high leaching are point sources including water treatment plants, forest and households.

Table 3.2 Leaching of N and P to Sagån river basin 1998-2004

Parameter	N (kg)	P (kg)
Households	11582	1698
Point sources	72274	1094
Agricultural areas	**421547**	**25342**
Forest	22812	1675
Open land	1321	147
Transitional woodland	5791	452
Urban fabric	1761	146
Wetland	1819	67
Total	538907	30621

The Sagån watershed has an area of 857 km^2 and is located at the border of two regions (Västmanland and Uppsala) and shared by four municipalities (Enköping, Heby, Sala and Västerås). The area has few lakes which imply that there is nothing delaying the water flow and Sagån, therefore, functions partly as a ditch with a fast transport of nutrients to Lake Mälaren. Soil use is dominated by forest (47 %) and agriculture (44%).

The soil use of the sub-basin of Frögärdesbäcken and Lillån is dominated by agriculture (53%) and forest (36%). A large part of the agriculture involves animal production, principally pig farming. The difference in terms of nutrient loss concerns aspects connected to the quantity of, and time of application of, fertilisers. The reason for choosing a small part of the sub-basin has been to investigate the effect of locally-collected information on the modelling results of nutrient loss. The calculation model used is the open American model Soil and Water Assessment Tool (SWAT). This study concentrates on identifying a cost-efficient programme of measures leading to a reduction of nitrogen and phosphorus from agriculture. However, analysis of action cost-efficiency addressing point sources and households was carried out for and is valid for the entire basin, and for Sweden as a whole.

3.2 Tools for assessing action efficiency

The environmental regional goals for the Norrström River Basin require an emission reduction of 30% for nitrogen and 20% for phosphorus, relative to the levels of 1995, by the year 2010. With these levels as a baseline, the total required reduction of nitrogen and phosphorus would be 638 kg of nitrogen and 38 kg of phosphorus for the Frögärdesbacken and Lillå study area.

The application for fertilisers in the area is approximately 110 kg nitrogen per ha for Spring crops and 150-160 kg nitrogen per ha for Autumn crops, and 20-25 kg phosphorus per ha. The leakage of nitrogen and phosphorus from farmland due to application of fertilisers has been estimated to be approximately 5.0 kg nitrogen per ha and 0.35 kg phosphorus per ha. The total leakage in the area amounts to 2126 tonnes nitrogen and 242 tonnes phosphorus.

3.2.1 Methodology

The cost-efficiency calculations for the proposed measures are derived from the IVL report "Samråd Västerås – information från lantbrukare som bas för modellering av åtgärdseffekter", hereafter referred to as the Lillå report or Lillå case study, which describes the chemical/ecological effects from the use of different abatement measures in Frögärdesbäcken and Lillån. Cost calculations are based on approximate costs from available research studies in different river basins in Sweden. All calculations are compared to current research in other parts of Sweden.

The cost-efficiency is presented as the costs divided by the effect, where the effect is expressed as kg reduced nitrogen or phosphorus:

$$KEm = Km / BEm$$

Where: KEm = cost-effectiveness of measure m (Euro / kg reduced N or P per ha)
Km = economic costs of measure m (Euro per ha)
BEm = reduced kg N or P per ha (i.e. the effect) as a result of the measure m

3.2.2 Cost-efficiency of proposed measures for the sector

The cost-efficiency calculations are based on the modelled results from the Lillå report. The effects are presented in Table 3.3. These results are compared to cost-efficiency calculations from other Swedish research studies for the same measures.

Table 3.3 Comparisons of modelled effects between different measures in the watershed Frögärdesbäcken

	Area losses kg/ha					
Crops	**Before**		**After**		**Difference**	
Measures	**P**	**N**	**P**	**N**	**P**	**N**
No soil preparation in Autumn - Spring crop	0.63	5.0	0.62	4.2	-0.01	-0.8
Catch crops Spring	0.63	5.0	0.63	4.1	0.00	-0.9
Reduction of fertilisers for Autumn wheat	0.34	2.6	0.34	2.6	0.00	0.0
Riparian buffer zones 1 (10m Spring crop)	0.63	5.0	0.17	3.6	-0.46	-1.4
Riparian buffer zones 2 (10m Autumn crop)	0.34	2.6	0.09	1.6	-0.25	-1.0
Riparian buffer zones 3 (20m Spring crop)	0.63	5.0	0.09	2.9	-0.54	-2.1
Riparian buffer zones 4 (20m Autumn crop)	0.34	2.6	0.07	1.3	-0.27	-1.3
Transformation of Spring crop - Salix	0.63	5.0	0.02	1.6	-0.61	-3.4
Mixed operation – grain operation Autumn crop	0.34	2.6	0.31	2.5	-0.03	-0.1
Mixed operation – pig operation, Autumn crop	0.34	2.6	0.35	4.6	0.01	2.0

Upstream measures

a. Cultivation of catch crops

Plantation of catch crops is a land-use measure aimed at reducing the leaching of nitrogen from the root zone. Catch crops are sown at the same time as the ordinary crop but continue to grow after the ordinary crop is harvested, thereby taking up residual nitrogen in the soil and reducing the nitrogen leaching from the root zone. There are indications that catch crop plantation in the Mälar region can reduce the amount of leaching by at most 20%. This reduction is less than what is possible in most other agricultural regions of Sweden. The low reduction of catch crops in the Mälar region can be explained by the domination of clay soils (Scharin, 2002).

Different cost –effectiveness values have been calculated for this measure. In the information project to farmers "Greppa Näringen"[2] the cost of cultivating 4000 kg catch crops per ha during Spring is approximately 4 Euro per kg reduced nitrogen, assuming a reduction of 12.5 kg nitrogen per ha.

In Scharin (2002), a 20% reduction of nitrogen was assumed with a cost of 38 Euro per ha and expressed in cost-efficiency as 12-13 Euro per kg reduced nitrogen.

In Kävlingeåprojektet, the annual cost per ha for cultivating catch crops was 50 Euro with a cost –efficiency of 5.6 Euro per kg reduced nitrogen. These calculations are based on the assumptions that the current soil leakage is 30 kg per ha and the reduction potential approximately 9 kg per ha. If catch crops are cultivated during Autumn, the cost will rise substantially.[3]

In the Lillå case study, the modelled effect for nitrogen showed a reduced area loss of 0.9 kg N but no change for phosphorus. The cost of reducing one kg of nitrogen amounts to 42 Euro.

b. Reduced quantity of fertilisers

The abatement cost of reducing the application of fertilisers represents the farmers' foregone profits when applying a lower quantity of fertilisers. In Scharin (2002), the reduction of applied fertilisers in Mälardalen was assumed to result in a 50% reduction of nitrogen with a cost-efficiency of 0.3 Euro at the source and 5-6 Euro at the recipient. Other studies show costs ranging between 2 to 6.4 Euro per kg reduced nitrogen.

In the modelling results in the Lillå report, no changes could be seen. However, these changes need a longer period of time to show results: in the Lillå report, these results are based on a relatively short time period.

c. Cultivation of energy crops

The leakage of phosphorus and nitrogen can be considerably reduced through the cultivation of energy crops. In Naturvårdsverkets report for Lake Glan, a current leakage of 0.2 kg phosphorus per ha was assumed and also that the cultivation of energy forest could reduce the leakage with 50%. This would imply a cost-efficiency of 100 Euro per kg reduced phosphorus. There exist few investigations concerning the leakage of phosphorus due to high levels of rainfall soon after fertilisers have been applied. However, it should not be any greater risk for phosphorus leakage than what is usual in normal crop plantations.

[2] http://www.greppa.nu/kunskapen/12godarad.4.8aeb74fa563c6d2d7fff746.html
[3] Kävlingeåprojektet, p. 34-35

Salix cultivation has a known low leakage of nutrients. The reasons are partly due to lower fertilisation and partly to a much longer growing period: Salix is a perennial crop and it takes around five years before harvest. This means that during a five-year period, the soil stands covered and is not bare which has a big effect on the nutrient leakage. A perennial crop also has a more developed root system than an annual crop, which also decreases the leakage. In Table 3.4 (from TWINBAS WP8, 2007), the annual cost per ha related to production of different crops e.g. barley as well as Salix is calculated.

Table 3.4 Production costs ($Euro_{2005}$ ha/year)

Barley (Spring)	Wheat (Winter)	Barley (Spring)	Hay	Salix	Buffer zones
389	633	500	417	333	47

The modelled effects for the Lillå case study are substantial, resulting in a reduction of area losses of 97% for phosphorus and 68% for nitrogen. Using the cost per ha calculated in the WP8 (2007) report, the cost-efficiency is 528 Euro per kg reduced phosphorus and 97 Euro per kg reduced nitrogen.

Plantation of Salix without subsidies is with today's price level just on the limit of being viable, according to the statistics from the Energy Authority in Sweden. The production cost for Salix in a farm with average soil quality is estimated to amount to 14 Euro / MWh. The price of wood chips in the year 2002 was below 12 Euro / MWh. Subsidies for farmers that plant Salix are around 1.5 Euro / MWh during a period of 22 years[4].

d. No soil preparation during Autumn with Spring crops

The Lillå case study shows reductions of 0.01 kg of phosphorus and 0.8 kg nitrogen per ha, corresponding to a 2% reduction for phosphorus and a 16% reduction for nitrogen, assuming a current leakage of 0.63 kg phosphorus per ha and 5 kg nitrogen per ha.

The costs for the farmer comprise harvesting losses and increased weed control. In addition, there is an indirect income for the farmer in terms of saved nutrients. The net cost has, however, been calculated by the Agricultural Agency of Sweden to be higher than the actual subsidy which amounts to 40 Euro per ha.[5]

e. Spreading fertilisers during Spring instead of Autumn

Spreading fertilisers during Spring instead of Autumn can give a significant reduction in the leakage of phosphorus. The effect depends on the soils' capacity to absorb the phosphorus, with reductions ranging between 7 and 33%. In the area studied in the Lillå report, the effect could reach a 33% reduction in the leakage of phosphorus. This measure has not been modelled in the Lillå case study, due to the fact that most farmers already adopt Spring fertilisation practices.

The cost per ha of increased costs was calculated for Lake Glan to be approx 100 Euro, resulting in a cost-efficiency ranging between 2170 – 2320 Euro per kg reduced phosphorus. This cost assumes a 12% reduction, resulting in 0.05 kg P/ha. The costs principally consist of increased need for storage, soil packing and possibilities of a reduction in production as the harvest can

[4] Finansdepartementet
[5] Jordbruksverket, Styrmedel och kostnader för jordbruksåtgärder

not be done at an optimal time due to fertiliser spreading[6]. With a 33% reduction, the cost efficiency could amount to approximately 770 Euro.

f. Ploughing at right angles to the slope.

This measure entails that the farmers plough at right angles to the slope, which could improve infiltration in order to reduce surface runoff. This practice meets resistance in some cases since the farmers prefer to till along the main direction. A change in this practice would imply increased costs in time for the farmer as they have to change routines and practices.

g. Controlled drainage

Another measure which has not been modelled in the Lillå case study is controlled drainage. This has the purpose of reducing the loss of phosphorus and nitrogen by retaining the water longer time in the ground and thus making it possible for enhanced uptake of nutrients in the retained water.

The cost of the implementation of this measure for Lake Glan was calculated as approximately 50 Euro per ha, and the cost-efficiency between 600 to 2400 per kg reduced phosphorus. The great variance depends on the amount of clay in the ground. The higher the degree of clay, the higher the effect will be. In the Lillå case study, the amount of clay is high, between 60-70 %, so controlled drainage would be very efficient, and costs amounting to 600 Euro per kg reduced phosphorus.

Downstream measures

h. Abatement at wastewater plants

In Scharin (2002), the calculated marginal cost for reducing nitrogen from wastewater plants in the Mälar region ranges between 0.5-3.0 Euro per kg nitrogen in different plants. The great differences depend on their current capacity.

i. Wetland construction

Research shows that wetlands can reduce more than 1 tonne nitrogen per ha per year.[7] However, the effect differs considerably depending on where in Sweden the wetlands are constructed.

For the Frögärdesbäckens and Lillå areas, the effect of wetlands has been modelled on two different wetlands sites (Table 3.5). These values, together with results from other studies, give a good view of the cost-effectiveness of wetlands.

The cost per ha wetland ranges between 500-1500 Euro per year. Differences lie principally in the expected lifetime of the wetland, ranging between 20 and 50 years. In Scharin (2002), the annual cost per ha for Mälardalen was calculated to be 500 Euro (50 years lifetime) and a reduction of 150 kg nitrogen per ha.

Considering a cost of 500 Euro per ha for the two wetland areas modelled, the cost-efficiency for the Frögärdesbäckens area would amount to 1.80-1.95 Euro per kg reduced nitrogen and 15-17 Euro per kg reduced phosphorus.

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[6] Naturvårdsverket, rapport 5288
[7] www.greppa.nu

Table 3.5 Retention for two different wetland examples

Catchment area of wetland (ha)	Area of wetland (ha)	Absolute retention (Kg/ha)	
		N	P
92	1	256	29
230	2.3	277	32

Source: Lillå report

Studies from other areas in Sweden show a cost-efficiency ranging between 1.5 and 4.4 Euro per kg reduced nitrogen.[8]

j. Riparian buffer zones

In the Lillå report, the effects from the buffer zones showed reductions of area losses of 0.46 kg phosphorus per ha and 1.4 kg nitrogen per ha for a zone of 10 m with Spring crops. For a zone of 20 m, the results were 0.54 kg phosphorus per ha and 2.1 kg nitrogen per ha. This implies a reduction of 73% for phosphorus and 40% for nitrogen, respectively. This proves that riparian buffer zones are important measures to reduce leakage of phosphorus and nitrogen.

The cost per ha has been calculated within the Geppa Näringen project to range between 42- 63 Euro per ha per year. This would imply that cost-efficiency for the Lillå case study would vary between 84-126 Euro per kg reduced phosphorus and 25-37 Euro per kg reduced nitrogen.

Other studies have shown cost-efficiencies ranging between 630 to 700 Euro per kg reduced nitrogen. The higher costs compared to the Lillå report are due to a lower reduction potential which was assumed to be 30% from a current leakage of 0.3 kg per ha. The costs also rise substantially if the need to eliminate grass is considered.

k. Improved household sewage treatment

Löwgren (2003) has calculated the reduction potential and the cost per kg reduced phosphorus for different technologies in household sewage treatment for the river basin Motala Ström in Sweden. Table 3.6 summarises the results.

Table 3.6 Costs in Euro per kg reduced P with different household sewage treatment technologies

Technology	Potential reduction	Cost per kg reduced P
Infiltration leach field, 70% reduction	70%	409[9]
Drained leach field, 60% reduction	60%	417[10]
Connection to municipal plant, 92% reduction	92%	586[11]
Urine sorting, 95% reduction	95%	587[12]
Mini treatment plant, 70 % reduction	70%	628[13]

Source: Löwgren (2003)

[8] Greppa Näringen; Scharin (2002); Löwgren (2003); Kävlingeåprojektet
[9] Investment costs: 37500 Euro, operational costs: 800 Euro per year, life expectancy: 15 years
[10] Investment costs: 42500 Euro, operational costs: 800 Euro per year, life expectancy: 20 years
[11] Investment costs: 100 000 Euro, operational costs: 1700 Euro per year, life expectancy: 30 years
[12] Investment costs: 60 000 Euro, operational costs: 2800 Euro per year, life expectancy: 15 years
[13] Investment costs: 55000 Euro, operational.costs. 1500 Euro per year, life expectancy: 15 years

l. Ditch dams

Another measure which could be very effective but not modelled in the Lillån case study is the construction of ditch dams. The purpose of ditch dams is that the water is not stopped until reaching the ditch. By retaining the water for some time, the phosphorus has a possibility to sediment.

3.2.3 Interactions between instruments and combinations of measures

The WFD guidance work on the economic analysis includes a German handbook which shows examples of instruments and corresponding measures[14]. For example, concerning the reduction of emissions of nitrogen and phosphorus, instruments such as taxes and subsidies support the implementation of the measures. Similarly, with the use of riparian buffer zones, instruments enable the measures to be implemented. Finally, cooperation between water industry and agriculture can lead to less expensive implementation of measures. In the German handbook, the focus is on two questions:

- How can the effectiveness of measures be higher through the use of instruments?
- How can measures and instruments be specified and dimensioned in relation to one another in order to produce a positive interaction?

Table 3.7 shows examples of measures and instruments that can be used for diffuse and point source emissions and their respective interaction.

Table 3.7 Interactions between measures and instruments

	Point sources					Diffuse sources			
Measure	Improvements in water treatment plant				Membrane filtration	Riparian buffer strips	Reduce emissions of N and P		Reduction of pesticides
Instrument	BOD, COD	NH4-N	Ntot	Ptot	Other substances	All substances	Nitrogen	Phosphorus	Pesticides
Subsidies		O	O	O		(U)	U	U	U (O,G)
Fertiliser taxes		O	O			(U)	U,G		
Taxes on pesticides						(U)			O,G
Cooperation between water industries and agriculture		G	G			(U)	U,G	U,G	U, (O,G)
Advice to farmers		O	O	O		U	U	U	U

Key: U= Instrument supports measure
B= Instrument necessitates implementation of the measure
O= Instrument causes measure to become obsolete
G= Instrument leads to a reduced / less expensive implementation of the measure

[14] Volkswirt Eduard Interwies, M.A. et al. (2004).

Sweden has a charge on nitrogen and phosphorus. Initially, the charge was 0.033 Euro/kg for nitrogen and 0.066 Euro/kg for phosphorus. In 1994, the charge on phosphorus was replaced by a charge of 3.33 Euro/g cadmium exceeding 50 gram/tonne phosphorus. During the same year, the charge on nitrogen in fertilisers increased to 0.2 Euro/kg. Simultaneously, the charge on cadmium in fertilisers changed to 3.33 Euro/g for cadmium content exceeding 5 gram/tonne phosphorus. Since 1995, the charge has been called a tax and, in 1998, the charges increased by 100%. Yet, while the cost to reduce nitrogen leaching by one kg is estimated to be 22.22 Euro (Swedish EPA, 2004), it seems that there is a need for higher taxes. Since 2001, fertiliser sale of nitrogen has gone down by 5%, while the sale of phosphorus has remained at the same levels[15].

Fertiliser demand is quite inelastic to price increases, so there are needs for other kind of incitements, such as improved information to farmers and subsidies for cost and lost incomes. As an example, farmers can receive 300 Euro per ha for the construction of wetlands, 500 Euro per ha of cultivation of Salix during the plantation year which corresponds to 1.5 Euro per MWh during a cultivation period of 22 years, and 300 Euro per ha for the construction of riparian buffer zones. Subsidies for catch crops are 90 Euro per ha, and for spring preparation 40 Euro per ha. Apart from these subsidies there exist programmes/ measures such as the project "Greppa Näringen" which take the form of increased information to the farmers related to:

- Optimisation of fertilisers relative to crop needs;
- Use of economically and environmentally sustainable production methods;
- Adaptation of livestock feeding associated to N and P content in fodder;
- Construction and conservation of buffer zones adjacent to lakes and water courses.

These programmes/measures to promote awareness of environmental issues have been in place since 1986. The programmes include individual services, field and farm courses and demonstration sites. These costs have not been considered in the abatement costs above. Naturvårdsverket estimated the costs for the promotion of some of the measures considered in this study. These costs are summarised in Table 3.8. The Agricultural Agency of Sweden has calculated administrative cost including subsidies for catch crops to be 6.3 Euro per kg reduced nitrogen and 8.4 Euro per kg reduced nitrogen for practising spring preparation of soil.[16]

Table 3.8 Costs in Euro of approximate administrative costs and subsidies for implementation of different measures

Measure	Kilo P per ha	Cost per kg reduced P
Energy forests	0.10	100
Riparian buffer zones	0.09	110
Changed application of fertilisers	0.05	200
Dams	10-20	0.5-1
Vegetation filter	2.7	3.7

Source: Naturvårdsverket rapport 5288

[15] Jordbruksstatisk årsbok 2004
[16] Jordbruksverket, Styrmedel och kostnader för jordbruksåtgärder.

3.2.4 Ranking of measures based on their cost-effectiveness

The cost-effectiveness ranking results in Table 3.9 are representative for the Lillå case study and for all this part of the Norrström River Basin (Sagån, Svartån, Örsundaån, Hedströmmen, Köpingsån, lower parts of Kolbäcksån, adjacent areas to Lake Mälaren) where the agricultural practices and soil conditions have the same characteristics as in the Lillån area. Table 3.10 shows results from other research studies in Sweden

The modelling results show some differences to other studies made with SWAT and Watshman, mainly because the TWINBAS modelling work used information gathered from local farmers which forced some changes to the model data. These changes included dates for fertilisation, harvest and soil preparation, the method of preparation, and the mix of fertilisers. Furthermore, information about the soil conditions and the drainage were included in the TWINBAS modelling work. These changes made the results differ substantially, although there were no greater differences concerning the quantities of fertilisers.

The cost-efficiency results differs also substantially between the two tables. The reasons are mainly that the figures in Table 3.9 are based on more detailed data whilst Table 3.10 represents other research from elsewhere in Sweden, where soil conditions and agriculture and drainage are different.

3.2.5 Socio-economic impacts of implementation of measures

In the cost-efficiency calculations made for the different abatement measures, other benefits and costs are not considered. If these costs are distributed on other positive effects, the total costs would be different and probably lower. The calculations also do not take into account who will bear the costs. For example, farmers receive subsidies for the construction for most of the abatement measures that they decide to implement, but these subsidies are transactions costs, which are ultimately borne by taxpayers in society. Other costs borne by society are costs for information campaigns and administration.

Furthermore, the abatement measures, as well as the consumer's response to changes, can have impacts on product prices and product quantities. This is not considered as it is assumed that the Sagån and Svartån regions are too small to impact on prices, although their costs may change in line with the rest of the country.

One of the most effective measures for reducing nutrient loss is the planting of Salix. However, this activity is not viable without subsidies, even considering that planting of Salix has economy of scale, production costs can be reduced and the price of wood chip will most probably increase in the future. The benefit from energy crops is, therefore, double in the sense that they reduce leakage and improve water quality, and can in the future provide a beneficial business for the farmers. On the other hand, there will be a loss of open landscapes. Some valuation studies have been done in this respect. In the contingent valuation study of Hasund (1998), the value of keeping open landscapes amounted to 170 Euro per ha per year.

In general, many positive effects can be seen from an improved water quality such as tourism, better fishing opportunities and improved health. The construction of wetlands, riparian buffer zones and dams are all measures that point towards long-term, sustainable agriculture, which will ensure viable farming activities and employment in the countryside. The construction of wetlands and buffer zones will also contribute to employment.

Table 3.9 Measures and cost-efficiency results for the measures modelled in the Lillå report (ranking does not take into account administrative costs & subsidies)

Measure	Euro per ha per year	Effectiveness kg N or P / ha	Euro per kg reduced N	Euro per kg reduced P	Rank	Admin. costs & subsidies
Wetlands	500	256-277 kg N 29-32 kg P	1.85	15-17	1	0.5-1(P)
Riparian buffer zones	42-63	1.7 kg N (40 %) 0.5 kg P (73 %)	25-37	84-126	2	110 (P)
Catch crops	38	0.9 kg N 0 kg P	42		3	6.3 (N)
No Autumn preparation		0.8 kg N 0.01 kg P	50	400	4	8.4 (N)
Energy crops – Salix	333	3.4 kg N 0.61 kg P	97	528	5	100 (P)
Reduction of use of fertilisers		No change in short term			6	

Table 3.10 Summary of measures and results from other studies in Sweden (ranking does not take into account administrative costs & subsidies) (For detailed information of sources, please see Appendix 1)

Measure	Euro per ha per year	Effectiveness kg N or P / ha	Euro per kg reduced N	Euro per kg reduced P	Rank	Admin. costs & subsidies
Reduction of use of fertilisers		50% (Scharin) 0-5 kg N at source 0-514 kg N at recipient	0.3-5.6		1	
Catch crops	38-50	10–12.5 kg N (20-30%)	4-13		2	6.3 (N)
Wetlands	500-1500	150 – 1000 kg N	15-44		3	0.5-1 (N)
Riparian buffer zones	42-63 Euro (Greppa Näringen)	0.1 kg P (30%)	85	630-700* 3000-4000 *	4	110 (P)
Energy crops - Salix		0.1 kg P	77	100	5	100 (P)
Spreading fertilisers in Spring instead of Autumn	105 (Lake Glan)	0.028-0.13 kg P	125	2200	6	
Controlled drainage	50 (Lake Glan)		60-240		7	
No Autumn preparation					8	8.4 (P)
Improved household sewage treatment		60-95%		408-629	9	

* Higher costs includes costs for eliminating grass.

3.3 Stakeholder consultation on proposed actions

The actions found to be of highest cost-effectiveness i.e. wetland installations and some of the management practice actions at field level, were discussed with the major stakeholders of the study area: the District Water Authority, the County Board and Västerås City, who accepted the results of the prioritisation process, and welcomed the output for further analysis.

The actions were also discussed on a general level with the farmers interviewed when collecting data on farm management practices and soil characteristics in the stakeholder participation process. This contact has been established through interviews with the majority of farmer stakeholders in the watershed. During discussions with stakeholders and farmers the following measures proved to have a clear potential for reducing P losses, and are not already practiced:

- For animal farmers to extend the distribution of manure to neighbouring farms (will reduce application on their own land and improve soil structure on neighbouring land).
- Wait with manure and fertiliser application until subsoil has thawed
- Reduce manure application (and thus P application) and add N fertiliser, so that both N and P are in balance.
- Plough at right angles to the slope in sloping fields, or alternatively introduce grass pasture on sloping clay fields.
- Catch crops.
- Leave crop residues.
- Deep tillage on fields with high risk for preferential flow and low risk for surface runoff.

In general, the farmers found the actions proposed reasonable. However, in order to discuss implementation of actions in practice, further technical analysis needs to be carried out, particularly of wetland installation objects, their size, efficiency and location, and the reasonable extent of wetland installations discussed with the farmers. Also, the analysis of effects of farm management practice actions needs to be extended to the other areas of Svartån-Sagån, and then to the entire Norrström, based on the methodology developed for the Lillån case study. When such investigative analyses have been carried out, the farmers will have a solid information base to discuss, and hopefully accept. Västerås City are supportive of such an investigation, and is looking into the possibility of funding a further similar project, which would provide an opportunity to build further on the TWINBAS results.

It should be noted, however, that in order to realise actions like wetland installations and changed agricultural management practices, the current (governmental and EU) environmental support to farmers would have to be somewhat raised since the farmer would otherwise suffer a loss of income, and also need to be more flexible as to allow adaptations to local variations in cost-effectiveness of actions. To illustrate, in some river basins, agricultural management practices preventing erosion loss on clay soils may be the most cost-effective way to reduce N and P loss, while in other areas, with other soil characteristics, measures to reduce macropore flow have a better cost-effectiveness. ,Currently, the economic support to the farmers does not take into account such variations, but stipulates support to a small group of measures that may be efficient for some conditions, but are comparatively inefficient for other soil and management conditions.

Table 3.1 Norrström River Basin - Proposed actions and impacts

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action	Constraints to efficiency
1	Lake Mälaren	Nutrient pollution from agriculture, point sources & rural households causing eutrophication symptoms such as algae blooms & oxygen deficit.	Wetland installations & restorations, changed agricultural management practices, governmental & EU support that allows local adaptation of measures.	Decrease in nutrient transport to the lake, reduced intensity in algae bloom events, less events with oxygen deficit & restored balance in fauna composition (e.g. fish species populations).	Installation of wetlands covering 1% of the agricultural area, plus identified changes in agricultural management practices is estimated to reduce transport to the lake with 20-30%.	Limitations in suitable locations for wetland areas. Inadequate economic governmental support to wetland installation & changed agricultural practices.
2	Stockholm archipelago sea outside Lake Mälaren	As above for Lake Mälaren.	As above for Lake Mälaren.	As above for Lake Mälaren.	As above for Lake Mälaren, plus improved wastewater treatment for households on the archipelage islands which will further reduce the input of nutrients.	As above for lake Mälaren, plus municipal lack of resources to control household treatment facilities.

4. Nura

4.1 Scope of problem

The Nura River Basin covers an area of 53,147 km^2 and is the most water deficient river basin in Kazakhstan. The 978 km long River Nura is the main river of the central Kazakhstan plain and terminates in the internationally important Kurgaldzhino State Nature Reserve, a designated Ramsar site. 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, and the majority of surface flow, therefore, occurs as Spring snowmelt. The size of the spring flood is extremely variable with peak flows between 40 and 980 m^3s^{-1}. The average annual discharge from the Nura river to the Tengiz-Kurgaldzhinsky lake system is estimated at 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 are heavily dependent on surface water. Groundwater resources are generally scarce and are mainly exploited for drinking water purposes. 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 (Figure 4.1). However, it is doubtful whether the canal is a viable option for the long-term water supply of the Karaganda-Temirtau region and the new capital city Astana, situated 300 km downstream of Temirtau and 150 km upstream of the wetlands. A 25 km link canal between the Nura and the smaller Ishim river is intended to supply additional water from the Nura to Astana, and the city plans to take 25% of the mean annual flow of the Nura. The estimated naturalised annual average flow of the Nura is 5.9 m^3s^{-1} at Karaganda, and 19.6 m^3s^{-1} near Astana, and there is widespread concern over the impact of changes in the river's abstraction regime on the terminal wetlands. Modelling results (WP4, 2006) have shown that any significant off-take of water for Astana would have serious detrimental impacts on the sustainability of the wetlands.

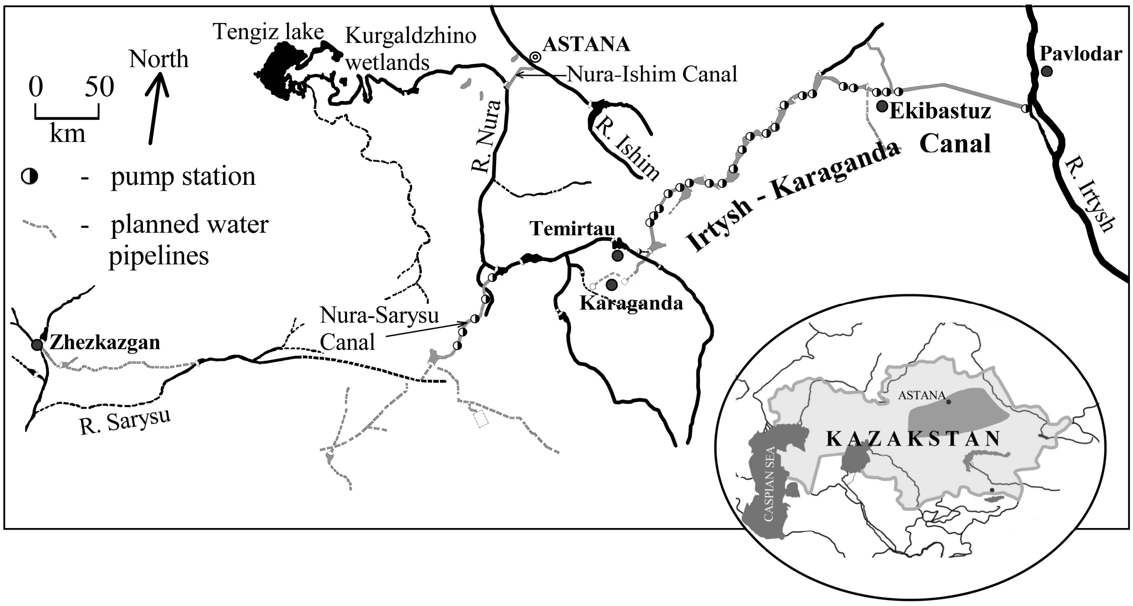

Figure 4.1 Map highlighting water resource issues in the Nura River Basin, Kazakhstan

Apart from water quantity, surface water quality is also a problem in the basin. 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. A project to clean up the most polluted section of the river downstream of Temirtau has recently been initiated by the World Bank, with remediation work scheduled to start in Spring 2008 and to finish by August 2010.

Rational use of water resources

Rational use of water resources in the basin requires the introduction of water saving technologies, increasing the volume of recycled and reusable water and, first and foremost, the reduction of losses. The introduction of new technologies demands time, however, and industrial development in the basin generally occurred under conditions of water scarcity and envisaged maximum application of recycling and reuse systems. Major losses of water are observed from internal and external water supply systems in all cities and industrial regions of the basin, mainly due to their deterioration and due to the absence of sufficient means for carrying out repairs and routine maintenance work.

As a result of the curtailment of agricultural production and, consequently, decreasing water consumption in the basin, a large number of the existing groundwater boreholes are not currently used. A significant proportion of these boreholes were constructed in water-bearing (artesian) layers where the pressure of underground waters is frequently higher than the surface of the ground, and water is spurting out. This situation leads to significant losses of valuable water resources.

Quality of water resources

An assessment of risk was carried out for the main water bodies of the Nura, on the basis that the main pollution occurs below Samarkand Reservoir, which is putting downstream areas at risk. The main source of pollution is the Temirtau industrial region. As the Nura flows through lakes, it also introduces pollution into these. Productive groundwaters in the basin are mainly alluvial aquifers that are close to the river bed and there is, thus, a hydraulic connection between the river channel and groundwaters. Groundwaters below Samarkand Reservoir are, therefore, also at risk. Irrigated agricultural lands along the Nura act as further diffuse pollution sources to the river.

Natural baseflow comprises between 100 and 1000 ls^{-1} but is not a major component of the flow regime of many of the rivers in the basin. Indeed, during the low flow period, over 80% of the flow in the Nura river below Samarkand Reservoir constitutes wastewater from the Karaganda-Temirtau industrial area (over 80%), and almost 100% for the Karakengir river.

The main sources of surface water pollution are municipal and industrial wastewaters from the cities of Karaganda, Temirtau, Shakhtinsk, Zhezkazgan and Satpayev. River Nura surface waters are generally classed as moderately polluted and maximum concentration limits are typically exceeded 1.3 times for mineralisation, up to 1.7 times for COD, up to 2.4 times for BOD_5 and up to 4.6 times for cadmium. Below Samarkand Reservoir, the river is severely polluted by mercury, which casts doubt on the safe use of the river for irrigation, bathing and fishing. The majority of wastewater treatment plants are worn out and do not clean the water effectively. They are, thus, in urgent need of restoration.

Monitoring

The existing programme for the monitoring and control of both the quantity and quality of surface and groundwaters is wholly insufficient. For example, there is no regular monitoring of surface water quality on the river, not even in places where wastewaters are being discharged.

Institutional factors

In the Nura River Basin, it is necessary to clarify the ownership status of important water bodies i.e. whether they are state-owned or private. Water bodies of strategic importance such as reservoirs should be state-owned and their maintenance should be financed by the Government. To improve control of the existing/available water resources, it is proposed that a management group is formed for each reservoir in the basin, with responsibility for standard hydrological and financial information. For the Nura-Sarysu River Basin, these are the Samarkand Reservoir in Temirtau, the Sherubainura Reservoir, the Kengirsk Reservoir and, in the longer term, also the Intumak Reservoir.

Ecological equilibrium of the Tengiz-Kurgaldzhino lake system

Feeding from the Nura river, the Tengiz-Kurgaldzhino lake system, which occupies an area of about 2,600 km^2, is considered one of the most important wetlands for migratory waterfowl in Kazakhstan and in all Central Asia. In 1974, the lakes were included in the Ramsar list of internationally important wetland sites and were strictly protected from 1975. The wetland is also currently under consideration for World Heritage Site status. About 112 kinds of waterfowl were counted on the lakes. The site is home to one of the most numerous populations of Greater Flamingo (*Phoenicopterus roseus*), as well as many rare and endangered species, such as the Dalmatian Pelican *(Pelecanus crispus)*, the White-headed Duck (*Oxyura leucocephala)*, the Ferruginous Duck (*Aythya nyroca),* and the Sociable Lapwing *(Chettusia gregaria)*, many of which are on the IUCN Red List of Threatened Species. Several rare and endemic plant species are also encountered in the Tengiz-Kurgaldzhino nature reserve, for example, *Marsilia strigosa, Damasonium alisma, Eleocharis oxilepis, Nymphaea lutea, Lemna minor* and *Utricularia intermedia,* and the endemic *Potamogeton macrocarpus*.

The Nura river is the basic source of water supply for the Tengiz-Kurgaldzhino lake system as well as for some other lakes. Significant fluctuations in river water levels, caused by either natural climatic variations or anthropogenic changes (e.g. the regulation of flow by upstream reservoirs) lead to a sequence of periodic wet and dry cycles, which has a negative influence on the dwelling grounds of waterfowl and other birds. Attempts have been made to construct artificial dams in order to maintain an optimum water level on Lake Korgalzhyn, but the dams frequently break. The decreasing water levels put Lake Korgalzhyn under threat and may lead to the fish kills. Furthermore, shallow islands on Lake Tengiz which serve as important nesting grounds e.g. for the flamingoes, are under threat of being flooded.

Large-scale damage is also caused by the annual Spring flood, and by anthropogenic releases of flood water from the reservoirs at the end of May - beginning of June, which coincides with the main breeding season. As lake after lake gradually fills with water, thousands of nests are destroyed. Moreover, newborn wild boars and other animals also perish in the water. Releases of water from Samarkand Reservoir during the winter time are also dangerous for the lakes, as the water introduces humic material from upstream swamps to the resting grounds of fish, which can lead to their death.

From the above discussion, it is concluded that one of the most important problems for preserving the biodiversity in the Tengiz-Kurgaldzhino lake system is the regulation of flow from the upstream reservoirs on the Nura. To solve this problem, it will be necessary to continue the hydrological and hydrochemical research work that began in the Autumn of 2004, so that recommendations for an optimum hydrological regime of the lakes can be developed on the basis of sound scientific data.

4.2 Tools for assessing action efficiency

Stakeholders in the Nura River Basin are only just beginning to appreciate the complexity of water resource management issues in the basin, outlined in Section 4.1. Therefore, the focus of many of the proposed actions is concerned more with stabilising and improving the current situation and with addressing fundamental problems (e.g. poor monitoring networks), rather than with the intricacies of assessing which action is more cost-effective than another. The suggested actions are listed in Table 4.1 and discussed in more detail below, including a detailed proposal for a long-term monitoring network providing information essential to address many of the identified water resource issues.

4.2.1 Measures for addressing water resource issues

Rational use of water resources

In the Nura River Basin, it is necessary to determine the proprietor of those boreholes without any readily apparent owner, to restore the corresponding infrastructure, and either to use the exploitable groundwater resources or to close those boreholes without an owner, thereby preventing losses of valuable water resources. It is also considered necessary to examine existing water consumption patterns and trends, and to introduce a scientific-educational program on rational water use.

Quality of water resources

The technical condition of the majority of wastewater treatment works at industrial enterprises is at a low level and, therefore, it will be necessary to strengthen the control of the state over releases of wastewater to water bodies, in particular to Samarkand Reservoir. The introduction of water recycling and local treatment systems is also necessary.

The ‘Nura River Clean-Up Project’ financed by the World Bank has now started. Apart from remediating the mercury pollution in the worst affected river sections, the project also aims to address the questions of rehabilitation of the Intumak Reservoir, the preservation of the Kurgaldzhino state nature reserve, and the restoration of the Nura-Ishim canal.

The majority of groundwater resources in the basin appear to be suitable for use. However, groundwater quality is compromised in the Haying, Saransk, Nurinsk and Rozhdestvenska reserves, with maximum allowable concentrations (PDK values) being exceeded up to 2-4 times for mineralisation, up to 3 times for mineral oil, up to 10 times for phenols, and up to 15 times for manganese, selenium and beryllium.

Monitoring

One of first steps for improving the water quality situation is the definition of emission limits for wastewater treatment plants. For each individual enterprise, emission limits should focus on several key chemical and biological wastewater parameters. In addition, monitoring of surface water quality in the river should be accompanied by improvements in general pollution status. All sources of pollution of surface and groundwaters should be assessed. It will also be necessary to make an inventory of all pollution sources, to strengthen water quality monitoring by setting up a continuous analytical control programme to monitor the quality status of reservoirs, to adequately equip the corresponding laboratories and to strengthen laboratory facilities in Karaganda, to educate the public about water quality monitoring, to create an independent body with responsibility for the management of analytical results, and to expand the existing parameter list of polluting substances.

At present, the financial situation of the RGP Kazhydromet, who are responsible for all hydrological monitoring in the basin, is very poor. The number of gauging stations for the assessment of water quality and quantity in the basin is also insufficient. Thus, there is currently no sound basis for water resources management in the basin. Institutional strengthening of Kazhydromet will be necessary, and the number of gauging stations will have to be increased. These measures should be financed from the general budget.

Institutional factors

In the Nura River Basin, it is necessary to clarify the ownership status of important water bodies i.e. whether they are state-owned or private. Water bodies of strategic importance such as reservoirs should be state-owned and their maintenance should be financed by the Government. To improve control of the existing/available water resources, it is proposed that a management group is formed for each reservoir in the basin, with responsibility for standard hydrological and financial information. For the Nura-Sarysu River Basin, these are the Samarkand Reservoir in Temirtau, the Sherubainura Reservoir, the Kengirsk Reservoir and, in the longer term, also the Intumak Reservoir.

Engineering measures for flow regulation in the Tengiz-Kurgaldzhino lake system

The existing system of engineered constructions comprises two tubular water-releases, one on Ablaiskaya dam and one that is in the process of being built on the Tabiyakskaya dam, with a throughput of up to 6 m^3s^{-1}, which allows for the passage of up to 120 Mm^3 during the warm period of the year. Tubular water-release from the Ablaiskaya dam would require reconstruction of a small reception antechamber that will allow the regulation of water releases into Lake Asaubalyk and the Nura delta. To do this, it would be necessary to lengthen the northern end of the Ablaiskaya dam by 100 to 120 m.

A significant part of the flow from the Kurgaldzhino system is released to Lake Tengiz via natural shallows between the Ablayaskaya and Tabiyakskaya dams. During field work in June 2005, water flow through the natural shallows was not observed, though the depressions were filled with water. The two existing depressions have an estimated throughput of up to 20 m^3s^{-1}.

Thus, the possible volume of water releases from the Kurgaldzhino lakes could be of the order of 400 to 450 Mm^3 per year. Actual flows, when considering evaporation losses (i.e. necessary release volumes W_R), are between 600 and 1744 Mm^3 in water abundant years (Table 4.2).

Table 4.2 Calculated release volume W_R from the Kurgaldzhino lake system (in Mm^3 per year)

Years	1986	1987	1988	1990	1991	1993	1995	2002	2004
W_R	690	530	976	1424	853	1798	801	869	1744

Two schemes for flow-regulating constructions on the Kurgaldzhino lake system have been investigated and are outlined below.

(a) Scheme 1

Scheme 1 foresees the reconstruction of the existing system of retaining structures, and construction of an open spillway for the Tabiyakskaya dam which would be operated as a kind of embankment dam. Experience of such a dam under local conditions has shown its high stability. Furthermore, a dam of this type does not require the presence of any on-site personnel, as excess incoming water is automatically released. The crest of the dam would be at 308.5 m BS (Baltic Sea level), which is the maximum operating level at an altitude of 309.5 m BS. For a throughput of 100 m^3s^{-1}, the width of the spillway would be 70 m, and the required volume of rock would be 2500 m^3. Assuming a distance of up to 50 km for the transport of rocks, the estimated cost of such a dam would be in the order of US$ 150,000.

(b) Scheme 2

Scheme 2 foresees the reconstruction of the existing system of retaining structures, in addition to two dam structures of open or tubular type in the shallow areas for release of water to the Kulanutpes river, and a natural drain. Throughput in each case would be no less than 10 m^3s^{-1} for maintenance of freshwater releases into the Nura delta. Regulation of the release could be carried out by floodboards, established in grooves of the reception antechambers. For the release of water to the Kulanutpes river, the Tabiyakskaya dam would incorporate a sluice constructed from monolithic steel-concrete with reinforced concrete plates. The crest of the sluice gate would be at 307.0 m BS and the throughput of this construction would be no lower than 80 m^3s^{-1}.

Compared to the first scheme, scheme 2 has the advantage that it would allow adjustment of the volume of water in the Kurgaldzhino lake system, and create a reserve volume of about 400 - 500 Mm^3 which could be used to compensate evaporation losses in dry years in Kurgaldzhino itself, or to fill up Lake Tengiz both via the channel of the Kulanutpes river and through the Nura delta.

4.2.2 Recommendations for setting up a long-term monitoring network

The management of water resources in the Kurgaldzhino State Nature Reserve by the Nura-Sarysy RBO and the control and regulation of water levels in the Tengiz-Kurgaldzhino lake system requires, first of all, the availability of good quality data. At present, the hydrometeorological monitoring system in the Tengiz lake basin has fallen into disrepair. Of the two gauging stations on the lower Nura (Almas and Romanovskoe), only the one at Romanovskoe is still working. However, this station is located 350 km upstream of the wetlands and does not give reliable information on water inflow to the Kurgaldzhino lake system, as a significant part of the flood water is lost on the flood plain and in other drainage lakes on the way. Former monitoring stations on the Kulanutpes river and the Kon river are also closed. Out of two existing meteorological stations in the reserve, only the one in Kurgaldzhino village is still working.

Kazhydromet have suggested restoring the former hydrometeorological network and flow gauging stations, so a comprehensive review of the characteristics and shortcomings of the former monitoring network in the wetlands is necessary. This should include consideration of:

- Restoration of the former Almas station on the Nura river
- Creation of an automated gauging station on Lake Sultankeldy
- Creation of an automated gauging station on Lake Tengiz
- Reconstruction of the former Aktubek station on the Kulanutpes river

Employees of the Kurgaldzhino State Nature Reserve should have access to all the hydrological and meteorological information of the Kazhydromet state monitoring network that concerns the area of the reserve as well as the adjoining territories. This includes the existing station at Romanovskoe and the restored station at Almas on the Nura river, the new automated gauging stations on Lake Sultankeldy and Lake Tengiz, the meteorological station in Kurgaldzhino village (Astana Center of Hydrometeorology), the restored station at Aktubek on the Kulanutpes river, and the lower dams at Tabiyakskaya (Karaganda Center of Hydrometeorology).

The data would be used to regulate the volume of water in the Kurgaldzhino lake system with hydraulic engineering structures and to draw up a water balance, for which it is necessary to monitor all the components on a monthly, annual and longer-term basis. The receiving part of the water balance includes:

- Surface flow (which is provided through observations of the state hydrometeorological monitoring network of Kazhydromet)
- Local surface flow (which necessitates special investigations and snow monitoring)
- Atmospheric precipitation (which necessitates the creation of a lakeside precipitation point)

The outgoing part of the water balance includes:

- Evaporation from open water surfaces
- Evaporation from reed beds and other vegetation (which necessitates the creation of a lakeside evaporation pond and the carrying out of two to three years monitoring of precipitation and evaporation points on islands, and small and large water bodies)

Therefore, in addition to the stations already mentioned, the following additions to the monitoring network are also proposed:

- A monitoring post on the Nura river at the outflow from Lake Sholak (stone dam) for controlling the inflow of water to the Kurgaldzhino lake system
- A network of water-level monitoring posts on lakes Sholak, Isei, Sultankeldy, Kokai, Asaubalyk and Maly Tengiz
- A network of hydrometric posts at the tubular water-release of the Ablayaskaya dam, in the two broad gullies between the Ablayaskaya and Tabiyakskaya dams, and in the tailwater pool of the Tabiyakskaya dams
- An automated meteorological station in Karazhar on the shore of Lake Sultankeldy with a standard evaporation pool (20 m^2)
- Networks of evaporators (such as GGI-3000) on the Kurgaldzhino lake system

It is proposed that a monitoring department is created within the Kurgaldzhino State Nature Reserve for conducting the hydrometeorological monitoring on the Tengiz-Kurgaldzhino lake system.

4.3 Stakeholder consultation on proposed actions

There are several conflicting water use interests in the Nura River Basin, the main ones of which are:

- Industry – the steelworks use a major part of the basin's water, leaving only small amounts for irrigation

- Domestic water use - the population of Astana is continuously expanding and the city will need increasing amounts of water in the future
- Environment - the terminal wetlands are in need of sustainable management

Stakeholder consultation is a new concept in Kazakhstan and, in the Nura basin, this process is only at the beginning. A number of meetings were held through the TWINBAS project, involving as many of the stakeholders as possible. During these meetings, it became clear that most of the stakeholders have no or little perception of the competing interests of each other's conflicting plans for the use of the basin's water resources. As a result, the stakeholder work package (WP3, 2007) very much concentrated on establishing a dialogue between them, and developing plans and strategies that could form part of a debate, at both river basin and national level, on how to move forward in providing a workable framework for sustainable water resource management within the local context.

The workshops were useful and generated a great deal of discussion, and it is felt that the stakeholders are all more aware of and informed about the problems inherent in the management of the Nura basin. However, true integrated water resources management is far in the future. Whilst the new Water Code of Kazakhstan fully encompasses the ethics and aims of the WFD, and is certainly a step in the right direction, it is not currently effective enough to change attitudes towards how water is used. The general position of stakeholders is that, unless the RBO gets more power to enforce and implement the Water Code, present water management practices in the basin are unlikely to change.

In terms of action plans for water resource management in the Nura basin, at this stage, specific tools for assessing the efficiency of actions and measures for the Nura basin are not needed. What is needed, instead, is a set of targets against which the development of water resource management action plans can be assessed, and improved water body monitoring against which the success of those plans can be measured. The targets proposed are:

- Development and implementation of a legal and institutional framework to give River Basin Authorities (RBOs) the powers and responsibilities to develop, implement and monitor water basin management plans
- Provision of an adequate funding mechanism that will allow RBOs to operate independently
- Provision of adequate staffing and training for the RBOs
- Adoption of a strategy for development of a sustainable water resource management plan
- Implementation of a performance monitoring system

In terms of monitoring the sustainability of the Kurgaldzhino wetlands, permanent and well-maintained gauging stations are needed on the Nura river at Almas and the Kulanutpes river at Aktubek, where they enter the wetlands, and permanent water level gauges need to be installed and monitored monthly throughout the wetlands. These will provide the data against which the effectiveness of water resource management in the wetlands, and the basin, can be assessed.

Table 2.1 Nura River Basin - Proposed actions and impacts

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action	Constraints to efficiency
1	Nura basin	Ratio of water availability to water demand indicates potential water shortages	Ensure people have a secure water supply	Water companies manage demand to meet people's needs & for the environment to thrive	Likely to be successful through continued use of demand management measures during periods of potential water shortage	Water demand increases more rapidly than predicted & existing water supplies cannot cope
2		Non-efficient use of water increases demand	Repair & restoration of systems of water supply	Losses of water during transportation will be reduced; people value water as a precious resource & use it wisely	Awareness of problem & willingness to act varies in different sectors of society leading to mixed success	Financial / economic situation in the country
3		Water pollution	Strengthening of governmental controls, introduction of water recycling & local cleaning systems, introduction of water-saving technologies for irrigation	Quality of water resources & ecological conditions of the terminal lakes of the Nura will improve which will also have benefits for the health of the population	Improvement of ecological conditions in the Nura basin	Financial / economic situation in the country
4		Monitoring	To restore hydrological monitoring network & to strengthen water quality monitoring	Improved information on hydrology & surface water pollution; capacity building	Uncertain as depends on commitment of financial resources & may also require some institutional change	Financial / economic situation in the country; existing institutional structure
5		Institutional factors	To define the state/private status of hydro-economic objects; strategically important waterbodies (e.g. reservoirs) should be the property of the state	The control over water resources & efficiency of decision-making in water resources management in the basin will improve	Uncertain, but some changes are happening, e.g. Samarkand Dam is now (apparently) controlled by the National Water Committee	Financial / economic situation in the country
6		Reconstruction of hydraulic engineering structures in the basin	To restore hydraulic engineering structures (dams, barrages, etc) & introduce automisation	Maintains optimum water level in terminal lakes & increases sustainability of internationally significant wetlands	Uncertain as depends on the commitment of financial resources	Financial / economic situation in the country

5. Okavango

5.1 Scope of problem

The Okavango River rises as the Cubango in south-east Angola. After 600 km, the river forms the boundary with north-east Namibia for a distance of 400 km, here joined by its largest tributary, the Cuito. It enters north-west Botswana, forming the terminal delta in the Kalahari sands, with a maximum flood area around 15,000 km^2. The total area of the basin in Southern Africa is 400,000 km^2. An initial survey of stakeholder concerns related to the hydrology of the delta, the largest wetland in the world, identified a range of issues:

- ***Upstream water resources development*** - reduction of inflow to the delta due to upstream hydropower and irrigation development causing a decrease in size of the delta and risk of ecosystem deterioration.

- ***Climate change*** - general increase in temperature will affect rainfall, alter delta dynamics, and reduce the size of the delta.

- ***Delta water resource development*** - increased need for groundwater abstraction for urban and rural water supply lowering groundwater table in and around the delta.

- ***Non-hydrologic change i.e. pressure from tourism*** - increase in tourism facilities and associated activities deteriorating local environment and disturbing ecosystem function.

- ***Channel intervention*** - cutting vegetation and dredging channels to maintain present river channel flows and access to delta water bodies affecting natural ecosystem balance and creating unforeseen vegetation blockages and changes in flow patterns.

- ***Non-hydrologic change i.e. invasion of alien species*** – spreading vegetation cover of alien species blocking the natural channel dynamics and water flow in the delta.

For each of the stakeholders concern issues, listed above in priority order, it was assessed to what extent TWINBAS project activities could help address these issues and support the development of the Okavango Delta Management Plan (ODMP). In order to achieve this, during the TWINBAS project, three partners were involved in the work in the Okavango River Basin, CEH and Rhodes University working in the upper basin to model the impacts of the various change scenarios on the flows into the delta (Folwell & Farquharson, 2006; Andersson et al., 2006; Hughes et al., 2006; Wilk et al., 2006), and DHI working in the delta itself, assessing the impacts of the scenarios and using the results to inform the ODMP (DHI, 2006a).

5.2 Tools for assessing action efficiency

The hydrology of the delta is extremely complex, with surface water flows through channels and swamps, evaporation from open water and soil, uptake of water by vegetation from the surface water and soil moisture, transpiration from the leaves, infiltration to groundwater and groundwater flows. In order to address the priority issues of concern listed in Section 5.1, the hydrological and hydraulic tools to be developed for the Okavango Delta must provide a complete description of the complex hydrology, both surface and groundwater, and enable assessments of:

- The future impact of continued water resources abstractions from the delta

- The impact of potential future water resources developments, in the delta and in the basin upstream
- The potential impact of climate change

5.2.1 The Integrated Hydrologic Model

Given the need to represent the combined hydrologic processes of evapotranspiration, surface and groundwater, including sediment transport, the only solution was to go for the development of an Integrated Hydrologic Model (IHM), capable of giving an accurate account of the total land phase of the hydrologic cycle. Figure 5.1 illustrates the structure of the MIKE-SHE IHM, with integrated layers representing the atmospheric waters, surface waters (channels and flood plains), and groundwaters (unsaturated and saturated). The evapotranspiration processes are described by a Surface-Vegetation-Atmosphere Transfer (SVAT) module. The surface waters are described by a one-dimensional hydrodynamic module for the channels and a grid-based two dimensional kinematic module for the swamps and flood plains. The unsaturated or root zone is described by a one-dimensional approximation of the Richards' equation, based on gravity and pressure forces in a vertical soil column. Finally, the saturated zone or ground water flows are described by the three-dimensional Boussinesq equation, though the current model set-up only uses one groundwater layer. Each module is coupled to the other three, making a truly integrated hydrologic model, simulating the essential hydrologic processes of the wetland. However, of the above processes, the IHM will neither simulate the vegetation dynamics nor the salt balance. While the modelling system can describe the movement of salt in the surface and ground waters, this application is beyond the present scope. Vegetation dynamics are not sufficiently well understood to be described in mathematical terms. A full description of the IHM set-up and calibration is presented in WP4 (2006).

5.3.2 Impacts of actions

The IHM was run to simulate natural undeveloped conditions in the basin and delta, present development conditions, and development conditions as they may be given a range of water resources development scenarios in the delta and the basin upstream, representing possible future conditions in the basin, notionally in the year 2025. Each scenario is compared against the present conditions which serve as a baseline. The Baseline scenario, therefore, describes the current state of the delta with respect to topography and channel configuration, and the upstream and delta surface and groundwater abstractions. The natural state of the basin implies no interference in the natural hydrologic processes in the form of land use changes in the catchments, structural interventions in the river system and abstractions from the surface or groundwater. The basin at present is close to its natural state, with only minor abstractions for domestic use, livestock and small-scale irrigation along the river banks. In the Natural State scenario, the present abstractions from the basin upstream and from the delta have been removed from the Baseline case. The difference in the various parameters between the Natural and Baseline states is barely significant. The additional inflow to the delta is equivalent to $28Mm^3$ per annum or 0.36% of the total.

The water resources development scenarios in the delta and the basin upstream considered included:

- Upstream water resource developments i.e. dams in Angola and Namibia
- Upstream water resource developments i.e. irrigation schemes in Angola and Namibia
- Deforestation in Angola and Namibia
- Regional climate changes

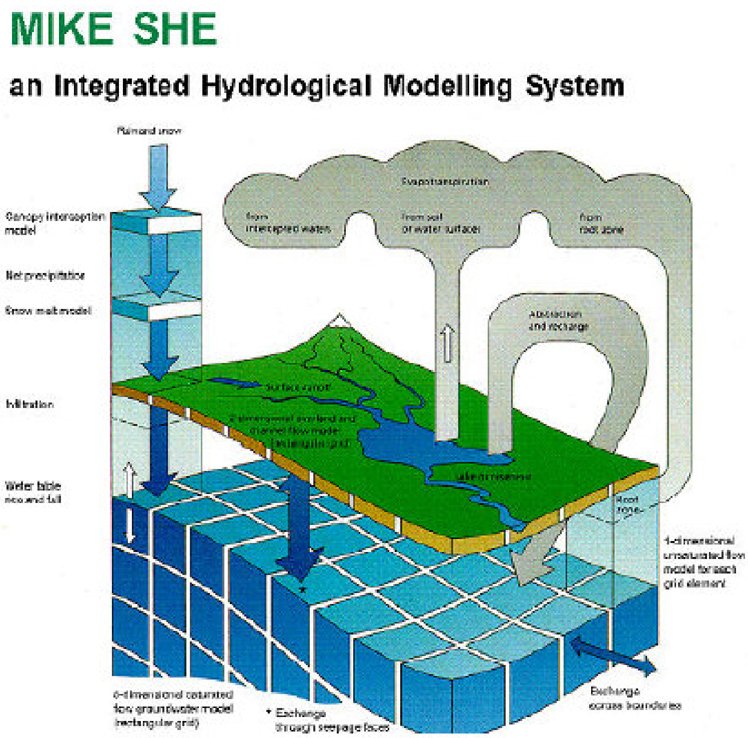

Figure 5.1 Schematic of MIKE-SHE IHM

- Surface and groundwater abstractions from the delta
- Clearing major blocked channels in the delta
- Combinations of the above scenarios

Two combinations of water resource scenarios have been analysed, representing a highly developed state of the basin i.e. Angola dams and irrigation in the upper basin, and surface and groundwater abstraction to meet local needs in the delta. One combined scenario is without climate change, and the second with climate change. The impacts of the combined scenarios are complex, as impacts from individual scenarios may accumulate, or cancel each other out. The impacts may accumulate for one period, and cancel for another period. The spatial distribution of the impacts is also variable. The impacts arising from the eight scenarios are briefly summarised as follows:

- The basin and delta are presently in a near natural state. To date, land use changes and abstractions from the basin upstream and the delta have a minimal impact on the delta as a whole, though local impacts may be significant.

- With environmentally sensitive operation, the potential dams in Angola with a combined storage approximately equal to the annual delta inflow do not have a major impact on the waters of the delta. There is no net water consumption, and little water is stored in dry years, with correspondingly small releases in the dry period. Actually, immediate 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, though in the longer term, larger dams may be constructed.

- Upstream irrigation in Namibia and especially Angola has a significant impact. The lower envelope of flooding i.e. the area that remains flooded throughout, is reduced by 40% in dry years.

- Present and future surface and groundwater abstractions from the delta are minimally significant, amounting to 0.3% and 0.5% of the inflow, respectively. Under future conditions, the upper envelope of flooding i.e. the area that may be flooded at some time, is decreased by around 70 km^2, or 0.6%.

- Projected climate change has the most severe impact, reducing both inflows from upstream and rainfall over the delta, and increasing temperature and the rate of evapotranspiration. The lower envelope of flooding is reduced by 68%, from 2770 km^2 to 900 km^2.

- The combined water resources developments with climate change have the most severe impact on the delta. The flooded area declines from a maximum of 14,424 km^2 to 4685 km^2, and the minimum from 2770 km^2 to 145 km^2.

The sediment transport implications on these scenario impact results could be significant and, therefore, sediment transport was introduced to the IHM, enabling general predictions of patterns of erosion and deposition in the main channels of the delta, for the Baseline and Development scenario conditions (see WP5, 2007):

- ***Sediment inflow to the delta*** – a reduction in the supply of sediment to the delta caused by major hydropower dams in the upstream basin. The Okavango Delta has been formed by sediment carried in flood waves from the basin upstream over tens of thousands of years. The continuing long-term development of the delta depends on this supply of sediment. The construction of large hydropower dams in Angola, and to a lesser extent the proposed dam at Popa Falls in Namibia, may be expected to limit the supply of sediment to the delta, particularly the coarser fraction. In order to make a preliminary assessment of the impact, an upper bound is placed by cutting off the supply of sediment to the Panhandle entirely. This is not likely to occur in reality, but it serves to demonstrate the worst possible scenario, and set bounds within which the impact of interventions can be assessed. Cutting off the supply of sediment, the upstream bed of the Okavango River erodes rapidly, by up to 4m over the upstream 30 km in the first 20 years of the IHM run. Over a longer time period, this erosion will migrate downstream until it reaches the apex of the delta proper. From the present trend, this would take over 100 years.

- ***Clearing channel blockages*** - clearing channels blocked by vegetation. An analysis of the impact of clearing channels choked with vegetation along the Maunachira is made for the water resources analysis (WP7, 2007). Clearing the blockages increases the peak flow within the channel by a factor of seven, and peak velocities increase from around 0.6 ms^{-1} to 2.2 ms^{-1}. The corresponding sediment transport volumes over the major flood year increase from an average of 24,000 m^3 to 130,000 m^3. The declining transport volumes downstream indicate deposition, leading to a backwater effect, declining flows and the channel becoming again blocked by encroaching vegetation.

- ***Channel dredging*** - dredging channels to increase the flow of water through the delta, and to provide water to areas downstream of the delta. In the late 1980s, a water development project proposed dredging the main distributary to increase the supply of water to the diamond mines at Orapa some 300 km downstream, and to villages along the course of the Boteti River. Work commenced in 1991, but was abandoned because of environmental concerns, both local and international. The impact the dredging works would have had on the flows and sedimentation in the delta was tested with the IHM. In the major flood year, the outflow from the delta increased by around 40%, from 20 to 28 m^3s^{-1}. The sediment transport rates in the lower distributaries is already low, and this is only slightly increased from 14,000 to 18,000 m^3s^{-1}.

- ***Water resource developments and climate change*** - the combined impact of upstream water resources developments and climate change over the basin and the delta. The combination of hydropower dams and irrigation schemes in the basin upstream, increased surface and ground water abstraction from the delta, and climate change, produces the most adverse scenario in terms of the volume and spread of water in the delta year round. The inflows to the delta decline by 55%, and the lower envelope of flooding i.e. the area permanently flooded declines from 4776 to 346 km^2 (WP7, 2007). There is a corresponding reduction in the sediment transport to the delta. The marked decline in the inflows from the upstream basin results in greatly reduced channel flows throughout the delta, and to a lesser extent velocities, as water levels decrease. Sediment transport volumes are greatly reduced. At the downstream end of the Okavango River, before the flows enter the delta proper, sediment transport in a major flood year is reduced from around 400,000 to 50,000 m^3. This has significant implications for the entire hydrological and biological functions of the delta.

5.3 Stakeholder consultation on proposed actions

In the upper basin in Angola, poor institutional arrangements continue to retard the advancement of sustainable water resource development and management (Huongo, 2007). Stakeholder involvement is relatively good in rural and peri-urban areas, particularly where NGOs are involved in water supply and sanitation projects with a specific community participation orientation. However, stakeholder involvement in the larger water resource management issue is all but non-existent. This should improve as catchment councils are formed and water management is decentralised, though care must obviously be taken here that one organisation still has an overview. Fostering effective coordination and collaboration among and between the diverse groups of stakeholders in the basin, for many of whom this type of process is a new concept, is proving to be a major challenge.

Throughout the entire ODMP design and planning processes, the Government of Botswana has made an effort to seek the views and opinions of stakeholders about what issues the ODMP needs to tackle, as well as to keep them informed about how these could or should best be addressed and institutionalised. The ODMP comprises various components of which TWINBAS project activities relate directly to the Hydrology and Water Resources and the Information components. The initial consultations with stakeholders under other ODMP components, including Wildlife Management, Vegetation Resources, Fisheries Management, Sustainable Tourism, Waste Management and Livestock Management resulted in the setting up of a Water Resources Working Group (WRWG) within the ODMP. Consultations and meetings within the WRWG identified, firstly, the issues listed in Section 5.1 as priorities for the work under the Hydrology and Water Resources component and, secondly, what outputs would be needed to support the development of the ODMP under the various components.

There was a general consensus in the WRWG that the Okavango Delta is in a rather pristine state and still under only limited pressure. The primary objective of the ODMP would be to preserve the present state allowing sustainable developments within various sectors. Emphasis under the Hydrology and Water Resources component would be to develop adequate management tools for assessment of the impact of various development scenarios, for identification of possible threats to the functioning of the entire delta ecosystem, and to ascertain actions to be taken to avoid future environmental risks. At the same time the importance of setting up proper monitoring systems to follow the functioning of the delta ecosystem and detecting any changes was emphasised.

During the ODMP design phase mission, various stakeholder group meetings were held where land users and other stakeholders were given a chance to have an input in determining the institutional set-up of the project as well as its aims, objectives, proposed activities and outputs. The following consultative meetings were used to give stakeholders an opportunity to highlight issues of concern in the management of natural resources in the Okavango Delta:

- A series of consultative meetings held during development of the draft wetlands policy and strategy.
- An expert workshop that resulted in the compilation of the major environmental threats to the Okavango Delta.
- Kgotla meetings carried out by the Okavango Community Consultants for the "Management Plan for the Controlled Hunting Areas Allocated to Communities in Ngamiland WMAs".
- Ngamiland district CBNRM forums; the documented results of these meetings and especially the conflicts relevant to the ODMP design and planning process that were highlighted.
- The documented issues raised during the "OKACOM Communication and Stakeholder Consultation in Namibia and Botswana".
- The "Socio-ecological Survey of the Okavango Basin" carried out in 2001 by the Applied Development Research Consultants for the Every River has its People Project.
- The results of the "National Stakeholder Workshop on the Design Mission of the Okavango Delta Management Plan".
- The results and suggestions of the "National Consultative Workshop" to discuss the ODMP Project Proposal.

The problems raised by stakeholders at these meetings, and the issues identified in Section 5.1, were compiled into a problem tree and used to shape the objectives and outputs of the ODMP during the design phase (ODMP Inception Report, 2004). The overarching issue identified is the threat of reduced inflows to the delta due to potential upstream hydropower and irrigation development. The critical activity to be enforced under the ODMP is, therefore, to engage the relevant authorities in Angola and Namibia in the basin-wide planning process under the OKACOM and within the Okavango Basin-wide forum.

Over three days in July 2006, and following a round of meetings and a workshop in 2005 to present and discuss preliminary results of the hydrology and water resources analysis, a second round of bilateral one-to-one meetings was held between the Department of Water Affairs and the individual departments participating in the ODMP. This was followed by a stakeholder workshop, at which approaches and tools for assessing action efficiency and the results of the scenario analyses were presented to all stakeholders, including local community representatives, with a total of 26 attendees. At this stage the ODMP was being formulated in its final version. The scenario analyses underlined the need for maintaining the tools developed under the TWINBAS project in order to effectively monitor developments in the delta ecosystem, and provide a scientific basis for discussions and decisions to be taken on a basin level in the OKACOM commission.

Based on the discussions at the workshop, the following key issues related to establishing a viable management infrastructure and use the tools developed under the TWINBAS project to sustainably manage the delta resources were identified:

- Limited availability of water quality and sediment data
- Inadequate hydrological monitoring network
- Inadequate knowledge of patterns of flow and sedimentation
- Limited manpower capacity within the hydrological unit in the Department of Water Affairs
- Difficulties in obtaining and updating information and data needed for the planning process

Following the workshop, the TWINBAS project provided support to Department of Water Affairs in setting up a strategy for implementing an efficient water quality monitoring network in the delta (DHI, 2006b).

Under the ODMP, actions will be taken to address the above mentioned issues, including strengthening the monitoring networks. The identified risks, pressures, proposed actions, expected impacts and predicted efficiencies are summarised in Table 5.1. The ODMP planning process has incorporated the main elements and concepts of the RBMP process. International donor support has been assured to support the OKACOM process and establish a permanent Secretariat to be placed in Maun, the main town downstream of the delta.

Table 5.1 Okavango River Basin - Proposed actions and impacts

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action	Constraints to efficiency
1	Upper and middle reaches of Okavango basin	Possible future dam construction for public water supply, irrigation &/or hydropower cause a decrease in flow variability, truncation of peak flows & excessive dry season flows	Water needs to be released for hydropower in the dry season & stored for future use in the wet season. Mitigate impact by a limited number of dams with environmenta-lly-sensitive operating procedures, to allow a sufficient proportion of the natural regime to reach the delta.	If the number of large dams is limited & a sufficient number of tributaries are left un-dammed, the impact should be to retain sufficient variability & maintain the flood flows into the delta.	A great deal will depend upon agreements to limit hydropower development to acceptable levels. Likely success of release of environmental flows good, but likely success of managed flood releases difficult to quantify in similar cases due to lack of information	Constraints might be related to both the lack of data & the perceived need for Angola to develop its hydropower potential to a maximum limited only be available funds.
2		Astractions directly from upper basin river, cause a decrease in dry season flows and a possible cessation of flow during droughts, exacerbated by natural channel losses in lower reaches.	Require operating procedures to ensure that minimum drought flows are retained in the river (based on the assumption that these will have significance with respect to ecological functioning).	Ensures that the low flow regime of the downstream parts of the river is maintained at some pre-determined acceptable level.	Likely success of determining environmental flow requirements is good.	Ability to determine acceptable environmental flows given information on the functioning of the system. Agreements by all parties on low flow operating rules & restrictions during drought periods.
3	Okavango Delta	Reduction of inflow to the delta due to upstream hydropower & irrigation development causing a decrease in size of the delta & risk of ecosystem deterioration	Engage Angola & Namibia through the OKACOM process & Okavango Basin-wide forum. Implement efficient monitoring & reporting systems.	Raise awareness & establish management infrastructure to sustainably manage the delta resources on an international river basin level.	Likely success of raising awareness & establishing delta ecosystem monitoring & reporting systems good. Securing sustainable development plans on a basin level depends on active support & international focus on OKACOM activities.	Agreement & cooperation of three basin countries through OKACOM commission still not fully operational, lack of monitoring capacity & basin data especially in Angola, pressure for economic development in Angola & scarcity of water in Namibia.

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action	Constraints to efficiency
4	Okavango Delta	Climate change-induced impact of hydrology e.g. rainfall frequency, intensity & distribution, changed evapotranspiration, etc.	No actions identified at present.			
5	Groundwater aquifers around Okavango Delta	Increased need for groundwater abstraction for urban & rural water supply lowering groundwater table in & around the delta.	Identification of sustainable groundwater abstraction strategies, proper licensing of abstraction, monitoring & control.	Limit groundwater abstraction to sustainable levels preventing over-exploitation.	The likely success of controlling groundwater abstraction relatively good due to high public awareness that available groundwater resources are limited & vulnerable.	High water demand pressure from urban (increasing population), industrial (mining) & rural (livestock) development. Inadequate measures taken for water saving & identification of alternative water sources.
6	In-delta channel networks	Pressure from lodge owners, villages & settlements to maintain present channel flows & access to the Delta	Provide alternative access routes &/or relocate lodges & settlements if required	Reduced or eliminated need for channel regulation leaving the Delta to maintain its natural river network development	Regulations are in place that enable relocation of lodges as they have time-limited permits. Procedures are in place that enable re-location of settlements.	Lodge owners & inhabitants of villages & settlements wish to maintain status quo, not adapting to the natural Delta aquatic ecosystem developments.
7	Wetland areas exposed to tourism activities	Increase in tourism facilities & associated activities deteriorating local environment & disturbing ecosystem function.	Adequate planning & licensing of lodges & camping sites & control of tourism development with eco-friendly zero-impact waste & wastewater handling.	Prevent any impacts on the delta environment from tourism activities.	Likely success of environmentally responsible tourism development is good with increased focus on eco-friendly tourism as a main economic asset.	Insufficient awareness & training of tourism staff, inadequate monitoring & control of possible emissions & impacts of tourism activities.
8	Delta channel system	Invasion of alien species spreading vegetation blocking natural channel dynamics & water flow in the delta.	Weed control using biological agents.	Reducing & preventing the spreading of alien species.	Programme for weed control implemented & pilot activities show very positive results.	Insufficient funding & staffing of weed control activities. Staff resources inadequate & difficult to hire new, qualified staff

6. Thames

6.1 Scope of problem

The Thames River basin covers an area of 13,000 km^2, representing some 4% of the area of the United Kingdom. However, it houses a population of over 12 million people (one fifth of the UK's population), and generates more than a quarter of the Gross National Product (GNP). 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. 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 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. Approximately 55% of the runoff in the Thames basin is abstracted, of which 85% is used for public supply and the remainder by agriculture and industry. Much of this is returned to the river at some point for reuse further downstream. During the summer months there is no water surplus for approximately 80% of the basin. During the winter months, there is currently a surplus. For groundwater sources, approximately 50% of the basin has no surplus.

The population of the Thames basin is forecast to grow by 0.7% between 2002 and 2015, and the total number of households is predicted to increase by around 1% per annum (Defra, 2005a). The demand on land and water for homes, offices and other developments creates intense pressure on the natural environment and stress on the basin's water resources and waste disposal capacity. Predicted impacts of climate change include warmer and wetter winters, hotter and drier summers, and deteriorating air quality and water quality, with a greater risk of flooding in winter, and possibly drought and water shortages in summer. Effective and sustainable management of the basin's water resources is becoming increasingly important. The three priority basin-wide concerns covered in this report relate to the future water resource supply, particularly during drought events, to flood risk and to water quality.

Water resource supply

Use of the water resources of the Thames basin must take the needs of both people and the environment into account. Water is abstracted from surface sources (rivers and reservoirs) and from aquifers. Off-line reservoirs in the basin include Farmoor near Oxford, and two groups to the west of London and in the Lee Valley, and are replenished from the rivers during high flow periods, but the absence of any major dams means there is a lack of storage to contain water for use during the drier months, when water demand is at its greatest. There are several major aquifers and a number of locally important minor aquifers underlying much of the region. The chalk aquifer under London is also recharged artificially from rivers during high flow periods.

In the Thames basin, approximately 55% of the mean annual runoff of 260 mm is abstracted from surface (~60%) and groundwater (~40%) sources, equating to about 5000 Ml per day. Some 85% of this is for public supply, and 15% for direct use by agriculture and industry. Of the water put into public supply, households use half, and industry a quarter; the remaining quarter is largely lost through leakage from the distribution system. On average each person in the basin uses 156 l of water per day compared with the national average of 150 l per day, an increase of 10% over the past decade (Environment Agency, 2001). Principal industrial and agricultural uses include cooling water for power generation, water for manufacturing, sand and gravel extraction, fish farming and cress growing, plus 20 Ml per day for spray irrigation concentrated in the summer months (Environment Agency, 2001). Much of the water abstracted is purified and returned to the river at some point for reuse further downstream, and during dry summer months, many river flows can consist of over 90% treated sewage. Indeed, in Summer, surface water throughout the basin are fully utilised by existing abstractions and environmental needs. Winter surface water resources are available, but need to be developed in conjunction with reservoir storage to provide a continuously reliable resource. Limited groundwater resources are available from the aquifers underlying the middle and lower basin, but elsewhere are at or approaching full utilisation. This situation will become more challenging in the future with pressures from more people, houses and businesses in the basin, combined with more frequent and severe drought events predicted as an impact of climate change (Environment Agency, 2001).

Flood risk

The majority of rivers in the Thames River Basin are in a natural or semi-natural state. In rural areas they flow unconstrained through generally undefended floodplains, though in urban areas some channels may have been modified to carry the flow through more efficiently. There is a risk of flooding throughout the basin, and some flood protection is provided by the capacity of the river channels and the natural storage of the floodplains. However, the flat and fertile land located near water also provides attractive sites for developers, particularly of housing, and for industries. Therefore, the number of people and properties at risk of flooding in the Thames basin, mainly towards the east of London and in the lower parts of the Thames river, is higher than it would have been had the floodplains not been developed (Environment Agency, 2007).

There are estimated to be over 180 km of flood defence embankments along the course of the Thames. On the lower reaches, the artificial Jubilee River, the largest flood alleviation scheme in the UK bypassing the towns of Maidenhead, Eton and Windsor, was completed in 2002. The Thames Barrier, on the river in London, protects the city from high tides. Since 1990, Thames Barrier closures against tidal surges have increased and this is expected to continue due to rising sea levels. Flood defence functions in the basin account for nearly half of Environment Agency expenditure and staff, making it a priority issue now and in the future when a predicted impact of climate change is more frequent and severe floods.

Water quality

The water quality of rivers in the Thames basin is generally good, with only 1% designated poor. Good water quality is essential for both people and the environment. Section 3.5.1 described how 55% of the runoff in the basin is abstracted for use by people, industry and agriculture. The remainder is used by the environment for rivers, lakes and wetlands supporting plants and animals, including fisheries, and also for recreation and navigation.

Water quality has improved steadily over the last 40 years but it is now under pressure from the growing population with its waste disposal needs, land use particularly agricultural land use, and climate change. A sustainable part of the basin is rural by nature and agricultural activities in these areas can and does impact on the environment e.g. diffuse pollution caused by the runoff from farmland of chemicals into rivers and groundwater is of particular concern. The WFD provides an integrated approach to maintaining and improving water quality across the Thames basin in the future.

6.2 Tools for assessing action efficiency

In the Thames basin, environmental management responsibilities, such as finding solutions to the three issues introduced in the Section 6.1, are split between numerous organisations which all have a slightly different environmental focus. The principal organisation is the Environment Agency, who works with the Department for Environment, Food and Rural Affairs (Defra), the Government body responsible for implementing the WFD in the UK. The Environment Agency also works in partnership with a wide range of other organisations and stakeholders towards the common goal of sustainable development. Stakeholders with an interest in, or who are affected by water, include regulators, public authorities, government agencies, professional bodies, local organisations and members of the public.

In its framework for river basin planning (Environment Agency, 2005a), the Environment Agency acknowledges that it needs to work with stakeholders, learn from them, influence their actions, and build on existing knowledge. The Environment Agency also has a statutory duty to work with industry to ensure it meets the laws and requirements imposed by the UK government and the EU. Mechanisms are, therefore, in place to involve all stakeholders in consultations about decisions that need to be taken and actions that need to be carried out in the in the Thames River Basin to maintain and improve the water environment, including assessment of the costs and economic impacts for each of the different sectors for which measures need to be appraised (Defra, 2005a). In many cases, there will be more than one action or combination of actions which could be used to meet a WFD objective, and also more than one delivery mechanism for implementing it (Defra, 2006). Therefore, information on costs and benefits, including environmental costs and benefits, is needed to inform the design of cost-effective programmes of measures and river basin management plans, and the consideration of other environmental objectives (Defra, 2005b).

An approach to the assessment of cost-effectiveness presented by RPA (2004), suitable for UK-wide application, is being developed as part of a collaborative research programme into a practical method to build cost-effectiveness into the river basin planning process (Defra, 2005b). The methodology comprises (RPA, 2004):

- Screening - overview of the likely pressures and impacts, and an initial assessment of the technical feasibility of measures;
- Costs - estimation of the costs of the measures in qualitative, quantitative and monetary terms;
- Effectiveness - prediction of the potential effectiveness of the measures across the pressures;
- Cost-effectiveness - assessment of the cost-effectiveness of the measures in order that they can be compared and combined into a programme of measures designed to meet good status.

The first screening of measures should take place at the national level, to identify those measures which appear most cost-effective nationally, and then be repeated at water body level, taking into account those measures to be applied at the national level and adding further measures addressing water body specific issues (RPA, 2004). This facility for application at a range of scales is a key advantage of the methodology.

The collaborative research programme into the assessment of cost-effectiveness provides and example of how the Environment Agency science programme is firmly rooted in carrying out applied research to support its regulatory and management functions, such as implementation of the WFD. These have driven the development and delivery of specific tools and techniques, and will continue to do so to prepare the Environment Agency for future environmental and policy changes.

The proposed actions for the identified water issues are listed in Tables 6.1-6.3 and discussed below together with the reasoning behind them and approaches used. The last two columns in the table give examples of the possible efficiency of the proposed action and possible constraints to the efficiency. These views are the authors' own and do not represent those of the Department for the Environment, Food and Rural Affairs, the Environment Agency, the Water Companies or any other organisations.

Water resource supply

To plan for future water resource supply in the Thames basin it is necessary to look ahead and considers the many changes that may occur over this time period and influence the demand for water (Environment Agency, 2001). The Environment Agency aims to improve the environment, while allowing enough water for human uses. Current and likely future demands in the basin are dominated by public water supply, where water use per person remains above the national average. The growing population and demand for new houses will add to the total demand for water in the future, and improved water efficiency must be an important part of managing water demand. This applies equally in the industrial and agricultural sectors, whose water needs are also affected by market considerations.

A scenario approach was used to consider a range of social and economic changes up to 2025 and forecast the resulting future water demands in the Thames basin[17]. The forecasts are based on an hybrid approach involving projections of current trends (adjusted for known developments in the driving forces), available models, expert opinions and stakeholders, and could be improved as more information on sector-specific parameters relating to likely future trends becomes available (Defra, 2005b). The forecasts show that the total demand for water in the basin could rise or fall, depending on the scenario followed, and provide boundary limits to guide water resource planning.

Proposed actions and impacts from the Environment Agency's 5-year plan (2006) to address the issue of water resource supply now and in the future are summarised in Table 6.1. The actions require the Environment Agency to continue to work closely with the public to use water more efficiently, and with water companies to meet the water demand needs of both people and the environment, control leakage and develop new resources as necessary.

Flood risk

In the Thames basin, over 1.5M people, more than 400,000 properties, 16 hospitals, 30 railway stations, 68 underground stations and 8 power stations are at risk of flooding (Environment Agency, 2006). Much of this risk is due to development on floodplains to satisfy the demand for suitable land for homes, offices and businesses.

Proposed actions and impacts from the Environment Agency's 5-year plan (2006) to address the issue of flood risk now and in the future are summarised in Table 6.2. The actions require the Environment Agency to work closely with planners and developers to ensure that inappropriate development in the floodplain stops, and that it can be used as a storage area for flood waters as is its natural purpose. New planning policy guidance (CLG, 2006) is intended to control floodplain development. The Environment Agency must also continue to improve its own

[17] http://www.foresight.gov.uk/

systems for flood warning, and to maintain existing flood defences and build new ones as necessary.

Flood defences in the Thames basin include strengthening river walls, embankments, realigning water courses, digging flood relief channels, and building new weirs and sluices. By their nature, flood defences require that river channels are maintained in good condition to pass flood water through quickly. This might involve removing obstructions, cutting back dead or dying trees that might fall and block channels, removing reeds and weeds that might cause blockages, dredging water courses to remove the build-up of silt, and making sure sluices, pumps, weirs and other essential structures work properly. Many of these activities are in direct conflict with environmental needs. In its flood defence work, the Environment Agency works with conservation specialists to try and create new wildlife habitats as well as preserve existing ones (Environment Agency, 2006).

Water quality

In the Thames basin, the water industry and agriculture form the two largest contributors to environmental damage caused by abstraction and water pollution, respectively, and together account for about 85% of estimated environmental damage costs. Other diffuse and point sources, such as diffuse urban pollution, landfill sites and contaminated land account for the remaining 15% of costs. Analysis of the operating costs of the eight water companies in the Thames basin suggests that around £122M of their annual costs are associated with mitigating the environmental impacts of water supply and sanitation services, and £50.5M of their annual costs arise from diffuse pollution largely from agriculture, and are mainly incurred to deal with nitrates, pesticides and other contaminants and in managing the risk from the parasite cryptosporidium (Defra, 2005a).

Agricultural sector activities in the Thames river basin predominantly comprise livestock husbandry and crop-growing in the rural parts of the basin. The common agricultural policy (CAP) has led to land use changes over the last 30 years. Agricultural intensification, such as increased stocking, fertiliser and pesticide use, has resulted in increased pressures and impacts on water bodies. Intensification has slowed in recent years, and the growth of organic farming and the implementation of CAP reform and Government initiatives such as catchment-sensitive farming, are expected to consolidate this trend and, thereby, provide some landscape, water quality and biodiversity benefits. Within the basin, a slight decrease in overall agricultural area is predicted, though this may hide potentially significant changes in the structure and intensification of the industry and how businesses are managed. Regional forecasts indicate that output from the agricultural sector in the basin will decline over the period to 2015 (Defra, 2005a).

Proposed actions and impacts from the Environment Agency’s 5-year plan (2006) to address the issue of water resource supply now and in the future are summarised in Table 6.3. The actions are in two main areas: waste water treatment and agriculture. The actions require the Environment Agency to work closely with water companies, developers and farmers to reduce point and diffuse pollution problems from urban and rural runoff and waste water throughout the basin.

6.3 Stakeholder consultation on proposed actions

In testing CIS guidance for aspects of the WFD and in implementing the WFD itself, the Environment Agency carried out a number of studies investigating processes for public participation, which led to the development of its framework for stakeholder engagement (Environment Agency, 2005b). In this, the Environment Agency advocates a "toolkit" approach, with a range of methods available to be used as appropriate for the degree of concern in different locations and the breadth of key issues. Through this, the Environment Agency plans to ensure that all its diverse stakeholders are able to contribute effectively by helping them understand river systems and how these systems affect their interests, as well as being clear about how and when decisions are made and where their input informs the decision-making process. The various methods in the toolkit are described in the WP3 (2007) report.

By bringing all stakeholders together, they can understand how their often conflicting demands can often not always be fully met given natural water availability and, thereby, provide a structured framework for negotiated compromise settlements. A mechanism is, therefore, in place in the Thames basin to involve stakeholders in decisions about proposed actions or combinations or actions to be tested, to address the three issues raised (Tables 6.1-6.3).

Table 6.1 Thames River Basin - Proposed actions and impacts for water supply (and drought)

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action*	Constraints to efficiency*
1	Thames basin	Ratio of water availability to water demand indicates potential water shortages	Ensure people have a secure water supply	Water companies manage demand to meet people's needs & for the environment to thrive	Likely to be successful through continued use of demand management measures during periods of potential water shortages	Water demand increases more rapidly than predicted & existing water supplies cannot cope
2		Non-efficient use of water increases water demand	EA work with water companies & others to help people to save water	People value water as a precious resource & use it wisely	Awareness of problem & willingness to act varies in different sectors of society leading to mixed success	Demand management measures fail e.g. due to lack of incentives to users
3		Leakage from water mains reduces water availability	Deal with water company leakage	Leakage in London is reduced to OFWAT-agreed targets	Mixed success across basin due to differing magnitude of leakage problem in different areas	Leakage control measures fail e.g. due to lack of investment in maintenance
4		Drought events reduce water availability & cause more severe shortages	EA have drought plans by 2007 & work with water companies on their statutory drought plans	Future development & water supplies are resilient to climate change	Likely to be successful through use of more stringent demand management measures during periods of severe water shortages	Drought events become more frequent and/or severe than predicted
5		New water supply resources increase water availability to match increasing water demand	EA work with water companies to assess the needs & options for new water supply resources	Water companies develop resources to meet people's needs & for the environment to thrive	Likely to be successful as new water supplies will most likely be developed despite some opposition	New water supplies are not developed rapidly enough to match predicted increasing water demand
6		Technology developments increase potential for efficient use of water	Ensure that housing development policies encourage people to use water efficiently	New homes reduce the amount of water they use to below 120 l per person per day & more existing homes fitted with water-efficient devices	Awareness of problem & willingness to act varies in different sectors of society leading to mixed success	Technology developments prove too cost-prohibitive to be embraced by new housing developers & existing home owners

* The **Predicted efficiency of action** and the **Constraints to efficiency** are the views of the authors and do not represent those of the Department for the Environment, Food and Rural Affairs, the Environment Agency, the Water Companies or any other organisations.

Table 6.2 Thames River Basin - Proposed actions and impacts for flood risk

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action*	Constraints to efficiency*
1	Thames basin	Inadequate flood warning reduces public awareness & preparedness	Offer more & effective flood warning services to those at risk	The public is more aware of their risk & can prepare & respond	Awareness of problem & willingness to respond varies in different sectors of society leading to mixed success	Flood events become more frequent and/or severe than predicted
2		Inadequate flood warning system increases flood risk & impact	Improve EA flood warning system to reduce the impact of flooding	Current & future flood risks have been lowered on a river basin scale	Likely to be successful due to recognition of problem & continued investment in & development of flood warning systems	Flood events become more frequent and/or severe than predicted
3		Development on natural floodplain reduces flood storage	Divert more flooding onto natural floodplain areas	Inappropriate development in the floodplain stops	Likely to be partially successful though some floodplain development will most likely happen despite opposition	Floodplains continue to be used for development in preference to flood storage
4		Inadequate investment in existing & new flood defences increases flood risk	Maintain & improve urban flood defences, & identify & build new flood defences	Existing & new urban flood defences last longer	Mixed success across basin due to areas where limited flood defence spending is prioritised	Maintenance of defences is inadequate e.g. due to lack of investment
5		Development on natural floodplain increases flood risk	Implement Planning Policy Statement 25 (PPS25) to control development in floodplain	Inappropriate development in the floodplain stops	Likely to be partially successful though some floodplain development will most likely happen despite opposition	Floodplains continue to prove attractive to developers despite flood risk of those areas
6		Flood defence works cause environmental degradation	Balance flood defence with needs of wildlife & environment as a whole	The environment is enhanced as better flood defences are built	Likely to be successful as public awareness of "green" issues & pressure from environmental stakeholder groups grows	Incorporating environmental needs becomes cost-prohibitive as more substantial flood defences are required

* The **Predicted efficiency of action** and the **Constraints to efficiency** are the views of the authors and do not represent those of the Department for the Environment, Food and Rural Affairs, the Environment Agency, the Water Companies or any other organisations.

Table 6.3 Thames River Basin - Proposed actions and impacts for water quality

	Water body at risk	Pressure/impact on water body	Proposed action	Potential impact	Predicted efficiency of action*	Constraints to efficiency*
1	Thames basin	Inadequate sewage treatment causes pollution	Reduce the discharge of >50M tonnes of untreated sewage to the river Thames through London	An improvement programme to reduce untreated sewage discharges is in place	Likely to be partially successful due to continued investment in sewage treatment	Maintenance of new & existing sewage treatment works is inadequate e.g. due to lack of investment
2		Inadequate sewage treatment causes pollution	Ensure there are enough sewers & sewage treatment works to support the levels of growth proposed in the basin	Regional/local strategies contain policies linking housing growth to adequate sewer & sewage treatment infrastructure	Mixed success across basin due to differing magnitude of sewage treatment problem in different areas	Maintenance of new & existing sewers & sewage treatment works is inadequate e.g. due to lack of investment
3		Inadequate urban runoff infrastructure increases potential for urban flooding & pollution	Ensure that investment is made in new infrastructure & new ways of dealing with waste water	Housing development contains sustainable urban drainage systems (SUDS) where possible	Mixed success across basin due to areas where housing developers incorporate SUDS	Incorporating SUDS in new developments becomes cost-prohibitive
4		Inadequate runoff infrastructure increases potential for rural & urban flooding & pollution	Deal with pollution from rural & urban areas	The number of category 1 & 2 pollution incidents from dairy farms is reduced by 50% by 2009	Mixed success across basin due to differing runoff infrastructure problems in different areas	New & existing runoff infrastructures are poorly maintained e.g. due to lack of investment
5		Existing farm practices cause largely diffuse pollution from both arable land & livestock	Undertake farming initiatives in priority catchments to improve farm practices & reduce pollution from agriculture	Agricultural waste is recovered & recycled at the same rate as other industrial & commercial waste	Mixed success across basin due to areas where agricultural waste recovery and recycling is prioritised	Incorporating environmental needs becomes cost-prohibitive
6		Lack of awareness of new laws increases potential for rural pollution	Work with farmers to ensure they meet new agricultural waste laws	There is a 50% reduction in pollution incidents from dairy farms by 2009	Likely to be successful as farmers are keen to avoid non-compliance penalties	Farmers fail to stay on top of increasing number of new regulations & laws
7		Existing farm practices cause largely diffuse pollution from both arable land & livestock	Promote schemes for farmers & land managers who manage all or part of their land organically	>50% of farms are invested schemes to undertake resource protection management options by 2011	Likely to be successful as popularity of organic food & pressure from environmental stakeholder groups grows	Growth in organic farming sector slows down e.g. due to high cost of produce repelling new customers
8		Past & existing farm practices cause environmental degradation	Encourage farmers to apply their land management skills to benefit the environment	20% of farms have environmental management systems in place	Likely to be successful as pressure from environmental stakeholder groups grows	Incorporating environmental needs becomes cost-prohibitive
9		Bureaucracy reduces potential for integration in agricultural sector	Undertake integrated farm visits to cut the regulatory burden on farmers	>85% of farm visits are integrated by 2009	Likely to be successful as farmers are keen to reduce bureaucracy	Farmers fail to stay on top of increasing number of new regulations & laws

* The **Predicted efficiency of action** and the **Constraints to efficiency** are the views of the authors and do not represent those of the Department for the Environment, Food and Rural Affairs, the Environment Agency, the Water Companies or any other organisations.

7. Summary and concluding remarks

The WFD river basin management planning process provides a decision-making framework for setting environmental objectives and a delivery mechanism for ensuring integrated management of the water environment. This report has covered the identification and assessment of possible actions or combinations of actions to achieve these environmental objectives. The results contribute to the river basin management plans considered in the second WP9 report (2007). However, river basin management planning is necessarily an iterative process, with many of the activities repeated in the next cycle, though informed by the results of the last cycle. For instance, objective setting is dependent on water body characterisation and assessment; reassessment of objectives in subsequent cycles depends on monitoring and how successful implemented programmes of measures were in the intervening period. Hence, the work reported here is simply a first step in the river basin management planning process, to be re-evaluated as information is continually improved and identified gaps in the knowledge base are filled, but ultimately leading to a more integrated approach to future water management.

Biobío

For any future action in the Biobío River Basin, it is necessary that the State has a role in the use, management and development of water resources. Of particular concern are new industrial projects that require water from, and will discharge effluent to, the Biobío river. Future actions in the Biobío basin, agreed by and acceptable to all parties include: improved territorial planning; better compatibility between the economic activities and environmental issues of concern in the basin; improved environmental monitoring on the Biobío river and its tributaries; fully implemented water quality standards; the development of mechanisms to achieve financial sustainability in water resource management systems, through subsidies and other incentives; institutional reforms including more effective regulatory authorities; and the creation of river basin organisations. It is recommended that a strategy for appropriate future management of the Biobío River Basin involves government authorities, industries and others stakeholders.

Norrström

Farmers in the Norrström River Basin generally accept the need for further actions to reduce diffuse pollution, but do not have the capacity to cover the associated costs. With reference to artificial wetlands in particular, they require an information base with detailed analysis of the extent and technical descriptions of wetland installations on a level that could not be produced in TWINBAS, to be able to take a position on whether to go ahead with implementation for their property, supported by Government incentives to implement actions. However, the modelling approach, including detailed information from farmers on soil conditions and current management practices, has proved to be a feasible way to initiate collaboration with the farmers regarding action implementation. The approach needs to be scaled up from the study area to the basin or region in order to use these results in RBMPs.

Nura

The institutional structure for sustainable water resource planning in Kazakhstan is lacking and, although there is clear awareness of the need for change within the sector, institutional inertia and vested interests limit the potential for implementing a sustainable river basin management plan (WP7, 2007). Therefore, the first step in the development and implementation of a sustainable water resource management plan for the Nura basin has to be institutional and legal reform in this sector. In their report of the Nura Ishim RBMP, Jacobs Gibb/Halcrow and Kazgiprovdkhoz (2004) highlight the problems in implementing a water resource management plan, and propose a rational way forward to achieve this goal, which has been further developed in the TWINBAS project. At this stage, specific tools for assessing the efficiency of actions and measures for the Nura basin are not needed. What is needed, instead, is a set of targets against which the development of water resource management action plans can be assessed, and improved monitoring against which the effectiveness and success of those plans can be measured.

Okavango

The Okavango Delta Management Plan (ODMP) planning process has borrowed from the Ramsar Planning Guidelines and the Ecosystem Approach to wetlands management. The ownership of the ODMP process is premised on participatory mechanisms, associated with international stakeholders and building partnership basin-wide. The ODMP planning process has proven to incorporate the main elements and concepts in the WFD RBMP process. However, the delta cannot be considered in isolation as many of the pressures on it are likely to come from developments in the upper basin in Angola, where there is a lack of firm data and information. TWINBAS has highlighted the need for an integrated approach to water planning and management: 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

Three priority water issues identified in the Thames River Basin are water supply, flood risk and water quality. Actions to address the associated risks include the twin-track approach of demand management including the recovery of 100-350 Ml/day of current abstraction and leakage reduction particularly in the London area, in parallel with the development of new strategic water resources, new planning guidance to restrict development on flood plains, and new incentives to reduce point and diffuse pollution problems from urban and rural runoff in the basin (Environment Agency, 2001). Through extensive consultation, stakeholders are fully involved in all stages of the development and testing of proposed actions or combinations of actions to meet environmental and other objectives, ultimately leading to the creation and evolution of RBMPs.

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Appendix 1 Calculated abatement costs in different studies in Sweden

Measure	Environmental impact (maximum reduction)	Cost per kg reduced N (SEK)	Cost per kg reduced P (SEK)	Cost per ha (SEK)	Area/study
Riparian buffer zones			6300[18]	630 small 420 large	GreppaNäringen
	30% reduction of a leakage of 0.3 kg per ha without elimination of grass		7000[19]		Löwgren Motala Ström
	30% reduction of a leakage of 0.3 kg per ha with elimination of grass		44 000		Löwgren Motala Ström
	30% reduction without eliminating grass. Max 110 kg/ kg P/year		7000-1800 incl. reduction of benefit of reducing N (depends on % of clay)		NV rapport 5288 Lake Glan
		MC=853 SEK/kg N that reaches Östersjön			Handbok NV Mälardalen
	30% reduction with eliminating grass. Max 110 kg/ kg P/year		30000-24000 incl. reduction of the benefit of reducing N (depends on % of clay)		NV rapport 5288 Lake Glan
Changed application of fertilisers	12% reduction in leakage of P at 0.4 kg per ha.		22 000		Löwgren Motala Ström
	Spring spreading instead of Autumn spreading. 7-33% reduction in leakage at 0.4 kg per ha.		21700-23200 (depends on % of clay)		NV rapport 5288 Lake Glan
	Reduced application of fertilisers. 50% reduction of leaking N.	AC=2.97 SEK/kg at the source and 56 SEK/kg at the recipient			Scharin Mälardalen
	Not available	63			Elofsson Mälardalen
Catch crops	Catch crops in Spring - 4000 kg per ha[20]. Reduction of 12.5 kg per ha.	40		507	Greppa Näringen
	Catch crops in Autumn - 7000 kg per ha[21]			599	Greppa Näringen
	Reduction of 20%	127		380	Scharin Mälardalen
	Reduction of 50%	99			Elofsson Mälardalen
	Reduction of 30% in leakage of N at 30 kg per ha	56		5000	Kävlingeå projektet

continued

[18] Cost of land not considered as a subsidy of 3000 SEK is paid by the Government
[19] Cost of land not considered as a subsidy of 3000 SEK is paid by the Government
[20] 900 SEK can be received / ha as subsidy. (not included in costs)
[21] 900 SEK can be received / ha as subsidy. (not included in costs)

continued

Measure	Environmental impact (maximum reduction)	Cost per kg reduced N (SEK)	Cost per kg reduced P (SEK)	Cost per ha (SEK)	Area/study
Energy crops	50% reduction in leakage of 0.2 kg per ha		1000		Löwgren Motala Ström
	Not available	MC=771 SEK/kg N that reaches Östersjön			Handbok NV Mälardalen
Salix				2997	TWINBAS WP8 M. Belhaj
Improved wastewater treatment for N	Approx 40% reduction of N if cleaning is already being done.	MC=5-32 SEK/kg N (Assumption: MC=AC)			Scharin Mälardalen
Wetlands	Reduction of 1 tonne per ha per year	15		15000[22]	Greppa näringen
	Reduction of 16% or 150 kg N per ha wetland	33.5 at source		5022[23]	Scharin Mälardalen
	Not available	44			Löwgren
	Reduction of 1 tonne N per ha per year	24			Kävlingeå projektet
Household sewage treatment	Infiltration, leach field 70% reduction.		4089[24]		Löwgren Motala Ström
	Drained leach field 60% reduction		4172[25]		Löwgren Motala Ström
	Connection to municipal plant 92% reduction		5859[26]		Löwgren Motala Ström
	Urine sorting 95% reduction		5868[27]		Löwgren Motala Ström
	Mini treatment plant 70 % reduction		6283[28]		Löwgren Motala Ström
Improved industrial wastewater treatment	Additional cleaning steps		16620[29]		Löwgren Motala Ström

[22] Investment cost 160 000 Euro, life expectancy 20 years, interest rate 6%
[23] Life expectancy 50 years, interest rate 5%
[24] Investment cost 37 500 Euro, operational costs 800 per year, life expectancy 15 years
[25] Investment cost 42 500 Euro, operational costs 800 per year, life expectancy 20 years
[26] Investment cost 100 000 Euro, operational costs 1700 per year, life expectancy 30 years
[27] Investment cost 60 000 Euro, operational costs 2800, life expectancy 15 years
[28] Investment cost 55 000 Euro, operational costs 1500, life expectancy 15 years
[29] Investment cost 80 milj, operational costs 25 milj