Chapter 7

Water Resources

Chapter 7 Summary

Water Resources

Water is a critical natural resource. It is used for drinking water, agriculture, wetlands services, and the production of hydroelectric energy, amongst others. Croatian fresh-water resources are abundant - indeed they are among the richest in Europe. Therefore, water resources are not considered a limiting factor for development in Croatia. However, while there is no shortage of water per se for use in Croatia, problems do exist.

- First, a large amount of pumped water is wasted, which leads to lost revenue of up to EUR 286 million (0.9% of GDP) per year and increased GHG emissions resulting from the additional use of electricity for pumping.
- Second, farmers often face water shortages at certain critical times of the year's growing season and, in general, the soil lacks moisture.

Croatia uses a small fraction of the water resources available (about 1%). However, climate change may stress some of the systems that depend upon freshwater. This may be especially important in terms of wetlands services and hydroelectric generation. Wetlands services include nutrient and pollutant removal from water, providing habitat for biodiversity, providing timber and providing hunting areas.

During 2000-2007, 50% of all Croatian electricity production was from hydropower. The Croatian energy sector is potentially vulnerable if climate change results in reduced river flows – which is likely given the predictions of climate models simulating a drier Croatia. Reductions in hydroelectric generating capacity would thus reduce the nation's level of energy security. For example, in 2003 and 2007, droughts caused significant losses in production compared to the average. This resulted in increased costs for electricity production of perhaps EUR 39-46 million in 2003 and EUR 102-120 million in 2007. Future decreases in hydroelectric production due to reduced runoff and river flows may require lost production to be offset by domestic or imported electricity. Both of these options are more costly than hydropower. It is important to note that increases in costs for electricity production would have multiplier effects throughout the economy.

Climate change is likely to have impacts on the water cycle in Croatia. This could include more droughts, which will affect agriculture and natural environments – especially wetlands. It could also result in decreased river flows, and perhaps even lower levels of ground water, which is used for drinking. Flood severity and drinking water quality/quantity may also be affected by climate change, though more research is necessary to investigate these possibilities. While sufficient information is not available to plan adaptation projects, there are a number of steps that should be taken:

- Water management planners should begin incorporating climate change into planning. This will require further information – such as incorporating regional climate models into planning for flood protection, ground water recharge, and river flows.
- HEP and the MELE should also include climate change impacts into projections of energy supplies in Croatia beyond 2020. The initial analysis shows that the projected impacts may result in a loss of EUR 16-82 million per year in direct losses, with multiplier effects throughout the economy.
- More research should be carried out to look at likely climate change physical impacts on wetlands. Similar research should be carried out regarding flood risks and any adaptation that may be necessary.
- Finally, Croatia should undertake measures to improve the efficiency of the public water supply. The current loss is immense and may lead to problems if water resources become scarcer.

7.1. Introduction

Water is among the most critical resources for the environment and for human development. Water is used by households for basic nourishment and for cooking, sanitation, watering the garden and for a variety of other functions. Fresh water is used for many purposes, in many processes. It is used in agriculture and other industries to irrigate crops, water livestock, process foods, make wood products and chemicals and to wash and clean raw materials and finished products. Fresh water is also used non-consumptively to treat human waste, cool conventional and nuclear power plants and to generate electricity. It is essential for water-borne transportation, for swimming, bathing, and a variety of other recreational activities. In addition, fresh water is used to sustain wildlife and habitats in both aquatic and terrestrial ecosystems. These ecosystems also have value in terms of their impact on runoff and on flooding. The 2006 UNDP Global Human Development Report identified water and water-scarcity issues as one of the most pressing human development concerns in the world today.[1]

This chapter analyses the value of water in Croatia. It also examines the potential impacts from changes in the water cycle due to climate change – in particular the effects on electricity production levels. It then identifies the information necessary to assess the vulnerability of Croatia to changes in water due to climate change. Finally, it makes recommendations for future research and "no regrets" options for addressing current problems related to water, that will also be helpful in coping with climate change.

7.2. Water quantity in Croatia

Before examining the impacts of climate change on water resources, the current water quantity and quality in Croatia must first be examined and how these influence both society and the economy. Croatian fresh water resources are among the richest in Europe, yet only a small amount of this water – less than 1% – is used.[2] The supply of water in Croatia is not always in the right place at the right time, and problems with water supply are often encountered locally (e.g. on islands and in solitary mountain settlements).[3] Nevertheless, water resources are not considered a limiting factor for socio-economic development in Croatia, due to the abundance of water, low population density and the level of economic development.[4] Box 7-1 provides a detailed description of waterways in Croatia.

7.3. Water quality in Croatia

Water quality testing is currently underway in various areas to provide an overview of the ecological and chemical status of waters in Croatia, according to the standards set by the EU Water Framework Directive (hereafter called the WFD).[6] Preliminary results show the following:

The status of Croatian waters is good in comparison to most European countries.

- The ecological status of about half of the surface water of the Black Sea basin (to which most Croatian rivers and lakes belong) is "good" or "very good," which means that it meets the set requirements for all quality indicators.
- The most frequent reason the water did not meet the requirements was related to organic and nutrient pollution. Untreated urban wastewater is the main source of organic pollution.
- Agriculture and households are both accountable for nutrient pollution, though the proportion varies in different areas. Data from the Croatian Water Resources Management Plan indicates that in many areas, agriculture accounts for more than 90% of the total nitrogen pressure on Croatian water resources each year.[7]
- The nutrient pollution appears to be causing water sources to have higher nutrient levels than they should in numerous water sources – especially in the cleanest "Class 1 waters."[8]
- A few water bodies register pollution by hazardous substances (9.5%), whilst hydromorphological changes (changes in disturbing the ecological function of water) have been observed in 11% of water bodies.[9]

Box 7-1: Basic Information about water resources in Croatia[5]

Croatia has two large river basins – areas where the water flows downhill towards a salt-water sea. The Black Sea basin area in the north makes up 62% of the territory and the Adriatic Sea in the south makes up 38% of the area. The watershed runs along the Dinarides barrier close to the Adriatic coast. All of the major Croatian rivers belong to the Black Sea basin. These include the Danube (the largest and richest in water, which flows through the eastern borderland of Croatia for 138 km), the Sava (562 km), the Drava (505 km) and the Kupa (the longest Croatian river – 296 km – which flows through all of Croatia). The Adriatic basin area has short, rapid rivers with canyons. The largest rivers are the Mirna, the Dragonja and the Raša in Istria, and the Zrmanja, the Krka, the Cetina and the Neretva in Dalmatia. There are also shorter non-stagnant waters in the karst area of the Adriatic basin that tend to sink and flow together along underground watercourses. The largest of these is the Lika River.

The Black Sea basin is richer in surface water. However, the specific discharge of the Adriatic basin area is twice as high as that of the Black Sea basin. This is due to the considerably larger quantity of precipitation (by over 40%) and the karst nature of the geological base. The total length of all natural and artificial watercourses in Croatia is about 21,000 km.

However, Croatia is not very rich in natural lakes. The best known and most beautiful are the Plitvice Lakes – 16 cascading lakes interconnected by travertine downstream beds, filled by the Korana River. The site is Croatia's most famous National Park and has been inscribed in the UNESCO World Natural Heritage List. Other large natural lakes include Vransko Lake near Pakoštane (31 km2), Prokljansko Lake (11 km2), Visovac Lake (8 km2), and Vransko Lake on the island of Cres (6 km2). Large artificial lakes (water accumulations) represent a total volume of 1 billion cubic metres and serve primarily as reservoirs for hydropower plants.

Croatia is also a wetlands-rich country, and wetlands occupy 7% of the territory. There are 3,883 sites singled out as integrated wetland areas, of which four are listed on the Ramsar list of wetlands of international importance: Kopački Rit, Lonjsko and Mokro Polje, Crna Mlaka, and the lower Neretva.

The EU WFD requires that all water bodies achieve "good" status by 2015.[I] Croatia plans to meet most of the requirements set for water protection through the development of public drainage (which fulfils the requirements set by the Urban Wastewater Treatment Directive) and via other measures which control the source of pollution, such as the EU's Nitrates Directive and the Integrated Pollution Prevention and Control Directive. Considering the technological and technical state of public water supply systems, the overall test results for the quality of drinking water from public water systems nation-wide is considered satisfactory. However, there are significant differences among counties,[10] (See Table 7-1).

Table 7-1: Percentages of unsafe drinking water samples 1990 and 2005[11]

	1990	2005
Share of chemically unsafe samples of drinking water	30%	5.9%
Share of microbiologically unsafe samples of drinking water	45%	5.5%

A large portion of the population not connected to the public water system is supplied through local water supply systems. There are hundreds of such systems, mostly in the Black Sea basin area. The local water supply systems do not have an established system for water quality control. Water is tested if and when the user decides this is necessary. This also applies to water from private wells, which may be a major concern, as an analysis of Croatian Public Health Institute data revealed that, from 2000-2006, one out of every three samples analysed from private wells exceeded the Maximum Acceptable Concentration (MAC) for nitrates.[12]

[I] Or in exceptional cases, within two consecutive six-year planning periods

7.4. Importance of water to Croatia

7.4.1. Water use 1: Personal, industrial, and agricultural consumption

In terms of the quantity of water per capita, Croatia is ranked fifth in Europe and forty-second in the world.[13] Approximately 75% of the population is connected to the public water supply system.[14] The share of population covered by the public water supply network is somewhat higher - about 80% in total.

Most (90%) of the water for the public water supply is obtained from groundwater reserves, either from wells (mostly in the Black Sea basin) or springs (mostly in the Adriatic Sea basin).[15] Based on information provided by Croatian Waters[16] and the Institute for Public Finance,[17] it appears that in 2006, the Croatian population, industry and agriculture sector consumed less than 1% of Croatia's average annual water supply.[18]

Most of the drawn water was used for the public drinking water system. Water loss during distribution is estimated at an astonishing 40-46% on average.[19] Up to 267 million m^3 of water were lost in the public water supply system en route to the end users (Table 7-2). Losses in the water network differ from region to region and can be the result of poor maintenance, illegal tapping and a leaky distribution system (pipes).[20]

Overall, the public water supply in Croatia is reliable. Occasional shortages occur in tourist resorts during the high tourist season, notably on the islands. However, as several water supply projects are currently in progress, this problem is expected to be solved soon.

Agricultural and industrial water usage is also significant:

- The quantity of water used by farming accounts for 2%-3% of total water use in Croatia – up to 20 million cubic metres.[21]
- Irrigation is practised only on a very small percentage (0.7%) of agricultural land, and the most commonly used water for irrigation is surface water from rivers, lakes and reservoirs of different sizes. In some cases groundwater is used.[22]
- In 1994, irrigation used approximately 30 times more water per hectare than in 2006, as a result of the more efficient irrigation systems now in use (e.g. drip irrigation).[23]
- Since the introduction of the national irrigation project in 2005, the irrigated area has increased by approximately 50% and by the end of 2007 approximately 15,000 hectares were included in the irrigation scheme, out of a total agricultural area of 1.2 million hectares (see Chapter 8).[24]
- An additional 2% is consumed by industry (not counting hydroelectricity production).[25]

Table 7-2: Water use in 2006.

			Litres per capita	
	Million m^3	%	Per Year	Per Day
Public water supply system		**87**		
Total drawn water	578	100	130,313	357
Distribution losses	267	46	60,252	165
Supplied to end users	311	54	70,061	192
of which to households	175	56	39,423	108
of which to industry & agric.	136	44	30,638	84
Industry & agric. own water sources	**90**	**13**	**20,275**	**56**
Total consumption	**668**	**100**	**150,588**	**413**

Source: Bajo and Filipović 2008; CW 2008a.

> "The tremendous amount of waste in municipal and non-agriculture industrial water use leads to lost revenues of up to EUR 286 million and increased emissions, as more electricity is used for pumping"

Overall, while there is no shortage of water in Croatia, there are two aspects that are problematic. First, the tremendous amount of waste in municipal and non-agriculture industrial water use leads to lost revenues of up to EUR 286 million and increased emissions, as more electricity is used for pumping (see Box 7-2). Second, water is often unavailable to farmers at certain critical times of the year and the soil, in general, lacks moisture.

Box 7-2: Water prices and the economics of water use

How water is priced will affect the extent to which it is conserved. However, the goal of conservation is sometimes constrained by cultural ideas about the value of water and the ability of various groups to pay. Water prices in Croatia vary significantly among different water suppliers and the price often takes into account the socio-economic situation of the country, as well as the fact that water resources are not equally distributed among all regions. There is a considerable difference in the price of water for households and businesses. In 2005, the average price of water for households was EUR 1.15 per cubic metre, while industries paid EUR 1.76 per cubic metre. In 2005, the total payment for all water was EUR 71.56 per person, of which EUR 38.39 was for households and EUR 32.58 was for industrial consumption.[26]

Although Croatia aims to follow the guidelines of the new European water policy, promoting the introduction of an economic price for water, prices charged by many Croatian suppliers still do not reflect this. Since water companies are owned by local government, they determine the price. Water prices are usually set below the economic price and local governments do not usually compensate the full difference (economic losses) directly to water utility companies. Due to this lack of revenue, the water infrastructure often cannot be maintained properly and falls into disrepair.

Water prices are based on variable, non-uniform criteria and currently vary from EUR 0.34-2.18 per cubic metre.[27] The large differences in price mostly result from the difference in the scope of the water services provided (water supply, wastewater collection, wastewater treatment). However, all water prices must include a charge of EUR 0.23 per cubic metre. This includes a water use charge of EUR 0.11 per cubic metre and water protection charge of EUR 0.12 per cubic metre. These charges are fixed for all. However, these fees have not changed over the last fifteen years. They are severely underestimated.[28] Croatia has recently begun following the guidelines of the new EU water policy promoting the "user/polluter pays principle." Consequently, it has gradually been introducing more economically efficient prices, including charges for water protection, anti-flood protection and measures against other eventualities.

In the last three years, the price of tap water has increased substantially. In the city of Zagreb, for example, the price of water for households in 2005 was EUR 0.9 per cubic metre. In 2008 it had increased to EUR 1.53 per cubic metre.[29] This is mainly due to the new wastewater service, which came on-line after the opening of the central wastewater treatment plant. The price rise can also be partly explained by water losses. On average, for every cubic metre of water delivered to end users, an additional 0.86 cubic metre is lost during distribution.[30] The cost of pumping and treating the lost water must be paid for by the utility, but there is no corresponding revenue. Therefore the utility must raise its water charges to cover the lost costs. In 2005, water losses amounted to EUR 286 million – an equivalent of about 0.9% of the entire national GDP.[31]

Climate change has the potential to push water prices up by creating local water shortages, by making water and waste treatment more expensive due to reduced water quality and by increasing the cost of pumping groundwater from greater depths. At the same time, any climate-induced increases in energy prices will also increase the price of pumping water and put even more upward pressure on water prices.

7.4.2. Water use 2: Electricity from hydropower

One of the most important ways in which water contributes to human development in Croatia is in the production of hydropower. The energy generated by hydropower in Croatia is substantial.[II] In the period 2000-2007 half of all electricity produced was from this source (Figure 7-1). However, since Croatia is an energy importer (including oil, natural gas, and nuclear power), the share of the hydropower energy consumed is a smaller percentage of the total energy consumption (See Table 7-3).

In the period 2000-07, the average annual share of hydropower in the total electricity consumption was 39%. This means that the Croatian energy sector is potentially vulnerable to climate change should it result in reduced runoff into the major hydroelectric reservoirs. Any climate-caused reductions in hydroelectric generation capacity would, in turn, reduce the nation's level of energy security by intensifying the demand for imported energy to replace the loss in hydroelectric generation.

The last hydropower plant to be built in Croatia was in 1989 (See Figure 7-2 for a map of plant locations). The breakaway from the former Yugoslavia and post-war recovery prevented the construction of new hydropower plants. Additionally, the best sites suitable

[II] Hydroelectric power plants owned by the Croatian Electric Company (HEP), both large and small, account for almost 98% of the renewable energy generated in Croatia. The rest is made up of hydroelectric power plants owned by the small business and individuals (1.75%), plants generating electricity from biomass (0.10%), are wind parks (0.30 %), and solar plants (0.0008%) (CEA 2008b).

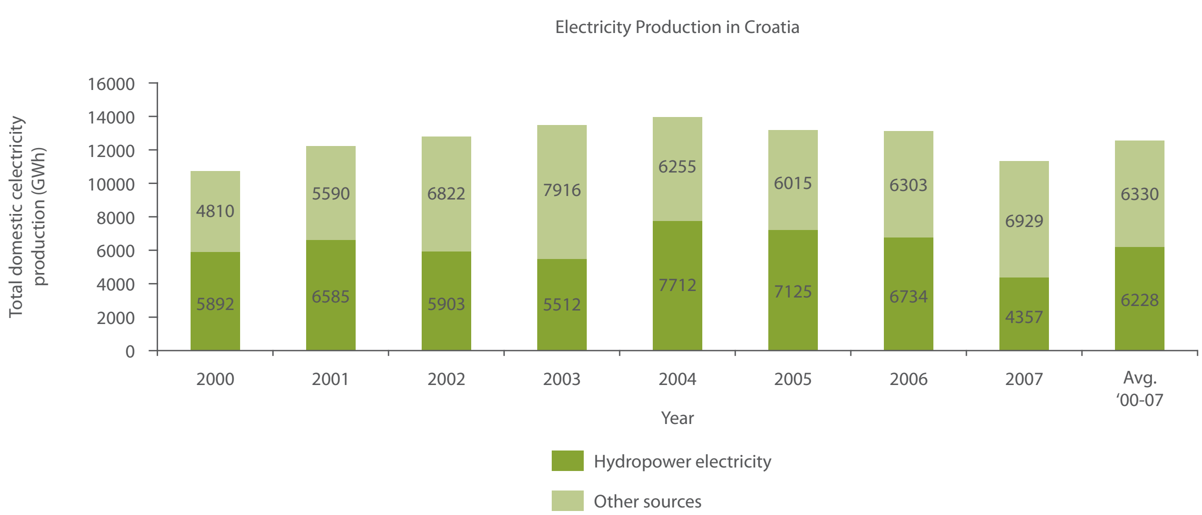
"The Croatian energy sector is potentially vulnerable to climate change should it result in reduced runoff into the major hydroelectric reservoirs"

Table 7-3: Primary energy production and gross inland consumption in the period 2001-05 (after MELE 2007)

	Unit	2001	2002	2003	2004	2005	Avg. '01-05
Primary energy production*	PJ	196	186	184	204	197	193
of which hydropower	PJ	66	52	46	69	62	59
of which hydropower	%	33	28	25	34	32	31
Gross inland consumption	PJ	372	376	396	412	412	393
of which hydropower energy	%	18	14	12	17	15	15

* Includes coal, solid biomass, crude oil, natural gas, hydropower and renewables

Figure 7-1: Annual (2000-07) share of hydropower in the electricity production.



Source: after CBS 2007 and HEP 2008b

"Wetlands provide a variety of ecosystem services: fishing, forest management, grassland farming, recreation, flood protection, carbon storage and regional climatic stabilization, water regime regulation and habitat for a number of plant and animal species, etc"

for hydroelectric generation have already been taken. New plants would need to be built in valleys with potential detrimental effects on the environment and on groundwater recharge. These poorer quality sites have less storage capacity and less force behind the water-propelled turbine blades. Therefore their final cost of production, including capital and operating costs, will be higher and their capacity will be lower than the old plants currently in operation. Only one hydropower plant is currently under construction – Lešće on the River Dobra – which should have a capacity of 43 MW. Several hydropower plants in Croatia – notably those in the Adriatic basin – depend on trans-boundary inflow from Bosnia and Herzegovina.

7.3.4. Water use 3: Wetland services

Wetlands provide a variety of ecosystem services: fishing, forest management, grassland farming, recreation, flood protection, carbon storage and regional climatic stabilization, water regime regulation and habitat for a number of plant and animal species, etc.[III] The MEPPPC (2006) suggests that aquatic and wetland habitats providing important ecological services, are

[III] The term "ecosystem services" refers to resource flows between the ecosystem and economic activity which makes it possible to place economic values on these flows and ultimately on the ecosystem assets that produce these flows.

Figure 7-2: Distribution of hydroelectric plants

Source: HEP 2008a

particularly vulnerable to changes in the quantity and distribution of precipitation, and that climate change is most likely to negatively affect these services.

Ecosystem services, while ubiquitous, are very hard to value without undertaking original research. In particular, it is difficult to measure the economic value of biodiversity – which is an important aspect of Croatia's environment. One ecosystem service – nutrient removal – can give us some idea about the magnitude of the economic importance of wetlands. This service involves wetlands and floodplain areas assimilating pollutants (for example Nitrates and Phosphates) and rendering them relatively harmless to the environment. The value of this service can be determined either by analysing the type of pollutant damage avoided, or the costs saved by not having to remove these pollutants by waste treatment. Using the results from a WWF study (1999)[III] the average value of the nutrient removal service (i.e. waste assimilation) of the floodplain and wetlands area of the Danube basin is EUR 250 per hectare per year. Using this estimate, the annual value of the nutrient removal service of 391,000 hectares of wetland habitats in Croatia would be EUR 98 million (1999 EUR value).

The value of other ecosystem services – and possibly the damages caused to them by climate change– could also be substantial. These other services include timber production, hunting land and grassland production. These three services total approximately EUR 1,000 per hectare per year (though this amount still does not include all ecosystem services, such as landscape values, GHG mitigation, fishing, etc.). Depending on the scenario of sustainable land use, the payment that society should provide for the ecosystem services of the Lonjsko Polje Nature Park wetlands was estimated at EUR 20-600 per hectare per year.[32]

Assuming that the value of these three services is about EUR 1,000 per hectare, per year for all Croatian wetlands, the value of these services at the national level would be EUR 391 million. Adding the previous value of EUR 98 million for nutrients removal, the total value of the combined ecosystem service would be about 2.36% of the average annual GDP in the period 2001-2005 (EUR 488 million). While this is a speculative

[IV] The study was carried out within the framework of a UNDP/GEF funded Danube Pollution Reduction Programme, involving more than 120 scientists from nearly all Danube Basin countries, co-ordinated by the Institute for Floodplains Ecology from Germany under the guidance of the UNDP/GEF team of experts from the Danube Programme Coordination Unit in Vienna. The study estimated that this value is based on the average nutrient removal potential of 100-150 kg N per hectare per year and 10-20 kg P per hectare per year.

Table 7-4: Ecosystem services and potential valuations

Ecosystem Service	Value	Notes
Nutrient Removal Service	EUR 250 per ha per year. For 391,000 hectares of wetland habitats in Croatia the value would be EUR 98 million (1999 EUR value).	- WWF (1999) study estimate of the floodplain and wetlands area of the Danube basin - Some wetland sites involved in this study had a much greater nutrient removal capacity. The Mokro Polje/ Lonjsko Polje wetlands exhibited a greater average nutrient removal potential (6 times more) than the average Danube wetlands. The Kopački Rit wetlands had a potential an amazing 53 times higher.
Timber production	EUR 500 per ha per year[33]	- Estimates for the Lonjsko Polje wetlands
Hunting	EUR 65 per ha per year[34]	- Estimates for the Lonjsko Polje wetlands
Grassland production	EUR 450 per ha per year[35]	- Estimates for the Lonjsko Polje wetlands

number, it shows the potential value of wetlands in Croatia. Additionally, wetlands are valuable due to the amount of biodiversity present within them. However, because there is insufficient information to evaluate the potential loss of biodiversity in economic terms in Croatia, this Report does not analyse this impact in depth. It is, however, important to note that a loss in wetlands would probably threaten biodiversity.

7.4.4. Other uses for water

Compared with agriculture, human consumption, electricity generation, and ecosystem services, all other water-related economic activities in Croatia appear to be of relatively minor importance. The network of navigable inland waterways consists of 804 km of the rivers Danube, Sava, Drava, Kupa and Una.[36] The Sava River between Slavonski Brod and Sisak is important for transporting oil to and from the refinery facilities. In 2006, inland water ports handled 2.9 billion tonnes of goods, less than 1% of the amount handled in the sea-ports.[37]

Lakes, rivers, ponds and other freshwater bodies are important for sport, swimming, angling and other forms of water-based recreation. Unfortunately, the economic value of these activities is not quantified in any official document. It might be particularly interesting to know the figures on the quantity and value of the fish caught by angling. It is apparent that for many low-income inhabitants, notably those living along the big rivers, angling represents an important part of a survival strategy.

The water-rich regions of the national parks (e.g. Plitvice Lakes, Krka, Kopački Rit) and nature parks (e.g. Lonjsko Polje) are important, both in terms of the richness of their biodiversity – especially for rare and protected birds – and the scenic beauty that attracts many tourists. The existence of several species of protected bird depends on the existence and management of carp ponds.[38]

There are also 70 commercial fishing ponds over 5 hectares in size.[39] In 2006 these ponds produced 5.1 kilo-tonnes of fish.[40] In the period 2004-2006, production increased by 50%.[41] However, the Water Management Strategy indicates that due to various socio-economic circumstances, this business is in decline.[42] Some ponds require a constant inflow of water, and maintaining a minimum inflow of water of a sufficient quality is difficult during drought periods.[43]

Figure 7-3: The Gacka River in the region of Lika

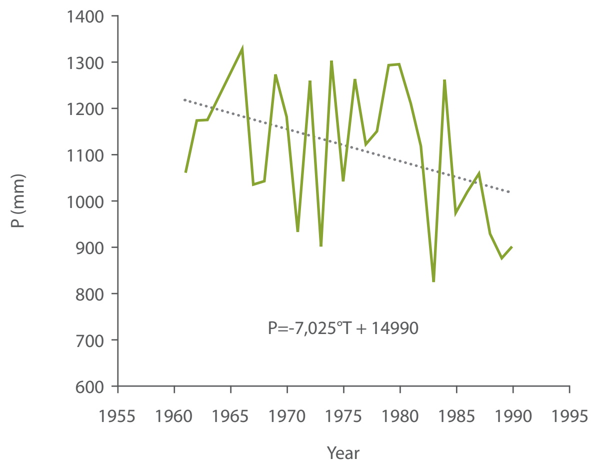
Source: Ivo Pervan

7.5. The impact of existing climate variability on Croatian water resources and water based economic activities

7.5.1. Existing impact in Croatian fresh water resources

It seems that water resources in Croatia are already facing impacts from changes in climate variability (See Table 7-5). Research suggests that changes in long-term climate variability are already having an impact on runoff, evapotranspiration, groundwater recharge, lake water levels and water temperature. Climate change is likely to cause more reductions in water availability and increases in fluctuations.

Figure 7-4: Sequence of annual precipitation amount P(mm) in Croatia with a linear trend 1961-1990.



Source: : MEPPPC 2006.

Table 7-5: Impacts of recent changes in the climate (adapted from MEPPP 2001 unless otherwise noted)

Characteristic Changes	Extent of the Impact/ Notes
Droughts have occurred with increasing frequency [44]	This has been a trend in recent decades. The intensity and duration of the 2003 drought was one of the most pronounced in the last 59 years. More severe droughts were registered only in 1946, 1947, and 1950.[45]
Potential evapotranspiration rates are rising[V]	Increase of 15% in Osijek (a part of the flat, fertile, continental region) and an increase of 7% in Crkvenica (in the coastal region). This is due to temperature increases in the last 100 years.
Actual evapotranspiration rates are rising	Increase of 8% in Osijek, though no increase in Crkvenica.
Precipitation trends are decreasing	In the period 1961-1990, a downward trend in average annual precipitation of about 7 mm per year - thus annual precipitation has dropped by some 210 mm over thirty years (Figure 7-4).
Declining runoffs and soil moisture	This is due to increased evapotranspiration rates, combined with decreases in precipitation - significant in Slavonia and Primorje.
Declining water levels in lakes and rivers[46]	Declining on the Sava and Drava rivers as well as Vrana Lake in recent decades. In 2003, the water level of the Sava River dropped to its lowest level in 160 years. The fall in lake water levels and river discharges is correlated with both increases in precipitation and temperature.
Declining annual mean flow rates of rivers	The River Danube at Bezdan in the period 1921-2001 shows a negative trend. A shift from glacial discharge to discharge from rivers and streams has been observed on the Drava River.
Increasing annual minimum and mean water temperatures of rivers[47]	The Danube River and its main tributaries in Croatia (the Kupa, the Sava and the Drava) have increased since 1988. This increase in water temperatures in Croatia has been attributed primarily to changing climatic patterns, including seasonal warming and reduced runoff from snowfall compared to precipitation. Alterations through regulation and drainage works, hydroelectric, hydraulic, and other large construction projects seem to be less important.
Drying of forest soils – endangering common oak forests among others	Due to the changed water regime and the decline in ground water levels - mostly in the lowland area of Central Croatia, the Spačva basin, in the wider surroundings of Našice and Osijek, and in the Podravina region.[48]

[V] Evapotranspiration is the discharge of water from the earth's surface to the atmosphere by evaporation from lakes, streams, and soil surfaces and by transpiration from plants.

Figure 7-5: Low water table of the Sava River in Zagreb on August 28, 2003.

Source: DHMZ 2005b.

7.5.2. Existing economic impact from climate variability related to water

Climate variability has already had adverse impacts on water supplies and water quality in Croatia. In agriculture, extreme droughts have caused hundreds of millions of Euros worth of damage – up to 0.6% of total GDP from 2000-2007 (See Chapter 8). On the other hand, the current declines in runoff, groundwater recharge, and lake water levels, do not appear to have had a severe economic impact on drinking water supplies or water quality, except for occasional water shortages in coastal communities during the peak tourist season, probably caused by lack of infrastructure and increased demand. This finding is logical since Croatia uses only a very small percentage of its available water resources in consumption. However, recent economic losses have occurred due to flooding and a decrease in hydroelectric power generation. These losses have not been estimated with a sufficient degree of accuracy, and it is too soon to tell whether there is a trend in these losses.

Water and climate variability already pose some risk due to floods.[49] Croatia is subject to periodic flooding which causes considerable economic damage. According to the Water Management Strategy[50] there are a number of different types of floods:

- River floods, due to extensive rains and/or sudden snow-melt;
- Flash floods in smaller watercourses, due to short rains of high intensity;
- Floods on karst (limestone) fields, due to extensive rains and/or sudden snow-melt;
- Floods of inland waters on lowland areas; and
- Ice floods.

Small-scale flooding is also caused by dams and barriers breaching, landslides and inappropriate construction.[51] In some urban areas, floods are induced by short, intense precipitation events (rain) combined with a high population and insufficient wastewater sewerage and drainage system capacities.

Since 1980, there were several big floods, among which the most important were:

- Sava River: in 1990 and 1998;
- Kupa River: in 1996 and 1998;
- Neretva River: in 1995 and 1999.

The damage caused by floods in the period 1980-2002 is estimated at EUR 409 million, representing 7.4% of all damages caused by natural disasters in this period.[52] In the period 2001-2007, floods caused damage amounting to EUR 74 million, accounting for 4.6% of all damage caused by natural disasters.[53] Some 58% of this was damage caused to agriculture.

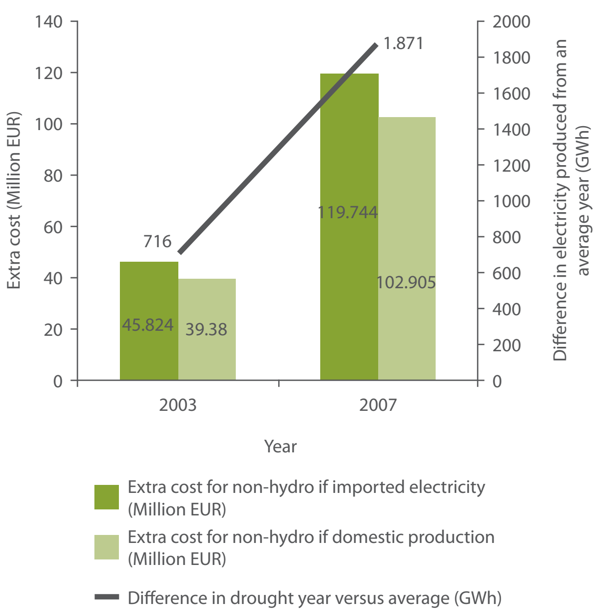
Investment in the maintenance of flood protection systems and their effectiveness was reduced after 1991.[54] The available financial resources for these measures were insufficient until the introduction of water protection charges for the water system in December 2005. Since then, revenues have grown significantly, but are still insufficient for all necessary investments to develop the protection system from water. The safety of the population and assets in many potentially flood-exposed areas is still insufficient. However, there are regional differences in this respect and the protection is generally much better in larger settlements and along larger rivers. In the Black Sea basin, the flood protection system has not been completed and there are still some unresolved issues even on the major rivers, such as the Sava and the Drava Rivers. In the Adriatic basin, protection against storm water requires substantial improvement.[55] The Government has plans to improve the effectiveness of the flood protection system[56], however, the ecological quality of waters should also be taken into consideration while designing these plans.

In addition to existing damage from floods, it should be noted that in 2003 and 2007, when there was a particularly strong drought, the amount of hydroelectric power produced dropped dramatically – by 716 and 1871 GWh respectively, compared to the average from 2000 – 2007. Decreases in electricity production due to reduced runoff may require the lost production to be offset by domestic or imported electricity, which is more costly than electricity produced by domestic hydropower.

The average extra cost of all other major sources of electricity (natural gas, coal, nuclear, importation) is approximately EUR 55 per MWh. Imports cost approximately EUR 84 per MWh (EUR 64 per MWh more than hydroproduction).[57]

Thus, the increased costs for 2003 and 2007 appear to be dramatic (EUR 39-46 million in 2003 and EUR 102-120 million in 2007).

Figure 7-6: Differences in amount and cost of electricity production in drought years versus the average from 2000-2007



7.6. Estimates of potential future climate change impacts on the water sector

7.6.1. Overview of potential impacts in general for Europe

The frequent alternation of flood and low flow events throughout Europe in the last decade has led to fears that the dynamics of the hydrological cycle have already intensified as a consequence of global warming.[58] The economic sectors, which are projected to be most affected by the impact of climate variability and extreme weather, are agriculture (increased demand for irrigation), energy (reduced hydropower potential and cooling water availability), health (worsened water quality), recreation (water-linked tourism), fisheries and navigation.[59] The major expected impacts are:

- Flooding in central Europe, concerns over hydropower, health and ecosystems in the northern countries, and water scarcity in the southern countries.[60]
- The number of drought-affected areas is likely to increase. Precipitation and seasonal runoff are projected to become increasingly variable, resulting in disrupted water supplies and quality and an increased flood risk.[61]
- In Europe, south of 47°N (which includes Croatia), annual runoff is expected to decrease by 0–23% by the 2020s and by 6–36% by the 2070s.
- Groundwater recharge is likely to be reduced in central and eastern Europe[62] and by up to 20–30% in south-eastern Europe by 2050.[63] This runoff reduction is particularly expected in the valleys[64] and lowlands, e.g. in the Hungarian steppes.[65]
- A decrease in runoff might become a serious problem particularly in the Mediterranean region, which is already sensitive to droughts. The Mediterranean climate is expected to become drier and water resources are expected to decrease, while water demand is expected to increase.[66]

- This change, together with population growth, is expected to increase the pressure on available water resources and may cause social instability in the area. Water conflicts might spread – notably between urban and agriculture users, as well as between upstream and downstream regions.

7.6.2. Overview of potential future climate impacts for Croatia

Climate change in Croatia is expected to result in changes to evapotranspiration, soil humidity and ground water recharge. Changes in the precipitation pattern are expected not only to affect runoff, but also to influence the intensity, timing, and frequency of floods and droughts.[67] Runoff in major Croatian basins is expected to be reduced by 10 to 20%, although in the eastern part of the country this change might be below 10%. During the summer months, it is possible that water shortages will occur, especially in the coastal areas where temporary water shortages are already experienced during the high tourist season. As Croatia is prone to the risk of forest fires, the projected decreased rainfall in the coastal area, notably during the summer period, is also expected to precipitate forest fires.[68] The water shortage in the soil during summer is expected to increase by 30-60% in the lowlands and 25-56% in the coastal areas.[69]

7.6.3. Potential climate change impacts on water supply for personal, agricultural, and industrial consumption

Croatia's latest report to the UNFCCC suggests that climate change might cause problems in water supply and in meeting the ever-growing drinking water requirements.[70] However, since Croatia is abundant in renewable groundwater reserves and since approximately 90% of the public supply of drinking water comes from the groundwater, Croatia will probably not experience drinking water shortages – except perhaps at the coast during the peak summer months. Climate change may, on the other hand, decrease the groundwater table, leading to an increase in the cost of water abstraction, resulting in an increase in water prices. With a lower groundwater table, it is very possible that a number of private wells, supplying water to nearly 22% of the population, may dry-out. This would impose an extra cost on their owners/users (mostly low-income groups living in remote areas) if they have to make the wells deeper. In some cases, due to geological conditions and/or the lack of adequate equipment, this might be technically difficult, if not impossible. The magnitude of the impacts of climate change on ground water supplies is difficult to determine. This is because of the uncertainty that surrounds climate change projections and because groundwater resources in Croatia have not been systematically and comprehensively mapped, nor have simulation models of the largest aquifers been developed. However, the number of people affected is not likely to be very high, as water supply plans have been developed to increase the population's access to the public supply system to 85 - 90% by 2020.[71] Climate change is also likely to affect agricultural production, which is covered in depth in Chapter 8.

Climate change also has the potential to cause a number of impacts on freshwater-based recreation. Decreasing lake levels and changes in the visual characteristics of both terrestrial and aquatic ecosystems in and around lakes may make lakes less attractive for recreation. Lowered lake and stream levels also decrease the capacity for assimilating waste and increase water pollution, making them less suitable for recreation. Finally, and perhaps most importantly, climate change may reduce runoff to the extent that river discharges will significantly decrease in karst formations, such as those of the Plitvice Lakes. These types of impacts have the potential not only to lead to reductions in tourism, but also represent a loss in ecosystem values of potentially staggering proportions.[VI]

[VI] See Chapter 4 for more on tourism and climate change.

7.6.4. Potential climate change impacts on the production of hydroelectric power

Changes in climate are likely to affect the production of electricity from hydropower. During 2001-05, the average annual GVA (gross-value added) of the production and distribution of electrical energy in Croatia amounted to EUR 444 million – 1.67% of GDP.[72]In the same period electricity produced by hydropower accounted for 37% of total electricity consumption. This means that the total value was approximately EUR 164.4 million (0.62% of GDP).

The Croatian electricity utility (HEP) makes annual electricity production forecasts based on data on aggregate water inflow into the reservoirs behind the hydro dams. Following this approach and assuming an average rainfall, the production forecast for 2008 was 5,890 GWh.[73] HEP assumes a linear relationship between the reduced water inflow and the electricity production from hydropower plants. In other words, a 10% inflow reduction will result in a 10% reduction in generated electricity. While no specific predictions exist for Croatia, macro-scale hydrological models predict that production in Southern European hydropower stations will decrease by between 20-50% by the 2070s.[74] Table 7-6 shows the potential impact of these reductions. In addition to reducing overall GDP, this scenario would require HEP to take one or more of the following measures:

1. Raise electricity prices significantly,
2. Reduce national consumption of electricity,
3. Replace the lost hydro-generation with production from existing, higher-cost (per kWh) domestic resources, or
4. Import more expensive electricity from neighbouring countries.

In addition to increasing the price of electricity (or reducing revenue from electricity sales if prices are not increased), this reduction would increase the country's vulnerability to the international electricity market conditions, which could be particularly problematic for HEP. Hydropower is by far the cheapest source of electricity in Croatia at present, costing approximately EUR 20 per MWh. Importing electricity costs approximately EUR 84 per MWh while the next cheapest domestic option – coal-fired plants – cost EUR 50 per MWh.[75]

An example of the potential economic impact of a 35% reduction in hydropower is presented in Table 7-7. While this scenario assumes that current costs for energy production stay constant – which is unlikely – it provides a sense of the scale of vulnerability of the energy sector to a loss of hydropower. The cost to HEP alone would represent 0.17- 0.31% of current Croatian GDP.

In the longer term, a sustained loss in the generating capacity of hydroelectric facilities – especially during the peak demand times, such as the summer – could require significant investment in new, higher-cost electricity generation from fossil fuels, nuclear power,

Table 7-6: GVA loss in the electricity sector due to 10-50% less inflow

		Anticipated reduction of hydropower-generated electricityinflow								
	Unit	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**
Lost GVA in the electricity sector	Million EUR	17	26	34	43	52	60	69	77	86
	%	4	6	8	10	12	14	15	17	19
Lost GDP	%	0.06	0.10	0.13	0.16	0.19	0.23	0.26	0.29	0.32

"A decrease in generating capacity would also have compound effects on the economy and on ordinary Croatians. Higher electricity production costs translate directly into either higher energy prices or lost revenue from the sale of electricity, both of which will be passed on to consumers"

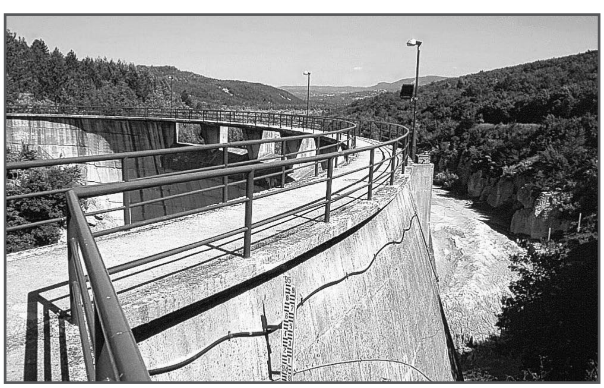
Table 7-7: Hypothetical cost for replacing a 35% loss of hydropower

Strategy for replacing a 35% loss of hydro-power	Cost per year for production
Replace hydropower with the cheapest alternative source (coal)	EUR 65 million
Import electricity at 2008 prices	EUR 117 million

other renewable resources, or the continuation of large imports of electricity from other countries, which presents some risk to Croatia's energy security.

No matter how the lost generating capacity is replaced, a decrease in generating capacity would also have compound effects on the economy and on ordinary Croatians. Higher electricity production costs translate directly into either higher energy prices or lost revenue from the sale of electricity, both of which will be passed on to consumers, who are already facing increased utility rates in Croatia. A further increase in utility rates and/or taxes may lead to increased economic hardship, especially among the poorer segment of society. As of 2006, one fifth of Croatian households surveyed were already reporting difficulties in paying their utility bills on time.[76] As energy prices go up, human development becomes more difficult and the options become more limited for those least able to pay. Additionally, a multiplier effect on the economy would be probable if electricity prices increased, driving up prices for many goods, such as food.

Figure 7-7: The Letaj Dam in Istria.



Source: Croatian Waters.

7.6.5. Potential climate change impacts on wetlands and ecosystem services

As was noted earlier, wetlands provide a variety of ecosystem services that can be valued in economic terms and whose value in Croatia is substantial - in the order of millions of Euros per year. Reductions in runoff, combined with higher evapotranspiration, have the potential to lower groundwater levels, increase eutrophication and, in the long term, eliminate wetlands and the ecosystem services they provide. Without detailed wetlands data and dynamic wetlands simulation models, it is difficult to even determine how changes in temperature and precipitation will affect the freshwater resource base in a given wetlands area, let alone the ecological response to reductions in runoff and water storage and the resulting loss in ecosystem services. However, the fragility of wetlands ecosystems and their heavy dependence on water availability is undeniable and there is no doubt that reductions in the water storage capacity of wetlands will jeopardise the services they supply to humankind.

Expected increases in air and water temperature and evapotranspiration rates, accompanied by decreases in runoff due to climate change, also have the potential to affect the functioning and health of other terrestrial and aquatic ecosystems. Unfortunately, the databases and the models needed to simulate the response of unmanaged ecosystems to climate change in Croatia have not been developed. While there is a great deal of visual and anecdotal evidence to suggest that recent climate trends have put several forest ecosystems at risk (oak, the common beech, and silver fir), the necessary data on growth, yields and inventories of forest types to quantify the damages is still being collected and needs to be processed.

7.7. Addressing climate change/ climate variability in the water sector

While freshwater resources are currently abundant in Croatia, climate change still has the potential to adversely affect hydroelectric generation, increase the intensity of floods and droughts and reduce the ecosystem services provided by wetlands. In the longer term, higher temperatures and reduced precipitation may also reduce the water stored in aquifers and threaten drinking water supplies. However, the current capacity to project the damages due to climate change, to estimate the economic value of these damages and to assess the effectiveness and the benefits and costs of possible alternatives for adapting to these impacts, is quite limited. For the private and public sectors to adequately meet the challenges of climate, both groups will need to further develop not only their analytical capacity, but also the institutional capacity needed to translate their findings into policies and actions that can be implemented on the ground to cope with climate change.

7.7.1. Information availability for decision-makers to assess vulnerability and adapt to climate conditions and climate change

Several organisations provide information relevant for the water sector:

- The Central Bureau of Statistics (CBS) collects and maintains annual data on water availability, supply and consumption.
- The Croatian Environment Agency (CEA) is in charge of monitoring, collecting and integrating data on the state and trends of water quantity, quality and impacts, as well as the response of society to impacts on the state and the quality of Croatian inland waters. It maintains environmental information databases and provides the statistics for reports on the national state of the environment. All this information is integrated into an environmental information system, which is accessible to the general public. The organisation exchanges information with the European Environment Agency (EEA) and its European Environment Information and Observation Network (EIONET).[77]
- Croatian Waters (CW) is the state agency responsible for water management. It is responsible for the collection and analysis of data and the evaluation of water quality in Croatia. They also publish yearly reports on water quality. Their work consists of investigating the quality of surface and ground water, as well as seawaters polluted by land-based activities. They investigate water quality indicators (oxygen patterns, nutrients, microbiological and biological indicators) as well as additional indicators (metal content, organic compound content, and radioactivity). Currently, the evaluation of water quality is being implemented in accordance with the "Regulation of the classification of water" which prescribes very high standards of quality. CW is also working on the implementation of the EU Water Framework Directive (WFD), which will standardize the evaluation and management of water in the Republic of Croatia and align it with EU standards. CW has an important role in implementing hydrological monitoring because it finances more than 50% of all monitoring stations. To protect against floods, CW has built its own automatic data collection system and remote control of hydro-technical devices. The data collected are used for monitoring and the prognosis of floods and provides a foundation for decisions on operational measures. All data are available to the public.
- The DHMZ is the central institution for meteorological and hydrological observations and data processing, and it has several hundred weather as well as water stations distributed over the entire country. It is currently undertaking research on the following topics:
  - Dynamical downscaling of climate change scenarios from the EH5OM global model: simulations for two 30-year periods, present climate (1961-1990) and future climate (2041-2070)
  - Estimation of present and future water cycles e.g. rainfall, evapotranspiration, surface runoff, particularly for the Mediterranean area

> "While freshwater resources are currently abundant in Croatia, climate change still has the potential to adversely affect hydroelectric generation, increase the intensity of floods and droughts and reduce the ecosystem services provided by wetlands"

> "The ability to better simulate the range of water resource-related impacts associated with climate variability and climate change is critical to the development of effective policies to cope with climate"

- Occurrence and changes of extreme weather events, notably droughts and rainfall
- Occurrence and changes in the amount and variability of seasonal and annual precipitation
- Changes in the frequency and intensity of heavy precipitation events.

- The civil engineering and geophysics departments of the Universities of Zagreb, Osijek and Split also undertake hydrological and other water-related research. Some of this research deals with climate-change-related issues, including:
    - The analysis of the change of the water temperature regime of Croatian rivers and changes in water flows
    - Spatial comparison, variability and trends of water balance components
    - Calculation of future climate water balance – computed from the data produced from climate scenario models.

Information is urgently needed to assess the economic vulnerability to climate change due to water changes. First, it is necessary to develop the capacity to simulate the physical impacts of climate on the supply, distribution and quality of freshwater resources. Many of the same databases and models that are needed to simulate the physical impacts of climate change are also needed to cope with existing climate variability. The capacity to simulate the water-related impacts of climate variability and change should be strengthened in the following ways:

- Improve the ability to downscale GCM results to the level of catchments - making the results suitable for correlation with data from existing runoff gauges and weather stations used for monitoring.
- Develop a national database and system of rainfall-runoff models to project the effects of rainfall changes (for climate variability and climate change) on runoff and discharges (including peak and low flows). This should be done in important river basins and catchments and linked to an expanded national runoff and flooding reporting system.
- Improve the capacity of HEP to simulate systems operations based on improved rainfall runoff and hydropower simulation models at all existing hydro sites.
- Undertake selected, multi-agency hydrologic and ecological studies to simulate the impacts of climate variability and climate change on ecosystems that may be endangered by reductions in runoff or declining groundwater levels.
- It may also be worthwhile to undertake a programme to map existing groundwater resources in a comprehensive fashion, and then develop the databases and models needed to simulate the effects of climate variability and climate change on groundwater recharge, storage and water quality.

The ability to better simulate the range of water resource-related impacts associated with climate variability and climate change is critical to the development of effective policies to cope with climate. However, these tools are not sufficient. They should also be combined with tools to estimate the economic and social consequences associated with the physical impacts of climate change and to assess the economic and societal benefits and costs of adaptation policies, options and projects to lessen the economic losses and adverse societal consequences of climate change.

Simulating the economic impacts of climate change and the economic costs and benefits of adaptation policies, options and projects is quite a daunting task. A class of models has been developed to simulate a wide range of the economic impacts of climate change and climate variability for both large and small river basins.[78] However, this type of model depends on a great deal of information that does not yet exist in Croatia. Therefore, it would make more sense for Croatia to focus initially on the specific types of impacts that have already been identified. These are described in Table 7-8.

Table 7-8: Areas for future economic analysis related to water

Area to address	Descriptive notes
Loss of hydroelectric generation capacity	These losses and the benefits and costs of replacing the lost capacity with alternative types of generating resources can be valued using an electricity sector model[79] or, more simply, determining the amount of production that is lost and then calculating the cost difference between the lost hydro capacity and the next best (lowest cost) alternative.
Flood damage	Valuing these losses and the benefits and costs of protection measures requires detailed hydrological and historical damage data from past floods, to translate peak discharges at flooded locations into flood stage levels. Then flood stages must be translated into physical damage and finally physical damage must be translated into economic damage across the entire spectrum of flood frequencies.
Loss of ecosystem services	Ecosystem services can be valued by estimating the likely damage that would be caused if the pollutants were not removed by the ecosystem. The likely climate change economic impact is the increase in damage that is caused if future ecosystem destruction leads to more pollution. This can also be measured by estimating the cost of removing those pollutants by waste treatment. Other services, such as wood production and hunting values can also be valued by estimating the likely impact of climate change on the resources of the ecosystem and translating that into monetary terms – including endangered species.
Long-term impacts on availability and cost of ground water	In an extreme case, long-term reductions in supply may lead to groundwater recharge being less than the amount taken out (groundwater mining). This problem can only be solved by reducing the amount of water taken out. To analyse this, it would be necessary to develop a multi-sectoral economic model of water use in concert with a three-dimensional groundwater model, to find the optimal level of groundwater extraction and the long-term economic losses to households and industries associated with reduced water consumption and higher water prices. [80]
Drinking water quality	The economic losses due to reduced drinking water quality can be approximated by assuming that current water quality standards will be maintained and calculating the additional cost of water purification and waste treatment to maintain that standard.[81] The benefits of improving water quality can be estimated by asking people how much they are willing to pay for improvements (or to avoid a situation where the quality becomes worse).[82]

7.7.2. Resource availability for adaptation and adaptation studies and the role of institutions and decision-making authorities

Croatian authorities have not yet taken climate change into account when planning the management of their water resources. Croatia's current efforts in the water sector are mostly focused on aligning the national legislation with that of the EU. This task absorbs nearly all available institutional capacity and human resources. Croatian water legislation is partially harmonised with the EU WFD and further harmonisation is envisaged.[83] Croatia's policy mechanisms for addressing climate change and water are still unrealized. The only official documents dealing with this issue are the National Communications under the UNFCCC.[84] These documents emphasize that possible changes in surface and groundwater regimes (inflow) should be taken into account when planning water management work, such as the construction of multi-purpose channels, irrigation systems, or hydroelectric power plants.

Although official documents stress that water will become the most important strategic resource in the future,[85] the authorities, scientists, water managers and water users do not seem to be considering the consequences of climate change on water resources in their future planning. The Water Management Strategy is the fundamental and long-term strategic water management document for Croatia. It calls for the establishment of a holistic water management policy and an integrated/ coordinated approach to improving the water system, in line with international commitments.[86] It also defines strategic goals, establishes current/future needs and services, and identifies how these might be met through management plans for the four river basins in the country.[87] However, it does not deal with any aspect of climate change, its impact on water resources, water vulnerability to climate change, adaptation measures, etc.

In building capacities in the water sector, Croatia relies heavily on projects funded by the EU and World Bank. These projects are primarily oriented towards improving water quality standards, improving monitoring systems, for consistency with EU norms, harmonising legislation and information systems with the EU, and investing in infrastructure projects such as waste water treatment plants, water supply, and sewage systems.[88] However, none of the EU-funded projects in the water sector seems to have addressed the issue of climate change.

The EU WFD is the regulatory document governing the water sector in the EU. It is complemented by the new Flood Directive (FD), adopted in 2007. By establishing a framework for water management and policy, based on integrated river basin management, the WFD aims to achieve the "good" status for all European waters by 2015. However, climate change impacts on freshwater resources have received little attention in the WFD. This has been the subject of criticism.[89] The WFD is potentially a powerful implementation tool for climate change adaptation policy. Its integrated river basin approach encourages strategic planning and water resources management that incorporates sustainable supply-side and demand-side management, drought measures, flood protection, water quality issues and the environmental health of the basin. While the WFD does not explicitly mention that climate change impacts need to be recognised, the approach of the WFD will serve as an important adaptation tool.[90] See Box 7-4 for further information.

In managing the impact on energy production, HEP representatives are already well aware that drought

Box 7-3: Public institutions involved in water management in Croatia

There are a number of institutions involved in the monitoring and regulation of water issues . Croatian Waters (CW) is responsible for the preparation of the Water Management Strategy, drafting river basin district plans, as well as the preparation and implementation of water management plans. CW also initiates and supervises projects, studies and investment programmes related to various aspects of water management. It regulates watercourses and other water bodies, manages irrigation and drainage systems, provides sufficient water quantities for different uses, monitors and safeguards overall water quality and protects people and assets from the damages caused by water. Finally, CW supervises the implementation of the water rights acts, concession agreements and the construction of water works. The organisation covers the whole country through its five regional water management offices, managing 32 catchment areas and collects water-related charges, which make up its primary revenue. CW submits yearly plans for approval to the Ministry of Regional Development, Forestry and Water Management (MRDFWM).

The Croatian Parliament adopts all relevant water-related legislation and water-related national strategies. It has a committee dealing with water, which issues opinions on specific acts and documents. The Government adopts the river basin district management plans and proposes relevant legislation and strategies to the Parliament.

The MRDFWM is the central Croatian authority dealing with administrative and regulatory tasks related to water management. This means monitoring and adapting water management to the needs of economic development: the regulation of watercourses; protection from flooding and erosion; land drainage and irrigation; protection of water resources; the use of hydropower; and the development and construction of the national public water supply and sewerage systems.

The MEPPPC is the central Government body responsible for the overall policy and the administrative tasks regarding environmental protection. It also co-ordinates all of Croatia's climate change efforts, including Croatia's international activities related to climate change. However, the MEPPPC's involvement in water protection policy is limited and is primarily focused on the protection of water resources in nature-protected areas and participation in some inter-ministerial committees. The MEPPPC takes part in various national steering committees, task forces and expert panels on water. It cooperates closely with MRDFWM, CW and other water-related organisations. However, it appears that this co-operation has yet to include climate change and water.

Box 7-4: The Water Framework Directive (WFD)

The approach of the WFD encompasses the following steps and actions:

1. Comprehensive stocktaking and monitoring;
2. Defining a target level of environmental status,
3. Identifying the necessary measures to improve the environmental status of waters in a comprehensive, multi-year plan, taking into account and integrating all environmental stresses, taking an ecosystem approach,
4. Planning long term, and repeating this planning cycle in 5-6 years in order to reflect developments.

Because the time scale for WFD implementation extends into the 2020s, it is apparent that Member States should take climate change into account in their water policies. It is unlikely that the first River Basin Management Plans (2009-2015) will address adaptation to climate change. However, the on-going discussions in the EU give a clear signal that specific adaptation measures will be included in the second River Basin Management Plan cycle (2015-2021). Some countries have already taken the first steps in this direction. Some activities related to climate change are envisaged under the EU-wide Common Implementation Strategy (CIS).

Croatia is fully committed to following the common European approach and methodology when implementing the WFD and the FD. In this respect, the main risks from climate change in Croatia should be taken into account in the context of meeting the WFD's objectives in the second planning cycle. This would mean examining the potential risks of climate change to key phases of the river basin management process that supports the WFD. Consideration of climate change impacts at an early stage might help the selection of the most effective measures to be included in the second River Basin Management Plans (due for 2015). This work may be well suited to form part of the on-going, EU-funded project *"Implementation of the EU Water Framework Directive in Croatia."*

and runoff impact the system and the economic situation. However, since no decisive study has yet been undertaken on the likely impacts of climate change, potential impacts have not been included into future energy planning scenarios. Carrying out a study looking at the likely impacts of climate on energy production seems to be another logical step in analysing the impacts of climate change related to water.

7.7.3. Analysis of available options for adaptation

Unless the global community drastically reduces its emissions of greenhouse gases in the next few years, climate change will probably have numerous impacts in Croatia, especially near the end of the 21st century and beyond. However, looking forward twenty to thirty years, the possible impacts may be as follows:

- Loss of hydroelectric generation capacity;
- Increased flood damage;
- Loss of some ecosystem services;
- Reduction in the availability of groundwater (unlikely); and
- Reduced drinking water quality (unlikely).

In each of these cases, climate change would lead to economic and social losses. Adaptation will always involve some changes in how water resources are managed and used by the public and private sector. In some cases, changes will be made through investments in infrastructure and existing or new technologies related to the storage, conveyance or use of water. In most cases, options for adapting to climate change already exist and are commonly implemented to respond to climate variability and other climate shocks. The rest of this section briefly outlines the most important alternatives for avoiding climate change damages.

Adaptation to loss of hydroelectric production

There are two broad alternatives for adapting to losses in hydroelectric generation capacity:

- Increase retail electricity prices to the point where the reduction in consumption, as a result of the price increases, matches the average electricity loss. The result of this policy would be to induce electricity users to conserve electricity by whatever means they find most cost-effective. There are, however, two problems with this approach. First, if the consumption of electricity is not very price-responsive (and it often is not), then prices may have to increase by a great deal to reduce consumption by a small amount. The second problem is related to vulnerable groups within the population. In 2006, 20% of Croatian households surveyed reported difficulties in paying their utility bills on time.[92] The poorest people are the least likely/able to change behaviour based on electricity price and are hurt most by this approach. This impact can be softened by subsidy programmes for the urban poor and by electricity conservation programmes to encourage more rapid adoption of using electricity-saving appliances and energy efficient building practices. New pricing schemes have already been introduced encouraging households that consume more energy to reduce consumption – especially at peak times.
- The second adaptation option for addressing losses in hydroelectric generation capacity is to replace some amount of the lost capacity with imported electricity or with new generating capacity from other energy sources, such as renewable energy (including building new hydroelectric dams), fossil fuels and nuclear energy.

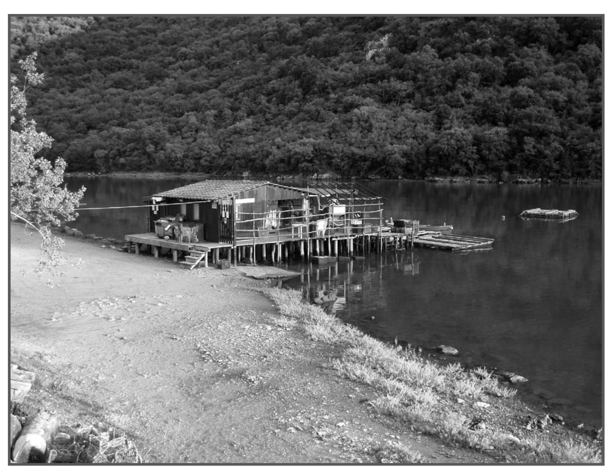
Adaptation to flooding

There are two broad approaches to flood damage reduction:

- Protective structures (protecting human activity from floods). The traditional approach to flood protection has been to protect highly valued property (such as population centres and buildings) from floods and allow damage to occur on low value land (such as agricultural land). This approach has not changed in thousands of years, but has become expensive. It can also be counter-productive, because once a flood plain is protected, it tends to attract more highly valued land uses. The land then becomes vulnerable to very large floods that are too costly to protect against anyway. These two factors have led to an increasing reliance in developed countries on the second broad approach.
- Non-structural measures (protecting flood prone areas from human activities – e.g. flood plain zoning measures). These measures either restrict settlement on flood plains or impose economic disincentives on activities that move onto flood plains - such as denial of insurance or requirements to flood-proof structures. These measures are effective against seasonal flooding but not always against flash flooding, caused by sudden intense storms that can threaten households in suburban or rural areas or campers, hikers, etc. In these situations, flood-warning systems that include sirens and wide dissemination by public broadcast media have helped to reduce the loss of human life in many countries.

While Croatia currently has numerous flood protection systems and is working to improve them, climate change may push these systems to the limit – especially in coastal areas that will have to deal with sea-level rise (see Chapter 5).

Figure 7-8: A small oyster farm on the coast in Lim channel



Source: Damir Vejzović

Adaptation to loss of ecosystem services

It is difficult to recover from the loss of many ecosystem services when the environmental "infrastructure" and the natural systems in it are very fragile. Thus, many ecosystems impacts are regarded as irreversible or nearly so. This is especially the case if there is a loss of biodiversity. On the other hand, some ecosystem losses are reversible in some situations. This applies in particular to wetlands that are susceptible to drainage due to agricultural encroachment or if the runoff areas have been adversely affected by human disturbances, such as logging. In these cases, human activity can be curtailed to prevent drainage for human use or to prevent logging and other disturbances, which influence runoff into the wetlands. However, in many cases the lost wetland services can only be replaced by human actions. In the case of lost waste assimilation capacity, the damages can be alleviated by treating the water (for example waste-water treatment). In general, projects to replace ecosystem values have to be evaluated on a case-by-case basis and some ecosystem services cannot be replaced by any adaptation measures.

Adapting to reduced groundwater availability

As already mentioned, the water loss in the Croatian public drinking water supply of 40-46% is exceptionally high. The EU's maximum acceptable water loss in a public water supply is 18%.[93] While seemingly unlikely, decreases in the water table may pose a risk to future water supplies. Adapting to the reduced availability of groundwater can take several forms.

- As the supply of water in some types of aquifers falls, the cost of access increases. Water can be pumped from greater depths or it can be pumped and transported longer distances as underground reservoirs dry up – or both. This means that the cost of supplying water will rise and, if consumers are charged for these costs, water prices will rise. As a result, consumers may cut back their consumption – a form of autonomous adaptation.
- In cases where Croatian water utilities experience large water losses due to water leakages, the increased pumping and distribution costs can provide an incentive to act to reduce these losses, another form of autonomous adaptation.
- If Croatian decision-makers choose not to price water because of economic efficiency principles – for example for reasons of equity or protecting vulnerable populations – governments can provide incentives to consumers and water utilities to engage in water conservation programmes.
- In addition, the authorities can improve the management of groundwater recharge areas to reduce water loss due to plant evapotranspiration.
- They can also regulate groundwater mining by imposing pumping restrictions.
- Finally, it is possible to find substitute sources of freshwater supplies and store this in above-ground or groundwater reservoirs. However, this is a very expensive adaptation measure.

Adaptation to reduced drinking water quality

Because most drinking water comes from groundwater in Croatia, it does not appear likely that its quality will be compromised in the near future due to climate change. If this does occur, there are only two ways to improve drinking water quality.

- Add more chemicals to the water being delivered to consumers.
- Clean the water that is discharged into the surface or groundwater reservoirs from which drinking water is pumped. This water treatment further reduces the volume and kinds of chemicals that have to be used to purify water.

In Croatia, as in most developed countries, point source pollution from existing industrial sources is declining and can be expected to reach a level close to zero within ten or twenty years. Meanwhile, non-point source pollution from agriculture is on the rise. The most toxic contaminants from non-point source pollution are pesticides and older herbicides. There is also substantial groundwater contamination from historical industrial pollutants, including highly toxic heavy metals and solvents. Except for some urban concentrations of these pollutants, the distribution of these pollutants is largely unmapped. Croatia is currently taking important steps to reduce water pollution and is expected to continue to do so in the future.

The EU accession process will also necessitate the introduction of further water quality improvements. Additional improvements to adapt to climate change would be limited and very costly, involving wastewater treatment such as filtration and nutrient removal. This may not be cost-effective. Should drinking water quality become a problem, it is likely that increased water purification by utilities will be the primary option available for adapting to climate change. As the Croatian economy develops further, water purification capacity will increase. Additional capacity to purify drinking water will probably be most pressing where water is drawn from alluvial sources (e.g. from rivers and streams) and not karst formations, due to the much higher flow rates and oxygenation in karst formations.

7.8. Conclusions and recommendations

Climate change will have potentially significant impacts on the water cycle in Croatia. These could include increased droughts affecting agriculture and natural environments – especially wetlands. It will probably result in decreased river flows, and perhaps even lower levels of the groundwater that is used for drinking. While sufficient information is not available to plan adaptation projects, there are a number of steps that can and should be taken.

First, authorities that are developing water management plans should incorporate the possible impacts of climate change into their planning. This may require the further development of specific information – such as developing and incorporating regional climate models into planning for flood protection, groundwater recharge, and river flows.

HEP and the MELE should also include climate change impacts into projections of energy needs and supplies in Croatia beyond 2020. As such, it would be helpful to initiate research on the probable impact of reduced inflow on hydropower-generated electricity. The initial analysis of this Report shows that the projected impacts may result in a loss of EUR 16-82 million per year in direct losses, with multiplier effects throughout the economy. HEP should also consider research into alternative strategies for electricity production that could cushion the impacts of a potential reduction in the electricity generated by hydropower.

In addition, more research should be carried out to look at likely climate change impacts on wetlands and their economic services. The value of these services is estimated at more than EUR 238 million per year, and they may be at risk. Similar research should be carried out regarding flood risks and any adaptation that may be necessary.

The above-mentioned research could also be implemented in co-operation with research institutes in other countries such as the EU-funded Seven Framework Programme. Alternatively, the MEPPPC might work with the Ministry of Science, Education and Sports (MSES) to fund more research projects on water and climate change.

Finally, it is strongly recommended that Croatian authorities urgently undertake appropriate measures to improve the existing infrastructure, management, and supervision of the public water supply. The current loss of EUR 286 million per year and 267 million cubic metres is immense and may lead to problems if water resources become scarcer.