Report [31/12/2001]

Heavily Modified Waters in Europe

Case Study on the Beiarelva watercourse

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1 Preface

[insert the standard preface - drafted by the project managers - briefly explaining the European project on heavily modified water bodies as the context for the individual case study. This should explain the context to readers of the case study, who may not be familiar with the European project.]

2 Summary Table

	Item	Unit	Information
1.	Country	text	Norway
2.	Name of the case study (name of water body)	text	Beiarelva watercourse
3.	Steering Committee member(s) responsible for the case study	text	Tor Simon Pedersen
4.	Institution funding the case study	text	Norwegian Water Resources and Energy Directorate
5.	Institution carrying out the case study	text	Statkraft Grøner AS, NTNU, Museum of Natural History and Archaeology, Dept. of Natural History
6.	Start of the work on the case study	Date	01.04.2001
7.	Description of pressures & impacts expected by	Date	20.06.2001
8.	Estimated date for final results	Date	30.11.2001
9.	Type of Water (river, lake, AWB, freshwater)	text	River
10.	Catchment area	km^2	766 (859 natural)
11.	Length/Size	km/ km^2	50
12.	Mean discharge	m^3/s	39,5
13.	Population in catchment	number	1350
14.	Population density	Inh./km^2	1.1

15.	Modifications: Physical Pressures / Agricultural influences	text	Hydropower development, rotenone treatment of salmon parasite 1994
16.	Impacts?	text	Reduced water flow, and thereby also reduced water cover. Gradually recovering towards the sea due to contribution form the tributaries. Changes in composition of anadromous fish.
17.	Problems?	text	Reduced invertebrate production in certain areas. Atlantic salmon heavily affected after 1981-82.
18.	Environmental Pressures?	text	Salmon parasite infestation *(Gyrodactylus salaris)* 1981-82
19.	What actions/alterations are planned?	text	None regarding hydropower development. Treatment against salmon parasite already carried out.
20.	Additional Information	text	Autumn 2001: The watercourse is again “healthy”, parasite declared eradicated
21.	What information / data is available?	text	Data available on most relevant subjects, but lack of information after regulation makes a comparison with pre-regulation condition more difficult
22.	What type of sub-group would you find helpful?	text	
23.	Additional Comments	text	

3 Introduction

3.1 Choice of Case Study

The history of hydropower in Norway is very much the history of the industrialisation and development of the country over the last hundred years. Until recently Norway has been self-sufficient with respect to electricity, but is now in the situation of importing this commodity. A possible change in the water management regime through the WFD could have an impact on this situation. Consequently both the Norwegian cases chosen for HMWB represent the sub-group hydropower.

Hydropower is the without comparison the most important source to electricity in Norway. About 99,7 % of the production comes from hydropower. Of a total economically available potential of 187 TWh, 118 TWh is developed (2000). About 36,5 TWh is within protected areas and is not developed. The rest consists of minor watercourses with a more limited economical potential and attempts to develop some of these has lead to strong conflicts between regulators and environmentalists and other stakeholders.

The river Beiarelva and the encroachments present here is of a kind common within modern hydroelectric regulation: The diversion and transfer of water from one catchment to a neighbouring one and a reservoir for production of electricity. This implies a minimum of physical installations in the watercourse, but locally the diversion can bring about serious implications. As such it could be said to be representative for this type of regulations.

The problem comprising introduction of new species has also been present in Beiarelva in the shape of the salmon parasite *Gyrodactylus salaris*, as it is in a number of other rivers in Norway. This also poses a challenge regarding the characterisation of the watercourse and the designation of HMWB.

The magnitude of surveys done on the watercourse and the availability of information is also an important reason for choosing this waterbody.

The contractors performing the study have to a great extent been involved in earlier studies in the watercourse.

The Norwegian Water Resources and Energy Directorate manages the Norwegian participation in HMWB.

3.2 General Remarks

The Beiarelva watercourse (box 1) is located in Nordland County, Northern Norway. The river system is affected by diversion of water from its upper areas (box 2).

The case study is placed in the sub-group Hydropower in the European Project on Heavily Modified Water Bodies.

4 Description of Case Study Area

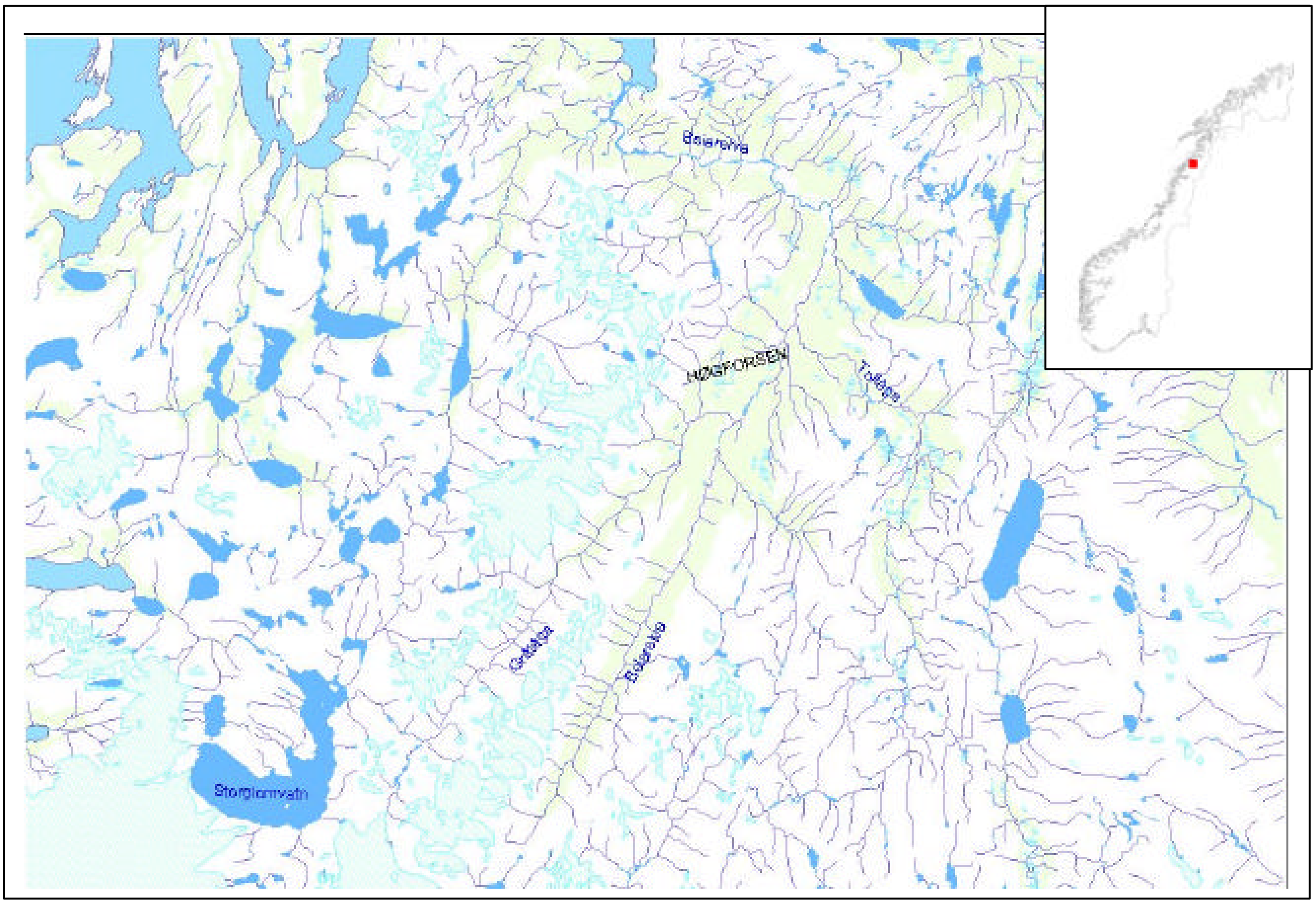
4.1 Geology, Topography and Hydrology

The Beiarelva river system (box 1) has a natural catchment area of 859 km², of which 7 % is covered with glaciers and more than 75 % must be regarded as high-mountain areas. The catchment is located at the eastern margin of the glacier system Svartisen, Norway's second largest plateau-glacier. The catchment reaches to altitudes above 1600 m a.s.l. Today the catchment area is reduced to 766 km², due to diversion of water for hydropower purposes from some of the upper parts of the catchment.

The total length of the main river is approximately 50 km, from its sources to the sea. It has two major tributaries, Tollåga from east with a length of about 30 km and Gråtåga from west with a length of about 20 km, and several smaller tributaries.

The bottom of the valley, along the river, is dominated by fluvial and glacifluvial material. The major part of the catchment consists of volcanic and sedimentary rocks. In some areas with limestone and marble typical karst landforms have been created, such as caves and underground drainage systems.

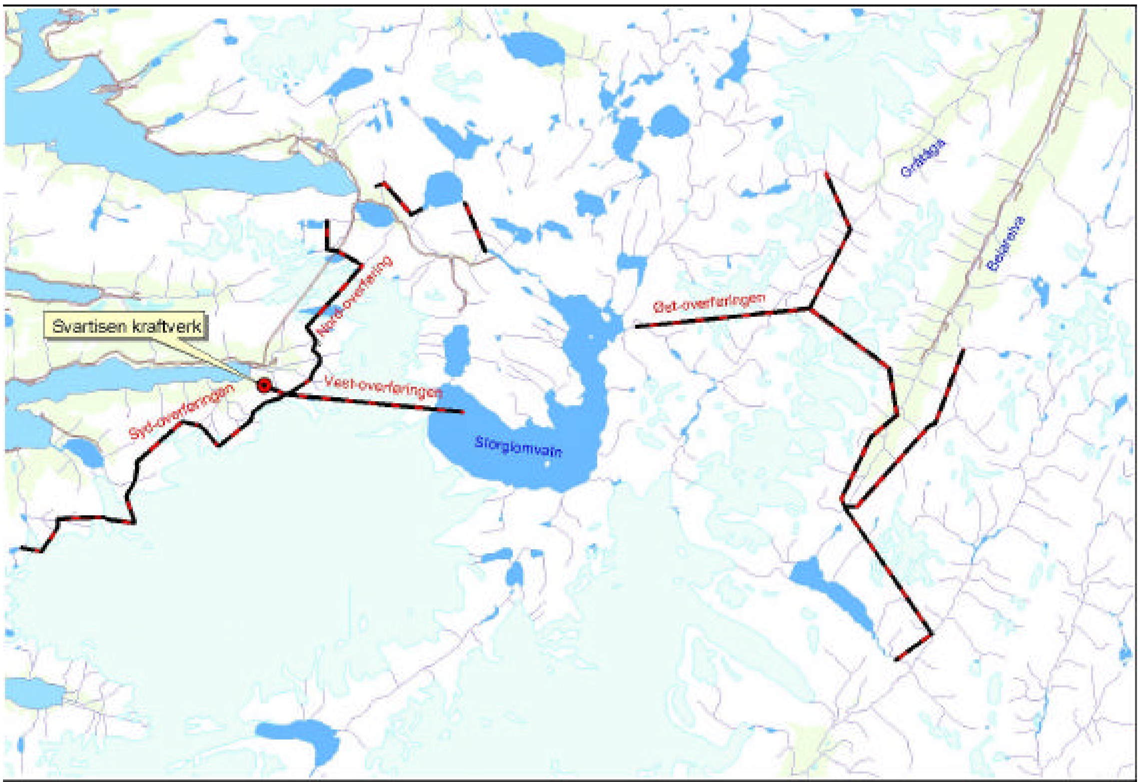
Box 1 The Beiarelva Watercourse



The mean annual precipitation varies within the catchment, from about 1400 mm in the bottom of the valley to much larger values at higher altitudes, and especially on the glaciers. Maximum precipitation normally occurs in October, and minimum in May. The annual mean temperature is about 3 °C, with temperatures below 0 °C in winter, usually with a permanent snow-cover throughout the whole winter. The river is usually ice-covered during the winter.

The flow distribution in the river is influenced by the climate, with the lowest discharges during the winter months November to April and maximum during the melting season ranging from May to August. Because of the glaciers in the catchment the melting season lasts through all summer months. Glacierfed rivers also show a distinct daily variation in the flow, with a maximum in the afternoon, due to daily variations in glacier melt intensity. Mean annual natural flow in Beiarelva, at the outlet into the sea, is 39,5 m³/s.

Box 2 The Upper Parts of Beiarelva and Gråřga are Transferred into the Reservoir Storglomvatn from the Eastern Side.



4.2 Socio-Economic Geography and Human Activities in the Catchment

The Beiarelva watercourse is located within the municipality Beiarn, with a population of approximately 1350, or about 1,1 inh./km². The municipal centre is Moldjord, close to river Beiarelva's outlet into the sea. Farming and forestry are the predominant industries, in addition to a woodworking factory and contracting firms. Tourism is also of great importance to the community. Much of that activity is connected directly or indirectly to the river system.

The anadromous fish species Atlantic salmon, brown trout and arctic char are found in the lowest 20 to 30 km of the river system. Two fish ladders exist in the river, one in the main river and one in the tributary Tollåga. None of these are at present in operation.

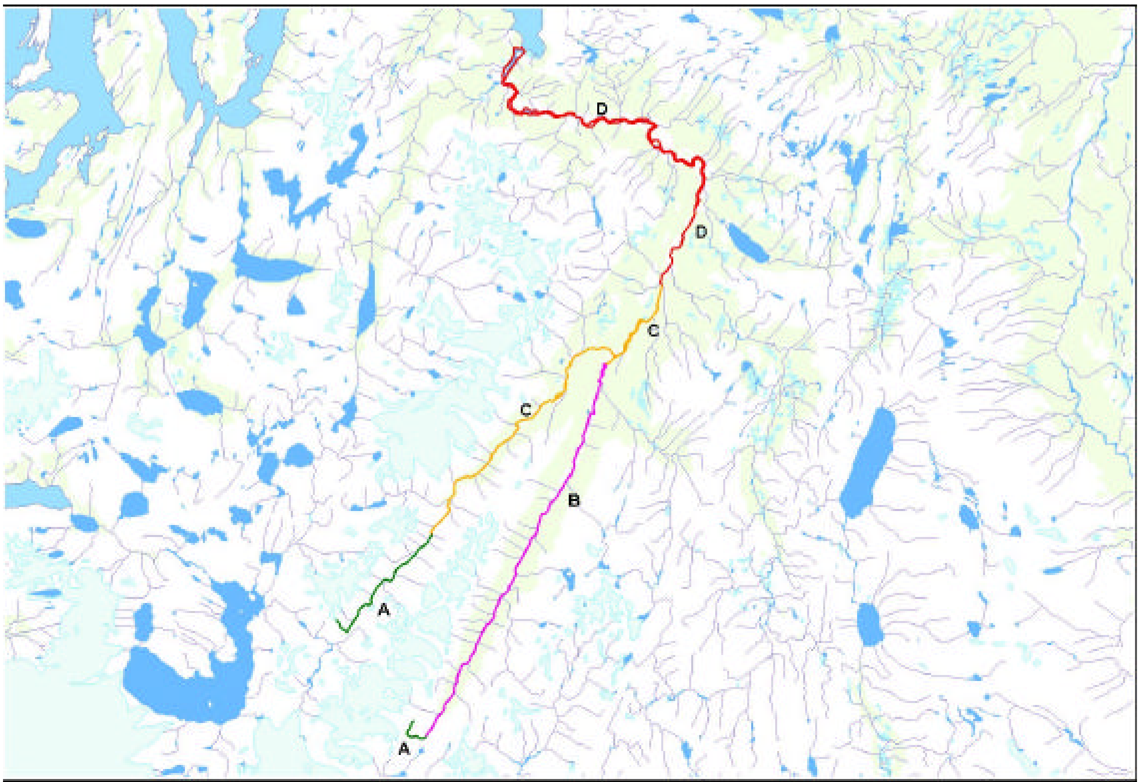
The river is to some extent used by farmers for irrigation and water for animals. At some sections the river feeds the groundwater, and water supply from wells and growth of the crop may depend on the groundwater level.

The watercourse has been influenced by hydropower development since November 1993. Water is diverted from the river system through 11 intakes located in different tributaries at elevations between 600 and 700 m a.s.l. One of the intakes is located in the main river itself. The water is permanently removed from Beiarelva and transferred to the reservoir Storglomvatn, west of Beiarn. Storglomvatn has the largest volume of water of all Norwegian reservoirs. Its water is utilised in Svartisen Hydropower Station located at sea level about 40 km west of Beiarn.

4.3 Identification of Water Bodies

The case study area, the Beiarelva watercourse, can be divided into four water bodies, all in the river category (box 3). Water body A is located in the uppermost part of the watercourse, and consists of the areas upstream the eleven intakes. Water body A is

Box 3 The Four Identified Water Bodies



not affected by hydropower development. Water body B is the upper part of Beiarelva, from the intakes and down to the confluence with the tributary Gråtåga. Water body C consists of Gråtåga from the intakes and down to the confluence with Beiarelva, and Beiarelva down to the waterfall Høgforsen, just upstream the confluence with the tributary Tollåga. The two water bodies B and C are most affected by reduced flow due to diversion of water. In water body B the river has changed from a river dominated by glaciers in the catchment to a river with much less influenced by glaciers. In water body C the influence of glaciers has not been altered in the tributary Gråtåga. Water body D is the part of the river system from Høgforsen to the sea. In the main river this body covers the maximum distance the anadromous fish species can migrate.

The types of water body, according to system A (WFD Annex II 1.2), are shown in table 1. For the water bodies B to D the main pressures are due to hydropower, i.e. the diversion of water from the catchment. The four water bodies constitute the total Beiarelva watercourse, and downstream the water body D is the sea, the fjord Beiarfjorden. This fjord is affected by the reduced flow in the river Beiarelva. Two larger rivers have their outlets into the sea at the same location, Beiarelva and Arstadelva. Arstadelva is also affected by hydropower development, through a dam and diversion of water. At the sea the discharge in Arstadelva today is reduced by more than 50 %.

Table 1 The Water Bodies of Beiarelva Watercourse

	Water body A	Water body B
Ecoregion:	Borealic uplands	Borealic uplands
Type:	High to mid-altitude (ca. 1000 to 600 m a.s.l.)	Mid-altitude to lowland (ca. 600 to 110 m a.s.l.)
	Small catchment (ca. 95 km²)	Medium catchment (ca. 160 km²)
	Mainly volcanic and sedimentary rocks	Mainly volcanic and sedimentary rocks
	Water body C	Water body D
Ecoregion:	Borealic uplands	Borealic uplands
Type:	Mid-altitude to lowland (ca. 600 to 100 m a.s.l.)	Lowland (ca. 100 m a.s.l. to the sea)
	Medium catchment (ca. 140 km²)	Medium catchment (ca. 470 km²)
	Mainly volcanic and sedimentary rocks, with some limestone	Mainly volcanic and sedimentary rocks

4.4 Discussion and Conclusions

The water bodies have been characterised by using “system A” (WFD Annex II 1.2). Being aware of the alternative “system B”, we are and still waiting for a determination or recommendation of which system to make use of for defining Norwegian water bodies.

5 Physical Alterations

5.1 Pressures and Uses

In the river Beiarelva the main pressure is:

- **Hydropower development.**

Other important uses of the river and riverbed, which also may cause significant pressure, are:

- Fishing – e.g. fish ladders
- Recreation, tourism
- Agriculture – e.g. run-off, clear-cutting of riparian forest
- Road construction on or near the riverbed, including bridges
- Sand-pits
- Some flood-retention walls
- Some excavation of gravel from the riverbed

5.2 Physical Alterations

The most important physical alteration is due to the nine river-intakes in the upper part of the main river and its tributaries and the two intakes in the large tributary Gråtåga. The normal situation is that the intakes divert all of the water. In some particular situations, such as during large floods or if the gate in the diversion tunnel is closed, a part, or all, of the discharge will pass by the intakes and contribute to the flow in the Beiarelva river system.

Many of the other physical alterations are not very important compared with hydropower development, but two should be mentioned:

- The two fish ladders built to make new sections of the river available for salmon and trout. The one in the main river, in the waterfall Høgforsen, is damaged and needs severe maintenance and repair before it can be set into operation. The other, and smaller, in the tributary Tollåga is not in operation today, but only minor maintenance is needed.
- Some removal of riparian forest

5.3 Changes in the Hydromorphological Characteristics of the Water Bodies and Assessment of Resulting Impacts

The physical alterations result in several hydromorphological changes especially related to flow conditions, water temperature, river ice conditions and sediment transport.

5.3.1 Flow conditions

Through the eleven intakes in Beiarelva and Gråålåga and their tributaries the water can be permanently diverted from the Beiarelva watercourse. No instructed minimum releases exist. The discharge just downstream the intakes must, in practice, be considered as zero. Steep valley sides dominate the topography. Most of the tributaries are quite small, with short distances from the intakes to the confluence with the main river.

The discharge in the upper part of the river Beiarelva is reduced, on annual basis, with 3,5 m³/s. A catchment area of 46 km² is diverted from the watercourse. From the main tributary Gråålåga another 47 km² with a mean annual discharge of 3,5 m³/s is diverted. These areas have been identified as water body A. The portion of the catchment that is covered by glaciers has been reduced after the diversion. A less portion of melt water from glaciers will cause a change in the annual flow distribution, especially in summer.

Mean annual flows at different locations in the main river and in the tributary Gråålåga are given in table 2. Together with the flow values the percentage glacier cover for each catchment area is given. Both mean flows and glacier covers are shown for both natural and regulated conditions, with about 7 m³/s diverted from the river system.

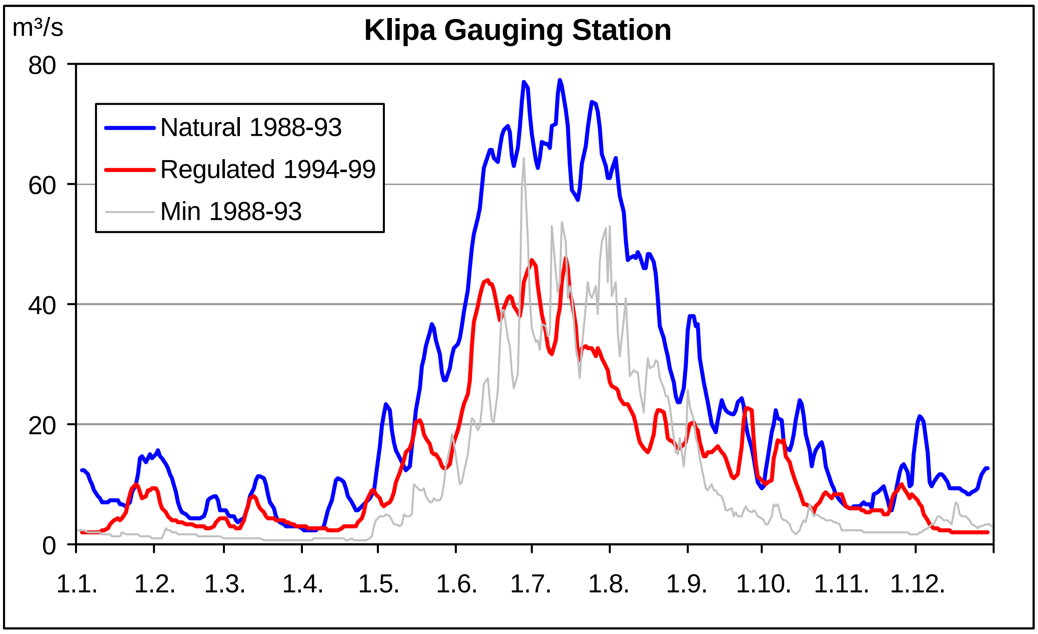
Table 2 Mean Annual Flows in the Beiarelva River System

	Natural		Regulated		
	Percentage Glacier-cover	Annual Mean Flow (m³/s)	Percentage Glacier-cover	Annual Mean Flow (m³/s)	Water Body
Beiarelva after Staupåga	25	4,9	9	1,4	B
Gråålåga before Beiarelva	20	9,1	19	5,6	C
Beiarelva after Gråålåga	15	19,4	10	12,4	C
Beiarelva after Tollåga	8	29,7	4	22,7	D
Beiarelva at the sea	7	39,5	4	32,5	D

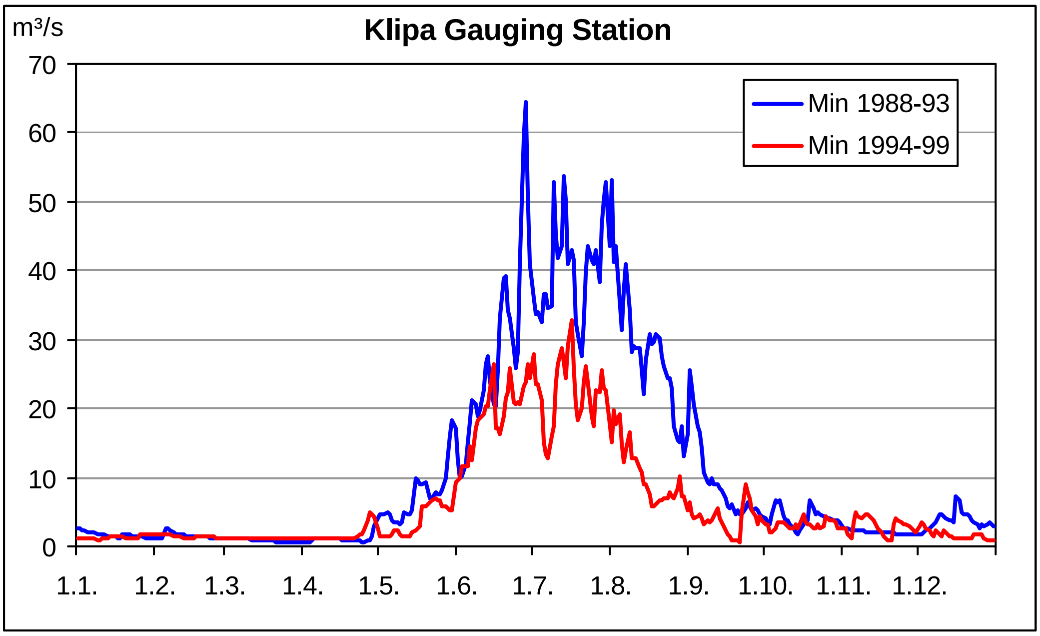
Two gauging stations are in operation in the river. One, named Klipa, is located approximately at the boundary between the water bodies C and D. The other, named Selfors, is located in the lower part of the river about 6 km from the sea.

Klipa has been in operation since 1988. 5-days moving averages of daily mean flows, from the periods before and after the diversion of water, are shown in the diagram in box 4. Together with the mean values daily minimum flows from the period with natural conditions are shown. In box 5 minimum of daily mean flows from both periods are compared.

Box 4 5-days Moving Averages of Daily Mean Flow at Klipa



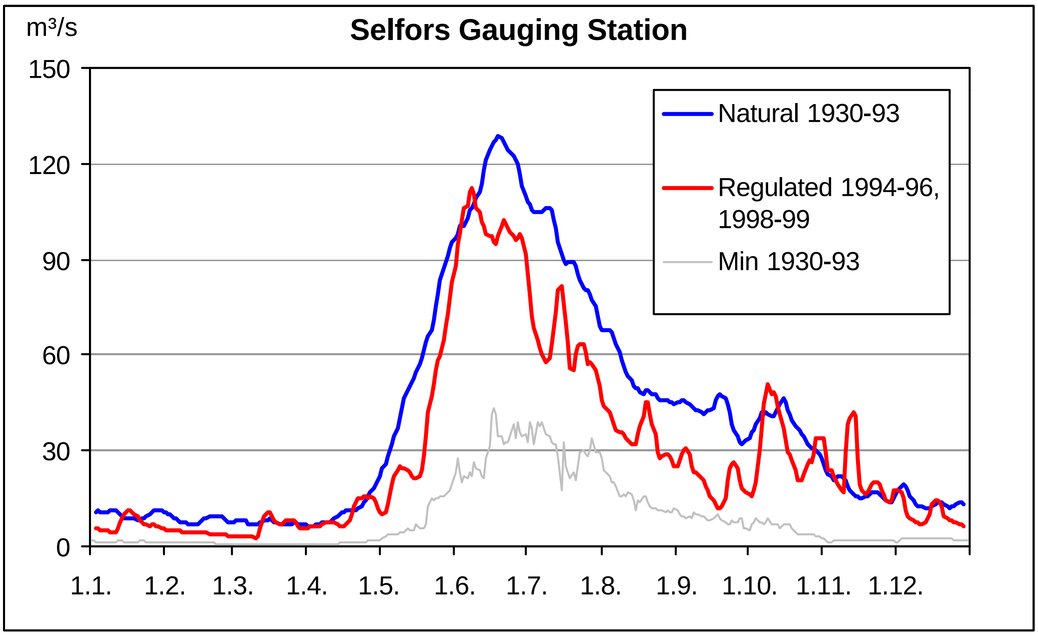
Box 5 **Minimum of Daily Mean Flows at Klipa**



Especially the discharges in the months May to September are significantly reduced after 1994. The diagram in box 4 shows that mean flows after 1994 in July and August are less than daily minimum flows from the years 1988 to 1993. In box 5 the diagram shows that during winter, from October to April, the minimum flows do not seem to have been reduced. Again, the effects of the diversion of water can be seen in the spring and summer months.

The Selfors gauging station has been in operation since the beginning of the last century. The diagram in box 6 gives 5-days moving averages of daily mean flows, from the periods before and after the diversion of water. Due to a severe ice run early in 1997 the gauging station was damaged. A new station has been put up on, and has been operating since June 1998. The diagram shows reduced flows in the months May to September, but only small differences in the winter months, well in accordance with the registrations at Klipa gauging station. The quite high flow in early June, and also the smaller peaks in October and November, for the situation after the diversion of water, is merely a consequence of only 4½ years with observations after diversion compared with more than sixty years of observations for the natural situation.

Box 6 5-days Moving Averages of Daily Mean Flow at Selfors

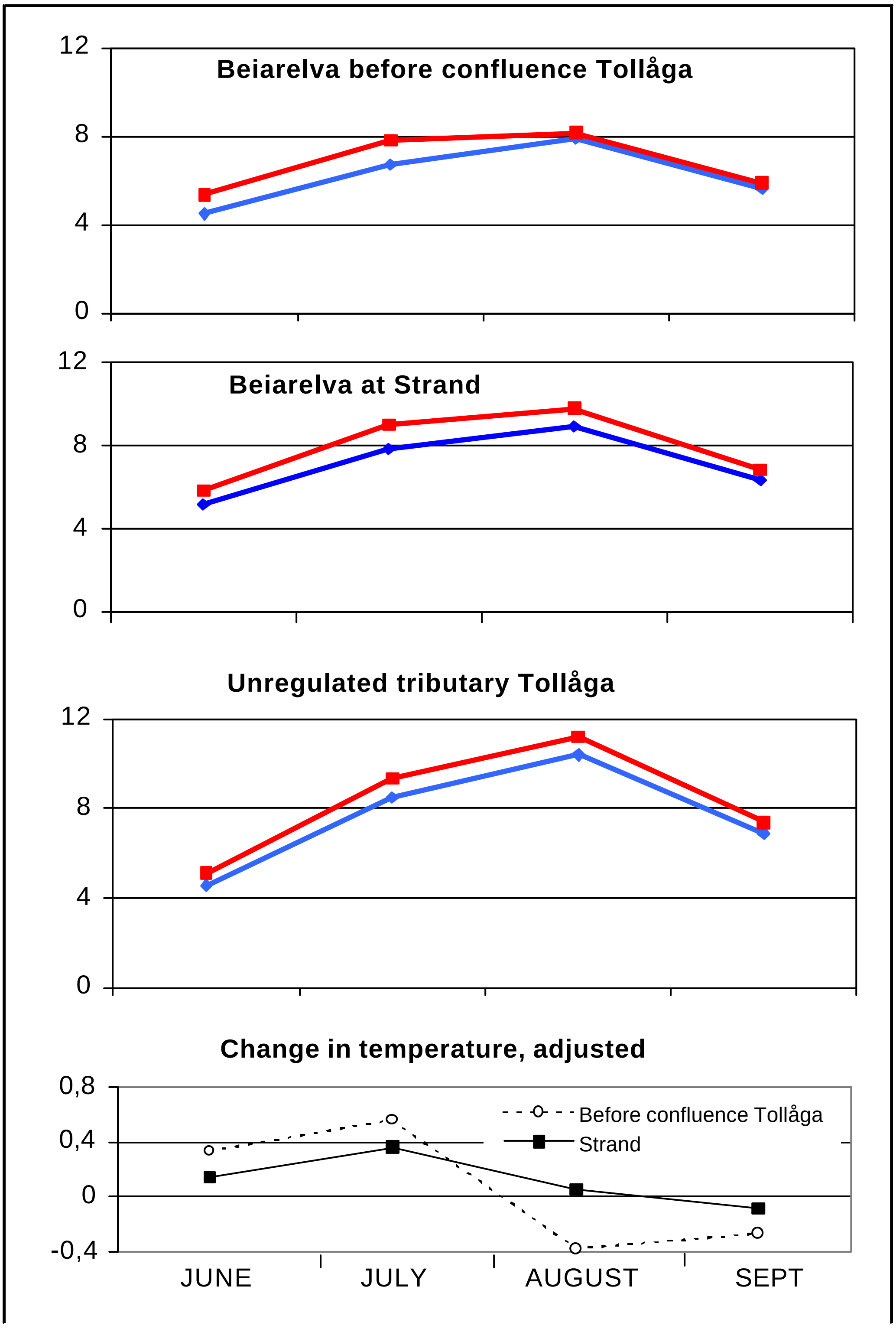


5.3.2 Water temperature

Water temperature has been measured in the tributary Tollåga and at two locations in Beiarelva, one just before the confluence with Tollåga, i.e. close to the boundary between the two water bodies in this case study, and one at Strand, close to Selfors gauging station. The registrations have not been taken in the months where ice can be present in the river, from October to May.

The diagram in box 7 shows that the period 1994-1999 had a slightly higher summer temperature than the period 1988-1993. But an increased temperature after regulation was also measured in the unregulated Tollåga. The reduced flow in the main river

Box 7 **Water Temperature (in °C) in Beiarelva before (blue) and after (red) the Regulation. (Data from Tvede 2000)**



seems thus to have had little impact on the temperatures. A minor increase can be seen in June and July, and a minor decrease in August and September, but as an average there is hardly any difference in Beiarelva if adjusted for the data from the uregulated tributary.

The main river Beiarelva, and the tributaries with glaciers within their catchments, are quite cold in summer. Monthly mean temperatures seldom exceed 9 °C before the confluence with Tollåga and 10 °C at Strand. However, in the tributary Tollåga, with no glaciers within its catchment, the mean temperature in August may reach 13 °C.

5.3.3 River ice

The reduced flow, and thus reduced water velocities, may have caused some increase in the length of the periods with permanent ice cover in the river, mainly in the upper parts of the river system. No negative impacts due to this have been reported.

The river Beiarelva often experiences severe ice runs. Reduced flow in the upper parts of the river system, in both Beiarelva and Gråtåga, has probably reduced the ice production during the winter. There is no significant change in occurrence of ice runs due to high elevation of river intakes (Pytte Asvall, pers. comm.).

5.3.4 Sediment transport

Transport of both suspended materials and bed load have been measured at Klipa gauging station, approximately at the boundary between the water bodies C and D. The measurements started in 1989.

After the diversion of water in 1993 the transport of suspended materials has gone through considerable changes. The yearly total load has, on average, been reduced to less than 50 %. However, the daily maximum concentrations seem to have increased after 1994. These maximum concentrations occurred during situations with more or less natural flow in the river and no, or very little, water diverted. In such situations an extra amount of sediments has been brought into the main river either as sediments from the tunnel system or as sediments from extra erosion in the tributaries just downstream the intakes.

One believes reduced flow, and especially reduced flood peaks, have caused accumulation of sediments, mainly in the upper parts of the river system. The river's transport capacity has been reduced. So far this has not been quantified, but cross sections are to be taken at five years intervals to monitor changes.

It is expected that the reduced sediment transport will cause future changes in the delta where Beiarelva runs into the sea.

5.4 Discussion and Conclusions

The problem of comparing the average of three years with observations over many years is already mentioned. In general there is a problem of having only a few years of observations both for water flow and temperature data. The average values may easily be altered by an extension of the data basis. However, by now we have presented the best available data.

Somebody may wonder why the water temperature has not increased more after diversion of water from a catchment covered by glaciers. There is, however, still a certain glacier cover, and the glaciers closest to the measuring stations are still contributing to the cold water of the main river. It is mainly water from the glaciers in water body A, most far away from the measuring stations, that has been diverted. A measuring station in water body B (further upstream than the existing ones) would probably have shown an increase in water temperature. And, as for the water flow data, the average water temperature may be changed when more years are added to the series.

6 Ecological Status

Since 1975 an extensive work has taken place in the Beiar watercourse, with leading Norwegian research institutions participating. The work started to document and assess impacts of planned hydroelectric schemes, and to study the growth and adaptation of juvenile Atlantic salmon and migratory brown trout under cold conditions. In addition there has been a monitoring programme of the infestation of the salmon parasite *Gyrodactylus salaris* as well as its attempted eradication through rotenone treatment.

A feature of the studies carried out in this watercourse is that there is a good documentation of the situation before the water was diverted in 1993. But there has been a rather scarce investigation to prove the impacts.

6.1 Biological Quality Elements

6.1.1 The salmon parasite *Gyrodactylus salaris*

More than 40 Norwegian rivers have been infested by the salmon parasite *Gyrodactylus salaris* since 1975. This parasite was found in Beiarelva's tributary Store Gjeddåga for the first time in 1981, and by 1982 it was spread to the rest of the watercourse. Jensen & Johnsen (1991) included Beiarelva as a case when describing the *Gyrodactylus* story of Norway, concluding that the populations of salmon parr had been severely reduced in infected rivers. Johnsen et al. (1999) presented the status of the salmon parasite both in Beiarelva and in Norway in general. The environmental department at the County Governor's Office in Nordland planned to eradicate the parasite by means of rotenone treatment (Stensli 1992). Use of rotenone means killing the juvenile fish and invertebrates. The plan was accepted, and in 1994 Beiarelva (the part which is within this study's water body D) and tributaries were treated (Stensli 1995), and a monitoring programme started (Sæter 1995). Several hundred juvenile fish have been examined during the following years, and late 2001 the watercourse was declared free from *Gyrodactylus* infestation by the County Veterinary Officer, who has the authority to decide when the river may be considered "healthy".

The infestation and the treatment of the parasite have hampered the possibility of monitoring the impact of the water abstracted since 1993. The anadromous fish have long life cycles, and it takes several years to return to a normal situation. The invertebrate community recovers normally within a few months. There might even be an indirect impact on the water vegetation, as feeding by invertebrates would be reduced for a period (Hessen et al. 1993).

6.1.2 Macrophytes and Phytobenthos

The water vegetation in Beiarelva was studied in the period 1990-1992 within the water bodies B and D, confirming the biological effects of cold water and a high quantity of particles. Green algae, normally forming an important component in Norwegian rivers, were scarcely represented, due to the little resistance to scouring by the transported particles (Hessen et al. 1993). Blue-green algae and diatoms dominated, and the species composition reflected a high content of electrolytes, and was characterised by cold water species typical in fast flowing rivers (Hessen et al. 1993). Among blue-green algae species covering stones, like *Chamaesipon fuscus* and *Homoeotrix* cf. *varians* dominated. Characteristics of the diatom community of Beiarelva was that *Tabellaria flocculosa*, though quite common in Norway, was hardly observed, and *Gomphonema olivaceum*, normally appearing in scarce quantities, could dominate at a couple of localities in the upper part of the study area (within water body B) (Hessen et al. 1993).

A slight influence of pollution was detected at the lower stations, but in general the algae community seemed little influenced by nutrients, confirming that the high phosphorous content, detected in the chemical analysis, hardly is biologically available. A station in the tributary Tollåga showed a higher species diversity than the stations in the main river, clearly illustrating the glacier impact of Beiarelva (Hessen et al. 1993).

Compared to algae the mosses resist more scouring from particle transport in the river. The water mosses had a scarce distribution in Beiarelva, with *Hygrohypnum ochraceum* and *H. alpinum* as the most important ones, both rather resistant to river currents and relatively common in Norway. The limited penetration of light might limit the growth of mosses in Beiarelva (Hessen et al. 1993).

Hessen et al. (1993) assessed the impact of the forthcoming abstraction of water from the upper parts of the catchment, predicting an increased growth due to reduced transport of glacier water and ooze, more light penetrating the river and a lower and more stable water flow. This increased growth of algae, mosses and other plants would again favour the invertebrate and fish production. The overall conclusion was, however, that the planned change in the river would not cause any comprehensive impact of the botanical conditions of Beiarelva. A study to monitor the development of the vegetation was suggested to be carried out about 2005 as any alteration is rather slow in such a cold river (Hessen et al. 1993).

6.1.3 Macroinvertebrates

The bottom fauna was examined in the Beiar watercourse in 1975-1976 and 1989-1992, and a new study has just started. In 1975-1976 samples were taken from 46 stations.

The major tributary Tollåga had the highest invertebrate density. But Beiarelva also had a relatively high density, on the average three to four times more than in the other examined watercourses in the Saltfjell/Svartisen area (Koksvik 1978, 1979). Differences consist mainly of the occurrence of mayfly larvae, but also other insect groups were considerably more numerous in Beiarelva and Tollåga.

The composition of invertebrates in Beiarelva between stations was compared in 1989-1992, and chironomid larvae dominated completely within water body B. Chironomid larvae and mayfly larvae changed in being the dominating group in water body D (Jensen et al. 1993). The total densities differed mainly between 300 and 800 individuals per m² within both water bodies. Both the highest and the lowest densities were measured at the lower stations, in June and October respectively (Jensen et al. 1993).

Eight species of mayfly larvae were found in water body D, of which two lacked further upstream. *Baëtis rhodani* was the most numerous one. Seven species of stonefly were found in both parts of the river, two more only in the lower part and two other species, but different ones, were observed only within the upper part of the river. *Diura nanseni* dominated strongly in water body D from April to September and *Brachyptera risi* in water body B. These two species had very strongly significant differences in density between the stations of the two water bodies (Jensen et al. 1993).

One station in Beiarelva within water body C was studied in 1975 and 1976, and mayfly and chironomid larvae dominated in the samples. In Gråtåga, also within water body C, stonefly and chironomid larvae dominated the bottom fauna (Koksvik 1978).

The tributaries of Beiarelva, with the exception of Tollåga, had a lower density of mayflies than the main river. A characteristic of Tollåga is the presence of the mayfly *Baëtis lapponicus,* hardly found elsewhere in the area. In the upper part of Tollåga the normally dominant *Baëtis rhodani* was in great part replaced by other *Baëtis* species (Koksvik 1978).

The impact of reducing the particle density in the river water through abstraction of the catchment of water body A was assessed in connection with the previous studies. Changes in the dominance situation and a reduced role of chironomid larvae within water body B, maybe favouring stonefly and caddis larvae were foreseen (Koksvik 1979, Jensen et al. 1993, Hessen et al. 1993). Preliminary results of the newly started study also indicate a change in the invertebrate composition, but not very significant (Box 8). More important is probably the reduced abundance of the invertebrates due to less water in that part of the river leading to a reduced production area, as pointed out by Koksvik (1979).

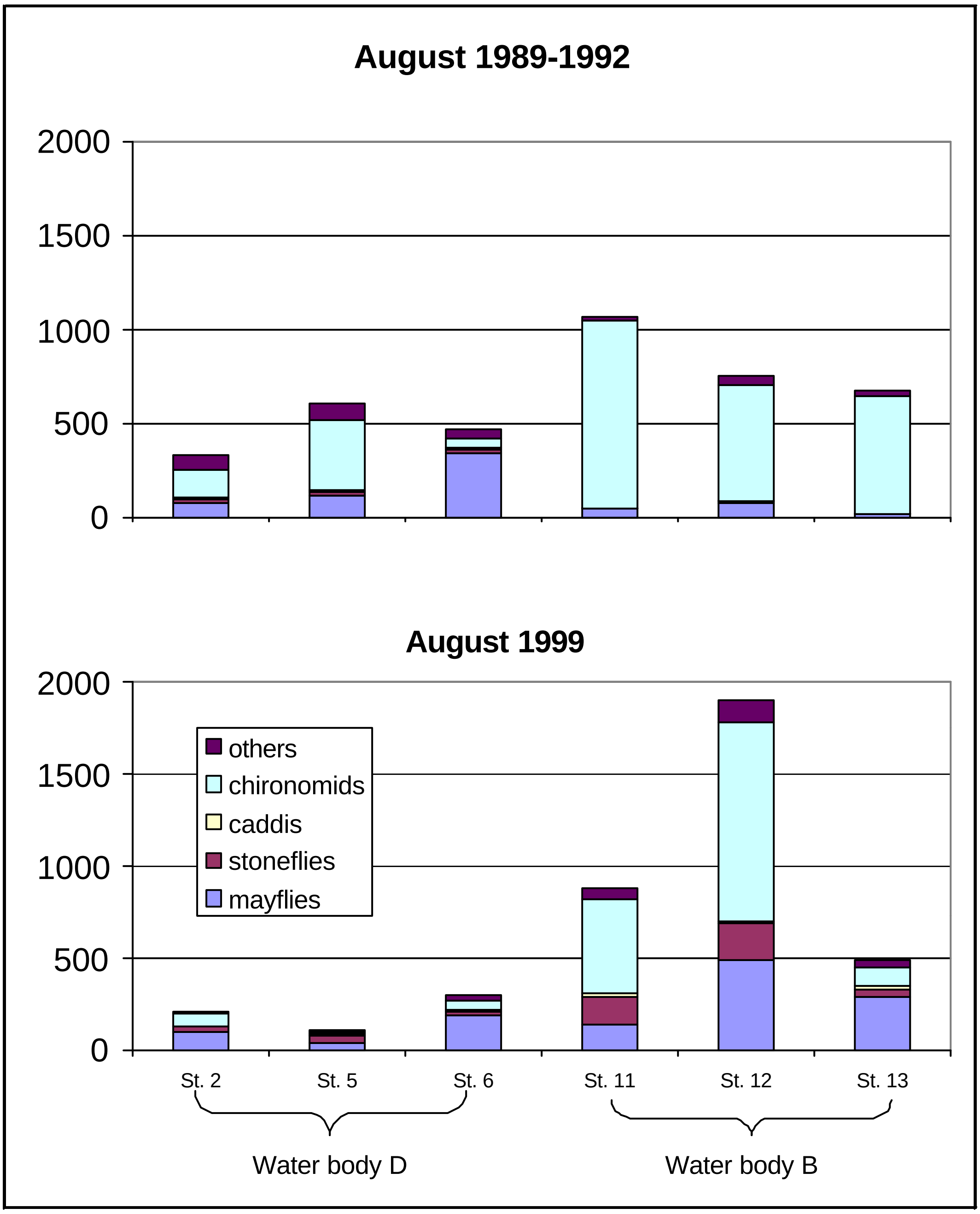
We therefore characterise water body B as having a moderate status, and extrapolate this for water body C as well. After the confluence with its major tributary Tollåga we assess Beiarelva (water body D) as having enough water cover to sustain its invertebrate abundance.

6.1.4 Fish

Berg (1964) reported that the anadromous fish hardly ascended the fish ladders (ref. 5.2), probably due to the low water temperature. If there is a physiological limit due to the cold water, even attempts to modify the ladders will hardly be successful. A distance of five km of Beiarelva above Høgforsen, water body C, is described as sandy, and representing a poorly fit habitat for spawning and juvenile rearing of Atlantic salmon (*Salmo salar)* (Halvorsen 2000).

Stationary brown trout *(Salmo trutta)* and arctic char *(Salvelinus alpinus)* are the fish species of the water bodies A, B and C, in the upper part of Beiarelva. Test fishing above Høgforsen resulted only in a few fish before water body A was diverted (Hvidsten & Jensen 1977, Jensen et al. 1993). The fishing interest at that upper part of the river is thus described as insignificant by Jensen (1995), in a paper presented to the District Court for appraisal of the salmon, trout and char fishery. Recent test fishing also resulted in only a few fish (Halvorsen 2000), confirming a stable situation. The

Box 8 **Composition and Densities (number per m²) of Invertebrates in Beiarelva 1989-92 and 1999. (Johnsen et al. 1993 and Koksvik unpublished data)**



water bodies A, B and C have not been affected by *Gyrodactylus.*

Below Høgforsen, in water body D, the fishing interest is significant, with the anadromous species Atlantic salmon, brown trout and arctic char. The latter is important as one of the southernmost stocks of sea running char.

The growth and adaptation of the Atlantic salmon and migratory brown trout in Beiarelva have been studied in correlation with low water temperatures and latitude (Jensen & Johnsen 1985, 1986, L'Abée-Lund et al. 1989, Jensen 1990a, b). The growth of salmon parr in Beiarelva of 21 mm/year is about the lowest ever reported. The low water temperature is probably the main cause of the very slow growth rate, according to Jensen & Johnsen (1985), who concluded that the temperature conditions in Beiarelva most likely are close to the limit of Atlantic salmon survival. The smolt age is above 5 years for the Atlantic salmon of Beiarelva, and 7 years old smolts are quite common (Jensen & Johnsen 1986). The average smolt ages may be reported differently in some studies, probably due to difficulties in ageing Atlantic salmon and brown trout as scales might lack among the yearlings in cold summers (Jensen & Johnsen 1982). Jensen & Johnsen (1986) compared the growth data of Atlantic salmon parr in Beiarelva with temperature data. The best correlation was found between growth and the number of days where the river temperature reached or exceeded 6,3 °C. The equivalent in river Saltdalselva, also in Nordland County, was 7,3 °C (Jensen & Johnsen 1986). Earlier 7 °C was considered as a limit to growth of juvenile salmon (Allen 1940). The low temperature growth limit of 6,3 °C was considered as an adaptation to the condition of Beiarelva, while the limit of 7,3 °C in Saltdalselva is probably a more normal lower limit to growth in other rather cold rivers (Jensen & Johnsen 1986).

Official catch statistics of salmon and sea trout exists from 1876. Salmon fishing has, however, been restricted since 1989, due to the parasite attack from 1981. Information about catches in the period 1973-1977 gathered by local contact persons revealed quantities from 10 to 30 times higher than those officially registered (Johnsen 1978). 5 tons has been estimated as a potential salmon catch in Beiarelva in good years (Berg 1964). Johnsen (1978) presented a result of more than 5 tons in 1976, indicating that result to be rather high, but summarised that the river was on of the three best ones in Nordland County. With that Beiarelva is also an important Norwegian salmon river.

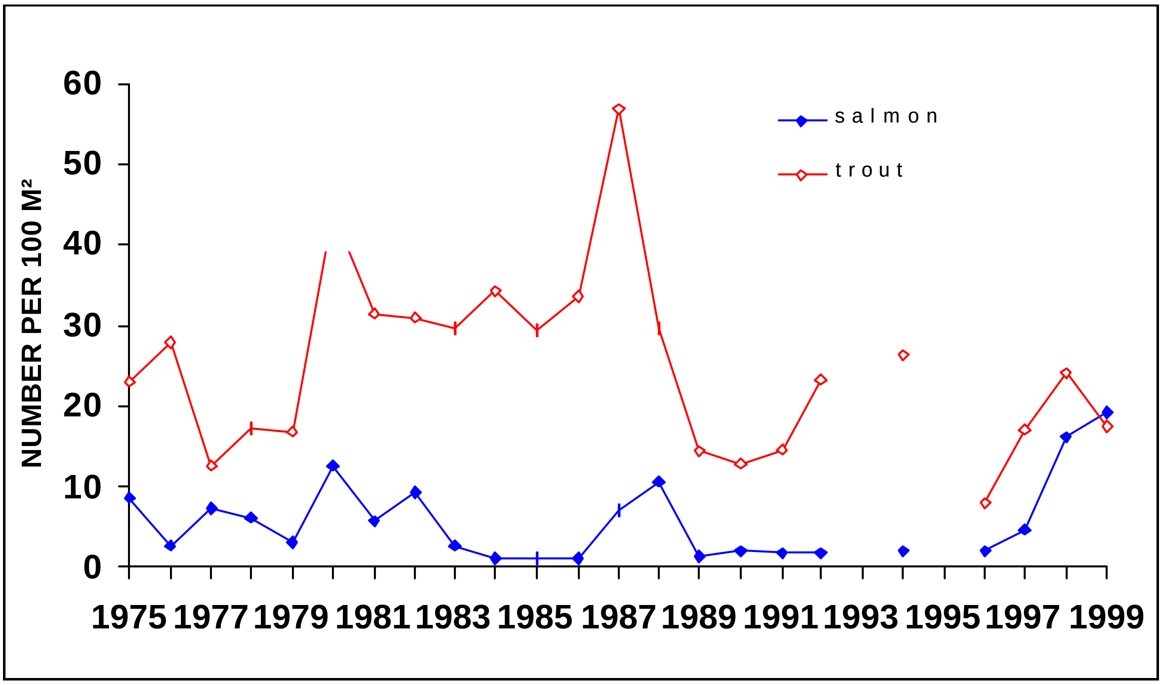
Box 9 shows the juvenile fish densities for the period 1975-1999 (from Johnsen et al. 1999). There is a clear decrease in salmon density after the parasite infestation in 1981, with the trout becoming the dominant fish species. After the rotenone treatment the juvenile salmon density has, however, increased to almost 20 fish per 100 m² (yearlings excluded).

The monitoring programme linked to the parasite infestation and the rotenone treatment includes checking juvenile fish for parasites (Johnsen et al. 1999, Anon 2000), reading of scales from adult fish (Skåt & Lo 2001) and diving to observe mature adults (Sæter 2000).

In connection with the appraisal of the anadromous fish in the District Court the impacts of the abstracted water were indicated to be a reduced production of juvenile fish as well as less mature spawners returning to the river (Jensen 1992a, b, 1993). The court presupposed a total fish recovery following the planned rotenone treatment, and its assessment was a reduced salmon catch by 30 % close to Høgforsen and 10 % close to Beiarelva's outlet, and compensations were given.

Based on fish counts in October 2000 Sæter (2000) estimated the egg densities of the salmon to be 14, 11,6 and 1,4 eggs per m² in the tributaries Tollåga, Store Gjeddåga and the main river respectively. The densities of the tributaries are considered to be more than required for a potential fish production. This was probably also the case for

Box 9 Mean Density of Juvenile Salmon and Trout older than Yearlings in Beiarelva. (Redrawn from Johnsen et al. 1999)



Beiarelva, taking account of the fish count as a minimum estimate due to limited sight in the water (Sæter 2000). Sæter (2000) also interpreted the increasing juvenile salmon densities as the river seeming to have a normal production of salmon, similar to the conditions before the *Gyrodactylus* infestation.

Skåt & Lo (2001) found the good registered return of adults as a result of previous releases of juvenile fish, based on material from the gene bank. Jensen (1995) stated that 10 years were needed to establish representative data after the rotenone treatment, because of the salmon's long life cycle. According to calculations based on the lengths of the salmon's and trout's' life cycles (Nyvold 1998) we still need a few more years to conclude a complete recovery of the *Gyrodactylus* infestation.

Even if the results from the current monitoring programme are promising, we find it hard at present to characterise the fish element of water body D as having a "good status". The river is just declared "healthy" by the veterinary authorities, and it is not yet opened for regular fishing. But the situation seems promising.

6.2 Physico-Chemical Elements

Hydrography studies at 20 river stations and three lakes were carried out in 1975 and 1976, and the water quality was found to be relatively homogenous. At normal water flow in summer both Beiarelva and Tollåga were poor in electrolytes, typical for the majority of Norwegian watercourses (Koksvik 1978, 1979). But during low spring and autumn flow high electrolyte values were measured (total hardness of 1,45°dH, conductivity 65 microohms/cm and pH 7,2).

The particle content due to the glaciers was considerable in summer in Beiarelva and Gråtåga (Koksvik 1978, 1979).

Studies in 1989-1992 confirmed the generally neutral pH, with small local variations caused by a varying Ca-concentration in the catchments of the tributaries. Turbidity and concentration of dry material showed clear patterns with respect to seasonal variation and station (Hessen et al. 1993).

The particle load varied with the water flow, with maximum values close to 100 mg/l at the upper station (within water body B). A striking chemical feature is the high phosphorous content. More than 30 µg/l total P was detected. A probable explanation is that the phosphorous is bound to the particles, and that much of it is released in the laboratory analysis. In the nature, however, this phosphorous is most likely biologically accessible only to a limited extent (Hessen et al. 1993).

For the majority of the measured parameters a distinction was found between the stations in the lower and upper parts of Beiarelva. Within the water bodies B and C there was on the whole a higher content of particles, higher turbidity, higher phosphorous content, but lower pH and calcium content than in water body D (Hessen et al. 1993).

The impact on Beiarelva from Gråtåga was modest, but Gråtåga had in general a lower pH and calcium content than the main river. The impact of Tollåga was more evident, with clearer water containing more calcium. The diluting effect of Tollåga and the tributaries below is demonstrated by the reduction of particle load (dry material) to about a half from the two upper stations (within water body B) to the two lower stations (within water body D) (Hessen et al. 1993).

The pH varied from 6,6 to 7,6 in the studies of 1975-1976 and 1989-1992 (Koksvik 1978, Hessen et al. 1993).

Beiarelva is also reported, as one of 155 Norwegian rivers, in OSPAR (Oslo-Paris) Commission's studies of direct and riverine inputs to Norwegian coastal waters (for example Holtan et al. 1999). Linked to that study the same 155 rivers are classified according to standards (SFT 92:06) given by the Norwegian Pollution Control Authority (Holtan & Holtan 1998). Beiarelva is thus classified in fourth category with respect to the quantity of particles or suspended dry material, in second category for its content of total organic carbon and still within first category, but close to second, for its content of total phosphorous.

6.3 Definition of Current Ecological Status

All classifications are based on "expert judgement".

6.3.1 Differences between the water bodies

The water body A is considered to be almost pristine although there is no data sustaining this conclusion. The water bodies below water body A are characterised by a reduced water flow, from more than 70 % at the upper part of water body B to less than 20 % of the water flow reduction at the lower part of water body D. Water body C is represented by less data than B and D. Water body D is the only one with anadromous fish and the only water body infested by the salmon parasite.

6.3.2 Biological elements

The reduced water flow and thereby also reduced water cover are the limiting elements inhibiting us from characterising the status as good for invertebrates of the water bodies B and C. Less water cover leads to less abundance of invertebrates after the regulation. The water flow has attained ¾ of its original magnitude in water body D, and we therefore assess the invertebrates there as having a good status. The assessment of fish in water body D is described at the end of 6.1.4.

Based on the biological elements the condition of the water bodies may briefly be described by this matrix:

Water body	A	B	C	D
Macrophytes and Phytobenthos		good	good	good
Macro-invertebrates	high	moderate	moderate	good
Fish fauna		good	good	moderate

6.3.3 Physico-chemical elements

The physico-chemical elements will hardly limit the ranking:

Water body	A	B	C	D
General conditions	high	good	good	good
Specific synthetic pollutants	high	high	high	high
Specific non synthetic pollutants	high	high	high	high

6.3.4 Hydromorphological elements

River continuity is broken between water body A and water bodies B/C. This is discussed in chapters 8-10. The morphological conditions are altered due to substrate changes from siltation and changed transport capacity in the river.

Water body	A	B	C	D
Hydrological regime		moderate	moderate	good
River continuity	high *	high *	high *	high
morphological conditions		moderate	moderate	good

* River continuity is regarded as high within each water body. But it is completely broken between the water bodies A and B in Beiarelva and between A and C in Gråtåga where the water is diverted.

6.3.5 Current ecological status

The current ecological status, combining the biological and the physico-chemical elements, will then be, with the biological elements as the limiting ones:

Water body	A	B	C	D
Current ecological status	high	moderate	moderate	moderate

6.4 Discussion and Conclusions

A general problem is that most of the available data is from before the abstraction of water. Even if the impacts were assessed in connection with the pre-regulation studies, more recent studies would have given a more reliable basis for comparison. It is, however, still a bit early after the rotenone treatment to conclude definitely about the anadromous fish, and for the botanical conditions more time may still be needed to be able to discover any changes.

The infestation of the salmon parasite, as well as its treatment, has confused the monitoring of the impacts of the hydroelectric development. But as the treatment is considered as successful, and the river fully recovering, we may also conclude that the impact of the diverted water is rather modest. Water body D may then be given “good status”. But so far other reasons than the impact of the regulation have limited the biological status of water body D, and may do so for a few more years.

For the purpose of the present study it would have been better with more samples taken from certain locations. But when the situation is rather homogeneous, we may extrapolate without committing big errors.

When considering the physico-chemical elements we keep in mind that the basis of the WFD is the natural condition. We therefore disregard classification systems just considering total amounts of particles, total organic carbon etc. when this load is due to the natural glacier influence. We assume that such classification systems are developed on basis of pollution, erosion caused by human activity etc. As the physico-chemical conditions generally are considered good, the biological elements will be the limiting factor when combining the elements.

It may not be fair to compare only one year's results of composition and densities of invertebrates with a four-year average. We have therefore disregarded these differences in our further conclusions.

Despite having reduced the status of the invertebrate element of the water bodies B and C due to the smaller water surface; we have not done so for fish, as we do not find any deterioration.

We have also distinguished between the water bodies C and D when it comes to the importance of the water cover for the abundance of invertebrates. As there is an increasing gradient of original area of the water surface through the water bodies B, C and D, it is a matter of judgement where to draw the limit between moderate and good status.

We clearly realise that another team might have concluded differently in 6.3, even based on the same information in the chapters 4, 5, 6.1 and 6.2. This illustrates a need of developing less subjective criteria in order to achieve a more uniform classification system of ecological status.

7 Identification and Designation of Water Bodies as Heavily Modified

7.1 Necessary Hydromorphological Changes to Achieve Good Ecological Status

Since the rotenone treatment is considered to have been successful and the river seems fully recovering from the salmon parasite, water body D may within a few years be categorised as having "good status". We therefore exclude any further consideration of that water body. No hydromorphological change could, however, have mitigated the parasite problem that existed since it had a completely different cause.

In order to increase the invertebrate abundance in the water bodies B and C to a level as before 1993, it is needed to increase the water surface to the pre-regulation conditions. That means in this context to cancel the present hydropower generation and let the abstracted water flow freely, and thereby restore the natural situation.

A minimum flow might have improved the situation. But in order to really amplify the water cover, such a flow must be of a considerable size, and being pragmatic we will therefore not suggest it. The river continuum is given an emphasis. The 11 tunnel intakes are, however, generally situated in steep parts of the tributaries, and it is hard to point out any substantial benefit for the biological elements.

Hydropower generation is referred to in Article 4.3 (a) of the Water Frame Directive:

"Member States may designate a body of surface water as artificial or heavily modified when: (a) the changes to the hydromorphological characteristics of that body which would be necessary for achieving good ecological status would have ***significant adverse effects*** *on: i) the wider environment, ii) navigation, including port facilities, or recreation, iii) activities for the purposes of which water is stored, such as drinking water supply,* ***power generation****, irrigation, iv) water regulation, flood protection, land drainage; or v) other equally important sustainable human development activities."* (Wording in bold done by us).

The significant adverse effects may here be defined as an economic cost by the reduced or ceased power generation. A cost benefit analysis of the transfer of water from the upper parts of Beiarelva and Gråtåga was carried out in connection with bringing the Svartisen Hydropower Scheme forward for approval by the Norwegian parliament in 1987. Now, with the project already implemented, and the investments done, there are most likely less economic reasons to cease the power production. Even if we now have a much stricter scrutiny of power projects in Norway, it is not likely that the diverted upper catchment of Beiarelva watercourse will be altered. The diversions of Beiarelva and Gråtåga have never been among the most controversal hydropower plans within the area.

Weir building could have been carried out to increase the water surface, but the water currents would have been quite different from the natural condition, and this is not considered as an appropriate remedial measure in the Beiarelva watercourse.

7.2 Assessment of Other Environmental Options

The Article 4.3 (b) of the Water Frame Directive reads: *”Member States may designate [...] as heavily modified, when: (b) the beneficial objectives served by the [...] modified characteristics of the water body can not, for reasons of technical feasibility or disproportionate costs, reasonably be achieved by other means, which are a significantly better environmental option.”*

Alternatives to the existing power generation must:

- be <u>technically</u> feasible;
- not be <u>disproportionately</u> costly;
- <u>reasonably</u> achieve <u>significantly</u> better environmental option.

It is possible to reverse the diversion of water from the catchment covered by water body A. It will, however, be disproportionately costly. Table 3 presents the production of about 300 GWh annually, based on 15 % of the total production of the Svartisen Power Scheme. With an estimated value of 0,02 EUR/kWh, the yearly power production represents a value of about 6 mill. EUR. A more profound economic analysis may also consider the investments already done, and that the work was done less than 10 years ago.

We may hardly achieve any significantly better environmental option. Alternative power production and better household of energy are topics better elaborated elsewhere.

For this study we may summarise that the consumption of electricity has increased considerably in Norway during the last decades, but also that the major period of hydroelectric development is over. There is, however, a potential of increasing the production when upgrading old power plants. On the other hand, there may be environmental requirements (minimum flows) restricting the exploitation of the potentials.

Nuclear power production has not been implemented in Norway, and it is not on the political agenda. As other European countries are phasing out their nuclear power production no introduction is likely in Norway for the first decades. Use of fossil fuel for electricity generation is a tense political issue in Norway. Even if the presently planned projects will be implemented, the acceptance of reducing the emission of greenhouse gases will restrict the extent of this production. Wind power will for the near future only contribute with a limited production, and even now we observe that certain plans are controversial.

There is a potential to save energy if the prices will increase. The largest realistic potential is a reduction in heating by means of electricity. Heating is a rather primitive way of using electricity compared to its use in electronic equipment. Installation of heat exchangers may become profitable for private houses. Higher electricity prices may lead to increased burning of wood for heating. But even if this process doesn’t contribute to extra emissions of greenhouse gases, an extensive burning of wood might cause undesired air pollution, especially in the urban areas.

The conclusion is that electricity generated from hydropower still will be needed in

Norway for the next decades.

7.3 Designation of Heavily Modified Water Bodies

To designate a water body as heavily modified or not the Water Framework Directive requires an assessment of whether it will attain a "good ecological status" by 2015, which again require that measures can mitigate the situation without having unacceptable consequences on certain other uses, in this case hydropower production.

Table 3 Template for Restoring Natural Conditions

Assessing the significance of the impact on use(s)	Actual use				Foreseen use with good ecological status				Comparison actual versus good ecological status				Assesment
	Use (quantity, quality)	Production	Turn over, income	Employment	Use (quantity, quality)	Production	Turn over, income	Employment	Use (quantity, quality)	Production	Turn over, income	Employment	
Hydropower		300 GWh/year	6 mill. EUR/yr			0 GWh	0 EUR/year			-300 GWh/year	-6 mill. EUR/year		15% of the prod. of the total scheme
Use 2													
Wider environment													
Significant impact on use(s) - Overall assessment													

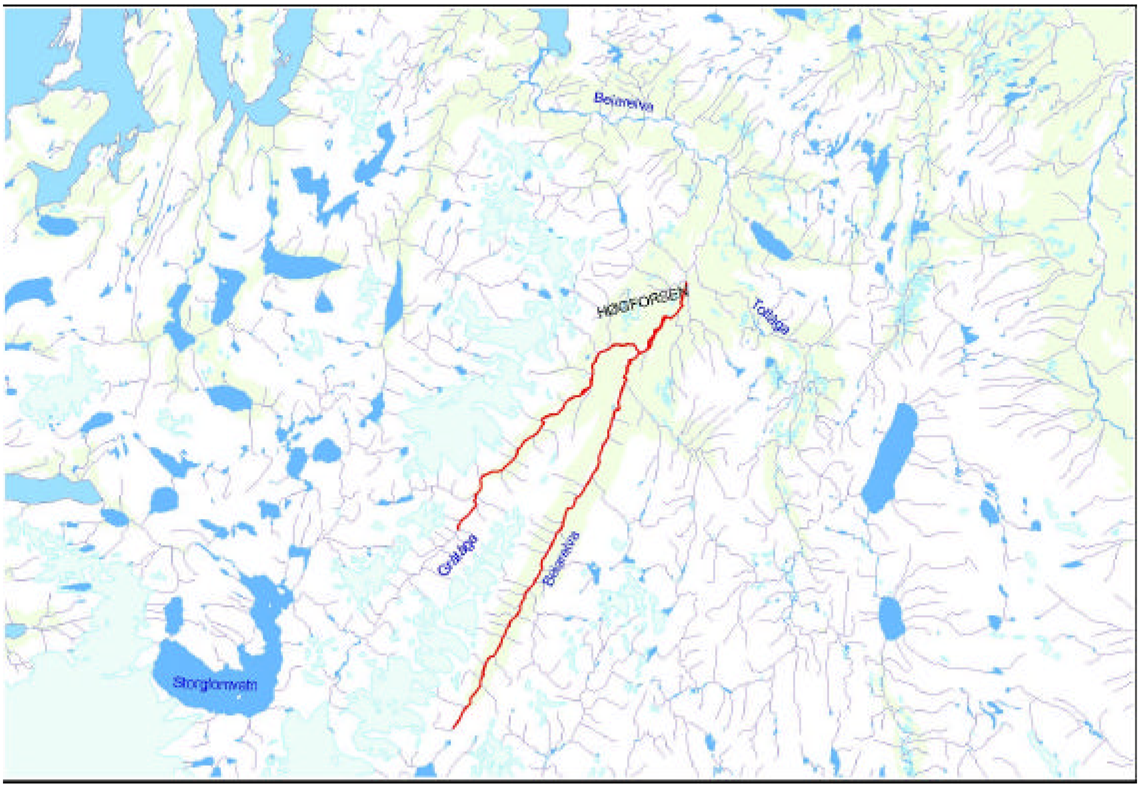
Comparing existing modification with alternatives serving the same beneficial objectives

Environmental impact	Actual Use			Option 1			Option 2			Option 3			
	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	
Air													
Water													
Soil													
Landscape													
Environmental impact - Overall assessment													

Costs	Actual use	Option 1	Option 2	Option 3	
Investment costs					
Operation & Maintenance costs					
Possible foregone economic benefits					
Total annualised costs					

As a consequence of the conclusion of 7.2, the water bodies B and C are designed as heavily modified water bodies, see map in box 10. The present use of the water for hydropower production is incompatible with achieving a “good ecological status” for these two water bodies.

Box 10 **The Heavily Modified Water Bodies**



7.4 Discussion and Conclusions

It is difficult to predict the energy demand and supply situation for the future. But even if a scientific development will take place, and the domestic energy politics may change, we foresee an important role of energy based on hydropower for still a long period.

When concluding, we remain with the same problems as in 6.4, where to draw the “border line” over a gradient between good and moderate status. The reduced abundance of invertebrates in the water bodies B and C were predicted, and fully considered before the decision was taken, and this situation will hardly be altered.

8 Definition of Maximum Ecological Potential

Maximum Ecological Potential (MEP) is defined as the state where the *"values of the biological quality elements reflect, as far as possible, those associated with the closest comparable surface water body type, given the physical conditions, which result from the heavily modified characteristics of the body"* (Annex V ,1.2.5).

The hydromorphological conditions of a HMWB at MEP must be *"consistent with the only impacts on the surface water body being those resulting from the heavily modified characteristics of the water body once all mitigation measures have been taken to ensure the best approximation to the ecological continuum, in particular with respect to migration of fauna and approximate spawning and breeding grounds"* (Annex V ,1.2.5).

8.1 Determining Maximum Ecological Potential

The requirements of the maximum ecological potential are intended to be derived individually for the heavily modified water bodies from comparable natural water bodies under consideration of existing uses; models can be used. The maximum ecological potential includes that all mitigation measures would have been considered. It is stressed to ensure the best approximation to ecological continuum, in particular with respect to migration of fauna and appropriate spawning and breeding grounds. Depending on the local conditions, additional requirements may be considered, like transport of suspended particles and sediments, etc. Regarding the physicochemical elements the same requirements are to be applied as for natural water bodies.

The assessment of these water bodies according to the maximum ecological potential is orientated to the situation when all mitigation measures would have been done and not by an unaffected reference status. Ecologically adverse conditions, which are estimated to be irreversible, are taken into account when assessing the reference conditions. The reference "maximum ecological potential" may therefore strongly deviate from the reference "high ecological status".

The maximum ecological potential of the two highly modified water bodies of Beiarelva must therefore be defined for the "reduced" river after the abstraction of water. For aquatic plants the foreseen impacts of less scouring must be taken into account. For the invertebrates the predicted change in species dominance and composition will give the basis also for the maximum ecological potential. No anadromous fish enter the water bodies B and C. The scarce population of stationary fish, both before and after the regulation, is also the basis of the new definition.

The requirements of maximum ecological potential may include a situation with a stable situation with the regulation. The tunnel intakes are thus assumed to be in function continuously in order to avoid disturbing in the downstream reaches of the Beiarelva and Gråtåga.

It is still premature to state exact values before more studies are carried out and evaluated.

8.2 Measures for Achieving MEP

One measure is to ensure that everything possible is done to ensure a stable river flow below the intakes.

A theoretical measure is to add sediment particles with the natural amount of phosphorous to attain a natural situation. A pragmatic approach will probably easily exclude such a measure.

Other measures are difficult to identify, but this is most likely the appropriate level of mitigation.

8.3 Comparison with Comparable Water Body

The intention of defining a comparable water body is to create a basis for judgement, especially if the shape has been changed, like from a river to a lake. We do not need that for Beiarelva. There is no river in the area with a better documentation of the biological or physico-chemical status than Beiarelva. The botanical studies and assessments are probably the best basis also for defining an ecological potential. The scarce fish population is supposed to remain unchanged. And as Beiarelva had more invertebrates than the neighbouring rivers, selecting a comparable river may just lower the requirements of the maximum ecological potential.

8.4 Discussion and Conclusions

Maximum ecological potential takes into account the biological response resulting from the altered hydromorphological conditions which are a consequence of the physical impact of the use (the use is justified by application of Art 4 (3a&b) designation tests). An exception is that "*all mitigation measures have to be taken to ensure the best approximation to ecological continuum, in particular with respect to migration of fauna and appropriate spawning and breeding grounds*". Paper 12 states: *„As the HMWB designation is based on acceptance of the need for the activity which causes the hydromorphological and hence biological impacts, MEP must be compatible with the identified activity. MEP should contemplate all the mitigation measures for approximating the ecological continuum that would have been present in the absence of the physical modifications and that are compatible with the human activity justifying designation".*

The ecological continuum is given much importance in the HMWB papers. It is a good example: obstacles of free fish passage created by man. On the other hand, in our case the fish passage question is to extend the natural reach of anadromous fish of Beiarelva and on tributary. This is most likely contradicting the whole idea of the water framework directive, where the natural condition is pointed out as a reference for high ecolocal status. But this is not on the agenda of this study. At the tunnel intakes there is a broken ecological continuum. The rivers and tributaries more or less end there, and have new starting points. The justification of emphasising the ecological continuum has been to ensure adequate habiatat for the entire life cycles of the various species. At the ponts of diverting water below water body A there is hardly fish. The invertebrate species present in the river hardly depend on an unbroken river. If a certain amount of water is to passby the tunnel intakes, this will reduce the power production, and thus be in conflict with with the human activity justifying designation.

9 Definition of Good Ecological Potential

The goal of the Water Framework Directive, for surface waters, is aiming to achieve "good ecological and chemical status" in all bodies of surface water, and also to prevent deterioration in the status of those water bodies.

The good ecological potential for heavily modified water bodies must meet requirements defined under type-specific conditions slightly below the maximum ecological potential. The good ecological potential is not a derogation, but an ecological objective which will, in itself, be very challenging to achieve.

9.1 Determination of Good Ecological Potential

As we assumed no unstable situation below the tunnel intakes when defining the maximum ecological potential, we may leave the theoretical approach and look more to reality when defining the good ecological potential. Even if we assume that the Svartisen Hydropower Scheme is run in the best possible way, certain problem of operation may occur, and if an intake is out of use, the water will flow through its former course.

The practicability aspect has thus influenced the definition of good ecological potential.

9.2 Identification of Measures for Protecting and Enhancing the Ecological Quality

As a consequence of the above, no measure is identified here.

9.3 Discussion and Conclusions

This case study seems a quite interesting one as to define the water bodies and designate the HMWB. But as there is no direct hydropower installation in the river stretches below the tunnel intakes, there is a limited possibility to identify measures.

10 Conclusions, Options and Recommendations

10.1 Conclusions

During this study it has been interesting, but also difficult, to define the water bodies and designate the HMWB. We have felt a need of clearer guidelines to distinguish between the different categories of ecological status. Some more feedback to questions raised during the process would have been appreciated.

Since the river has no direct hydropower installation, the chapters dealing with the ecological potential in this study will probably appear less interesting to the readers than where there exist several options of mitigation measures.

We have also found the case study of Beiarelva a little early to really be able to identify the impacts after the regulation. But being fully aware of the timetable of the European project, we have found the case study interesting, and we have used our own judgement where clear guidelines have been lacking. There will hopefully be a better basis for assessment when the aquatic plants have been able to stabilise completely and the anadromous fish species have passed more life cycles after the rotenone treatment.

For the purpose of our study the division in four water bodies has been usable. It has not been too detailed, and at the same time it has been easier to separate certain parts of the rivers when designating the heavily modified water bodies.

The infestation of the salmon parasite has also been a challenge to deal with. It has caused a reduction in the ecological status in the lower water body. After delivering the first part of the study in June 2001, the parasite has been declared eradicated, and the fish populations will probably recover completely.

In general, parasite or disease problems linked to fish also illustrate that looking at the invertebrate component is quite important.

This study illustrates that the emphasis on an ecological continuum not always has the same relevance.

We hope this study will be of relevance when implementing the classifications and designations of the Water Framework Directive. In other cases where water from one watercourse has been transferred to another catchment, the rivers will remain with lower water flow and coverage. But the conclusions may differ, depending on the characteristics of each watercourse.

10.2 Options and Recommendations

As already mentioned there is a need for clarification of the differences between the categories high, good, moderate, poor and bad.

In many HMWB papers there is the example linked to obstacle of fish passage. The river continuum is thus given a special importance. This is also relevant in many cases, and is an example, which is easily understood. But in certain cases the major problems may be of a different nature. It is therefore recommended to search for the minimum factor, or the bottleneck for fulfilling a species' life cycle. That may in certain cases be related to the operation of a hydroelectric plant. As an example, stranding of fish may occur if the discharge is not stable and there are operational problems. Changes in water temperature may cause problems for certain species. There is a possibility of losing the track of the major problem if all emphasis is given to the continuum.

The water temperature is in many cases altered due to hydropower schemes. If the use of water for power generation is accepted as a reason to designate a water body as heavily modified, the definition of maximum ecological potential will be done accordingly. But the water temperature requirement of maximum ecological potential, like the water chemistry elements, may not be modified due to the use of water for power production. This ought to be clarified.

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