WCD Case Studies

The Glomma & Laagen Basin

Norway

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This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
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Executive Summary

The Glomma and Laagen Basin in Norway: Case Study

This study is one of a series of case studies undertaken worldwide for the WCD process with a common approach and methodology to assess the development effectiveness of large dams. The Norwegian case study considers the development experience with an integrated system of 40 dams and reservoirs, watercourse diversions and 51 hydropower stations (total installed capacity of 2,165 MW) in the Glomma and Laagen river basin (G&L basin) in Southeast Norway. It considers the development of the basin over one hundred years and illustrates how decision-making and operation have evolved over time shaped by both national and local interests.

The study is organised around a number of common questions established by the WCD. The selected issues are assessed at the basin level supported with more detailed analysis of four non-focal dams in the basin, rather than a single focal dam. The questions include:

- What were the projected Vs actual benefits, costs and impacts?
- What were the unexpected benefits, costs and impacts?
- What was the distribution of actual and unexpected benefits, costs and impacts, who gained and who lost?
- Did the project(s) comply with the criteria and guidelines of the day?
- How were decisions made?
- How would this development be viewed in today’s context?

Context and Aim

The G&L basin was selected to illustrate the Norwegian hydropower development history and experience in the context of a run-of-river basin system with upstream reservoirs. The G&L development history reflects only partly representative for Norway because most of the hydropower dams in the G&L basin were built prior to hydropower dams in other parts of Norway. The following sections outline the National and basin context before responding to the six questions.

The National Context

Hydropower as a key driver in the development of modern Norway

In the 20th century economic development of Norway has depended considerably on exploitation of the country’s rich energy resources. Throughout this time hydropower and dam development has provided a basis for industrialisation, particularly for large-scale expansion of electro-metallurgical industry since the World War II. Norway is presently the 6th largest hydropower producer globally. Norway has the highest per capita use of electricity in the world (25,882 kWh in 1996) about 10 times the world average of 2,300 kWh per capita. The 99% water-powered Norwegian electricity generation system in 1996 produced energy with a market value of 19,43 billion NOK (approximately 3 billion US$).

From the early 1970s large reserves of oil and gas were discovered on the continental shelf in the North Sea, and today provides the basis for a large oil and gas industry sector. Norway ranks as the 2nd largest exporter of oil in the world. The technology expertise from hydropower development also has been crucial in development of the deep-sea oil development.
The political debate over the economic, social, technical and environmental merits of technology options for the power sector has been high on the public agenda in Norway during the last 15 years, particularly as the population has become more concerned with environmental issues. Until recently, hydropower has been viewed as the only acceptable source of energy. The idea of nuclear power was dispensed with in the 1970’s. Natural gas is presently being considered, but is still highly controversial because of pollution effects and international conventions on reduction of emissions (ex. the Kyoto protocol). This has contributed to slow down further expansion of power generation to the extent where Norway during the last 5 years has been a net importer of power from Sweden and Denmark. In neighbouring Scandinavian countries, electricity is in part generated by nuclear and coal-based technologies, and consequently imports to Norway are by many conceived as negatively branded on environmental grounds.

Hydropower provides almost 100% of electricity in Norway, and has relied on development of the country’s water resources by technical interventions in more than 1/3 of the nation’s main river landscapes. Investments in the hydropower sector equals that of industry in total, discounted at about 200 billion NOK (approx. US$ 25 billion) for each sector. Based on the hydropower system, Norwegian utilities on average hold some of the lowest prices for power supply globally at 0.162 NOK/kWh (1997). Cost recovery has been attained in the system, however with some cross subsidisation within individual government owned companies. Undeniably, hydropower development has had a role in contributing to development effectiveness in Norway as a nation. However, its debatable whether Norwegian dam- and hydropower development and management has been environmentally sustainable.

During the 20th Century River regulation and expansion of the Norwegian power system had firm parliamentary support. Until the 1980s electricity supply was broadly regarded as a public good and as a driver in economic development with considerable multiplier effects. Publicly, this was given as justification for the high investments needed in dams and hydropower. Providing adequate power was seen as a basic welfare issue, as was the attitude of socially sharing wealth within the nation. However, paramount changes came in 1991, when Parliament decided to deregulate and unbundled the power sector. Competition and profit motivation were introduced to provide incentives for making utilities more efficient. Hydropower suddenly became a market commodity, and the ownership structures are changing. Deregulation came as a result of changes in economic models as economists for a long time had pointed to the high investment and low returns and cross-subsidisation in the power supply industry. Hydro-expansion was no longer to be based on centrally planned demand forecasts, but be based on the market forces supply and demand in order to increase efficiency. With deregulation in process, industry is still willing to continue invest in hydropower, largely because its still seen as “clean”-energy in environmental terms. The Norwegian WCD case demonstrates some of the dilemmas decision-makers are faced with in dealing with options assessment, and how solutions have been sought in practice.

Current hydropower
Presently Norway has a total installed capacity of 27 359 MW that provided a hydropower production of 103,9 TWh in 1996. Norway currently has 350 registered large dams. In contrast to the G&L case much of recent hydropower expansion, has relied on high-head development along the mountainous west coast (up to >1000 m). Such developments have taken place in smaller, even glaciated high precipitation river basins, in some cases including inter-basin transfers, and applying rock tunnelling and high pressure turbine technology, underground powerhouses, and frequently discharging underwater from the turbines near or at sea-level. Hydropower production may vary as much as 10 per cent on the national level annually due to hydrological variability.

Of Norway’s 179,7 TWh economic hydro-potential, 113 TWh is developed, and new generation licenses have been granted for an additional 1.9 TWh. Environmentally important, rivers with a hydropower production potential equalling 35,3 TWh have been protected against hydropower
development through four Protection Plans for Watercourses (NVE 1999). Power generation is well distributed and today fully grid-interconnected, also with the Nordic neighbouring countries. As per 31.12.1998 the ownership of the hydropower generating capacity was 86,8 % public (the state-owned Norwegian Energy Co-operation - Statkraft 30,3 %, county and municipal power companies 56,5 %) and 13,2 % private, mainly industrial enterprises (NVE 1999). Electricity consumption is shared between heavy industry, services, and households, about 1/3 of total supply to each. Domestically, electric space heating during wintertime takes a considerable share of the supply. Due to broad public consensus on the desirability of electric power, this allows electricity costs that competitive with petroleum based products, and wood that was the traditional fuel in Norway.

Stakeholder interests and decision-making

Compared to inland fisheries, estimated earnings from water-based tourism, irrigation, and water and sanitation fees, hydropower holds the dominant position and accounts for 85-90% of direct earnings from freshwater uses in Norway. Allowing room for stakeholder interests is common in the Norwegian institutional practice. Presently the main other stakeholder interests relate to flood protection, inland fisheries and angling, tourism/water sports, environmental conservation, water supply and sanitation, and irrigation. Previously log driving, inland navigation and milling also counted as significant stakeholder interests on Norwegian rivers.

Historically, development of hydropower electrification has been driven and influenced by two, later three, basic interest groups. International and national industrialists began in the early part of the 20th century to realise the potential for developing cheap hydropower in Norway. Simultaneously, municipal governments and counties were motivated to develop local hydro-resources to create new employment opportunities and welfare for local inhabitants. The two groups may crudely be termed urban centralists and district regionalists.

In the process of developing a national system of hydropower utilisation a third powerful interest group emerged as concerns over the environmental impacts of hydropower mounted. A conservation movement arose as river landscapes increasingly were encroached upon. One result is that rivers representing the equivalent of 35,3 TWh are now protected against hydropower development through parliamentary approved Protection Plans for Watercourses. This may be seen as an indication of public willingness to pay for protection. Similarly, hydro-projects constituting the remaining undeveloped potential were subjected to a comprehensive national hydropower Master Plan exercise in the 1980ies. Stakeholders were widely involved in this exercise, and projects were categorised according to their economic and technical, as well as environmental-social merits. The objective was to achieve a more publicly acceptable sequencing of future projects to come on line. The Master Plan has since served as a regulatory tool for national authorities, and has been revised 2 times. Currently a third revision is underway. The elaborate licensing process for water resources development has become a corner stone in the decision making process. A salient prerequisite in this process is stakeholder involvement. Consequently, considerable emphasis has been laid on institutional capacity building, knowledge development, public awareness and participation, and efforts to streamline the hydropower licensing process.

Options assessment

Currently Norway is experiencing a heated debate on the future of electricity supply. Issues that are considered are imports, building of gas power stations in Norway, more hydropower development, and more efficient use of energy. In spite of Norway’s extremely abundant resources of gas and oil in the North Sea, as well as potential for wind-power, it is only during the past 15 years such options have been considered as substitutes for further hydropower development. While there is a need for more power to meet rising, this is widely contested, and only little new generation capacity has come on line in this period. In the mean time, the power utilities and industry itself have sought opportunities for gaining more power from the existing system through upgrading, refurbishment and associated research and development to make upgrading more profitable and the total power-supply system more efficient. Bringing down the costs of upgrading and taking advantage of a high degree of
national and international co-ordination of supply in the system is the most cost effective option in a country the size of Norway. The opportunity for attaining greater efficiency and output from the system is well documented. Substantial upgrading and system improvement is taking place, like inter-linking more strongly with the Northern European power market.

The mainly thermal power based European power market is deregulating, and sub-sea cable interconnections are expanded from Norway to Denmark, Holland and Germany. Many Norwegian power companies are looking to these markets to take advantage of high prices for exports of daytime peaking power, while cheaper thermal generated base-load can be imported for night-time supply, and to replace the emerging national deficit in Norwegian power generation for self-sufficiency. The gas power debate has divided the Norwegian Parliament and the current minority Governments resigned in Mars 2000 due to the gas power controversy.

The G&L Basin Context

The G&L basin is the most populated river basin in Norway clearly influenced from various sorts of human impact especially during the last century in addition to the hydropower development. The influence is typical for industrialised countries and include land use changes (new farmland, deforestation, flood embankments, housing, industrial development, infrastructure, etc) and pollution. The basin comprises 42 000 km² of which approximately 1 per cent is in Sweden. The western and northern headwaters of G&L are mountainous with high precipitation, partly glaciated, and with the highest peak reaching 2 469 m.a.s.l. These vast highland areas are snow-covered half the year, constituting a formidable reservoir of water that is released in spring floods and through summer.

A typical feature of reservoirs in G&L and most of Norway is that they were originally natural lakes where storage capacity has been increased by dams, often located in remote highland areas, and not involving resettlement of people. The rivers Glomma in Østerdalen valley and Lågen in Gudbrandsdalen both run about 250 km south and southeastwards through these glacially sculptured rural valleys, forming the upper parts of the G&L basin. The confluence of the two rivers is downstream of Lake Mjøsa, the largest lake in Norway, some 150 km from the sea. Downstream of Mjøsa the river system crosses lowland agricultural and urban areas, reaching the sea in the urbanised south between Norway’s capital Oslo and the Swedish border.

The basin has two main rivers, Glomma in Østerdalen valley and Lågen in Gudbrandsdalen valley (Figure 1).
Hydropower operation and history

The hydropower development in the G&L basin represents a history of more than 100 years. The main construction period in the basin was during the period from 1945 to 1970. Most regulation dams and power stations in the G&L basin were built more than 30 years ago in a context quite different from the present situation in the G&L basin. The first regulation reservoirs were developed in the large lowland lakes (Lake Mjøsa and Lake Øyeren) at the middle of the 19th century for a combination of flood protection and transportation purposes. Later most reservoir capacity was developed primarily for hydropower production purposes, but also with flood mitigation in mind.

During the early development phase run-of-the-river power plants feeding the established industries were built in the lower parts of the river basin, and in tributary rivers close to the industries. Later,
reservoirs were built in the mountain areas far upstream of the power plants. The development took place when each power company supplied electricity for a specific region, and several of them were built before the distribution grid was fully unified. In the period after the World War II the Norwegian State was active in developing hydropower projects to feed the power based melting industry and other heavy industry projects with power to substantially lower prices than the other markets, ex the household market. Hydropower development projects were also initiated to support specific districts in periods of depression and high unemployment rates.

Today the G&L basin encompasses 40 regulation reservoirs with a total capacity of approximately 3.500 million m³ of storage, equivalent to 16 % of the basin runoff. The hydropower reservoirs typically are natural lakes with water level fluctuation of 2 to 12 meters after regulation. Lake regulation capacities result from a combination of heightening and lowering of natural water levels. The increase in total basin lake area is approximately 46.6 km². The highest dam in the basin (Raudalsvatn) is 40.8 meters and many of the lower dams qualify for the ICOLD definition of large dams due to the size of the reservoir they regulate. The largest power station in the basin has an installed capacity of 300 MW. The total installed capacity in the basin is 2 165 MW, with an average capacity of 42 MW for the 51 power stations.

Today the operation and management issues of the basin involve several governmental institutions (5 counties, 5 county governors and 60 municipalities in addition to the national ministries and directorates) with jurisdiction of different acts, different types of planning processes and monitoring, forecasting and research activities. Operation and management also include participation of non-governmental organisations (NGOs) and management of the different water user interests by professional associations. The NGOs have a similar 3 level organisation; national, regional and local, while the only NGO organised on basin level is the Water Management Association - GLB. Monitoring activities include measurement stations for precipitation and temperature, hydrology, water quality, air quality and flora and fish. Specific activities are hydrological and meteorological monitoring for reservoir and flow forecasting and for short and long term hydropower production planning. Basin modelling activities include river system simulations and flood zone mapping.

The Norwegian hydropower history is well reflected in this basin. The integrated G&L basin operation is the most comprehensive in Norway. The last hydropower license process handled by the Parliament was a project involving further development of the Øvre Otta river in the western part of the G&L basin. The project was a symbol for hydropower proponents and opponents and included conflicts nationally and locally. In September 1999, The Parliament refused to grant the applicants licence for the applied hydropower scheme of approx. 1 TWh, but opened up for a reduced scheme of approx. 540 GWh. The premises given by the Parliament on the refusal in September 1999 can be interpreted as an instruction to the government to grant a license for a reduced project if the applicants would choose to reapply. An application for a reduced project in accordance with the premises given by the Parliament was filed with NVE in February 2000.

Stakeholder interests
Historically, milling and log driving were important user interests in the G&L basin. Hydropower development has been a dominant interest throughout the 20th century, while environmental protection has become a major interest only during the last 30 years. Water quality, flood protection and fishing have on the other hand been important issues throughout the whole period of hydropower development. Other important user interest in the G&L basin include tourism, recreation, water sports etc. Although important in terms of public services, water supply for urban areas, industries and for irrigation has so far been regarded as subsidiary interests.
Projected and actual impacts of the G&L basin hydropower development

Hydropower: Predicted vs Actual Generation: The study assessed the predicted versus actual power generation by comparing the generation and capacity at the time of the permit application for the hydropower facility with the actual generation from the basin. It is important to note that regulation dams that have been built to regulate river flows and lake levels may have more than one power station associated with the reservoir.

The results presented in Section 3 of the report show that with technology development and change over time including upgrading of equipment, unplanned expansion of generation facilities, and optimisation of the operations in an integrated manner, the generation from the basin today is greater than the original estimates provided by the individual permit applications. This is illustrated in the following table.

<table>
<thead>
<tr>
<th>Power Station</th>
<th>Year</th>
<th>Increase in installed capacity (MW)</th>
<th>Increase in production (GWh/y)</th>
<th>Planned New production (GWh/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Røstefossen ¹)</td>
<td>1987</td>
<td>1.9→3.1</td>
<td>10.3→16.5</td>
<td>20</td>
</tr>
<tr>
<td>Kongsvinger ²)</td>
<td>1988</td>
<td>20.9→20.9</td>
<td>106→129</td>
<td>120</td>
</tr>
<tr>
<td>Eidefoss ³)</td>
<td>1983</td>
<td>1.5→12.0</td>
<td>9.7→71.4</td>
<td>75</td>
</tr>
<tr>
<td>Nedre Vinstra ⁴)</td>
<td>1990</td>
<td>200→300</td>
<td>1073→1097</td>
<td></td>
</tr>
<tr>
<td>Rånåsfoss ⁵)</td>
<td>1983</td>
<td>61.8→99.0</td>
<td>356→486</td>
<td></td>
</tr>
<tr>
<td>Solbergfoss ⁶)</td>
<td>1985</td>
<td>118→215</td>
<td>687→878</td>
<td>890</td>
</tr>
<tr>
<td>FKF ⁷)</td>
<td>1985</td>
<td>22.0→212</td>
<td>800→1087</td>
<td></td>
</tr>
<tr>
<td>SUM</td>
<td>-</td>
<td>426.1→862</td>
<td>3042→3764,9</td>
<td>-</td>
</tr>
</tbody>
</table>

The building of new power stations and upgrading of old ones has thus been a continuous process during the last 100 years. Most of the power plants in the G&L basin have increased the production during their period of operation. Increased capacity is gained by installation of new units, by renewal of the power stations or by building of new power stations. For 7 power stations renewed during the last 20 years, the installed capacity has increased from 426.1 to 862 MW (102 %) and the production increased from 3042 to 3764,9 GWh (24%) during their time of operation over the production estimates at the time of the original permit and approval.

Predicted vs Actual Costs: The assessment of predicted versus actual costs of dams for reservoir development is affected by the following conditions:

- Time consuming (up to 25 years) licensing procedures
- Changes of plans (mostly reductions) during licensing procedures
- Changes of technology during construction period.
- Changes of interest rates or financing environment (taxes, VAT etc.) before completion,
- Changes in legal framework such as Labour Act, Planning and Construction Act etc. during construction period,
- War-time and post war obstacles (WW - I and WW - II)
- Variation in employment situation and competition for manpower

Cost estimates from the time of license approval and actual costs of the projects have been available from the 4 non-focal dams in the G&L basin (Olstappen, Rauddalsvatn, Fundin and Mjøsa III). A common feature for all of the projects analyzed is that the actual costs of the projects have been higher than the estimated cost at the time of license approval (table 2). The main reasons for the deviation are the delay of 3-5 years in the start of construction for each of the projects and that the compensation part of the total costs (mainly for land acquisition) have been higher than estimated.
Table 2: Planned and actual costs of non-focal dams (Source: GLB)

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Fundin</th>
<th>Raudalsvatn</th>
<th>Olstappen</th>
<th>Mjøsa (III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permission</td>
<td>1966</td>
<td>1948</td>
<td>1950</td>
<td>1961</td>
</tr>
<tr>
<td>Construction start</td>
<td>1966</td>
<td>1949</td>
<td>1953</td>
<td>1958</td>
</tr>
<tr>
<td>In operation</td>
<td>1970</td>
<td>1952</td>
<td>1955</td>
<td>1963</td>
</tr>
<tr>
<td>Period of cost calc.</td>
<td>1962-74</td>
<td>1946-55</td>
<td>1948-60</td>
<td>1952-90</td>
</tr>
<tr>
<td>Estimated cost (Million NOK)</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>10,7</td>
</tr>
<tr>
<td>Actual cost (Million NOK)</td>
<td>9,6</td>
<td>5,1</td>
<td>5,7</td>
<td>18,5</td>
</tr>
<tr>
<td>Est. Cost (Million NOK1999)</td>
<td>41,9</td>
<td>43,4</td>
<td>21,3</td>
<td>97</td>
</tr>
<tr>
<td>Act. Cost (Million NOK1999)</td>
<td>59,8</td>
<td>63,5</td>
<td>60</td>
<td>103,5</td>
</tr>
<tr>
<td>Deviation (Million NOK1999)</td>
<td>+17,9</td>
<td>+20,1</td>
<td>+38,8</td>
<td>+6,5</td>
</tr>
<tr>
<td>Deviation (%)</td>
<td>+43 %</td>
<td>+46 %</td>
<td>+182 % (126 %)</td>
<td>+7 %</td>
</tr>
<tr>
<td>Construction part of total cost (%)</td>
<td>76%</td>
<td>66%</td>
<td>79%</td>
<td>37%</td>
</tr>
<tr>
<td>Compensation part of total cost (%)</td>
<td>24%</td>
<td>34%</td>
<td>21%</td>
<td>63%</td>
</tr>
</tbody>
</table>

1) Deviation after transfer of expenses to the power plant in 1972

Predicted vs Actual Schedules: Generally there has been a considerable time span (5-23 years) from an application for license is forwarded to when the permission was given and the power stations/reservoirs are commissioned. The reasons why several development plans have been delayed may be legal or environmental disputes resulting in changes/reduction of plans during the licensing process, controversies on ownership, shortage of funding, World War II or combinations of one or more factors.

Other Unexpected Impacts: Among other factors the study indicates that there were no predications of sedimentation of reservoirs and this in fact did not occur in the lower reaches of the basin. The sedimentation load in G&L basin rivers is relatively low and not an issue in terms of their operation for power generation. This is because the regulated segment of the reservoirs encompasses only the reservoir top layer. Some of the glacier feed rivers as well as other unregulated rivers in the higher mountains in the northwestern part of the basin has a higher sediment load. The presence of regulation dams in these locations has reduced sediment transport downstream. One exception is the reservoir of Lake Øyeren where the effective regulated volume has decreased to some extent from expansion of the inlet delta in the last century however this is caused from erosion from nearby cultivated areas.

Some of the regulated reservoirs in the G&L basin have their low supply level some meters below the natural level for the actual lake and have experienced some erosion in the zone between full supply level and low supply level in a Norwegian context.

Flood control
Although flood mitigation was cited as a major reason for constructing the regulation dams there were no specific targets set for flood control in terms of predictions to reduce flood levels, flooded area or damage. There has been a general trend towards reduced flood levels in the G&L basin during the last 150 years concurrently due to the establishment of reservoirs that permit co-ordinated flood management decisions. The basin degree of regulation increased from 4 % to 16 % during the 20th century. In addition to the use of the reservoirs during major flood events other protective measures in the low areas of the basin include flood banks, and since 1995 flood hazard mapping, zoning and public information during flood periods.

The G&L basin have experienced several large floods during the last century with the 1995 flood as the most severe. In the central part of River Glomma the return period of the 1995-flood has been
estimated to 200 years. As a consequence of the G&L 1995 flood a governmental commission on flood protection measures were established, and the G&L basin was used as the focal area for a research program on flood (The HYDRA-program) headed by The Norwegian Water Resources and Energy Directorate (NVE) during 1996-1999.

Calculations of flood peak attenuation of the major floods in the main rivers from 1900 to 1999 show that today’ reservoirs capacity yield considerable extra flood attenuation, ex. of flood attenuation by reservoir storage at the 1995 flood in Glomma at Elverum (figure 2).

Figure 2. The reduction of the 1995 flood by reservoir storage in River Glomma at Elverum.

The 1995 flood was a near optimal flood protection scenario by the existing dams in the G&L basin. The large effect of the reservoirs was possible because this was a spring flood. The effect was especially important for Lake Øyeren where the calculated water level at flood peak was reduced by 1.9 m by utilising the upstream reservoirs. Also in River Glomma the storage in reservoirs reduced the.

The additional flood reduction potential by increasing reservoir capacity is still significant in the G&L basin. The 10 regulation projects proposed by the Commission on Flood Protection Measures would increase the degree of river regulation from 16 % to 23 %. So far none of these projects are planned for license application or will probably not be so in the foreseeable future due to the current opposition against further dams, even if flood protection is the main purpose.

Available quantitative economic data on flood damages prior to 1980 are limited. During the last 20 years only the floods in 1987 and in 1995 have resulted in damages of substantial economic values. In spite of the significant flood reduction the total estimated flood damages of the 1995 flood was 1.8 billion NOK (280 mill US$). It was estimated the damage would have been in the order of 2.1 billion NOK without the regulation by dams and subsequent damages avoided were in the order of 0.36 billion NOK.

Irrigation and Agriculture

The G&L basin contains some of Norway’s main agricultural areas, which comprise 2 400 km² or 5.8 % of the total basin area. The climate and the distribution of rainfall in Norway do not call for high interest for dam building in relation to irrigation. The agricultural land is widely distributed and still there is a high variability of production. Most irrigation plants depend on existing lakes and rivers and to a small extent to smaller irrigation ponds which supply water for a short period.

None of the reservoirs in the basin are built for irrigation purpose and there was no expected water withdrawal for irrigation from the reservoirs when they were licensed. In total, 3 265 properties in the
basin had installations for irrigation in 1989 and the irrigated area was 385 km² or 16 % of the agricultural area. Few of the irrigation installations withdraw water from the hydropower reservoirs and water withdrawal for irrigation is negligible compared to the discharge of the main rivers of the basin. The lack of conflicts between irrigation and hydropower production interests is also due to the fact that most irrigation installations are established after the hydropower reservoirs. However, in some smaller tributary the potential for future irrigation may have been reduced due to upstream hydropower regulation.

Both the flood attenuation from reservoirs and flood protection measures like flood banks and erosion control measures as a result of hydropower development have been favourable for the agricultural interests, and have contributed to a more effective utilisation of floodplains for agricultural purposes. Conflicts between the agricultural and hydropower development interests seems to be occasional changes in ground water level in some areas, loss of land from reservoir inundation and loss of fence-effect in rivers with reduced flow during summer. All these conflicts are minor in the G&L basin perspective, although they can be important for a few local farmers. According to the Norwegian legislation, the affected land owners/farmers will be compensated either by mitigation measures or money.

**Municipal and Industrial Water Supply**

The municipalities in the basin has 227 water supply plants serving 682 000 inhabitants with water from main rivers, tributary rivers, lakes and ground water resources within the basin. Lake Mjøsa is the only reservoir in the G&L basin with considerable municipal water supply interests. Of the approximately 150 000 people living in the immediate surrounding of the lake, about 35 000 persons use Lake Mjøsa as their source of drinking water. The annual water abstraction from Lake Mjøsa is according to records from the Directorate for Public Health 4,75 million m³. Most of the water returns to the lake as runoff from sewage treatment plants and has minor effect on hydropower production.

Industrial Water Supply in the basin is mainly for cooling purposes and has minor impact on river discharge, and thus for hydropower production.

**Recreation, Tourism and Fisheries**

There are no examples of distinct recreational opportunities or activities that have been completely eliminated by establishment of reservoirs and power plants and by changes in river flow rates from hydropower developments. However there are examples of hydropower development projects that have been stopped due to the recreational interests, ex. the early development plans for Jotunheimen. Locally the quality of recreational activities have been reduced due to aesthetic properties of rivers and valleys, which have been negatively affected by dams, landfills, roads and transmission lines. Conversely, access opportunities have been provided through new roads related to construction activities. It is difficult to assess whether hydropower development has affected tourism.

Sport fishing and subsistence fishing with more catch efficient methods such as gill nets is a major user interest in the G&L basin. The participation rates are quite high in Norway. Locally more than half the population participate in fishing once or more annually. Historically the commercial fishing in the lower part of Laagen and in Lake Mjøsa was the most important inland fishery in southern Norway. Brown trout, cisco and whitefish as well as other species were caught with a wide range of locally adapted catch methods. Today, recreational fisheries are among the most popular outdoor recreation activities in the G&L basin as well as in the rest of Norway. The middle section of the G&L river system constitute very important recreational in the river reaches above the cities of Lillehammer and Elverum. Rod and line fishing for brown trout and grayling and to some extent also whitefish is the main attraction in these rivers. Also the fishery of large-grown brown trout in the reservoir of Lake Mjøsa is a fishery of special interest. Of the annual catch of 10-15 metric tonnes, one half is caught by netsmen and the other half by trolling anglers.
Regional and National Impacts

Undoubtedly, hydropower development has played a significant role in developing settlements, economics, infrastructure, and public services in the G&L basin. However, hydropower development has not provided the G&L region with any noteworthy economic and population development that differs significantly from similar regions without hydropower development. Power development has provided some municipalities with increased income resulting in improved general welfare and public service compared to other municipalities without income from hydropower developments. The direct economic effects primarily derive from revenues to the municipalities and to a certain extent to the counties. The revenues to the private sector are small. The revenues for municipalities are taxes (profits taxes, nature resource taxes, basic interest taxes and property taxes), license fees, sale of compulsory energy, owner incomes (dividends) and municipal compensation funds. The State subsidies for municipalities receiving large energy revenues are reduced. Accordingly the municipalities’ net effect of energy revenues are reduced.

The Norwegian energy sector has been highly regulated and dominated by public management for 90 years. During the period of hydropower development in the G&L, all of Norway was being electrified. Electric power was made available in all parts of the country, independent of the regions’ own production of hydropower In 1991 an Energy Act was introduced which turned the production and sale of electricity into a market-based activity. The transmission of electricity, which has a natural monopoly character, was still to be organised as a regulated monopoly.

Key features of the Norwegian reform include:

- A separation of high-voltage transmission systems from the State Power Company, Statkraft. A new state company, Statnett now administers the national grid, while Statkraft is a state owned generating company.
- The principle of common carriage and third-party access for all transmission lines. Suppliers lost their exclusive right to supply their franchise area, and were subjected to price competition.
- Opening up for consumer participation in the spot market for occasional power.
- No restrictions on which consumer segments were allowed to trade in the liberalised electricity market.
- Forcing vertically integrated companies to ring-fence generation form distribution through separate divisions with separate accounts.
- A shift towards peak-production according to changing price night/day. This operation may have environmental impacts caused by rapid changes in water runoff and water levels.

The reform did not change:

- The ownership structure, implying that the main part of the electricity system still remains public.
- Concession rules, which strongly favours public ownership.
- Did not demand organisational separation of the transmission from the production and trade functions at the regional and municipal level. This implied a weakening of the control against cross-subsidisation between the monopoly and competitive parts of the electricity industry.
- The existence of a foreign trade regime for electricity based on licences for long-term agreements, and thereby prevented normal international trade from taking place.
- The limits on the special contract market for power to energy intensive industry.

Social effects

There has been no resettlement in the G&L basin due to the building of the reservoirs or hydropower development. This is attributed to the scale of the development (run-of-the-river basin) and the features of the topography and population distribution in Norway. Generally in the lowland areas, which were relatively dense populated, run-of-river power plants were developed with existing upstream lakes as reservoirs. The remaining reservoirs were developed in the mountain areas with
little or no population at the time. This is typical for most Norwegian hydropower projects and the resettlement is generally very low.

The most significant social effects of the hydropower development in G&L basin are connected to changes in local and regional economies. The effects include providing jobs both during the construction period and permanently in operation of power plants and reservoirs, as well as distributational effects of taxes, licenses fees, owner incomes and different kinds of compensations to inhabitants and interest groups in the development areas. All the distributational economical effects are covered in more detail in the paragraphs on regional and national effects and on distribution of cost and benefits.

Dam safety is also an issue in the G&L basin, and in 1977 there was a small dam failure with considerable damage to technical installations and infrastructure, as well as the landscape, but fortunately not on humans, in one of the tributaries to Laagen.

**Ecological effects**

Environmental effects of hydropower in the basin account for both the construction and operation phase and can be related to the reservoir itself, regulation of water-level and -flow and the distribution net and associated structures. Effects also arise from the combination of impacts from hydropower developments with impacts from agriculture, flood protection, use of riparian areas and infrastructure developments.

Effects of the reservoirs have involved loss of habitat due to flooding, erosion and sedimentation and raised water level in bordering terrestrial habitat. Physical gradients and processes governing plant successions have been permanently disrupted, leading to loss of specific vegetation types over time. The land areas lost can be vital, e.g. winter survival or nesting places for birds. The creation of a large water body probably also has positive effects on some water birds, notably ducks, in the basin. The fluctuations in water level may have increased sedimentation and particle content in the water especially in the first year after first impoundment, and this has affected biota in various degree in the reservoir as well as further downstream. Productive, shallow areas have become unstable and “washed out”. However the regulated zone are not always barren. This depends on substrate, climate, depth gradient, amplitude and speed of water fluctuations. In some reservoirs this zone can have a significant production of semi-aquatic species and be important areas for bird and fish species.

Below the dams and diversion/inlet tunnels the natural river water flow is changed. These changes vary from minor reductions to a complete absence of water. In general, the effects on the natural biota of such a reduction in water flow are negative. Especially vulnerable to regulation are for instance some bryophytes and the specific waterfall vegetation that totally depends on constant wet or very humid conditions.

The access roads to reservoirs and hydropower stations represent a loss of terrestrial habitat and act as migration barriers. Roads also open up areas and increase recreational as well as commercial use. In the G&L basin, few new roads were actually built in connection with hydropower projects (totally … km road for the G&L hydropower projects) especially when considered relatively to roads built by other interests such as forestry, tourism, communication etc. The transmission lines impact habitat in the clear-cut areas below the power lines in forested areas, and through reduced use of the area connected to the power line corridor due to avoidance behaviour. The latter effect has been noted for reindeer. Although habitat changes in the corridor area are beneficial to some species, the transmission line is a threat to bird life. Collisions with and electrocution by the power lines affect a number of bird species, particularly forest species and birds of prey, and is significant mortality factor. No data are available on transmission lines as a mortality factor from the G&L basin.

Traditionally, watercourse regulations were thought to have strong negative impacts on salient fish species like brown trout, char and whitefish, and on spawning and hatchery areas and hence
recruitment. Potential effects on productivity were also considered to be minimal. Thus, it was for
long believed that that the waters could still support the same biomass of fish and the same fishery,
provided stocking of hatchery reared fish to compensate for loss of natural recruitment. This was a far
too optimistic view. The littoral fauna, which is the main food resource of brown trout, is greatly
reduced by fluctuations in water level. Planktonic fauna is less, or even positively affected by
regulation, and can to some extent replace the littoral fauna as brown trout food. However, if
whitefish and/or char are present, brown trout is will not compete with these more specialised
plankton feeders. Brown trout production and yield has in general decreased, in spite of stockings. An
exception is a few mountain lakes and large lakes where the food base is unaffected because several
of the planctonic species tolerate water level fluctuations. The recruitment of char and whitefish are
often negatively affected by the regulation. However, if the pre-regulation populations were dense
and slow growing, reduced recruitment has in some cases been positive for individual fish growth and the
fishery. In nutrient-rich, lowland lakes like Lake Øyeren, it seems that the dominance of cyprinids
have further increased after regulation. It is not known that fish production by area has increased in
any reservoir as a result of the regulation (where fish production has increased this is related to
increased nutrient supply). Small lakes dammed up to large reservoirs can, however, hold more fish
after regulation.

Changed water flow below dams and diversion tunnels and slow-flowing conditions above dams,
have to a large extent affected fish populations in the G&L rivers. Important spawning and nursery
areas are often totally or partly destroyed by the reduction in water flow. Slow-flowing conditions
above dams have been detrimental, especially to brown trout and grayling in River Glomma
downstream Elverum where few rapids and riffles as spawning and nursery habitats are left. The
slow-flowing conditions have favoured other species like cyprinids, pike, perch and turbot.

The dams also act as migration barriers. Before the regulation dams were constructed, it was possible
for brown trout and grayling in River Glomma to migrate several hundred kilometres, from Lake
Øyeren in the south to the uppermost reaches. After the regulation dams were constructed, the
migration patterns are probably to a large extent broken down, in spite of construction of fish ladders.
This is especially true for grayling; there are still examples of marked brown trout migrating more
than 100 kilometres. The long-migrating individuals, although few, may have an important role in the
terms of exchanging and maintaining genetic diversity.

In River Laagen, the fish migrations are minimally affected by dams. Only one dam, Hunderfossen,
interferes with natural migrations of the large-sized brown trout, but the efficiency of the fish ladder is
quite good. However, a minimum discharge in the important spawning and nursery area below the
dam is the bottleneck for natural fish production.

Stocking of fish (brown trout) is the traditional mitigation measure, which shall compensate for loss in
recruitment. A prerequisite for stocking is the existence of a necessary food supply, and in many cases
this is not the case. Another issue emerging in the past 15-20 years due to new knowledge, is the
significance of the nativeness. Supplementary stockings of brown trout have usually involved
non-native, hatchery-reared individuals. In recent years, the stocking policy are more turned in the
direction of using native fish, and the nativeness aspect is now considered in all new license terms.
The success of stocking programs has been assessed by several marking experiments to distinguish
naturally produced from the hatchery-reared fish. As a result, stocking have been terminated or
reduced in some reservoirs. In other localities, natural recruitment is very limited and fish production
almost completely depends on stocking. The so-called Hunder-trout, a famous, large-sized strain of
brown trout which can attain weights up to 20 kg, was initially threatened by the hydropower project
at Hunderfossen, but a successful stocking program secure the viability of this fish population.

Habitat improvement efforts comprise construction of weirs, pools and stream deflectors and creation
of a more diverse habitat for aquatic or semi-aquatic biota. Many licenses, for instance in River
Glomma, authorise the establishment of habitat improvements. In river stretches with a minimum
water flow, weirs are important in order to maintain the water level in definite pool areas. Improvement efforts in large rivers and also smaller rivers much affected by flood are often very expensive, because the efforts have to be robust and well founded in order to withstand large fluctuations in flow rates. Spawning and nursery habitats are to a large extent lost in connection with river dams in the main rivers, and tributaries have become more important for the recruitment of fish. Often, tributaries are also affected by hydropower regulations and/or have been modified (cleared, channelised) due to log driving activities, and thus might also have needs for habitat improvement efforts. When considering cost - benefit, habitat improvements clearly have the greatest potential in the smaller tributaries. The efforts are more simple and easy to accomplish in such localities, and the effect on fish populations can be substantial.

In total, there are 34 fish ladders in the G&L watercourse. Only 26% of the ladders are considered to have a good efficiency, 41% are less good and as much as 32 % are not working at all. Twelve of the ladders are located in dams in the main rivers, Glomma and Laagen. In general the efficiency is considered low, and thus fish migrations are severely affected. There are considerable variation in efficiency and the most important factors determining fish ladder efficiency are: 1) entrance of the fish ladder in relation to the main waterflow, and 2) waterflow in the ladder compared to dam overflow. These factors vary between different ladders and with different waterflows, and results in large annual variations in number of migrating fish.

Cultural heritage
Categories of cultural monuments found along the G&L rivers include log-driving constructions, sawmills and grain mills, mining facilities, power stations, industrial constructions linked to the river, settlement constructions, hunting-, fishing, and harvesting remnants, bridges and roads, defence constructions, and prehistoric foundations and sites. Studies of any extent on effects of implementation of hydropower projects on cultural heritage issues were not carried out until the 1970-ies. During the past 15-20 years cultural heritage has become a salient topic of investigation when water are exploited. Data from the G&L basin are largely missing. It is probable that in a number of early hydropower developments in the basin prehistoric cultural relicts and monuments were lost or partly destroyed.

Distribution of costs and benefits
The hydropower development in the G&L basin did not result in resettlement of households and only a small fraction of the area that was submerged comprised agricultural land. The flood reducing effects are considerable, which benefits all activities in the flood zone (i.e. infrastructure, settlements, industry and agriculture). However, negative effects occur on the flood vegetation. The predicted effects on fisheries were considerable and the quality of fishing is reduced in the affected areas. The most severely affected areas are some of the mountain reservoirs and the migrating fish species in the Glomma river and in the lower reaches of Laagen.

For many local communities, the long construction period represented growth in employment, increased tax revenues and increased demand for goods and services. Only a few of the municipalities have higher incomes than they would have had otherwise. Approximately 250 persons are employed in the production part of the hydropower sector, that is, excluded transmission, marketing and sales which are the better part of the employed persons. For the entire power sector approximately 2 100 persons are employed within the G&L basin. The direct economic effects in the G&L region today come from revenues to the municipalities in the form of taxes, license fees, sale of licensed energy and owner incomes (dividends). Of the accumulated public income of 534 million NOK (71 mill US$) from the energy sector in G&L, 414 million (55 mill US$) or almost 80 per cent went to the G&L region. The large revenue entries are owner incomes and taxes. The energy revenues for the municipal sector (municipal and counties) in the G&L region constitute approximately 1.9 per cent of the total incomes to the municipal sector. A few municipalities in Norway do however, receive a substantial income from the hydropower sector.
Annual state subsidies make up a large portion of the municipalities’s income. The subsidies partly compensate for standardised fees and partly for low earnings. Municipalities with large energy incomes receive lower subsidies than municipalities without energy incomes. When considering that the State subsidies are reduced for municipalities with large energy incomes, the net effect of the energy revenues probably lie around 1.5 per cent of the municipal sectors’ aggregate annual incomes in the GL region. In a few municipalities, the revenues of the power installations make up more than 5 per cent of the incomes.

Planning and decision making system

The energy sector in Norway has generally been managed in a planned-economy approach, with dominant monopolistic structures in production, transfer and consumption. A Norwegian market reform was introduced in 1991 (The New Energy Act 1991) so that the various functions in the electricity system are separated. Functions like transport, transmission, and distribution have been organised as regulated monopolies. Others like production and trading have been exposed to competition. The current situation is the result of a long political and industrial history. Today, the relevant legislation for river basin management involve multiple sector acts administered mainly by the Ministries of Petroleum and Energy, Environment, and Agriculture. Administrative tasks are further delegated to their respective directorates, as well as institutions on the county and municipal levels. Key elements of this history are briefly outlined below.

From the late 19th century to 1906 there was an intense activity by private financial actors (domestic and foreign) in buying and selling rights to utilise waterfalls by foreign and Norwegian companies resulting in Parliamentary action in 1906. In 1907 the state established a substantial “buy-back-the-rights-to-waterfalls”-policy lasting until 1917. The first watercourse state authority The Norwegian Water Resources and Energy Directorate (Vassdragsvesenet), was established in 1907. Ownership to waterfalls became based on a licensing system with licenses granted for a limited period (normally 60-80 years), whereupon the ownership is transferred to the state without financial compensation.

The period from 1920 to the end of World War II was rather inactive. The period from 1945 to the end of the 1960ies was the era of physical development in Norwegian power policy. The state took an active financing, development and operative function. The political goal was the re-construction of society after the World War II, and one of the means was to feed the power-based melting industry and other heavy-industry projects with enough cheap power. In pre-war Norway industry and the municipalities were mainly producing their own power, the state played a more withdrawn role. Power for household consumption was given second priority. The state increased its ownership in the hydropower industry from around 10% in 1940, to about 30% in 1995. In the same period the part of the industry owned by the local authorities and county authorities increased from 36% to 55%, while the private owners have decreased their share from 42% to 15%.

At the end of the 1960ies criticism from environmental interests grew. Criticism focused (1) The decentralised and thematically fragmented system of water management politics, (2) the centralised and “technocratic” nature of the hydro-power production apparatus, and (3) the ideological critique of a society allegedly obsessed with economic growth depleting natural resources. During the 1970ies and 1980ies substantial reforms took place in the policy-making and in the political and administrative tools operative in this policy field. The establishment of the Ministry of Environment in 1972 was a particularly important institutional action. A planning system was introduced as an instrument to create a comprehensive hydropower policy. It included one set of plans for protection, and one set of plans for utilisation.

The first Protection Plan was passed the in Parliament in 1973, giving permanent protection to 95 “items” (6,9 TWh), and protection for the next 10 years (temporary protection) of further 8,1 TWh. A revised plan, the so-called Protection Plan II, passed the Parliament in 1980, adding 51 items
(potential production capacity: 2.6 TWh) to the list of permanent protection. The last revision of the protection passed the Parliament in 1993. 341 river systems are presently protected under this planning system against further hydropower development, with a potential production capacity of 35 TWh. The objective of the protection plans is to shield especially valuable watercourses from hydropower development projects. The protected rivers, lakes and waterfalls are to be utilised for outdoor recreation, for research and education, and are intended to act as a reference for the long term natural development of more pristine watercourses. The protection is political and not legal and is an instruction to the Government as how a possible hydropower license application shall be concluded. Several of the protected watercourses have experienced pollution, road building, flood protection and other impacts from different activities damaging the values protected from hydropower development.

Conservation plans also spurred the work with a Master Plan for the remaining river systems providing an instrument to assess and utilise the resources in a holistic manner, balancing multiple interests and giving a more transparent decision making process. The tool used, was to organise and make a priority list of all remaining hydro power projects, by referring them to one of two categories: (1) those already approved for applying for licensing (MP-CATEGORY 1), and (2) those who the authorities are in principle prepared to deal with at a later date (MP-CATEGORY 2). The Master Plan also initially included a Category 3. The rivers classified to MP-category 3 were transferred to Protection Plan IV. Thus only two categories remain. All applications for hydropower development, including those in MP category 1, has to run formally through the licensing process and the Parliament have the final decision. The Master Plan was from the outset a contested tool in hydropower policy, especially in the hydropower industry. Salient modifications in the development of the Master Plan procedures since its inception include: 1) the improvement of the transparency of the process through the introduction of a public notification of the intention to apply for a licence, 2) through the introduction of more comprehensive and public accessible impact assessments of both nature and society to be carried out as part of the application process, and 3) the obligation to propose measures and/or alternatives to avert negative consequences on nature and society of a development project.

Basin Operation

“ The Glommen Water Management Association (GB)” founded in 1903 and The Glommen’s and Laagen’s Water Management Association (GLB)” founded in 1918, operates the reservoirs as a sector organisation for the hydro power producers in the G&L basin. GLB members include 21 hydropower and industry companies. GB and GLB hold licenses for a complex of 26 regulated reservoirs of small and medium size which together provide some 3 500 million m³ of storage, equivalent to 16 % of the runoff in the G&L basin.

Optimising the water resources for hydropower production is the main objective of GLB. However as a consequence of the still growing number of issues within water resource development the association also does other types of management work in the joint reservoir system for example in relation to environmental issues. According to legislation (licence conditions), a complex system of water sharing rules between the members of GLB and agreements between environment interests, municipal and county authorities, private power and industry water users, as well as various associations representing farmers, land owners and civil society groups, a next to impossible “tight-rope” activity is performed.

The GLB have an important role in co-ordinating the operation of the complex system of reservoirs on behalf of their members. It’s also a communication partner for other interests co-operation on ecological issues and mitigation improvements to reduce conflict levels. The operations of the reservoirs are supposed to adapt step-by-step to the new Energy Act and the system of market liberalisation. Yet, the degrees of freedom are limited due to physical and legal constraint. GLB has an important role in reducing flood damage, as there is a considerable flood abatement effect in optimal basin operation. However, the basin operation is not yet optimal from an economic point of view. An additional income potential of 25 mill NOK (3.8 mill US$) was estimated in 1995.
During the last 10-15 years, the GLB, the individual power companies and the environmental authorities as well as landowner representatives have co-operated on fish issues related to the hydropower sector. The aim of this work has been to identify the optimal use of resources to improve the conditions for fish production and angling. The work include test fishing, registration of fish migrations in fish ladders, catch statistics and data to evaluate mitigation measures, as well as implementation of various mitigation measures such as fish stocking, habitat improvement, fish ladders and minimum water flow. The experience from these projects is very positive and shows some of the benefits from an open dialogue and co-operation between the stakeholders. In this way cost-effective measures can be developed to substitute those implemented in the license process.

Summary of findings on key WCD questions

Findings are summarised below and in the Table 2 which follows this text.

Projected versus actual benefits, costs and impacts

Hydropower development has played a significant role in developing settlements, economics, infrastructure and public services in the G&L basin. For many local communities the long construction period represented growth in employment, increased tax revenues and increased demand for goods and services. The hydropower development represents an annual hydropower production of 9-11 TWh (annual value 159–253 mill US$). The production have exceeded the projected production at the time of license approval due to expansions, rebuilding or building of new reservoirs increasing winter production. The construction and operation have created important employment opportunities. Today the hydropower sector alone employ 250 persons, when including the system and utilities producing power services employment is 2100 persons. The total income in 1998 encompassed 71 mill US$. The larger revenue entries were taxes (44 mill US$) and public owner incomes (20 mill US$). The reservoirs have a capacity of 16 % of the annual runoff. During the catastrophic spring flood of 1995, peak flood levels on stretches with dense population were reduced by 1.0-1.9 m. Although flood protection has been a subsidiary interest, and flood damages both on floodplain agricultural areas, settlements and infrastructure have been considerably reduced. Negative effects of hydropower development are primarily related to environmental conditions and to some extent to agricultural activities. Few environmental effects were predicted in pre-regulation studies with the exception of effect on harvested fish populations. Fish production has been reduced in impounded lakes and regulated rivers. Negative effect on fish recruitment has been partly mitigated through stocking of hatchery reared fish as well as habitat improvement, release of minimum water flow and construction of fish-ladders. The negative effects for agriculture include loss of land from reservoir inundation, loss of fence effect in rivers with reduced flow during summer and periodically dry wells in some areas due to reduced river flow rate. The effects for the agricultural sector have been predicted and generally been compensated.

Unexpected cost, benefits and impacts

Many old hydro-facilities are running well beyond their projected life-times and/or have been upgraded, making considerable earnings and providing profits and incomes for concession and fiscal taxes. The deregulation of the energy market with the new Energy Act in 1991 represents a significant change of context for production and sale. The energy sector, traditionally has been regulated and dominated by public management. Price competition and third-party access to transmission lines increase the market-consciousness in the power companies. Management is now directed towards competition and profitability. Actual cost of the projects analysed exceeds the estimated cost at the time of license approval. The deviation is due to the delay in the construction of the projects, and cost for compensation for land acquisition and to third party interests. Recent knowledge on the differences in adaptability and behaviour of the different strains has changed stocking policy with a substantial increase in production cost for compensation stocking material. Log-driving, an important interest in the first half of the last century, decreased gradually until the end in the 1980ies. The was
not foreseen in the licensing process and the log-driving paragraph still exist in G&L reservoir operation rules.

**Distribution of cost, benefits and impacts (who won and who lost)**
Annual fees and compulsory delivery of electricity to the local municipalities to secure local benefits was included in Norwegian legislation in 1917. Land acquisition has been taken care of through comprehensive compensation. Similarly, third party interests, mainly environmental and social safeguards, are protected through law, license covenants and the rules of operation for dams. Compulsory maintenance flow releases are a common feature in most rules of operation and so are fish stocking and other mitigation measures. Almost 80 % of the 71 mill US$ income goes to the G&L region. The total annual incomes of the municipalities in the region are approximately 1.6 billion US$. Energy revenues comprise 53 mill. US$ or 3 % of the total municipal incomes. The municipal income from energy revenues is unevenly distributed. In a few municipalities the revenue is more than 5 %, however the variation is partly compensated by reduced subsidies from the State. The regional distributions also include a lump sum of resources for development of local industry, as well as employment and secondary income from the increased activity during and after the construction period. Infrastructure elements such as communications (roads and telecommunications), quays, public halls, utilisation of surplus rock from excavations and underground works for roads and other construction purposes etc.

**Compliance with criteria and guidelines of the day**
GLB and the power companies have a good record of compliance with guidelines for construction, safety, compensation, mitigation and operation as of the time licences were granted. Conditions implemented in the hydropower licenses can not be substituted without a formal process, e.g. revision of the conditions according to the legal mechanism. The opportunity to re-evaluate old licences were changed in 1959 when an option to revision after 50 years were included in the legislation. In 1992, this was reduced to 30 years and all licenses older than 50 years may be re-evaluated and the conditions revised. Old licenses can thus be re-evaluated and conditions set according to present knowledge and attitude regarding environmental issues, including minimum flow and other mitigation measures.

**How were decisions made?**
The decision-making process for water resource development has undergone a considerable evolution over time. Since early in the 20th century a requirement for licensing provided the procedures that have constituted the backbone of the decision making process. From 1921 the government granted licences based on applications. The applicant was confronted with detailed instructions on the technical content of the application, and there were demands to be met to analyse benefits and disadvantages following the project. Changes in licensing procedures in 1969 included public notification of the intention to apply for a licence, demand for more comprehensive impact assessments and an obligation to propose measures and/or alternatives to avert or mitigate negative impacts on nature and society. In the 1970-ies and the 1980-ies substantial reforms in the policy making procedures and in the administrative tools operative in the hydropower policy field took place. In 1972 the Ministry of Environment was established. In 1960 Parliament took an initiative to establish regional plans for protection of rivers and waterfalls, and around 1980 the question was raised to make a Master Plan for all the remaining hydropower development projects. The aim was to get a more unified approach to decision making in particular projects. These plans led to avoidance of (further) hydro-impacts in the river selected for protection, and thereby reduction of conflict levels.

**The G&L hydropower development in today’s context**
With the shift in framework conditions for production and sale of electricity and focus on cost recovery and rate of return after the deregulation in 1991, the proponents are observing risk of investments much more closely than earlier. The dilemma for hydropower developers is the conception of how market prices will develop. The market price of electricity is today too low to make most of the new potential hydropower development plans profitable, and the possible gas power
developments further complicate the estimation on future market prices. In today’s context environmental impacts of further hydropower developments as well as of gas power development are considered as serious, and the choice of strategy will be a question for the Parliament. Currently there are plans to upgrade and refurbish power plants and dams, for new company structures and also for one new project (The Øvre Otta project). The municipalities were in favour of the hydropower projects because of the local economic benefit, however, during the last decade the municipalities have become more negative to hydropower development. The Master Plan has handled 65 different alternatives for further hydropower development, 31 tributaries are included in The Protection Plans for Watercourses and National Parks. Public support for new reservoirs, even in the context of flood protection after the 1995 flood, is low in the basin. It is thus very likely that viewed in today’s context strong resistance from various stakeholder groups would have met the construction of many of the present G&L reservoirs.

Table 2 Predicted, Actual, and Unexpected Outcomes of the G&L hydropower developments.

<table>
<thead>
<tr>
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<th>Predicted</th>
<th>Actual</th>
<th>Unexpected</th>
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<tbody>
<tr>
<td>Schedule</td>
<td>Determined by license applications</td>
<td>Variable</td>
<td>Delays in older dams affected by World War II</td>
</tr>
<tr>
<td>Design</td>
<td>Provided in license applications</td>
<td>Almost all dams change from initial planning, through licensing to final approve project. Projects generally were reduced through the licensing processes</td>
<td>Deviation in project costs due to delays in construction and higher payment of compensations than predicted</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Not significant factor</td>
<td>Not significant factor</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Project costs</td>
<td>203.6 Million NOK in 1999 currency for 4 non-focal dams</td>
<td>286.8 Million NOK in 1999 currency for 4 non-focal dams 140% increase on average</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Irrigation and irrigated agriculture</td>
<td>No impact on irrigation withdrawals from lakes and rivers</td>
<td>No impact on irrigation withdrawals from lakes and rivers</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Municipal water supply</td>
<td>No impact on municipal withdrawals from lakes and rivers</td>
<td>No impact on municipal withdrawals from lakes and rivers</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Loss of land from inundation of reservoirs. Local loss of fence-effect from reduced river flow-rates during summer and dry well from changed ground water level</td>
<td>Effects as predicted. Effects generally are compensated and mitigated.</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Hydropower generation</td>
<td>Several G&amp;L hydropower plants were initially established prior to the licensing system, have been rebuilt and upgraded step by step, and are influenced by new reservoir developments. The question of predicted production is therefore very complex and is answered by analyses of selected power plants, not on basin level</td>
<td>Mean annual G&amp;L production of 10 145 GWh from an instnalled effect of 2 165 MW. Production have far exceeded the predicted for the power plants analysed</td>
<td>The increase in generation from technical changes, expansion of facilities and optimisation of flows at basin level for power were not expected at the time of development of several of the power plants</td>
</tr>
<tr>
<td>Flood control</td>
<td>Dams will reduce the incidence of damaging floods in lower parts of the G&amp;L system</td>
<td>Flood peaks have been reduced by about 20%. The 1995-flood culmination level in Lake Øyeren was reduced by 1,9 m by reservoir storage.</td>
<td>Flood reduction is a subsidiary not predicted positive effect of most reservoirs</td>
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<tr>
<td>Tourism and</td>
<td>Unquantified</td>
<td>Unquantified</td>
<td>Impacts on attractiveness of</td>
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Summary of Lessons learned

One main objective of the WCD process is to identify new knowledge from past experience with large dams. The basin focus for lessons learned in the Glomma-Laagen context seeks to demonstrate accumulated experience representing the long time period of the development and the multitude of stakeholders in the basin. Some of the lessons are generated specifically from the G&L Case Study, whereas some are more general for the Norwegian hydropower development context. The summary of the some of the main lessons generated by the study team is provided below. These are elaborated in the main report.

**Lesson:** The step-by-step development history/process in the G&L basin, with alpine natural lake reservoirs and downstream power stations, has reduced the conflicts to other user interests and sectors.

The step-by-step hydropower development took place during a period of more than 100 years. All, but one reservoir, are modified natural lakes. The water level fluctuations are small. Reservoirs with great water level amplitudes are located in remote mountainous areas. The conflicts during the licensing process and the construction phase have been very moderate. Projects with strong opposition have not been developed. There are divergent views on this issue among stakeholders, but there is general agreement that the current impacts do not cause major conflicts.

**Lesson:** Periodic, planned re-evaluations of project operations provide a mechanism for incorporating changes in science, technology, and changes in social values and user interests into project operations.

The legal opening for periodic evaluation of existing licensed conditions provide a mechanism for introducing new developments in science and technology into water management operation as well as changes in political and public concerns. Hydropower production has increased by new technology. Performance can also be improved in relation to ecological, social and other user interests. New knowledge on ecological impact and effect of mitigation has been important in developing operation...
schemes and mitigation measures. Divergent views among stakeholders were not registered on this issue.

**Lesson:** The Protection Plan for watercourses and the Master Plan for Water Resources have been important tools to plan hydropower development.

A large number of hydropower projects were forwarded for licensing to the Parliament in post-war Norway, and a growing frustration among politicians for having to deal with these applications one by one. A binary planning system was developed, with one set of plans for protection (The Protection Plans for Watercourses), and one set of plans for development (The Master Plan for Hydropower Development Projects). The Master Plan defines an order of priority for the consideration of individual hydropower projects on the basis of economic considerations and the degree of conflict with environmental and other user interests. The Master Plan was from the outset a contested tool in hydropower policy, and it remains an uncertain question if the plan has had a conflict reducing function or not in the public debate on power policy. The various stakeholders have divergent views on the planning system and this is particularly related to the Master Plan.

**Lesson:** Regional distribution of income from hydropower development in the Norway is ensured by a and dependent upon a formalised system involving compensation, taxes, license fees, sale of licensed energy and owner incomes.

Regional distribution is an important issue in Norwegian hydropower development and is recognised in the legislation. There is general agreement among the stakeholders that the regional economic impact was substantial.

**Lesson:** In the G&L basin, the combination of a moderate regulation and special flood operation procedures has high flood prevention effect.

The G&L basin has experienced reduced flood levels during the last 150 years due to the use of the reservoirs during major flood events, as well as other protective measures in the low areas of the basin include flood banks. The 1995 flood was a near optimal flood protection scenario by the existing dams in the G&L basin and flood levels were reduced by 1-1.9 meters. Since 1995 also flood hazard mapping, zoning and public information during flood periods is also used. There is a wide spread agreement among stakeholders on the flood abating effects of the regulation.

**Lesson:** Flexibility in the authorisation of mitigation and co-operation in the G&L basin have yielded more effective measures to compensate for negative impact from hydropower development.

During the last 10-15 years, the GLB, the individual power companies and the environmental authorities, as well as landowner representatives have co-operated on fish issues related to the hydropower sector. The experience from these projects is very positive and demonstrates some of the benefits from an open dialogue and co-operation between the stakeholders. In this way cost-effective measures can be developed to substitute those implemented in the license process. There is a general consensus among stakeholders on the need to develop more effective and ecological sound mitigation measures. Some stakeholders feel however that that the measures in operation are not sufficiently comprehensive and that more efforts should focus on changing the physical characteristics of the actual regulation.

**Lesson:** The Glomma – Laagen Water Management Association (GLB) is an important institution in the integrated operation of the G&L basin with respect to hydropower production, flood dampening and environmental mitigating procedures.

The GLB play an important role in co-ordinating the operation of the complex system of reservoirs on behalf of their members. It is also a communication partner for other interests co-operating on
ecological issues and mitigation improvements. GLB has an important role in reducing flood damage, as there is a considerable flood abatement effect in optimal basin operation. However, the basin operation is not yet optimal from an economic point of view. There is consensus among stakeholders that the GLB is an important institution in the basin. However, there are divergent views on the role of GLB and some claim that it is only a water user association representing the interests of the hydropower sector.

Lesson: In the G&L basin systems for monitoring and sharing of data are needed in hydropower production, flood prevention, to illustrate compliance with current regulations and to measure social and ecological impact.

Data series and subsequent modelling of the water course is a salient management tool to meet the various and often conflicting demands in the short and long term operation of the basin, including flood issues, impact assessments, economic simulations, operational planning, and development planning. Additionally, detailed descriptions of reservoirs, basin, power stations and other technical facilities, in addition to reliable market forecasts are required to produce good modelling, analysis and management strategies. There are no divergent views among stakeholders on this issue.
The Study Team

The following consultants have contributed as writers and co-ordinators of the report, as contributors of sectoral reports and as members of the case study working group:

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<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Sector</th>
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<tr>
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<td>Norwegian Hunters and Anglers Association</td>
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This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>WCD</td>
<td>World Commission on Dams</td>
</tr>
<tr>
<td>G&amp;L</td>
<td>Glomma and Lågen</td>
</tr>
<tr>
<td>GLB</td>
<td>Glommens and Laagens Water Management Association</td>
</tr>
<tr>
<td>MD</td>
<td>Ministry of Environment</td>
</tr>
<tr>
<td>OED</td>
<td>Ministry of Petroleum and Energy</td>
</tr>
<tr>
<td>LD</td>
<td>Ministry of Agriculture</td>
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<tr>
<td>NVE</td>
<td>Norwegian Water Resources and Energy Directorate</td>
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<tr>
<td>DN</td>
<td>Directorate of Nature Management</td>
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<td>SFT</td>
<td>Norwegian Pollution Control Agency</td>
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The WCD case study on Glomma and Lågen have been an intensive process involving different consultants, research institutions, ministries and other governmental organisations as well as representatives for the different stakeholder group within the G&L basin.

We would like to thank all the contributors to the report. Especially we want to thank the members of the case study working group Pål Mellquist (Glommens and Laagens Water Management Assosiation) Kurt Ole Linn (Norwegian Farmers’ Union), Arne Erlandsen (ENFO), Geir Y. Hermansen (Ministry of Petroleum and Energy and NORAD), Throind Berge Larsen (Ministry of Environment) and Øyvind Fjeldseth (Norwegian Hunters and Anglers Association) for vital contributions during the different stages of the work on the Final Report. Also a special thank to Dan Lunquist co-ordinating the sectoral reports and the data contributions from Glommens and Laagens Bruksfighteren as our main subcontractor. We also want to thank by Larry Haas and Jeremy Bird at WCD Secretariate for very inspiring co-operation.

Additionally, we are indebted to individuals representing various stakeholder groups, which included local municipalities, environmental organisations, farmers organisations, hunting and angling organisations who participated in the 1st Stakeholder Meeting in Scoping Phase of the case study work, the 2nd Stakeholder Meeting when the Final Report Draft was presented. In addition the stakeholders contributed by interviews on telephone and by answering questionnaires.
1. Introduction

Norway has considerable experience in water and energy resource development and is active in the promotion of water and energy resource development at many levels internationally. The World Commission on Dams is interested in Norway’s development experience with dams and the evolving issues and practices in hydropower development and regulated river basin management.

The Glomma and Lågen river basin was selected as a case study for this purpose called the G&L case study. Through the G&L case study, the WCD intends to gain a perspective on the development effectiveness of dams and watercourse developments in the Norwegian context, reflecting sustainable development principles. An equally important aim is to generate a series of “lessons learned” from the Norwegian experience around dams and hydropower development in the G&L basin, as well as other aspects of river basin management and operation.

The G&L basin includes a large number of small to moderate sized facilities (e.g. dams, reservoirs created from existing lakes and river course diversions), close geographic proximity of facilities in comparative terms, and an integrated operation of the facilities by the Glommen’s and Laagen’s Water Management Association (GLB), operating as a basin level entity. The WCD concept of the focal dam is extended to consider the development experience with an integrated system of dams in a basin in the G&L case study. This includes how these aspects have evolved and adapted over time, and stakeholder perspectives of the process and outcomes. Additionally the concept of “zooming in” on some of the dams within the GLB basin will be necessary to address more local issues related to development effectiveness.

The case study thus affords the opportunity to look at the development effectiveness of a whole basin with a complex system of dams, reservoirs and watercourse diversions operated in an interdependent manner. There is also an opportunity to demonstrate the evolution of basin and local development effectiveness, policy/legal/ regulatory, institutional, consultation issues and evolution of basin planning/management systems and impacts of industry deregulation.

The World Commission on Dams (WCD) was established with a 2-year mandate to address central issues of controversy with respect to large dams and provide an independent review of their effectiveness in sustainable development. A description of the WCD mandate, the WCD case study procedure and the methodological framework for the case study can be found in annex 1.

The G&L case study has used existing data sources and reports to inform its assessment, as time has not permitted additional research to be undertaken. Data availability has been limited for the oldest part of the G&L hydropower development history, while the amount of data and reports of different basin topics from the last 20 years is large but unevenly distributed between the case study topics.

The report is broadly structured to answer the 6 key WCD questions (Box 1).

Box 1. Key WCD questions

- How were decisions made?
- What were the projected vs. actual benefits, costs and impacts?
- What were the unexpected benefits, costs and impacts?
- What was the distribution of actual and unexpected benefits, costs and impacts, who gained and who lost?
- Did the project comply with the criteria and guidelines of the day?
- How would this project be viewed in today’s context?
Chapter 2 in the report introduces the G&L basin context with main user interests and basin characteristics. Chapter 3 deals with the projected versus actual benefits, costs and effects structured by sector. Chapter 4 contains a distribution analysis, while chapter 5 deals with the development of the planning and decision-making system for hydropower. Chapter 6 is discussing the integrated basin operation and management issues. Chapter 7-10 are summary chapters on findings, lessons learned, stakeholder views and conclusions.
2. The Context and Scope of the Case Study

The G&L basin was selected to illustrate the Norwegian hydropower development history and experiences in the context of operation of a complex run-of-river basin system developed over a considerable time span. Besides the the context of developing legislation, public participation, integrated basin operation and ecological impact studies and mitigation measures are main reasons for selecting a Norwegian river basin as one of the WCD case studies.

In several aspects the G&L basin is not representative of the Norwegian hydropower scheme. However it might also be said that no development scheme is representative due to the uniqueness of each project in the natural physical and ecological conditions, (i.e. topography, climate, fauna and flora etc), the available technology at the time of development and so on. Chapter 2 as well as some other paragraphs of the G&L-report include general information on the Norwegian hydropower development as well as information specifically from the G&L basin.

The G&L case study context differs from the other WCD case studies and the methodology used in the other studies of course have not been designed specifically for the basin purpose. Due to the age of most of the basin projects and the complexity of the basin in a number of characteristics, i.e. number of reservoirs and hydropower stations, step-by-step development over time and so on, the description of each of the basin project have to be more like a "bird eye view" than the other WCD case studies. The main focal issues of the G&L case study are the integrated operation of a river basin with numerous hydropower reservoirs and power stations, the development of the planning and decision making system, flood control, mitigation of environmental effects and distributional effects of the hydropower development.

2.1 The Norwegian Context

The total land area of Norway included freshwater is 323 877 km². Urban areas encompass only 0.7 % of the total land area. At the beginning of 1999 the Norwegian population was approximately 4,445 million people (Central Bureau of Statistics 1999). 74 % of the population live in the urban areas. In the 1950s approximately the same percentage of the population were living in rural areas.

In 1996 Norway was the 6th largest hydropower producer in the world with a total installation of 27 359 MW and a hydropower production of 103.9 TWh (NVE 1999). Norway was the highest per capita user of electricity in the world (25 882 kWh in 1996) compared to a world average of approximately 2 300 kWh per capita), and hydropower stations supply virtually all Norway’s electricity. The 99 % water-powered Norwegian electricity generation system produced in 1996 energy with a market value of 19.43 billion NOK (3 billion US$) calculated from a national engros prize of 0,187 NOK/kWh in 1996.

The Norwegian hydropower production potential as of 31.12.1998 is 179.7 TWh, of which 113 TWh is developed and 35.3 TWh have been protected from hydropower development in four Protection Plans for Watercourses (NVE 1999) (Table 2.1.1). The rest of the hydropower potential is either under construction or have been granted for licence, is exempted from or have not been treated in The Master Plan or is placed in The Master Plan category I (development licence may be approved) or category II (reserve for future energy demand).
Table 2.1.1 Norwegian hydropower potential as of 31.12.1998. Mean annual production (TWh).

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<thead>
<tr>
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<tr>
<td>Developed</td>
<td>113.0</td>
</tr>
<tr>
<td>Under construction + licence granted</td>
<td>1.9</td>
</tr>
<tr>
<td>Exempted from + Not treated in The Master Plan</td>
<td>5.9</td>
</tr>
<tr>
<td>Master Plan cat. I</td>
<td>15.1</td>
</tr>
<tr>
<td>Master Plan cat. II</td>
<td>8.5</td>
</tr>
<tr>
<td>Protected</td>
<td>35.3</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>179.7</strong></td>
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Source: NVE 1999.

The electricity consumption is divided between heavy industry, services, and households, about 1/3 of total supply to each. Electric space-heating wintertime takes a considerable share and is a common feature throughout the country. This is a result of prices for power that is competitive with petroleum based products and wood that was the traditional fuel in Norway. In addition there has historically been a broad consensus in Norway that electricity should be used for heating purposes, and in urban areas flats have for some periods been built without pipes of this reason.

Power generation is well distributed and today fully grid-interconnected, also with the Nordic neighbouring countries. As per 31.12.1998 the ownership of the hydropower generating capacity was 86.8% public (Norwegian Energy Cooperation - Statkraft 30.3% and municipal 56.5%) and 13.2% private (NVE 1999). Hydropower stations that are not owned by the central or local government revert to the state free of charge after normally 60 years.

Till recently ownership was spread between a large number of municipal and county utilities (monopolies), power companies and industry. After the deregulation of the energy market from 1 January 1991, the structure is gradually changing. Deregulation came resulting from new legislation spurred by a paradigm-shift brought about by economists. They had for a long time pointed to the high investment and low returns and cross-subsidisation in the power supply industry. No longer should hydro-expansion take place based on centrally planned demand forecasts. The new melody is that market forces would regulate supply and demand and increase efficiency. Many Norwegian power plants have been in operation beyond the time of depreciation of the original investment to bring them on line, and they today run as virtual money-machines which give important tax incomes the state and the municipalities. Estimated national income in 1996 from taxes to the state and the municipalities from the publicly owned power companies was 2 190 million NOK (315 million US$) (Proposition No 23 (1995-96) to the Odelsting).

With a solid base in dams and hydropower, Norway has pioneered power pooling and trade, as well as deregulation and unbundling of utilities, a development that today has resulted in the first truly international (Norway/Sweden/Finland) spot- and futures power market, increasingly facilitating power trade in the region. Norwegian expertise is also actively engaged in hydropower development internationally, with particular competence in rockfill dams, high head hydro-, rock tunnelling-, underground powerhouse- and remote operational control technologies, as well as promotion of lessons learned from power-pooling, and with emphasis on environmentally considerate designs of hydropower systems.

In spite of Norway’s extremely abundant resources of gas and oil in the North Sea, and also potential for wind-power, it is only in the past 15 years these have been seriously considered as an alternative to
further hydropower development. Although there is a need for more power to meet rising demands and the Master Plan has opened for further development, public and political controversy over environmental impacts of the different technologies has led to that virtually no new generation capacity has come on line in this period. The power utilities and industry itself have in the meanwhile sought opportunities for gaining more power from the existing system through upgrading, refurbishment and associated research and development. This is also most cost-effective in a system the size of Norway’s, by bringing down the costs of upgrading. The opportunity for attaining greater efficiency and output from the system has thus been well documented and considerable activity with upgrading is taking place.

Also, as the mainly thermal power based European power market is being deregulated, and sub-sea cable interconnections are expanded from Norway to Denmark, Holland and Germany, many Norwegian power companies are looking to these markets to take advantage of high prices for exports of daytime peaking power, while cheaper thermal generated base-load can be imported for night-time supply, and to replace the emerging national deficit in Norwegian power generation for self-sufficiency.

Currently there is an ongoing debate in Norway on future electricity supply. Issues that are considered are import, building of gas power stations in Norway, more hydropower development or more efficient use of energy. This is a debate that has divided the Parliament and the current minority Governments resigned at the 9th of Mars 2000 due to the gas power controvery.

**2.2 Historical Context - Water Use Interests**

Norway has a great variety of watercourses characterised by multiple user interests. The main interests have changed considerable during the last 2-300 years. Historically, milling and log driving were important watercourse interests. Hydropower development has been a dominant interest throughout the 20th century, while environmental protection has grown strongly during the last 30 years. Water quality, flood protection and fishing have been important interests during the whole period. Water supply for industrial and urban areas and agriculture has been subsidiary interests.

**Log driving.** It is difficult to estimate when the log driving activity started on Norwegian watercourses, but it is known from several sources from the 16th century that trading with timber took place. During the period from 1500 to 1800 the log driving activity grew more important, it became organised and it expanded to new areas. The log driving activity peaked from 1900 to 1921, and during the 1980’s the last log drive in Norway was closed down (Vestheim 1998). Early in the 20th century there was a controversy between the log driving interests and the hydropower development interest because the hydropower dams presented barriers for the log driving. Dams therefore were constructed with measures to pass logs, and hydropower licenses had separate conditions on water release for log driving purposes.

**Hydropower Development.** The first use of hydropower in Norwegian watercourses goes back to the second half of the 17th century. At this time hydropower was used in the running of sawmills and other mill plants. By the middle of the 19th century hydropower was supplying industrial users. The establishment of electricity intensive wood-processing industry and electro-metallurgical industry based on hydropower dates back to the beginning of the 20th century and is considered to be the start of the modern phase of the Norwegian hydropower development.

Foreign enterprises became interested in Norwegian hydropower around 1900, and began to co-operate with Norwegian companies in buying waterfall rights. After the dissolution of the Norwegian-Swedish union in 1905, a strong opposition against the foreign buy-ups of waterfall rights developed. The Norwegian national authorities recognised the social and economic value of hydropower
development for the Norwegian society. Consequently the government started to buy waterfall rights, and approved laws and licence regulations, which could exclude foreign enterprises from the hydropower development. The laws were practised liberally, but forced the foreign enterprises into a tight co-operation with the emerging Norwegian industry.

During the world depression to the end of World War II, dam construction activity decreased in Norway. After the war, the need for industrial production once again grew rapidly, and several major hydropower dams were developed. Contrary to earlier periods where dams were located in the lower reaches of rivers (close to the sea or in urban areas), the new dams included development of reservoirs in the upper, mountainous parts of the watercourses.

Statistics from the International Committee on Large Dams (ICOLD) indicates that Norway now has over 330 dams above 15 meters, the majority of which are for hydropower. Other dams are for water supply (11 dams) and navigation (2 dams). The numbers of dams built in Norway (above 15 meters height) each decade this century is shown in Figure 2.2.1.

**Figure 2.2.1** Number of large dams in Norway commissioned by decade in the 1900’s

![Number of Large Dams in Norway](image)

Source: ICOLD Dams Registry

As seen from the above graph, the pace of construction large dam construction has dramatically slowed in the 1990’s. There is a combination of causes resulting in the steep decline of the dam building activity in Norway during the last 20 years. The majority of the best hydropower dam projects and more than 75% of the hydropower energy potential are already developed. Additionally, new energy sources have appeared, and new national tools for planning and developing hydropower, a still growing focus on reduction of energy use, as well as the controversy on dams have slowed down the dam building activity. The last decade, hydropower development have consisted mainly of renewal of old power plants, smaller hydropower developments and changes to market conditions both in Norway and for Nordic region power trade.

A new Energy Act entered into force on 1 January 1991, and governs matters specifically relating to the power supply sector. The generation and sale of electricity is regulated so that electricity companies and others compete for customers. Energy transmission is a natural monopoly in which prices and other terms are monitored by the authorities. It must be organised in such a way that it ensures the efficient use of resources. The power reforms Norway introduced in 1991, were intended to reduce regional differences in the cost of power and introduce a greater degree of competition in the sector. The operations of the government owned power company, Statkraft were split into a new
national grid company, Statnet SF, and a production company, Statkraft SF. At the same time all transmission networks were opened to third party access. By 1996 there were 326 utilities in the electricity supply sector including both production plants, whole sale plants, distribution plants and integrated plants. A spot market for power trade now exists.

Norway has power interconnection with neighbouring Scandinavian countries and has traded power regionally for decades. Recently the power trading system changed dramatically from trading under the older Nordel agreement among vertically integrated power companies to more open market systems. In many respects Norway has led the power market transition in the region. Norway and Sweden established a common power Market called Nord Pool in 1996, and Finland joined in 1998. Norway relies mainly on dams and hydropower, Denmark on thermal plants mainly from imported coal and Sweden has a mix of about half nuclear and half hydro. Finland has a mix of nuclear, hydro and thermal. Changes in the individual country policies on power generation and industry regulation may have an impact on the Norwegian situation in future both in terms of new supply and how existing hydropower facilities are operated.

Historically, industrialists and county and municipal governments have been main driving forces in the development of electrification of Norway. International and national industrialists did from early in the 20th century realise the potential for developing cheap hydropower in Norway with its high mountains, abundant precipitation, and opportunities for building dams for storage in sparsely populated highland areas. Simultaneously, municipal governments and counties were motivated to develop local hydro-resources to create new employment opportunities and welfare for their local inhabitants. Basic attitudes of the two groups may crudely be termed urban centralists and district regionalists.

From the late 1960s, when higher national and public prosperity had been attained and more than 1/3 of Norway’s 179.7 TWh hydro-potential had been developed, a third powerful interest group emerged as concerns over the environmental impacts of hydropower mounted (see paragraph on environmental awareness and protection).

It is in the fields of interests and tension between the above-mentioned three main groups of players and the public interests, that Norwegian politics and the governance system has developed and evolved the decision making framework for development and operation of dams and hydropower in Norway (see further description in chapter 6.1 Basin Operation and Management Issues). A corner-stone in decision making has been the licensing process for water resources development that through the century has become more and more elaborate. Associated with this, considerable emphasis has been laid on institutional capacity building, knowledge development, public awareness and participation, and efforts to stream-line the licensing process.

**Flood Protection.** Norway generally has a cold winter season with heavy snow-cover. Rivers and lakes generally are covered by ice. In spring, flood periods occur with the snowmelt. Sometimes also the break-up of the ice-cover on rivers result in provisional ice-dams and local flooding. Floods induced by heavy rain may occur during summer and autumn, especially in the western and coastal part of the country.

Norwegian rivers are steep, high-energy rivers running through narrow valleys. Their floodplains are relatively small. At the same time the small floodplains are very attractive for several user interest (agriculture, settlements, road and railroad building). Consequently, the use of floodplains and riparian areas are intensive along several rivers, and throughout the 19th and 20th century flood protection measures have been executed in many rivers and lakes. The most common types of measures have been flood banks, bank revetments, channelization, degradation and erosion control measures.

Although most of the larger regulation dams in Norway are built and used mainly for hydropower purposes, flood protection considerations were important in the planning processes and for the
decisions to build several of the dams with lake reservoirs early at the 20th century. In addition the licensing conditions of several hydropower reservoirs give permission to pre-release water from hydropower reservoirs to prepare space for anticipated floodwater volumes.

The southeastern part of Norway and especially the G&L basin, experienced a severe flood in early June 1995. As a consequence of the 1995 flood a Commission on Flood Protection Measures was established to recommend measures for reducing the vulnerability of society as a whole to floods and flooding (NOU 1996). In a Parliamentary White paper (St. meld. nr. 2, 1995-96) the total flood damage was calculated to be NOK 1.6 billion. The Commission on Flood Protection Measures has later updated this estimate to NOK 1.8 billion. About 1.0 billion of this was insurance payments.

Environment Awareness and Protection: The roots of the nature protection in Norway go back to the middle of the last century. The Norwegian Tourist Organisation was founded in 1868 as the first Norwegian organisation with nature conservation interests. The attention to the environment impacts of hydropower dams projects arose in the early 1900’s and several regional nature protection organisations were founded. As river landscapes increasingly were encroached upon throughout the century, the movement for conservation of nature grew stronger and the environmentalists became an important stakeholder group in hydropower development projects. The conflict between hydropower development interests and nature protection groups culminated around 1970 to 1975 with the demonstrations in Mardøla and Alta-Kautokeino. The Alta-Kautokeino hydropower development affected an ethnic minority, the Sami.

One outcome of the growing environmental awareness has been that rivers representing the equivalent of 35.3 TWh now are protected against hydropower development through parliamentary approved Protection Plans for Watercourses. This may be seen as an indication of public willingness to pay for protection. Similarly, hydro-projects constituting the remaining undeveloped potential were subjected to a comprehensive national hydropower master plan exercise in the 1980s. Stakeholders were widely involved in this exercise, and projects were categorised according to its economic and technical, as well as environmental-social merits. The objective was to achieve a more publicly acceptable sequencing of future projects to come on line. The Master Plan has since served as a regulatory tool for national authorities, and has been evolved 2 times. and currently there is a third revision.

After the early 1970’s several local protection groups have been founded around project-specific issues and advocacy environment organisations emerged at the national level. The non-governmental environmental organisations and the non-governmental user organisations have been increasingly aware of the environmental impacts of flood protection measures, agricultural activities on floodplains and riparian areas, infrastructure development and water pollution from municipalities and industries during the last 20 years, and have raised public awareness of these issues.

The first Norwegian Nature Protection Act was approved in 1910. The Act was revised in 1954 and in 1970. The Nature Protection Act (Naturvernloven) from 1970 has multiple protection categories: National Parks, Landscape Protection Areas, Nature Reserves, Nature Monuments, Wildlife Protection Areas, Bird Protection Areas and Plant Protection Areas. In addition endangered or rare plant-species and animal-species are protected by the Act. In 1980-81, a White Paper on protection of Norwegian nature was approved (St. meld. nr. 68 1980-81). The aim of the White Paper was to protect a representative section of the Norwegian nature.
2.3 The Glomma and Lågen Basin

2.3.1 G&L basin user interests

The G&L basin is Norway’s largest river basin and the G&L user interest include all the main user interest described at the national level historical review in section 2.1.1. The next section therefore will give a short supplement on basin characteristics concerning the user interest and issues discussed in this report.

Hydropower. The hydropower development era in the G&L basin started around year 1900 when power plants feeding industries were located at the lower part of Glomma between Lake Øyeren and the river outlet, and in smaller tributary rivers such as Mesna with its outlet to Lake Mjøsa. The power plants were generally built near by the reservoirs in the first development phase in the G&L basin. In the later development phases the power plants were often situated far downstream from the reservoirs (a more detailed description of the G&L hydropower development objects and the design characteristics is given in chapter 2.4).

Today the G&L basin hydropower plants supplies approximately 10 TWh annually, or about 9 % of national electricity supply.

Different alternatives for hydropower development in the G&L system have been handled in The Masterplan and in The Protection Plans (I-IV) (Annex 3). Several parts of the G&L basin have been protected, while other project still are in the licensing process, such as Øvre Otta in the upper reaches of the G&L basin. Several additional hydro projects in the G&L basin have been considered in The Masterplan, and ranked through that process as among the most acceptable, such decisions are vested with Parliament.

Flood Protection. Historically the G&L basin experienced several major floods. The one in July 1789 called “Storofsen” is the largest known in the G&L basin ever. Storofsen appeared after a long period of heavy rain and caused several landslides. During the last century big floods have appeared in G&L in 1910, 1916, 1927, 1934, 1939, 1966, 1967, and 1995. The last one in May/June 1995 was the most severe.

The work by the Commission on Flood Protection Measures was initiated because of the 1995-flood in the G&L-basin. The commission report from 1996 contains discussions of different types of emergency planning and flood warning systems, risk analysis in the assessment of flood protection measures and proposals for new measures to prevent flooding and erosion in the G&L basin (NOU 1996).

Some regulation dams and reservoirs are already used for flood protection purposes in addition to their primary hydropower production purpose. In addition, flood protection and different types of erosion control measures have been built during the last century to protect agricultural areas, infrastructure and settlements from flood damage.

Irrigation and Agriculture. Water from the G&L river system is to some extent used for agriculture irrigation during the growth season in summer. During the 1980’s and 1990’s the number of irrigation installations have increased. However, most of them are small, single farm installations. It is only in small tributary rivers of the G&L basin that water extraction for agriculture irrigation to some extent can influence the water-flow rates.

The G&L basin contains one of Norway’s main agricultural areas. The total agricultural area in the G&L basin is approximately 2400 km² or 5,8% of the total drainage area. The lower section of the
basin, from Lake Mjøsa and southwards, has the most significant agricultural areas. Runoff from the agricultural areas and leakage from agricultural point sources were one of the main sources to the heavy water pollution that were experienced in parts of the G&L basin during the 1970’s (see further description in paragraph on ecological effects). Throughout the whole G&L basin efforts have been made during the 1980’s and 1990’s in reducing diffuse contributions of pollution/effluents from agriculture.

**Municipal and industrial water supply.** Several municipalities in the G&L basin abstract water from G&L for municipal and industrial water supply needs. About 55 000 of the 150 000 people living in the immediate surroundings of lake Mjøsa use water from the lake as their source of drinking water, and 217 000 people are connected to municipal drinking water plants with water from river Glomma (Ministry of Environment 1992).

In the rural area of the basin households have private wells and are not connected to municipal water supply systems. Changes in ground water levels on floodplains due to hydropower developments can result in dry wells. Reduced flow rates downstream hydropower dams can also influence the recipient capacity and give less satisfactory water quality for private household water supply.

The industrial use of water from the G&L-river system is mainly for cooling processes and has little impacts on water flow rates and water quality.

**Recreation and Tourism.** Recreation and tourism is a still more important basin management issue in the G&L basin. The basin contain attractive, relatively pristine mountain and forest areas for fishing, hunting and walking for local inhabitants as well as for visitors. The most famous spots for rafting in Norway is situated in river Sjoa which is a tributary river to river Lågen. Tourism and natural heritage protection has increasingly become a major interest over the years with the basin planning and operation.

**Social effects.** At the end of the last century resources industries such as pulp and paper were established in the lower reaches of the G&L basin. This motivated the construction of dams for hydropower production as near as possible to the industry plants. After World War 2, reservoirs were built in the mountainous and northern areas of the G&L drainage system primarily to supply power to the national grid, and secondary for flood management to protect towns and agriculture investments in the lower reaches.

There are no resettlement issues in the G&L basin, as the reservoirs which affect the largest area are located in sparsely populated mountain areas where there are few permanent dwellings. The conflicts in connection to dams and regulation basins are different throughout the various parts of the G&L system. In the mountainous areas, nature protection, fishing, hunting and recreation are the most important interests. In the valleys and the lower part of the watercourse flood protection of agricultural areas, infrastructure and housing are the main interests in addition to nature protection and recreation. For some of these interests, dams and regulation basins may represent positive effects while they may represent negative effects for other interests.

Land acquired over the years was a mix of private and government land. However there have been legal proceedings on land acquisition in the past either by private or third party mainly focusing on compensation issues for land take, access, and loss/change of fishery potential and pastures.

**Ecological effects.** The main types of environmental impacts of river regulation are relatively well known from national research programs and from impact studies for specific hydropower projects. Several of these programs include studies from spots in the G&L basin. In the G&L basin sports fishery is a strong use interest, particularly the fishing on migratory fish species, such as the large piscivorous trout, whose migration has been blocked by some of the hydropower dams. Besides
important spawning areas have been disturbed by changes in water flow. As a consequence, attention is increasingly focused on mitigation efforts for sports fisheries and issues with fish stocking, fish ladders and habitat mitigation and rehabilitation. There is a degree of co-operation between regulators, operators, county authorities and local stakeholders and interest groups on optimising flows to mitigate impacts especially on fisheries and on physical habitat mitigation.

Lake Mjøsa was heavy polluted during the 1970’s and experienced increased algae growth and algae blooms with unpleasant smell and several other indications of being out of ecological balance. A separate action plan (The Mjøsa Campaign) resulted in implementation of several abatement measures in the drainage area to lake Mjøsa. The action has been a success, and the lake water quality has improved considerably.

There are negative impacts on water flora and fauna both in the regulation reservoirs themselves and on the river stretches where the flow rates are changed. The last 20 years the demand for environmental impact assessments prior to and during the license application process has been high. Effects of the proposed project on the multiple use of water, historical and cultural monuments, and biological diversity are now important aspects in the licensing review process.

Environment protection. Within the G&L basin, a total of 27 smaller watersheds (i.e. parts of the G&L river basin area) are protected against hydropower development, by the National Protection Plans adopted by the Norwegian Parliament (see list of Protection Plan watercourses in the G&L basin in annex 3). These watersheds comprise approx. 30% of the total G&L river basin area, and have a power potential of 4.1 TWh.

The G&L basin area, also have three National Parks, established in the period 1962-1980; Jotunheimen National Park, Rondane National Park and Dovrefjell National Park. The National Parks have a very strong legal protection against development projects or other impacts that may affect the environmental values. New parks and landscape protection areas, as well as enlargement of existing areas have been proposed.

2.3.2 G&L basin facts

Catchment. The G&L basin in southeast Norway covers an area of approximately 42 000 km² from Røros in the Northeast, Grotli in the Northwest and down to Fredrikstad in the south (Figure 2.3.1). 1% of the basin is in Sweden and the basin encompasses a total length of 600 km. The basin covers 13% of Norway’s total land area. The basin has 2 main rivers, River Glomma in Østerdalen and River Lågen i Gudbrandsdalen valley. The headwaters are in the high mountains and are partly glacier-fed. The confluence of the two rivers is downstream of Lake Mjøsa, the largest lake in the basin and in Norway. Lake Mjøsa is 362 km² and is a long and narrow typical Norwegian fjord lake with a maximum depth of more than 400 m.
Topography. The river basin covers altitudes from sea level and up to 2469 m at the top of Galdhopiggen, the highest mountain of Norway (see also table 2.3.1). The whole G&L basin was covered by ice during the last glacier-time and the basin topography has been formed by the ice and by the glacio-fluvial erosion- and sedimentation processes connected to the ice withdrawal 10 000 years ago.
Table 2.3.1 The altitude distribution in the G&L basin. (Source: Grønlund et al. 1999).

<table>
<thead>
<tr>
<th>Altitude zones</th>
<th>Area (km²)</th>
<th>Percentage of drainage area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 300 m</td>
<td>7 691</td>
<td>18</td>
</tr>
<tr>
<td>300 – 600 m</td>
<td>9 181</td>
<td>22</td>
</tr>
<tr>
<td>600 – 900 m</td>
<td>10 135</td>
<td>24</td>
</tr>
<tr>
<td>900 – 1 200 m</td>
<td>8 690</td>
<td>21</td>
</tr>
<tr>
<td>1 200 – 1 500 m</td>
<td>4 004</td>
<td>10</td>
</tr>
<tr>
<td>&gt; 1 500 m</td>
<td>2 272</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2.3.2 The distribution of major land use classes in the G&L basin. (Source: Grønlund et al. 1999).

<table>
<thead>
<tr>
<th>Land use category</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>5.8</td>
</tr>
<tr>
<td>Forest</td>
<td>48.9</td>
</tr>
<tr>
<td>Bogs and wetlands</td>
<td>7.1</td>
</tr>
<tr>
<td>Open areas with vegetation cover</td>
<td>36.8</td>
</tr>
<tr>
<td>Snow and glaciers</td>
<td>0.8</td>
</tr>
<tr>
<td>Urban areas</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Climate. The basin climate reflects the differences in latitude and altitude. The mean annual precipitation varies from 250 mm per year in the rain shadowed arid/semiarid areas in Ottadalen valley, to more than 1 500 mm per year in the higher elevation areas towards the water divide to the West Coast of Norway. The average basin precipitation is app. 780 mm per year. Figure 2.3.2 shows the yearly variation of precipitation at Skjåk in Ottadalen Valley and at Bygdin in the mountains of Jotunheimen.

Figure 2.3.2 Precipitation at Bygdin and Skjåk (averages 1961-90) (Source: GLB).

Temperatures also vary considerably within the basin. Parts of Østerdalen Valley with extreme inland climate can have very low winter temperatures, while areas in the south have a much milder and less...
fluctuating coastal climate. Figure 2.3.3 shows the yearly variation of temperature at Aursunden close to Røros in the northeast of the basin, and at Sarpsborg close to Fredrikstad in the south.

Figure 2.3.3 Temperatures at Aursunden and Sarpsborg (max and min 1978-95) (Source: GLB).

Hydrology. The hydrology of the G&L catchment reflects the large variations in climate within the catchment, from the high mountains in the north to the lowlands in the south. The runoff regime in river Lågen is somewhat different from river Glomma because the snow melt in spring starts later and prevails longer into summer in river Lågen because of higher percentage of areas of high mountain altitudes and glaciers in the Jotunheimen area. A more detailed description of runoff regimes in the G&L basin is given in Annex 2. This annex also gives a review of changes in runoff regimes, flood characteristics and groundwater regimes.

Population. About 620 000 (14.5%) of Norway’s population of 4.3 million people live in the G&L basin area, which includes some of the countries richest agriculture lands. The northern part of the basin is sparsely populated with small settlements in the valleys. The area from lake Mjøsa and southwards is denser populated with towns like Lillehammer and Hamar in the Lake Mjøsa region, and Fredrikstad in the southern part of the basin near the river outlet (figure 2.3.4).
2.3.3 The G&L basin as an Ecological System

The G&L basin encompasses a large variety of habitats, due to the presence of the climatic and physical gradients. The main influential gradients are:

- A north/south gradient, giving variation in climate, season and daylight.
- An elevation gradient, from the mountainous catchment areas above 2000 m a.s.l. to sea level. The elevation gradient overlaps the north-south gradient to a large extent.
- A climatic, east-west gradient, broadly described by oceanic-influenced climate in the westernmost mountain areas of the Lågen branch and dry, continental climate in the more inland, eastern parts of the basin (most of the basin). Main effects are higher precipitation in the oceanic-influenced parts and lower temperatures (and subsequently longer winters) combined with low precipitation in continental parts, giving, among other effects, a lower tree line (see figure 2.2. and 2.3). Further south, the large inland valleys of the basin have continental climate down to the warmer, coastal areas at the outlet.
- The post-glacial marine limit, the line of former sea level formed when the ice withdrew about 10 000 years ago and the land rose. The marine limit is at 208 m a.s.l. at Jessheim and at 192 m at Minnesund at the outlet of Mjösa, and thus defines a southern, low-lying region of the G&L basin. Below it, marine sedimentation has formed the landforms and soils, whereas glacial processes (erosion and moraine formations) have influenced areas above the marine limit. The marine deposits...
provide a much richer substrate than the glacio-fluvial substrate, giving higher productivity and diversity in these areas.

In addition, variations in geology/geomorphology affect vegetation types and water quality across these gradients, ranging from acidic spargmites to rich, calcareous soils. Also, there is a gradient with respect to human influence and urbanisation; population density and influence from agriculture, industry, transportation etc. increases towards the southern parts of the basin, nearer the coast.

Aquatic habitats. The aquatic habitats of the Glomma-Lågen watercourse vary from remote and pristine subalpine lakes to rivers in urban settings affected to various degree by pollution. Especially in the Lågen branch, many of the regulated lakes are in the subalpine region, i.e. altitudes of about 700-1100 m a.s.l. The biota in this area reflects the low temperature, which during a long winter period can be quite extreme, and water very poor in nutrients. In general the number of species is low and ecological systems are simpler compared to the lowland region further downstream. The main rivers, Glomma and Lågen, and the tributaries are fast-flowing with many riffles in the upper parts, but change to more slow-flowing rivers and lakes with much more complex biota and ecological interactions in the lower parts. Temperature is higher, and the nutrient load from agriculture, industry, household and the adjacent terrain also increases significantly as the rivers move downstream. Concurrently, the sediment load and the sedimentation of bottom habitats also increase and have marked biological effects.

The fish community can exemplify the great variety of G&L as an ecological system. Steep gradients and impassable waterfalls in the upper reaches were topographical barriers for most species of fish when the ice withdrew during the last deglaciation some 8 000 – 9 000 years ago. Large subalpine and mountainous areas thus remained uncolonized or had few fish species. However, extensive introductions followed human settlement in new areas, because fish, especially brown trout, were an important food source (Huitfeldt-Kaas 1918). Brown trout and to some extent char is the only fish species to have inhabited many of the waters in the upper catchment area for a long period of time. However, in recent years, several new fish species have been introduced into the mountainous area. This is especially true for European minnow, which have been accidentally introduced into several lakes and streams (Hesthagen & Sandlund 1997). The lower part of Glomma-Lågen has the largest number of freshwater fish species in Norway. A total of 29 species are registered. The number of species decreases further upstream, but in the main river branches there are still as much as 17 species in the lower part of Lågen and 11 species in the uppermost part of Glomma (Svarte 1983, Eriksen & Hegge 1994). The dominance of species in the different reaches reflects the physical and chemical conditions and the competitive ability of the species under different conditions. In general, cyprinids, pike and perch are dominating in the slow flowing, nutrient-rich lower parts whereas salmonids like brown trout, grayling and whitefish dominate in the upper parts.

Terrestrial habitats. The terrestrial habitat types in the G&L river basin shows much of the same variation pattern with respect to productivity and biodiversity. A coarse classification of habitats gives an overview of the biological complexity of the G&L basin:

**Alpine areas above the tree line (2469-1000 m a.s.l.):** Vegetation cover and level of productivity is dependent on altitude, climatic influence, particularly precipitation, temperature and length of winter season. Vegetation is treeless, and mosses and lichens are prevalent. These areas constitute important habitat for reindeer, wolverine, several species of birds of prey in addition to invertebrates and small mammals. The flora is very diverse across the mountainous areas, as both oceanic and continental conditions, rich and poor soils are included.

**Subalpine birch forest (1100-700 m a.s.l.):** The subalpine birch forest has a richer field layer including numerous herbs and shrubs. Willow grouse (*Lagopus lagopus*), which is an important hunting species, is widespread in this habitat, as well as numerous mammals, passerine birds and birds of prey.
Diversity of plants and invertebrates is higher than in the alpine areas.

_Boreal forest - pine (in dry areas) and spruce (900 m.a.s.l.-0):_ Boreal forest is very extensive in Norway, and by extent, this is the dominant terrestrial habitat in the basin (table 2.2). Pine and spruce forests largely cover the Glomma branch of the basin. Important mammal species are moose, brown bear, fox, pine marten, wolf and several species of rodents. Important bird species are capercaillie, black grouse and woodpeckers, of which some species are on the national Red List (Directorate for nature management 1999).

_Mixed deciduous forest (200 m a.s.l.-0):_ This type of forest is found in warmer climatic conditions in the southern, low-lying parts of the basin. It has the highest diversity of plants, invertebrates and birds, and also a diverse mammal fauna. Forests contain the highest proportion of Red List species compared to other habitats (45.9% of total, all forest types combined (Directorate for nature management 1999).

_Riparian habitat:_ River banks, associated swamps and alluvial plains are affected by water level, water flow and flood periods, giving different vegetation types depending on substrate stability and grain size, drainage and formation of swamp conditions. Riparian zones are highly productive habitats and important for the invertebrate, bird and mammal fauna. Includes many pioneer plant communities and specialised species which are particularly vulnerable to changes in water flow. The Lågen branch has a particularly rich variety of these habitats, and several rare species are found.

_Mires/wetlands:_ Mires, which are found in most forest types and in different climatic and soil conditions, harbour a number of specialised and rare species. On a national scale, important wetlands and deltas are found at the outlet of Lågen into Mjøsa, Akersvika at the outlet of Svartelva into Mjøsa and in Lake Øyeren. These are important bird habitats.

_Cultural landscapes (1000 m a.s.l. –0):_ Landscapes formed by human use, grazing and harvesting, extending from traditional mountain farms at around 1000 m a.s.l. to modern day farms and grazing areas in the lowland. Cultural landscapes often have a specialised flora, high diversity of invertebrates and birds, especially old meadows. Cultural landscapes have a high proportion of Red List species (28.5%).

_Urban areas:_ Urban areas, with high population density, are concentrated in the southern part of the basin, which in undisturbed areas also has the highest biodiversity and warmest climate. Secondary habitat, parks and small pockets of natural habitat can be especially valuable here, as some species reach the northern limit of their range.

Most of the regulations combine damming with lowering the natural water level (draw-off). Effects can then be found both related to damming of previously terrestrial areas, and exposure of the former lake or valley bottom. The extent and type of effects in each case is dependent on the dominance of damming vs. exposure effects, size of area affected (slope of reservoir at water level) and regulation pattern (speed and amplitude of water level changes).

2.3.4 Basin Planning and Management

_Public Planning and Management._ The last 20 years the demand for impact assessments prior to and during the license application process has been high. Effects of a proposed hydropower development project on the multiple use of water, historical and cultural monuments, and biological diversity are now important aspects in the licensing review process.

In addition to licensing review processes for hydropower development projects, several types of local and regional planning processes are now carried out for both river Lågen and river Glomma with a diverse set of government participants and other stakeholders. Some of the processes are partly
integrated basin wide processes, while others are specific for separate tributary rivers, for counties or municipalities. Examples of inter-municipal plans co-ordinating the multiple uses of the different sections of the G&L basin are The Action plan for River Glomma (Ministry of Environment 1992) and The Watercourse Plan for River Gausa (Gausdal kommune and Lillehammer kommune 1994 a and b).

Several public authorities undertake the water management work connected to public interests in the G&L basin. The authorities are both national level (ministries and directorates), regional level (5 counties and 5 county governors), and local level authorities (60 municipalities). Decisions affecting the public interest are made by all authority levels and from different sector based acts as well as from general acts (Water Act, Land Use Act and Pollution Act), see also chapter 6.1.

**Basin Operation.** In addition to the basin management done by public authorities, G&L has a basin level water user association called “The Glommen’s and Laagen’s Water Management Association (GLB)”. GLB is the largest basin-level water users association in Norway.

GLB members include 21 industries and hydropower companies. They hold licenses for a complex of 26 regulated reservoirs of small and medium size which together provide some 3 500 million m$^3$ of storage, equivalent to 16 % of the runoff in the G&L river basin.

Although the hydropower production interest is the main objective of GLB, the association also does other types of management work in the joint reservoir system according to legislation and a complex system of water-sharing rules and regulations set down by negotiation between environment interests, municipal and county authorities, private power and industry water users, as well as various associations representing farmers, landowners and civil society groups. A more detailed description of basin operation is given in chapter 6.

### 2.4 Objectives, Components and Design Characteristics of the G&L Basin Development Project

**Objectives**

With a few exemptions the regulation reservoirs in the G&L basin have been build primarily for hydropower production. Only the first regulation of lake Mjøsa and Lake Øyeren in the middle of the 19th century are examples of regulations for flood protection purposes. In addition 3 reservoirs established in the 1920s were planned from flood protection purposes (see section 3.2 on flood control). All the present reservoirs are used for hydropower production as their primary function. Figure 2.4.1 shows the complex system of reservoirs and hydropower plants in the G&L-basin today.
The hydropower reservoirs in the G&L basin are mainly natural lakes with low regulation heights after regulation and with low levels of storage. Lake regulation capacity is often gained both from increasing and decreasing natural water levels (Figure 2.4.2 and Table 2.4.1). The largest hydropower

**Figure 2.4.1 Reservoirs and power plants in the G&L basin (Source: GLB)**

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
dams in the basin are in the high mountains. Dams in the lower portion tend to be run-of-river cascades along the river.

From a total of 40 dams/reservoirs throughout the catchment area shown in table 2.4.1, 16 reservoirs are situated above 900 m.a.s.l. (between 900 and 1130), 13 between 600 and 900 m.a.s.l., 7 between 300-600 m.a.s.l. and 4 below 300 m.a.s.l. Regulation heights range from 0,75 m to 30,3 m, with most reservoirs regulated less than 5 m. Of the remaining reservoirs only one lake (Raudalsvatn) is regulated more than 30 m. The increase in water surface area following damming ranges from 0,1 km² to 12,3 km². We do not have data on the size of regulation zones, and because of the influence of slope around each reservoir, this cannot be inferred directly from data on regulation heights and water surface area. However, the increase in water surface area does bear a minimum indication of the area affected. In total, the creation of reservoirs has led to an increase of water surface area of 46,6 km² in the G&L basin, measured at FSL.

The effect of regulation on river flow-rates are considerable downstream of the mountain reservoirs like Raudalsvatnet, Olstappen and Fundin. Further downstream the changes in flow rates are smooted, and the differens between regulated and unregulated flow rates are less significant (figure 2.4.3).

**Figure 2.4.2** Maximum and minimum licensed water level relative to unregulated water level in selected G&L reservoirs. (source: GLB)
Table 2.4.1 Dams/reservoirs in the G&L basin. (Sources: GLB 1995, 1997)

<table>
<thead>
<tr>
<th>Reservoir /dam</th>
<th>Regulation limits</th>
<th>Dam height (^1) (\text{m})</th>
<th>Reservoir capacity (^3) (\text{Mm}^3)</th>
<th>Dam built (^4) (year)</th>
<th>Licence given (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSL(^1)</td>
<td>LSL(^2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lågen branch of G&amp;L:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aursjø</td>
<td>1097.50</td>
<td>1085.00</td>
<td>10.2</td>
<td>60</td>
<td>1920/1962-65</td>
</tr>
<tr>
<td>Breidalsvatn</td>
<td>908.00</td>
<td>895.00</td>
<td>8.8</td>
<td>70</td>
<td>1942/1986</td>
</tr>
<tr>
<td>Raudalsvatn</td>
<td>916.30</td>
<td>886.00</td>
<td>40.8</td>
<td>166</td>
<td>1942/1952</td>
</tr>
<tr>
<td>Tesse</td>
<td>853.90</td>
<td>841.50</td>
<td>3.5</td>
<td>130</td>
<td>1941/1978</td>
</tr>
<tr>
<td>Bygdin</td>
<td>1057.40</td>
<td>1048.50</td>
<td>4.7</td>
<td>336</td>
<td>1928-36/1982</td>
</tr>
<tr>
<td>Vinстран</td>
<td>1031.50</td>
<td>1027.50</td>
<td>10.4</td>
<td>102</td>
<td>1942/1948-51</td>
</tr>
<tr>
<td>Nedre Heimdalsvatn</td>
<td>1052.20</td>
<td>1050.00</td>
<td>3.5</td>
<td>15</td>
<td>1957-59</td>
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<tr>
<td>Sandvann/Øyvatn/Kaldfjorden</td>
<td>1019.00</td>
<td>1013.10</td>
<td>12.0</td>
<td>76</td>
<td>1956</td>
</tr>
<tr>
<td>Øyangen</td>
<td>998.00</td>
<td>996.00</td>
<td>7.5</td>
<td>8</td>
<td>1956</td>
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<tr>
<td>Ølstappen</td>
<td>668.00</td>
<td>655.00</td>
<td>21.2</td>
<td>31</td>
<td>1953-55</td>
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<tr>
<td>Goppollen</td>
<td>979.10</td>
<td>976.90</td>
<td>-</td>
<td>3</td>
<td>1947/85</td>
</tr>
<tr>
<td>Djupen</td>
<td>916.85</td>
<td>913.85</td>
<td>-</td>
<td>2</td>
<td>1947/84</td>
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<tr>
<td>Grunnvatnet</td>
<td>881.00</td>
<td>880.00</td>
<td>-</td>
<td>0.5</td>
<td>1947</td>
</tr>
<tr>
<td>Våsjoen</td>
<td>873.75</td>
<td>870.25</td>
<td>-</td>
<td>3</td>
<td>1947/89</td>
</tr>
<tr>
<td>Øvre Ongsjøen</td>
<td>1003.00</td>
<td>1002.00</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Nedre Ongsjøen</td>
<td>947.00</td>
<td>943.60</td>
<td>-</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Bennsjøen</td>
<td>827.25</td>
<td>825.00</td>
<td>-</td>
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<td>Hornsjø</td>
<td>844.70</td>
<td>841.20</td>
<td>-</td>
<td>10</td>
<td>1973</td>
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<tr>
<td>Roppjtjern</td>
<td>827.80</td>
<td>823.00</td>
<td>-</td>
<td>3</td>
<td>1973</td>
</tr>
<tr>
<td>Rausjøen</td>
<td>720.50</td>
<td>715.00</td>
<td>-</td>
<td>5</td>
<td>1949</td>
</tr>
<tr>
<td>Reinsvatn</td>
<td>905.00</td>
<td>902.50</td>
<td>-</td>
<td>8</td>
<td>1920</td>
</tr>
<tr>
<td>Melsjøen</td>
<td>892.80</td>
<td>889.80</td>
<td>-</td>
<td>3</td>
<td>1920</td>
</tr>
<tr>
<td>Mjøgsjøen/Kroksjøen</td>
<td>882.20</td>
<td>879.20</td>
<td>-</td>
<td>14</td>
<td>1920</td>
</tr>
<tr>
<td>Sjusjøen</td>
<td>809.80</td>
<td>805.60</td>
<td>-</td>
<td>5</td>
<td>1954</td>
</tr>
<tr>
<td>Sør-Mesna</td>
<td>521.40</td>
<td>513.90</td>
<td>-</td>
<td>40</td>
<td>1910/20/34</td>
</tr>
<tr>
<td>Nord-Mesna</td>
<td>519.60</td>
<td>511.30</td>
<td>-</td>
<td>41</td>
<td>1910/20</td>
</tr>
<tr>
<td>Næra</td>
<td>339.95</td>
<td>336.95</td>
<td>-</td>
<td>29</td>
<td>1908</td>
</tr>
<tr>
<td>Einavann</td>
<td>398.36</td>
<td>396.06</td>
<td>-</td>
<td>29</td>
<td>1897</td>
</tr>
<tr>
<td>Skjellbreia</td>
<td>408.68</td>
<td>406.18</td>
<td>-</td>
<td>7</td>
<td>1897</td>
</tr>
<tr>
<td>Skumsjøen</td>
<td>432.00</td>
<td>429.00</td>
<td>-</td>
<td>4</td>
<td>1897</td>
</tr>
<tr>
<td>Mjøsa</td>
<td>122.94</td>
<td>117.69</td>
<td>-</td>
<td>1312</td>
<td>1856/07/58-63</td>
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<tr>
<td>Hurdalsjøen</td>
<td>176.15</td>
<td>172.55</td>
<td>16.7</td>
<td>122</td>
<td>1905</td>
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<td><strong>Glomma branch of G&amp;L:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Aursunden</td>
<td>690.00</td>
<td>684.10</td>
<td>6.8</td>
<td>215</td>
<td>1921-24</td>
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<td>Elgsjø</td>
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<td>1124.65</td>
<td>6.0</td>
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<tr>
<td>Fundin</td>
<td>1021.25</td>
<td>1010.25</td>
<td>23.5</td>
<td>64</td>
<td>1966-70</td>
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<tr>
<td>Marsjø</td>
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<td>1060.00</td>
<td>4.8</td>
<td>10</td>
<td>1910-11</td>
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<td>Savalen</td>
<td>707.20</td>
<td>702.50</td>
<td>6.3</td>
<td>61</td>
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<td>Storsjøen</td>
<td>251.64</td>
<td>248.00</td>
<td>10.1</td>
<td>175</td>
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<td>Osen</td>
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<td>430.90</td>
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<td><strong>Lower Glomma:</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Øyern</td>
<td>101.34</td>
<td>96.54</td>
<td>157</td>
<td>1857-62/17-24</td>
<td>1934</td>
</tr>
</tbody>
</table>

1 – FSL = Full Supply Level (meters above sea level)
2 – LSL = Low Supply Level (meters above sea level)
3 – The ICOLD definition of large dams is reservoir capacity > 3 Mm\(^3\) or dam height >15 m
4 – More than one year in the column indicate that the regulation height has been increased or the dam has been rebuilt.

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Tabell 2.4.2 provides a list of the power plants in the G&L basin with name of the owner companies, the installed effect, the mean annual production and the year of licence for the power plants.

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Owner company</th>
<th>Installed effect MW</th>
<th>Mean annual production GWh</th>
<th>Licence given (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lågen branch of G&amp;L:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skjåk I</td>
<td>K/L Opplandskraft</td>
<td>33.0</td>
<td>105</td>
<td>1962</td>
</tr>
<tr>
<td>Øvre Tessa</td>
<td>A/S Eidefoss</td>
<td>16.0</td>
<td></td>
<td>1983</td>
</tr>
<tr>
<td>Midtre Tessa</td>
<td>A/S Eidefoss</td>
<td>7.2</td>
<td>253</td>
<td>1983</td>
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<tr>
<td>Nedre Tessa</td>
<td>A/S Eidefoss</td>
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<td></td>
<td>1983</td>
</tr>
<tr>
<td>Eidefossen</td>
<td>A/S Eidefoss</td>
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<td>75</td>
<td>1916</td>
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<td>1960</td>
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<td>Roppa + small power plants</td>
<td>Lillehammer og Gausdal El-verk</td>
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<td>1963</td>
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<td>Tyria II</td>
<td>Mesna Kraftselskap</td>
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<td>1958</td>
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<td>Mesna Kraftselskap</td>
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<td>Mesna</td>
<td>Mesna Kraftselskap</td>
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<td>Moelv</td>
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<tr>
<td>6 power plants in Hunnselva</td>
<td>Gjovik El-verk/Toten kom E-verk</td>
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<td>1915</td>
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<td>5 powerplants in Andelva</td>
<td>Hafslund ASA</td>
<td>6.1</td>
<td>34</td>
<td>**</td>
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<td><strong>Glomma branch of G&amp;L:</strong></td>
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<td>Kuråsfossen</td>
<td>Rørøs E-verk AS</td>
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<td>55</td>
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<td>Røstefossen</td>
<td>Rørøs E-verk AS</td>
<td>4.6</td>
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<tr>
<td>Einunna</td>
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<td>Savalen</td>
<td>K/L Opplandskraft</td>
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<td>160</td>
<td>1966</td>
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<tr>
<td>Solna</td>
<td>A/L Nord-Osterdal K/L</td>
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<td>1966</td>
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<td>Storfallet</td>
<td>Anders Kiaer</td>
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<td>11</td>
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<td>Osa</td>
<td>Hedmark Energi AS</td>
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<td>Kvernfallen</td>
<td>Hedmark Energi AS</td>
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<td>1917</td>
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<td>Hamarregionen Energiverk</td>
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<td>Skjefstadfoss</td>
<td>Elverum El-verk</td>
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<td>Funnefoss</td>
<td>Akershus Kraft AS</td>
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<td>185</td>
<td>1973</td>
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<td><strong>Lower Glomma:</strong></td>
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</tr>
<tr>
<td>Rånsfoss</td>
<td>Akershus Kraft AS</td>
<td>99</td>
<td>480</td>
<td>1917</td>
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<td>Bingfoss</td>
<td>Akershus Kraft AS</td>
<td>32</td>
<td>160</td>
<td>1975</td>
</tr>
<tr>
<td>Mørkfoss/Solbergfoss</td>
<td>Statkraft SF/Oslo Energi Prod. AS</td>
<td>215</td>
<td>900</td>
<td>**</td>
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<tr>
<td>Fossumfoss -Kykkelrud</td>
<td>A/S Kykkelrud</td>
<td>212</td>
<td>1096</td>
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</tr>
<tr>
<td>Vamma</td>
<td>A/S Vamma Fossekompagni</td>
<td>217</td>
<td>1240</td>
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<td>3 power plants in Sarpsfossen</td>
<td>Hafslund ASA and Borregaard Indust. Ltd.</td>
<td>158</td>
<td>860</td>
<td>**</td>
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<tr>
<td><strong>Sum G&amp;L</strong></td>
<td></td>
<td>2 165</td>
<td>10 145</td>
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</tr>
</tbody>
</table>

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** Waterfall rights bought earlier than 1909 are free of licence. New regulations on time restricted licences were approved in 1909.

**Figure 2.4.3** Effects of regulation on flow regimes at selected points of the G&L river system

(Source: GLB)

**Design characteristics**
Table 2.4.3 Data on selected dams in the G&L basin representing the variety of dam types, dam and reservoir sizes and geographical situation.

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Start of com. product-ion</th>
<th>Dam type</th>
<th>Dam height (m)</th>
<th>Reservoir area (km²)</th>
<th>Reservoir active storage (mill m³)</th>
<th>Distance from river outlet (km²)</th>
<th>Altitude (meter above sea level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mjøsa</td>
<td>1910&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Gated gravity d.</td>
<td>-</td>
<td>363</td>
<td>1312</td>
<td>170,0</td>
<td>123</td>
</tr>
<tr>
<td>Olstappen</td>
<td>1955</td>
<td>Buttress dam</td>
<td>14</td>
<td>3,3</td>
<td>31</td>
<td>378,4</td>
<td>662</td>
</tr>
<tr>
<td>Raudalsvatn</td>
<td>1952</td>
<td>Arch dam</td>
<td>41</td>
<td>7,3</td>
<td>166</td>
<td>500,2</td>
<td>916</td>
</tr>
<tr>
<td>Fundin</td>
<td>1970</td>
<td>Rockfill dam</td>
<td>23</td>
<td>10</td>
<td>64</td>
<td>508,8</td>
<td>1021</td>
</tr>
<tr>
<td>Storsjøen</td>
<td>1969</td>
<td>Earthfill dam</td>
<td>5</td>
<td>48</td>
<td>175</td>
<td>349,4</td>
<td>251</td>
</tr>
</tbody>
</table>

Pictures of non-focal dams are available as separate files:

**Figure 2.4.4** Svanfoss at the outlet of nonfocal dam Mjøsa

**Figure 2.4.5** Non focal dam Olstappen

**Figure 2.4.6** Non focal dam Raudalsvatnet

**Figure 2.4.7** Non focal dam Fundin

**Figure 2.4.8** Non focal dam Storsjøen
3. Projected and Actual Impacts of the G&L Basin Hydropower Development

3.1 Hydropower

3.1.1 Predicted versus Actual Hydropower Production

System level
The consumption of electricity in Norway increased 10 fold from approx. 15 to 120 TWh during the last 50 years. This growth rate was around 1970 anticipated to continue more or less exponentially, and the forecasts had a tendency to overestimate future consumption levels. Forecasts during 1980-87 has been more realistic (Figure 3.1.1). During the last 50 years the total production of electricity from hydropower increased from approximately 15 to 113 TWh in an average year. The hydropower production from the GLB-basin increased from 3 to 10 TWh during this period. During the last 50 years the GLB proportion has decreased from approximately 20% to 9% of the total hydropower production in Norway. The reason for this is that several large hydropower development projects have been carried out in other parts of the country during this period while most of the G&L developments are older.

Before World War II, the major consumers of electricity were industrial enterprises and the investors therefore were mainly private. After World War II, the development of hydropower resources were done mainly by public companies. In 1999, more than 85% of the total electricity production from hydropower was on public hands. The remaining 15% is also partly public as for example the company Norsk Hydro involve 51% public interest. The post World War II development came mainly in the municipal and county sector, which in 1999 counted for 55% of the electricity production. The State controls about 30% through the State owned company Statkraft SF.

Figure 3.1.1 Hydropower consumption and production in Norway from 1940 to 1998. (Source: Norwegian Official Statistics (NOS) and GLB)

Until 1991, when the new Energy Act was implemented, each power company supplying end user customers in their licensed area had an obligation to supply their customers. Hence they had to match
the increase in consumption by developing more hydropower or to buy power from those power producers having a surplus. The balance between demand and supply and the forecast for the coming years were handled on county and national levels (but not on a basin level). Since the political consensus was to have enough power to rebuild and develop the nation according to a variety of political goals, the authorities promoted a sequence of power projects to be planned and ready for licensing procedures to avoid shortages. The power companies on their side in the mean time acquired necessary waterfall rights and accumulated capital as basis for financing the new projects. A more detailed analysis of the effects of the new Energy Act is given in Annex 4.

The guidelines for national planning intend to give a production capacity capable of meeting the demand in nine years out of ten (dry year insurance). The result, as illustrated by figure 3.1.1, was that in most of the years until 1995 there was a slight surplus of hydropower relative to the national demand. Today, however, the situation is changed. Without further development of hydropower or input from alternative energy sources, Norway will have to either stabilise the consumption at approximately the present level or to continue importing energy from neighbouring countries. These countries produce energy from fossil fuels or nuclear power.

**Basin and project level**

The G&L-basin area has not been self-sufficient with power from its own plants for a long period. The areas along the middle and southern part of the G&L basin are in the Norwegian context densely populated with industries and numerous small urban communities, while the largest sources of hydroelectric power are located close to the coast in western and northern Norway. Here the slope gradient is more favourable and the precipitation is much higher. Power consumption in the G&L-basin area is at present three times the output of the power plants in the Lågen and Glomma river systems.

Building of new powerstations and upgrading of old ones has been a continuous process during the last 100 years. For obvious reasons it is not easy to present evaluations of planned versus actual increase in production for all of these cases. The more recent developments therefore have been selected for an analysis. Most of the power plants in the G&L basin have increased the production during their period of operation. Increased capacity is gained by installation of new units, by renewal of the power stations or by building of new power stations (Ex. Kuråsfossen, Osfallet, Osa, Kvernfall, Skjefstadfoss, Tesse, Nedre Vinstra, Rånåsfoss, Solbergfoss, Kvernfallet, Kykkelsrud, Vamma and power plants in Sarpsfossen). In table 3.1.1 powerstations upgraded during the last 20 years are presented with data on planned and actual production data. It should be noted that the period of operation so far is rather short to establish the proper average production to be compared to the planned one. For the 7 powerstations in the table the installed capacity has increased from 426,1 to 862 MW (102%) and the production increased from 3042 to 3764,9 GWh (24%).

**Table 3.1.1** Powerstations upgraded during the last 20 years. (Source: GLB).

<table>
<thead>
<tr>
<th>Powerstation</th>
<th>Year</th>
<th>Increase in installed capacity (MW)</th>
<th>Increase in production (GWh/y)</th>
<th>Planned new production (GWh/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Røstefossen 1)</td>
<td>1987</td>
<td>1.9 → 3.1</td>
<td>10.3 → 16.5</td>
<td>20</td>
</tr>
<tr>
<td>Kongsvinger 2)</td>
<td>1988</td>
<td>20.9 → 20.9</td>
<td>106 → 129</td>
<td>120</td>
</tr>
<tr>
<td>Eidefoss 3)</td>
<td>1983</td>
<td>1.5 → 12.0</td>
<td>9.7 → 71.4</td>
<td>75</td>
</tr>
<tr>
<td>Nedre Vinstra 4)</td>
<td>1990</td>
<td>200 → 300</td>
<td>1073 → 1097</td>
<td></td>
</tr>
<tr>
<td>Rånåsfoss 5)</td>
<td>1983</td>
<td>61.8 → 99.0</td>
<td>356 → 486</td>
<td></td>
</tr>
<tr>
<td>Solbergfoss 6)</td>
<td>1985</td>
<td>118 → 215</td>
<td>687 → 878</td>
<td>890</td>
</tr>
<tr>
<td>FKF 7)</td>
<td>1985</td>
<td>22.0 → 212</td>
<td>800 → 1087</td>
<td></td>
</tr>
<tr>
<td>SUM</td>
<td>-</td>
<td>426.1 → 862</td>
<td>3042 → 3764.9</td>
<td>-</td>
</tr>
</tbody>
</table>

---

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
1) Two turbines substituted by one. A second turbine of 1.5 MW is never used because of economical reasons, it increases the tailwater level and needs more manual care.

2) Head increased by 0.75 m. No new installation.

3) Completely new station. Production in some years exceeds 75 MW.

4) Additional turbine, new inlet tunnel and reduction in other loss factors.

5) Additional turbine.

6) Additional turbine. Without bypass of water in a few years theoretical production would have been 891 GWh/y. Increase by 150 GWh/y from increased production and by 50 GWh/year from new transmission lines.

7) Additional turbine.

Figure 3.1.2 shows the annual hydropower production in the G&L area from 1950 to 1993. The increase in production is partly due to implementation of new power plants and new reservoirs and partly extension and rebuilding of existing power plants. Several of the G&L basin power plants were initially built prior to the introduction of the hydropower licensing system. Since then they have been rebuilt step by step, and new licences have been given for each of the renewals. The question of predicted versus actual production accordingly is very complex. A possible increase in installation and production have been foreseen in several of the power plants and they were prepared for installation of additional units when they were first built. In other power plants a future increase and in production were not projected and the actual production have far exceeded the initially projected production at the start of operation. In 1950 the G&L hydropower production was approximately 3 TWh/year. From 1990 there has been no increase in production capacity and the production have been from 8 to 12 TWh/year depending on precipitation and reservoir inflow.

![Graph showing hydropower production in the G&L basin from 1950 to 1993 (Source: GLB)](image)

**Figure 3.1.2** Hydropower production in the G&L basin from 1950 to 1993 (Source: GLB)

### 3.1.2 Predicted versus Actual Schedules and Timing of Hydropower Projects

Generally there is a considerable time span (from 5 to 23 years) from an application for license is forwarded to the authorities and to the commission of the power station or reservoir (Table 3.1.2). Almost all the hydropower development projects in the G&L basin have been changed in the process from initial planning through the licensing process to the final approved project (if the license is granted at all). During this process several hydropower development plans have been reduced considerably (e.g. Jotunheimen/Øvre Otta described in chapter 5). In other cases the consequences of the process have been less significant for the final hydropower output. Accordingly it is important to
relate the definition of projected hydropower generation to a defined phase of the planning process, for example the approval from the authorities (granted license).

Table 3.1.2 Overview of selected hydropower project schedules.

<table>
<thead>
<tr>
<th>Project</th>
<th>Application</th>
<th>Permission</th>
<th>Decision</th>
<th>Postponing</th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aursunden</td>
<td>1919</td>
<td>1921</td>
<td>1921</td>
<td></td>
<td>1921</td>
<td>1924</td>
</tr>
<tr>
<td>Storsjøen</td>
<td>1941/1946</td>
<td>1943/1947</td>
<td>1941</td>
<td>Dam site</td>
<td>1967</td>
<td>1969</td>
</tr>
<tr>
<td>Øsen</td>
<td>1923</td>
<td>1928</td>
<td>1932</td>
<td>1)</td>
<td>1935</td>
<td>1941</td>
</tr>
<tr>
<td>Raudalsvatn</td>
<td>1937</td>
<td>1941</td>
<td>1941</td>
<td>World War II</td>
<td>1941</td>
<td>1944</td>
</tr>
<tr>
<td>in temporary</td>
<td>-</td>
<td>1948</td>
<td>948</td>
<td>None</td>
<td>1949</td>
<td>1952</td>
</tr>
<tr>
<td>Rauldsvatn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in final</td>
<td>1941</td>
<td>1942</td>
<td>1942</td>
<td>2)</td>
<td>1932</td>
<td>1933</td>
</tr>
<tr>
<td>Ostappen</td>
<td>1941</td>
<td>1942</td>
<td>1942</td>
<td>2)</td>
<td>1932</td>
<td>1933</td>
</tr>
<tr>
<td>in temporary</td>
<td>1948</td>
<td>1950</td>
<td>-</td>
<td>-</td>
<td>1953</td>
<td>1955</td>
</tr>
<tr>
<td>in final</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mjøsøa I</td>
<td>1903</td>
<td>1906</td>
<td>1908</td>
<td>3)</td>
<td>1908</td>
<td>1910</td>
</tr>
<tr>
<td>Mjøsøa II</td>
<td>1940</td>
<td>1947</td>
<td>1947</td>
<td>Existing facilities</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Power Station

<table>
<thead>
<tr>
<th>Project</th>
<th>Application</th>
<th>Permission</th>
<th>Decision</th>
<th>Postponing</th>
<th>Construction</th>
<th>Operation</th>
</tr>
</thead>
</table>

1) The period prior to the construction phase for the regulation at Lake Osensejøen was prolonged due to controversies on the states ownership, local participation with shortage of funding, legal evaluation and finally World War (GLB II. p. 218 ff.).

2) After the regulation of Lake Bygdin a dam for log driving purposes was established at Lake Olstappen in 1932 and this facility was also used temporary to store water during winter from 1942.

3) The discussion of the application from The Water Management Association (Glommens Brukseierforenings) for Lake Mjøsøa I in the Parliament the autumn 1907 created a lot of political drama and lasted for five days. "... The case which here is put forward, was at first indeed viewed as a technical matter, however due to the events it has become a political matter of great importance..." and prime minister Michelsens stated: "The proposals put forward here this evening will decide the future of the government. ..." (GB p. 27 ff.)

When referring to the forecasted hydropower generation as in the approved license, almost all the hydropower development projects in the G&L basin have reached their production goals. Some of the projects, however, have been delayed due to a number of reasons, such as controversies relating to the ownership that had to be settled, difficulties in selecting the dam site, the World War II and technical challenges related to the dam and tunnels.

There are also some examples from the G&L basin on hydropower development projects initiated mainly to create employment to specific districts in periods of depression and high unemployment rates. One example is the use of unemployed miners from the mining industry at Røros, to do tunnelling during the construction period at Aursunden Reservoir.

3.1.3 Predicted versus Actual Costs

Most of the hydropower reservoirs in the G&L basin are more than 30 years old and the only available numbers on estimated cost have been the propositions raised for the parliament at the time of licence approvals (Table 3.1.3). The cost estimate have been further complicated by the fact that the time span...
from licence approval to the start of construction and the time when the new reservoirs were set in operation have been from 3 to 5 years from 4 of the dams selected as non-focal dams in The G&L case study (Raudalsvatn, Mjøsa III, Olstappen and Fundin), and as long as 23 years for the 5th non-focal dam (Storsjøen). For Lake Storsjøen the original development plan was never realised, but a larger project was launched without the normal application procedure. Relevant data on planned costs and production potentials have therefore been difficult to get.

A common feature for the 4 non-focal dams is that the actual development cost have been higher than the estimated cost at the time of licence approval. This is partly due to the above mentioned time lag between approval and start of construction, and partly due to the fact that the compensations have been significantly larger than anticipated in the project plans.

**Fundin.** According to the plan (St.prp.nr.109, 1964-65) the new reservoir was to have a regulated height of 17 m and a regulated volume of 65 mill. m³. The plan estimated a cost of 6 mill. NOK (41,9 mill. NOK1999, 5,6 mill. US$1999) and a production potential of 94 GWh (if utilised in a total head of 664 m with an efficiency of 0,87). During construction the regulated height was reduced to 11 m, but still with a regulated volume of 64 mill m³. The actual cost of the project over the period from 1962 to 1974 was 9,6 mill NOK (59,8 mill NOK 1999, 7,9 mill. US$1999). The compensation part of the total cost was 24 %.

**Raudalsvatn.** According to the plan (St.prp.nr.23, 1947) the reservoir was to have a regulated height of 30,3 m and a regulated volume of 166 mill. m³. The plan estimated a cost of 3 mill. NOK (43,4 mill NOK1999, 5,8 mill. US$), and a production potential of 34 GWh (if utilised in the total head of 104,6 m of the existing power plants in Glomma). The reservoir was constructed according to the planned capacity and the actual cost over the period from 1946 to 1955 was 5,1 mill NOK (63,5 mill. NOK, 8,4 mill.US$1999).

**Olstappen.** According to the plan (St.prp.nr.50, 1950) the old dam with a regulated height of 2,2 m and a regulated volume of 4 mill. m³ was to be substituted by a new dam with a regulated height of 13 m and a regulated volume of 33 mill. m³. The plan estimated a cost of 2 mill. NOK (21,3 mill NOK1999, 2,8 mill US$1999), including compensation to landowners, and a production potential of 30 GWh in River Vinstra and an additional potential of 6 GWh in the existing power stations in Glomma. The increased degree of regulation was estimated to contribute with 32 GWh of the total 36 GWh. The final result was a slight reduction of the regulated volume to 31 mill. m³, but with the initial regulated height of 13 m. The actual cost of the project over the period from 1948 to 1960 was 5,7 mill NOK (60 mill NOK, 8,0 mill US$1999).

**Mjøsa.** According to the plan (Innst.S.nr.168, 1959-60) the old dam was to be substituted by a new dam for an increase of the regulated height with 0,75 m and the regulated volume with 272 mill. m³. The plan estimated the cost of the new dam at Svanfoss to 3,7 mill. NOK, tunneling to 2,0 mill.NOK, administration to 0,9 mill. NOK and compensation to landowners to 4,1 mill. NOK - a total of 10,7 mill. NOK (97 mill NOK1999, 12,9 mill US$1999). There were however remarked that the cost of compensation to landowners might be larger than mentioned in the plan. The estimated increase in production potential in downstream powerstations was 51GWh. The actual cost of the project over the period from 1952 to 1990 was 18,5 mill NOK (103,5 mill NOK1999, 13,7 mill US$1999).
Table 3.1.3 Planned and actual costs of non-focal dams (Source: GLB)

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Fundin</th>
<th>Raudalsvatn</th>
<th>Olstappen</th>
<th>Mjøsa (III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permission</td>
<td>1966</td>
<td>1948</td>
<td>1950</td>
<td>1961</td>
</tr>
<tr>
<td>Construction start</td>
<td>1966</td>
<td>1949</td>
<td>1953</td>
<td>1958</td>
</tr>
<tr>
<td>In operation</td>
<td>1970</td>
<td>1952</td>
<td>1955</td>
<td>1963</td>
</tr>
<tr>
<td>Period of cost calculation</td>
<td>1962-74</td>
<td>1946-55</td>
<td>1948-60</td>
<td>1952-90</td>
</tr>
<tr>
<td>Estimated cost (Million NOK)</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>10,7</td>
</tr>
<tr>
<td>Actual cost (Million NOK)</td>
<td>9,6</td>
<td>5,1</td>
<td>5,7</td>
<td>18,5</td>
</tr>
<tr>
<td>Est. Cost (Million NOK1999)</td>
<td>41,9</td>
<td>43,4</td>
<td>21,3</td>
<td>97</td>
</tr>
<tr>
<td>Act. Cost (Million NOK1999)</td>
<td>59,8</td>
<td>63,5</td>
<td>60</td>
<td>103,5</td>
</tr>
<tr>
<td>Deviation (Million NOK1999)</td>
<td>+17,9</td>
<td>+20,1</td>
<td>+38,8</td>
<td>+6,5</td>
</tr>
<tr>
<td>Deviation (%)</td>
<td>+43 %</td>
<td>+46 %</td>
<td>+182 % (+126 %)</td>
<td>+7 %</td>
</tr>
<tr>
<td>Construction part of total cost (%)</td>
<td>76%</td>
<td>66%</td>
<td>79%</td>
<td>37%</td>
</tr>
<tr>
<td>Compensation part of total cost (%)</td>
<td>24%</td>
<td>34%</td>
<td>21%</td>
<td>63%</td>
</tr>
</tbody>
</table>

2) Deviation after transfer of expenses to the power plant in 1972

Economic value of G&L hydropower production

Based on annual total production data in section 3.1.1 it is possible to present a time series of annual economic value of the power generation only for the period from 1993 to 1998 (Table 3.1.4). For this time period national engross-prices are available. Before the introduction of the Energy Act in 1991, mean engross-prices are not available on electric power sold from the G&L area, and mean national engross-prices is not possible to use on this time period.

Table 3.1.4 Economic value of the hydropower production in the G&L basin.

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual production (GWh)</th>
<th>Mean national engro-prices NOK/kWh</th>
<th>Value of hydropower production Mill NOK (Mill US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>10 182</td>
<td>0,111</td>
<td>1 130 (159)</td>
</tr>
<tr>
<td>1994</td>
<td>10 220</td>
<td>0,146</td>
<td>1 492 (211)</td>
</tr>
<tr>
<td>1995</td>
<td>9 611</td>
<td>0,135</td>
<td>1 297 (205)</td>
</tr>
<tr>
<td>1996</td>
<td>8 738</td>
<td>0,187</td>
<td>1 634 (253)</td>
</tr>
<tr>
<td>1997</td>
<td>9 953</td>
<td>0,162</td>
<td>1 612 (228)</td>
</tr>
<tr>
<td>1998</td>
<td>11 366</td>
<td>0,135</td>
<td>1 534 (203)</td>
</tr>
</tbody>
</table>

3.1.4 Unexpected Impacts and Other Issues of Hydropower Development

Details on development of capacity and installations over time

The general setting for hydropower development in Norway is easily exploitable water resources, with elevation gradients concentrated over short distances and natural lakes available for regulation, without much need for damming large areas. The result in the G&L basin therefore is rather small regulated water variations, typically 3.5-6 meters (see figure 2.4.2). Furthermore there has been a combination in development with downstream main river hydropower stations without reservoirs and reservoirs in the mountainous upper parts of the catchment.
The step by step development of the G&L basin over the last century has, when evaluated today, resulted in some sub optimal solutions as well as bottlenecks in some of the power plants especially in the lower sections of the river basin. Consequently, the capacities of these power plants were later increased, following the growth of energy demand, utilising new technical solutions (Table 3.1.5) and of course reflecting the improved economic situations of the power companies. Several of the power plants were actually prepared for further development already when constructed, and in these cases the increase of capacity has been easily performed. In the same way some of the reservoir volumes have been increased in two or three steps.

The oldest hydropower plants in the G&L basin characteristically have lived through two main phases of development. During the first phase, additional turbines and generators were installed in the original powerhouse, while the second phase was construction of a larger unit, separately or as an integrated part of the existing power plant.

As a main conclusion the projected capacity have been reached in all but one of the power plants in the G&L basin. The one exception is the power plant Bingsfoss, where an originally planned future expansion was not carried out due to a combination of economic and environmental reasons.

In the early hydropower development history of the G&L basin, the regulation of Lake Mjøsa triggered the development of the waterfalls in the lower part of River Glomma from Rånåsfoss to the sea. Several new reservoirs in the basin during the period from 1950 to 1970 increased regulated flow rates as planned. The power plant owners then had to consider an increase of the capacity in existing power plants. Several of these power plants were old and due for a major overhaul anyway.

### Table 3.1.5 Historical development of some power plants in G&L basin

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Production initiated</th>
<th>Expansions</th>
<th>Other remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glomma</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuråsfossen, old</td>
<td>1896</td>
<td>1952, 1966</td>
<td>Closed down 1965. Now restored as a museum. See note 1</td>
</tr>
<tr>
<td>Kuråsfossen new</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osa watercourse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kvernfallfallet</td>
<td>1939</td>
<td>1949</td>
<td></td>
</tr>
<tr>
<td>Osa</td>
<td>1981</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Skjefstadfoss 1</td>
<td>1910</td>
<td>1914, 1918, 1939</td>
<td>Old power station still in use at high discharges. Capacity installation quadrupled in new plant.</td>
</tr>
<tr>
<td>Skjefstadfoss 2</td>
<td>1972</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lågen and tributary rivers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesse</td>
<td>1942-56</td>
<td></td>
<td>(See description in GLB HIII)</td>
</tr>
<tr>
<td>Nedre Vinstra</td>
<td>1953</td>
<td>1958, 1990</td>
<td>New tunnel and enlargement of old power station hall. The capacity was increased by 50%, the production only with 9.5%</td>
</tr>
<tr>
<td>Mesna watercourse</td>
<td></td>
<td></td>
<td>(See description in GLB HIII)</td>
</tr>
<tr>
<td><strong>Lower Glomma</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rånåsfoss I</td>
<td>1921</td>
<td>1922</td>
<td>When Bingsfoss was built downstream in 1977 the head at Rånåsfoss was reduced from 14.5 to 12.7 m</td>
</tr>
<tr>
<td>Rånåsfoss II</td>
<td>1983</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Bingsfoss</td>
<td>1977</td>
<td>Planned, not fulfilled</td>
<td>See note 3</td>
</tr>
<tr>
<td>Solbergfoss</td>
<td>1924</td>
<td>1931 and 1939</td>
<td>Additional units installed +550 m3/s. New, separate power station.</td>
</tr>
<tr>
<td>1985</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kykkelsrud &amp; Fossumfoss:</td>
<td>1906</td>
<td>1912, 1937, 1948, 1948-63</td>
<td>1963: Old power station used at high discharges</td>
</tr>
<tr>
<td>Kykkelsrud</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
<table>
<thead>
<tr>
<th>Fossumfoss</th>
<th>1963</th>
<th>1985</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vamma</td>
<td>1919</td>
<td>1927,1945</td>
<td>1971, 1995</td>
</tr>
<tr>
<td>Fossumfoss power station. Reduced head when headwater at Vamma was raised.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+500 m3/s in one unit in new power station hall. Flood channel modernised, headwater raised 1 m.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sarpsfossen:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borregaard</td>
<td>1892/98</td>
<td>1910,1930s,1945</td>
<td></td>
</tr>
<tr>
<td>Hafslund</td>
<td>1899</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sarp</td>
<td>1978</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Kuråsfossen I: Old Kuråsfossen power plant was opened in 1896 and was one of the first plants for production of electric power in Norway. The reason for building Kuråsfossen power plant was the energy demand at the copper mines and industries of Røros.

2) Osen/Kvernfallet: Kvernfallet in Søre Osa was built to provide electricity for the construction works in connection to the regulation of Lake Osen. In a period in the 1930s with severe unemployment in the municipality of Åmot, GLB accepted a speed up of the initiation of the construction work to employ local workers.

3) Bingsfoss: The potential head utilised at Bingsfoss was considered too small to make it profitable to install another unit of 250 m³/s to increase the maximum flow to 1 000 m³/s as the powerplant is prepared for. In addition there was some environmental concerns (fish migration and spawning).

Lower Glomma – renewal

In 1980 the Norwegian Water Resource and Energy Administration (NVE) was in contact with the power companies in Lower Glomma to define a framework for utilisation of the remaining hydropower potential in the River Glomma downstream the confluence with the River Lågen (Vorma).

The resulting report provided a technical description of the existing hydropower installations, the planned expansions and the expected production. The conclusion however was that the necessary basis for a common adjustment to the maximum flow rates in the power plants in Lower Glomma was not present. The main reason was large differences in marginal development costs for the individual power plants due to difference in head, and the fact that some of the installations were rather recently renewed.

The new power stations at Rånåsfoss (Rånåsfoss II), Solbergfoss (Solbergfoss II), a third unit in FKF and a new unit in Vamma were commissioned with little co-ordination. From time to time, this makes it complicated to find optimal draw down procedures, compared to a situation with equal flow capacities through all the power stations. The lack of possibilities to smooth the daily variations in the small intake reservoirs of the run-of-the-river cascade powerplants also contributes to a periodically sub-optimal utilisation. Table 3.1.6 shows maximum flow rates of the power plants downstream the confluence of River Glomma and River Lågen and the date of last expansion of the power plant.
Table 3.1.6 Maximum flow capacities of the power plants downstream the confluence of River Glomma and River Lågen (Source: GLB)

<table>
<thead>
<tr>
<th>Power Plant</th>
<th>Maximum flow on each unit (m³/s)</th>
<th>Total maximum flow (m³/s)</th>
<th>Last enlargement (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rånåsfoss I + II</td>
<td>480 + 450</td>
<td>930</td>
<td>1983</td>
</tr>
<tr>
<td>Bingsfoss</td>
<td>3 x 250</td>
<td>750</td>
<td>1977</td>
</tr>
<tr>
<td>Solbergfoss I + II</td>
<td>750 + 550</td>
<td>1 200</td>
<td>1985</td>
</tr>
<tr>
<td>FKF + Kykkelsrud</td>
<td>840 + 135</td>
<td>975</td>
<td>1985</td>
</tr>
<tr>
<td>Vamma</td>
<td>400 + 500</td>
<td>900</td>
<td>1971</td>
</tr>
<tr>
<td>Sarpsfossen</td>
<td>260 + 240 + 450</td>
<td>960</td>
<td>1978</td>
</tr>
</tbody>
</table>

The planning group of 1980 also recommended a total assessment of the effects on flood levels in lower Glomma before any building of new flood protection measures along River Glomma in the Østerdalen Valley.

The utilisation of the hydropower production capacity of non focal dam Olstappen

Of the five non-focal dams in the G&L basin, there is only one, Olstappen, which can be directly related to a specific power plant. Olstappen Reservoir therefore is used to illustrate the utilisation of the installed production capacity. Olstappen is a natural lake situated in a tributary river to River Lågen (River Vinstra) with a regulation amplitude of 13 meter, a reservoir capacity of 31 mill m³ and an energy content of 48 GWh. The power plant Nedre Vinstra downstream of Olstappen has a utilised head of 446 metres, an installed capacity of 310 MW and a maximum flow of 84 m³/s. Data on water inflow, hydropower production and spilled water on a monthly basis are available from 1978 to present (table 3.1.8).

The inflow to Olstappen reservoir is heavily affected by the upstream reservoirs (Bygdin, Vinsteren, Heimdalsvatn, Kaldfjorden and Øyangen). The monthly winter inflow is high compared to natural conditions and the summer inflow rates are correspondingly low. The monthly hydropower production from Olstappen in Nedre Vinstra power plant has an annual cycle with a production from December to May 50 % larger than the production from June to November.

Like the rest of the G&L basin, there is no significant non-power extraction of any magnitude at Olstappen. The difference between the predicted and the achieved energy generation throughout the period from 1978 to 1998 has been small. The available inflow for hydropower production has been utilised maximally during the winter months. During some wet summer and autumn months the water inflow has exceeded the power plant capacity, but the spill is generally very low at Olstappen.
Table 3.1.8 Monthly reservoir inflow, bypassed water and hydropower production at Olstappen. 1978-1998.

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>m³/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflow</td>
<td>44,1</td>
<td>42,6</td>
<td>35,1</td>
<td>30,3</td>
<td>48,2</td>
<td>36,9</td>
<td>23,4</td>
<td>27,3</td>
<td>28,1</td>
<td>28,7</td>
<td>32,1</td>
<td>41,1</td>
<td>34,8</td>
</tr>
<tr>
<td>Bypass</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
<td>2,4</td>
<td>3,0</td>
<td>2,6</td>
<td>6,9</td>
<td>2,7</td>
<td>1,7</td>
<td>0,2</td>
<td>0,0</td>
<td>1,6</td>
</tr>
<tr>
<td>GWh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bypass</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
<td>7,1</td>
<td>8,4</td>
<td>7,5</td>
<td>20,0</td>
<td>7,6</td>
<td>5,0</td>
<td>0,5</td>
<td>0,0</td>
<td>4,7</td>
</tr>
<tr>
<td>Production</td>
<td>120,1</td>
<td>108,6</td>
<td>109,9</td>
<td>90,0</td>
<td>105,3</td>
<td>85,1</td>
<td>57,3</td>
<td>56,4</td>
<td>68,7</td>
<td>73,9</td>
<td>84,9</td>
<td>112,2</td>
<td>89,4</td>
</tr>
</tbody>
</table>

Sedimentation in reservoirs

Due to generally hard bedrock, the sediment load of rivers in the G&L basin is very low in an international perspective. Some sediment transport from glacier fed rivers occurs, but so far no noticeable fill-up of reservoirs has been reported. In most G&L reservoirs the regulated volume is only a fraction of the total volume. Since the regulated segment of the reservoirs is the top layer, and sediments fall to the bottom, siltation is not regarded as a potential problem in foreseeable future. The only exception where a trace of this effect can be found, is Lake Øyeren. The effective regulated volume has decreased to some extent during expansion of the inlet delta in the last century. This however has no effect on power production, since Lake Øyeren for most of the year mainly is used as an intake reservoir to the power stations downstream.

Erosion in reservoirs

Some of the regulated reservoirs in the G&L basin have their low supply level some meters below the natural water level for the actual lake. In such reservoirs the erosion in the zone between full supply level and low supply level can be considerable in a Norwegian context, but not compared to international experiences (see ex. chapter 3.9 on ecological effects). In many lakes the slope of the lake bottom is not very steep and the bottom substratum consist of coarse gravel and stone. Due to this erosion is moderate.

Effects of other water resource developments

The effects on hydropower production of other water resource developments like irrigation, water supply and other kinds of water use in the G&L basin have so far been ignorable. Only a couple of public water works have so far paid compensation for withdrawal of potable water. This has however only resulted in minor reductions on the hydropower output, without any practical importance. Today most of these smaller public water works have turned to groundwater instead of surface water (see chapter 3.5). Individual irrigation schemes by local farmers/landowners neighbouring the rivers and lakes also exist, but without significant importance to the hydropower output (see chapter 3.4). With the exception of increased transpiration as a result of artificial irrigation, withdrawn water is kept within the basin and has little effect on the long-term water balance.

3.1.5 Atmospheric pollutants Avoided by Not Using Fossil Fuel Power Plants

A benefit of power generated by the 51 hydropower plants in the G&L-basin concerns emissions of atmospheric pollutants avoided. Hydropower is not entailed by the release of atmospheric pollutants as is the case for combustion of fossil fuels in production of electricity. These benefits are real. There is no widely accepted procedure though for calculating the monetary value of those benefits. Moreover,
attempting to generate numerical values of tons of atmospheric pollutants avoided requires that many assumptions be made.

In the G&L-basin case there are some major site-specific difficulties for calculating the relevant amounts of emissions avoided. These site-specific difficulties are:

- The development of the basin has been a step by step development over a century involving a large number (now 51) of power plants. Production capacity has been increased both through putting new power plants into operation, and through upgrading existing facilities. This makes it difficult to reconstruct details on how production capacity has developed, and to what extent a similar development would have been opted for a given a non-hydropower concept.
- Due to the length of the time span involved in this case study, several generations of the various fossil fuel combustion electricity generators would have to be taken into consideration.
- One would have to take into account the availability and preferences for various fossil fuels given the specific historical and political setting for the various development projects in order to get a realistic picture of what pollutants that it is fair to say was avoided.

In addition to these difficulties the relevant amount of emissions avoided, there are global difficulties in estimating the monetary benefits. The WCD methodology (reference) includes a range for the monetary value of carbon dioxide emissions avoided from a low of $2 per ton to a high of $25 per ton. This range alone introduces a very high degree of global uncertainty in the calculations, to which we have to add the high degree of site-specific uncertainties. Under these circumstances, we have reservations about attempting to quantify the benefits of atmospheric pollutants avoided by developments in the G&L-basin instead of fossil fuel fired power plants.

However, the hydropower production in G&L has during the last century substituted a considerable amount of fossil fuel generated emissions of CO₂, SO₂ and NOₓ. To illustrate the size of the emissions avoided the accumulated hydropower production in the G&L basin over the period from 1944 to 1998 has been approximately 380 TWh. Regionally, the avoided emissions of SO₂ and NOₓ have considerable significance in the context of acid rain. In South Norway and Sweden aquatic and terrestrial ecosystems as well as certain infrastructure are heavily impacted by acidification from long-transported SO₂ and NOₓ originating from other parts of Northern Europe.

**Findings on hydropower**

- The consumption of electricity in Norway have increased 10 fold from approximately 15 to 120 TWh during the last 50 years, and the total production of electricity have increased from 15 to 113 TWh in an average year. The consumption growth rate was in 1970 anticipated to continue more or less exponentially, and the forecasts had a tendency to overestimate future consumption levels. Later the forecasts have been very accurate.

- Until the implementation of the new Energy Act in 1991, each power company in Norway supplying end user customers in their licensed area had an obligation to supply their customers. Hence they had to match the increase in consumption by developing more hydropower or to buy power from those power producers having a surplus. The balance an the forecasts have been handled on county and national levels and not on a basin level.

- Before World War II, the major consumers of electricity in Norway were industrial enterprises and the investors therefore were mainly private. After World War II, the development of hydro power resources were done mainly by public companies. As per 31.12.1998 the ownership of the
hydropower generating capacity was 86.8% public and 13.2% private. The “private” part is also partly public as for example the company Norsk Hydro involve 51% public interest.

- The integrated system of regulation reservoirs and power stations for hydropower production in the G&L basin consist of 40 regulation reservoirs and 51 power plants.

- The total annual hydropower production in the G&L basin during the last decade has been 9 – 11 TWh depending on available inflow rates representing an annual economic value of 1.13 to 1.63 billion NOK (159 – 253 mill US$).

- Cost estimates and actual costs have been calculated for 4 of the development projects in the G&L basin (Olstappen, Raudalsvatn, Fundin and Mjøsa III). A common feature for all of the projects analysed is that the actual cost of the projects have been higher than the estimated cost at the time of license approval. The main reasons for the deviation are the delay of 3-5 years in the start of construction for each of the projects and that the compensation part of the total costs have been higher than estimated.

- Most of the power plants in the G&L basin have increased the production during their period of operation. Increased capacity is gained by installation of new units, by renewal of the power stations or by building of new power stations. Also some of the regulation reservoirs have been enlarged during their period of operation (Ex. Mjøsa, Bygdin).

- Generally there has been a considerable time span (5-23 years) from an application for license is forwarded to the permission is given and the reservoir is constructed and set into operation. The reasons why several development plans have been delayed are legal evaluation resulting in changes/reduction of plans during the licensing process, controversies on states ownership, shortage of funding and World War II.

- The sedimentation load in G&L basin rivers is very low in an international perspective and no sedimentation fill-up of reservoir have been predicted. The regulated segment of the reservoirs encompasses only the reservoir top layer and sedimentation is not regarded as a potential problem in foreseeable future. The only exception is the reservoir of Lake Øyeren where the effective regulated volume has decreased to some extent from expansion of the inlet delta in the last century.

- Some of the regulated reservoirs in the G&L basin have their low supply level some meters below the natural level for the actual lake and have some erosion in the zone between full supply level and low supply level in a Norwegian context. The erosion is however not significant in an international context.

- Unexpected effects on hydropower production from other water resource developments like irrigation and water supply in the G&L basin have so far been ignorable.

3.2 Flood control

3.2.1 Predicted versus actual flood benefits

Historical development of predicted flood control from new reservoirs
The first technical interference in the G&L watercourse were the regulation done by the Norwegian State in Lake Mjøsa in 1854 and Lake Øyeren in 1857. Both these projects were flood protection measures. The regulation of Lake Øyeren in 1857 was predicted to limit lake flood levels to maximum 7.3 meters above LSL (GLB 1947). The effect was soon proved to be more limited than predicted, and
the 1910 flood resulted in considerable flood damage in the Øyeren area. The Parliament than initiated an investigation on possible flood protection measures in the G&L basin. It was soon evident that despite the regulation of Lake Mjøsa and Lake Øyeren, the only way to control floods in the lower part of the basin was to build reservoirs at the outlet of selected natural lakes in the upper part of the G&L basin. Accordingly, flood protection was an important factor for the initiation of the planning process of several dams/reservoirs in the early development phase of the G&L basin from 1900 to 1920 (see also chapter 5 on Planning and decision making processes). Only 3 of the planned regulation reservoirs were however decided to licence for flood control purposes during the 1920s: the reservoir of Lake Aursunden and Lake Osensjøen in the Glomma branch, and of Lake Bygdin in the Lågen branch of the G&L basin. All the other regulation reservoirs established in the G&L basin throughout the century are mainly developed for electricity production purposes. Several of the reservoirs have however a supplementary function as flood protection reservoirs and are used for flood attenuation during major floods.

Flood protection provisions in regulation schemes

Most flow regulation schemes granted after 1917 contain a provision that “the river’s previous floodwater flow must not be increased.” This is a weak formulation intended only to ensure that reservoirs will not give conditions worse than they were before the reservoirs were regulated. It has become more common in recent years to strengthen the flood protection obligation and today standard licenses for the flow schemes contains a paragraph stating that large floods shold be mitigated to avoid damage. Licensing authorities have then already at licensing time considered the practicality of requiring that the regulator implement flood-mitigation measures. There are examples of this in the new licence for regulating Aursunden. Here, GLB is required to refrain from filling up the last 10 cm to HRV until after September 15. The reservoir volume capacity in the top 10 cm must remain available as assurance against a possible flood situation.

In the flow scheme for Lake Mjøsa and Lake Øyeren, the flood situation has been given special status in that the NVE will take charge of flow management when the flood exceeds a certain size. Such cases may require quick assessments of inflow developments and water-level forecasts calling for very special flow management of two or more reservoirs in order to reduce possible damage. Working closely with NVE, GLB then contributes data, calculations and suggestions on optimal utilisation of the reservoirs. After the major flood of 1995, the NVE and GLB entered into a general agreement on routines and co-operation during floods to ensure the best possible management of flood situations.

An optimal utilisation of dams and reservoirs in the G&L basin for flood reduction purposes can not be performed within the frames of the granted licences for regulation for each of the dams/reservoirs. Situations like this show the importance of a basin-wide running of the watercourse through critical floods events. It also demonstrates the importance of a tight co-operation between the basin operation organisation (GLB) and the public authorities (NVE and the local municipalities) for optimising flood protection efforts and for having functional emergency planning systems in critical flood situations.

For both the Glomma and the Lågen river systems there are considerable preventive measures (flood banks and erosion control measures), e.g. in Solor, that can ensure low-lying areas along the rivers against inundation during floods. Such facilities have been viewed only minimally in context with rules and regulations relating to power plant reservoirs.

Flood management and research

As a consequence of the 1995 flood in the G&L basin the Ministry of Industry and Energy advised the establishment of a commission on flood protection measures. The Commission was established by Royal Decree in June 1995. The report from the Commission gave recommendations on improvements of emergency planning systems, flow forecasting and flood warning systems, and analysed different types of flood protecting measures to reduse risks associated with flooding. The significans of river basin regulations of historical flood situations were analysed, and the possibilities for further flood
attenuation through hydropower developments were analysed for approximately 50 different projects. The Commission recommended 10 different projects with considerable flood reduction capacity within the G&L basin. These projects were partly establishment of new regulation reservoirs and partly further regulation of existing hydropower reservoirs (NOU 1996). All the projects also have a potential for hydropower production. In Parliamentary White Paper No. 42 of the 1996/97 session the parliament approved a stronger attention to flood protection issues. The parliament approved the recommendation from the Commission on the 10 regulation projects for flood protection purposes. This means that the projects are placed in Master Plan category I, which is the category for projects that can be applied for license. However, this does neither mean that approvals for licenses will be raised nor that licenses necessarily will be given, and the projects will have to go through the same licensing procedure as ordinary hydropower development projects.

In 1995 the Norwegian Water Resources and Energy Directorate (NVE) suggested a research programme on floods (The HYDRA-program). The working hypothesis of the programme was that the sum of all human impacts may have increased the risk of floods. The 1995 flood in the G&L actualised the research program and the G&L basin has been the focal area of the HYDRA-program. The HYDRA-hypothesis has been investigated within several topics, (e.g. land use, runoff from urban areas, flood regulation, protection and management, risk analyses, environmental consequences of floods and flood prevention measures, and modelling floods in the G&L basin). Also in the HYDRA program flood reduction from existing regulation reservoirs and possible further flood reduction from new development of regulation reservoirs have been analysed (Tingvold 1999) (see chapter 3.2.2). Modelling results from the HYDRA research program show that the effects of human interferences like urbanisation, changes in land use (agriculture and forestry) and establishment of flood protection measures in the G&L basin during the last century have had minor effects on flood culmination levels and the moments of culmination. However, the effects of the hydropower reservoirs have been significant for the historical floods analysed (NVE in prep).

The different flood management topics investigated through the work by The Commission on Flood Protection Measures (NOU 1996) and through the HYDRA research program (Final report in prep.) are key elements in the flood management strategies for the Norwegian society as well as for the G&L basin.

In the G&L basin main elements of the flood protection strategy are optimalisation of flood attenuation by reservoirs within the frames of the regulation schemes. This also includes pre-release of water during floods. Another element traditionally used is building of flood banks to protect agricultural areas and settlements on floodplains. The strategy also include real time hydrological forecasting and special emergency plans and plans for public warning. Transfer of water through watercourse diversions is a more limited part of the flood protection strategy and in the G&L basin only the transfer from Glomma to Rena has considerable flood reduction effect (problems with ice dams and drift of ice in Glomma during winter has been reduced after the transfer).

### 3.2.2 Actual flood benefits from regulation reservoirs

**Analysis of the effects of reservoirs on historical floods**

The effect of the regulations on flood conditions is well documented by the historical records of flood levels at Lake Mjøsa and Lake Øyeren (figures 3.2.1 and 3.2.2). The frequency of large floods has clearly decreased during the last 150 years. In Lake Øyeren the flood levels have been further decreased by an increase in the outlet capacity after the 1967 flood. This was done by excavations and an increase in the capacity of the power plant at the outlet. After this, it is only the extreme 1995 flood that has resulted in high flood levels in this lake.
The main explanation of this trend towards smaller floods is the hydropower regulations. Statistical analyses of long time series has showed that there are no significant climatic trends that has influence on the floods in the basin (Roald, 1999). Other investigations have concluded that human activities have no significant influence on floods in the main rivercourse of Glomma and Lågen, except the hydropower regulations. Modelling of land use changes, urbanisation and flood protection measures indicate that this factors have had no significant influences on selected historical floods in the G&L basin (Hydra, in prep). The size of the floods in the G&L basin therefore has been gradually decreasing, as a consequence of the increased degree of regulation, from some 4% in the beginning of the century to 16% at present (see figure 3.2.3).

The flood reduction capacity in the G&L basin is considerable, considering the low degree of regulation. Table 3.2.1 gives a summary from a recent analysis done by Tingvold (1999). Results are presented as calculated flood peak attenuation at major floods in the main river courses during the period 1900-99. The values
Figure 3.2.3 The historical development of hydropower regulations in the G&L basin. (Source: GLB).

The table also shows the possible additional attenuation that could be reached after implementation of 12 proposed new regulation projects increasing the total degree of regulation in the basin from 16 to 23%.

Table 3.2.1. Flood peak attenuation at major floods 1900-99 (%). (Source: GLB).

<table>
<thead>
<tr>
<th>Location</th>
<th>Stai (%)</th>
<th>Elverum (%)</th>
<th>Lalm (%)</th>
<th>Losna (%)</th>
<th>Mjøsa (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>11</td>
<td>19</td>
<td>22</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>1916</td>
<td>11</td>
<td>19</td>
<td>30</td>
<td>17</td>
<td>45</td>
</tr>
<tr>
<td>1927</td>
<td>12</td>
<td>21</td>
<td>9</td>
<td>40</td>
<td>26</td>
</tr>
<tr>
<td>1934</td>
<td>10</td>
<td>17</td>
<td>23</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>1939</td>
<td>23</td>
<td>17</td>
<td>23</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>1966</td>
<td>19</td>
<td>24</td>
<td>32</td>
<td>26</td>
<td>-</td>
</tr>
<tr>
<td>1967</td>
<td>16</td>
<td>23</td>
<td>5</td>
<td>33</td>
<td>-</td>
</tr>
<tr>
<td>1995</td>
<td>-</td>
<td>23</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>14</td>
<td>20</td>
<td>21</td>
<td>25</td>
<td>28</td>
</tr>
</tbody>
</table>

"Pres." refers to the extra attenuation at present compared to that possible at the time of the flood.

"Future" refers to the additional attenuation compared to the present after further development.

Figure 3.2.4 shows time series of floods with linear trends indicated and time series of the degree of regulation at selected locations in the G&L basin. A comparison of the flood levels with the increasing degree of regulation, give a strong indication of a flood reduction effect of the regulation dams/reservoirs in the G&L basin for main flood events during the period from 1900 until 1999. With the present regulations the scale of flood peak attenuation as a result of additional storage provided in the system would have been 20% on an average.

The 1995 flood in the G&L basin

During the spring of 1995 the G&L basin experienced a major flood. The factors initiating the flood was large volumes of snow and low temperatures in the month of May. High temperatures combined with rainfall at the end of May caused the flood to be the largest in the 20th century in central parts of the Glomma branch of the G&L basin. The return period for the flood in this parts of the basin has been estimated to 200 years (NOU 1996). Annex 5 gives a description of the forecasting and abatements of the 1995 flood.

For the 1995-flood a much more detailed analysis of the flood dampening effect is available (Tingvold 1999). In this study the attenuation of the flood peak is calculated relative to the natural conditions without the regulations, but with the natural effect of the original lake at the site of the reservoir. Table 3.2.2 gives the main results from this work. The relatively large effect of the regulations in 1995 was possible because this was a spring flood, like most large floods in the G&L basin. An autumn flood on
filled up reservoirs would not be possible to reduce as significant as a spring flood on only partly filled up reservoirs. Fortunately large autumn floods are seldom, and not present among the eight largest floods during the last century presented in table 3.2.1. As a conclusion one could state that the 1995 flood is a near optimal flood protection scenario by the existing dams in the G&L basin.

**Table 3.2.2** Flood peak attenuation from individual reservoirs during the 1995-flood (m$^3$/s and %).

<table>
<thead>
<tr>
<th>Location</th>
<th>Stai</th>
<th>Elverum</th>
<th>Lalm</th>
<th>Losna</th>
<th>Mjøsa inflow</th>
<th>Øyeren inflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aursunden</td>
<td>225</td>
<td>11</td>
<td>225</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Einunna Savalen</td>
<td>100</td>
<td>5</td>
<td>100</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Storsjøen</td>
<td>-</td>
<td>-</td>
<td>225</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Otta</td>
<td>-</td>
<td>-</td>
<td>125</td>
<td>17</td>
<td>120</td>
<td>5</td>
</tr>
<tr>
<td>Vinstra</td>
<td>-</td>
<td>-</td>
<td>205</td>
<td>8</td>
<td>165</td>
<td>5</td>
</tr>
<tr>
<td>Mesna etc.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>325</td>
<td>16</td>
<td>800</td>
<td>24</td>
<td>125</td>
<td>17</td>
</tr>
<tr>
<td>Flood peak</td>
<td>2000</td>
<td>3350</td>
<td>715</td>
<td>2500</td>
<td>3200</td>
<td>3800</td>
</tr>
<tr>
<td>Reduced water level (m)</td>
<td>0,70</td>
<td>0,90</td>
<td>0,40</td>
<td>0,40</td>
<td>0,40</td>
<td>1,90</td>
</tr>
</tbody>
</table>

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
3.2.3 Power production versus flood reduction

The flood reducing option of the regulation dams has a considerable economic value by reducing damages on floodplain settlements, agricultural areas and crops, and infrastructure elements (roads, ...
railroads, telecommunication). In flood situations even small reductions in flood culmination levels may give significant reduction of the flood damages, for example, if utilisation of a regulation reservoir prevents overtopping or breakdown of flood dikes. During the last years flood zone maps have become a more common tool for land use planning and the planning of flood protection measures, as well as risk analysis in the assessment of flood protection measures (NOU 1996).

Power production and flood protection has common interests. They both benefit from a reduction of the amount of uncontrolled release of flood water from the reservoirs. In general it is therefore no direct cost of providing flood storage in terms of foregone power production. By the same reason it is not possible to quantify the capital expenditures for the different G&L project's flood control function.

There are however a few examples where flood reduction by reservoir operation has resulted in additional costs for the GLB. Such cases are usually connected to the prerelease of water when a flood is expected. If the flood does not fill up the reservoir again, the part of the prerelease that was bypassing the turbines at power plants is lost. This happened in October 1987 at Osensjøen, where some 20 mill. m³ was lost at the Osa Power Plant. This is the equivalent of 10-15 GWh or approximately 1,5 mill. NOK (0,2 mill US$1999). In addition 2-3 GWh of the prerelease were lost at power plants further downstream. It is estimated that 2-3 such incidences occur every 10-15 years, resulting in an average yearly loss of 0,3 mill. NOK (40 000 US$1999).

Of course one could argue that the best flood protection would be always to keep enough storage available for the largest flood event possible. This obviously would not be favourable for power production and would certainly introduce a significant cost of prioritising flood storage. Today's practice however is to optimise reservoir operations by hydrological forecasting. Even if the optimisation primarily is done considering power production, this will also reduce uncontrolled release of flood water from the reservoirs, thereby also reducing flood damages. During extreme events, like the 1995 flood, considerations to power production are set aside, in favour of flood protection. The combination of hydrological forecasting and active reservoir operation is considered extremely important in such situations.

### 3.2.4 Flood Damage

Unfortunately there are no good quantitative records of flood damages older than 1980. The most systematic ones are records of flood damages covered by the Natural Disaster Pool of Norwegian insurance companies. These records show that, with the exception of 1987 and 1995, there have been very few damages to economical values in the G&L basin (figure 3.2.5). The 1995 flood is by far the most significant one considering damages caused by floods. These records, however, do not give the total value of flood damages. They only reflect the damages compensated for by the insurance companies. In addition come damages covered by the state from the Natural Disaster Fund and damages not covered at all. In 1995 it was estimated that the total value of flood damages was some 1,8 billion NOK (284 million US$1995), which is approximately 3 times the damages covered by the Natural Disaster Pool. On this basis it is very difficult, if not impossible, to estimate both the actual cost of damages for earlier floods, and the value of damages avoided as a result of the hydropower dam projects in monetary terms.
Figure 3.2.5 Flood Damages as covered by the Natural Disaster Pool of Norway. (Source: GLB)

To analyse this further one would have to define and classify river segments with or without dikes. For segments without dikes one might have a possibility of estimating the increased damage potential at a higher flood level. But for segments with dikes, not only the height of the dike, but also the constructional safety, would have to be considered. The 1995 flood at Kirkenær is a good example of the extreme consequence of overtopping or failure of dikes. The damages to the village after overtopping of the surrounding dikes should, according to calculations made by the research programme HYDRA, amount to approximately 900 mill. NOK (142 mill US$1995). Thanks to additional sandbagging on top of the dikes, the overtopping was avoided, and damages reduced to approximately 100 mill. NOK (16 mill US$1995).

Two other examples from the 1995 flood is appropriate to mention. The first one concerns the town of Elverum. At the peak of the flood one was afraid that the flood would submerge a bridge in the town. To reduce the danger of having the bridge washed away, extra load was put on top of the bridge to keep it in place. If the bridge had been lost, it would have been stopped by a another bridge just downstream. In case this had happened, the centre of Elverum would most probably have been flooded, with very large economic consequences. The two nearest regulated reservoirs upstream Elverum were at this time regulated as to cut as much as possible of the peak of the flood. Without the combined effects of all the reservoirs in general and these two reservoirs in particular, damages at Elverum could have been extremely large.

The second example concerns the city of Sarpsborg. The riverbanks just upstream of the city consist of glacial deposits, moraines, which were not expected to withstand the pressure of a large flood for a very long time. If the banks had collapsed, damages would have been enormous measured by a Norwegian scale. In this area the flood remained at the same magnitude for approximately one week. It is not possible to establish at what stage the banks would have collapsed. It is a fact however that the peak of the flood was reduced with some 20% also in this part of the basin.

Findings on flood protection

- The first regulation reservoirs in the G&L basin were established for flood protection measures and were predicted to reduce the flood levels in the big lakes (Lake Mjøsa and Lake Øyeren) in the lower part of the G&L basin.
• The formulations in old regulation schemes of hydropower reservoirs in the G&L basin are weak concerning obligations to perform flood protection. In later years new schemes include provisions that large floods should be mitigated to avoid damage.
• Today flood protection is performed in several of the hydropower reservoirs by pre-release of water during major floods and by specification in regulation schemes of free reservoir capacity available in possible flood situations.
• The frequencies of large floods have decreased in the G&L basin during the last 150 years.
• The existing regulation reservoirs in the G&L basin had considerable flood reduction effect on the 1995 flood.
• Modelling results from the HYDRA research program show that the effects of human interferences like urbanisation, changes in land use (agriculture and forestry) and establishment of flood protection measures in the G&L basin during the last century have had minor effects on flood culmination levels and the moments of culmination. However, the effects of the hydropower regulation reservoirs have been significant for the historical floods analysed (Killingtvedt in prep).
• Calculation of flood reduction effects on data from 8 historical floods from 1910 to 1995 in the G&L basin shows that for all the analyzed major floods in this period the regulation reservoirs would have reduced the flood culmination level and delayed the moment of flood culmination.
• For the 1995 flood the total value of flood damages was 1.8 billion NOK (284 mill US$1995). The main part of the damage was within the G&L basin.

3.3 Irrigation and Agriculture

Irrigation plants in the G&L basin
The Watercourse Act has a separate paragraph stating the land owners right to withdraw water for use on different purposes on own property. The Act also has a paragraph ranking the priority of water extraction for different types of uses. The first priority use is for household purposes, the second for farming, and the lowest priority is for irrigation and for technical use. The water withdrawal right is restricted to where a watercourse crosses the property area itself. For landowners without a watercourse on the property an agreement with watercourse ground owners will be necessary for water withdrawal rights. For the establishment of bigger irrigation plants causing damage or drawbacks for common interests, it is necessary to apply for a licence and the amount of water withdrawal may be restricted by minimum flow requirements (NOU 1994:12).

Irrigation plants are sometimes built as joint property plants within the G&L basin, but most plants are small single property plants. Table 3.3.1 shows the number of properties with irrigation plants in the G&L basin and the capacity of the plants measured as possible irrigated area. Totally for the whole G&L basin the number of properties with irrigation plants was 3 265 in 1989, and the total possible irrigated area was 385 km² or 16 % of the total G&L basin agricultural area. Most of the irrigation plants were small single farm plants. In 1979 the corresponding number of irrigation plants was 3097 and the total possible irrigated area was 308 km².
Table 3.3.1 Possible irrigated area and number of properties with irrigation plants, 1989

<table>
<thead>
<tr>
<th></th>
<th>Possible irrigated area</th>
<th>Number of properties with irrigation plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>G&amp;L basin total</td>
<td>384,622</td>
<td>3265</td>
</tr>
<tr>
<td>Østfold county part of basin</td>
<td>43,838</td>
<td>295</td>
</tr>
<tr>
<td>Akershus county part of basin</td>
<td>32,890</td>
<td>208</td>
</tr>
<tr>
<td>Hedmark county part of basin</td>
<td>162,485</td>
<td>1059</td>
</tr>
<tr>
<td>Oppland county part of basin</td>
<td>144,619</td>
<td>1698</td>
</tr>
<tr>
<td>Sør-Trøndelag county part of basin</td>
<td>0,820</td>
<td>5</td>
</tr>
</tbody>
</table>

Source: Central Bureau of Statistics.

Effects of irrigation

The conflicts between irrigation interests and hydropower development interest in the G&L have so far been small. This is partly due to the fact that a small part of the irrigation plants withdraw water from the actual regulation reservoirs and that the water withdrawal from irrigation plants are minor compared the flow-rates in the main rivers of the G&L basin. Another reason for the lack of conflicts is that most irrigation plants have been established more recently than the hydropower development reservoirs, and their possibility to withdraw water from rivers and reservoirs have not been changed during their period of function. However, in some tributary rivers of the basin, the possibility for water withdrawal for irrigation purposes on shorter river stretches may be restricted because the river flow rates during dry low-flow periods in summer already are reduced from hydropower regulation.

Most irrigation plan in the G&L basin have surface water (rivers and lakes) as their water source, and ground water extraction from irrigation plants are very rare, and the effects on ground water levels are ignorable even in the lower part of the drainage area.

Agricultural areas in the G&L basin

The G&L basin contains one of Norway’s main agricultural areas. The total agricultural area in the G&L basin is approximately 2400 km² or 5.8% of the total drainage area. The lower section of the basin, from Lake Mjøsa and southwards, has the most significant agricultural areas. Runoff from the agricultural areas and leakage from agricultural point sources were one of the main sources to the heavy water pollution that were experienced in parts of the G&L basin during the 1970’s. Throughout the whole G&L basin efforts have been made during the 1980’s and 1990’s in reducing diffuse contributions of pollution/effluents from agriculture.

The water quality deterioration during the 1970s was most dramatically in Lake Mjøsa, an the increased influx of pollutants resulted in algae blooms and high concentrations of coliform bacteria. An extensive lake resoration program (The Mjøsa Campaign) was initiated in 1977. The aim of the campaign was to reduce the influxes of pollutants to an acceptable level by the end of 1980 (Ibrek et al 1991). The Mjøsa Campaign has succeeded and the lake water quality has improved considerably due to several abatement measures both in the agricultural sector (agricultural point sources and runoff from agricultural land) as well as in other sectors (pipe network improvements, sewage treatment plants, sludge treatment, detergents, and waste management).
Findings on Irrigation and Agriculture

- Irrigation plants of the G&L basin typically are small single farm plants.
- 385 km² (0.9%) of the total G&L basin area is possible to irrigate from the irrigation plants.
- Water withdrawal for irrigation from the regulation reservoirs have no practical influence on hydropower production in the G&L basin.
- Runoff from the agricultural areas in the middle and lower part of the G&L basin had significant effects on water quality of Lake Mjøsa during the 1970s.

3.4 Municipal and Industrial Water Supply

Municipal Water Supply from G&L

Several municipalities abstract water from G&L river for their water supply needs. In the Lågen branch of G&L the only considerable water withdrawal from regulation reservoirs is from Lake Mjøsa, while several small municipal water supply plants use water either from river Lågen and its tributary rivers or infiltrate ground water from these rivers. Lake Mjøsa have 150 000 people living in the immediate surroundings of the lake with main population centres in the cities of Lillehammer, Gjøvik and Hamar as well as in a number of smaller communities. About 55 000 persons use Lake Mjøsa as their source of drinking water.

In 1992 approximately 217 000 persons were connected to 7 municipal drinking water plants with water from river Glomma, and approx. 34 000 persons were connected to 8 plants which infiltrate groundwater from the river (Miljøverndepartementet 1992). Typically all the largest water supply plants are situated in the densely populated areas of lower part of the river downstream the confluence of Glomma and Lågen.

Today the G&L drainage area has a total of 227 water supply plants serving 682 000 inhabitants with water from main rivers, tributary rivers, lakes and ground water resources within the basin (table 3.4.1). Typically the number of small plants is large, and only about 60 plants are serving more than 1000 persons. It is also typical that the small plants have ground water as theirs water source, while the larger ones use rivers and lakes as their source.

Table 3.4.1 Water supply plants in the G&L basin. 1999

<table>
<thead>
<tr>
<th>G&amp;L basin water supply plants</th>
<th>Number of plants</th>
<th>Persons connected</th>
<th>Annual water abstraction Mill m³/year</th>
<th>Percent of plants with ground water sources</th>
<th>Percent of person supplied from ground water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total for municipalities in G&amp;L basin</td>
<td>227</td>
<td>682 000</td>
<td>89</td>
<td>60</td>
<td>26</td>
</tr>
<tr>
<td>Østfold county part of basin</td>
<td>17</td>
<td>305 000</td>
<td>37</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td>Akershus county part of basin</td>
<td>23</td>
<td>118 000</td>
<td>14</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Hedmark county part of basin</td>
<td>116</td>
<td>130 000</td>
<td>17</td>
<td>73</td>
<td>60</td>
</tr>
<tr>
<td>Oppland county part of basin</td>
<td>49</td>
<td>115 000</td>
<td>20</td>
<td>65</td>
<td>40</td>
</tr>
<tr>
<td>Sør-Trøndelag county part of basin</td>
<td>22</td>
<td>14 000</td>
<td>1</td>
<td>45</td>
<td>61</td>
</tr>
</tbody>
</table>

Source: Directorate for Public Health (Folkehelsa) 1999
Industrial water supply from G&L
The industrial use of water from the rivers and reservoirs of G&L are mainly for cooling processes and have little or no impact on the water quality and river flow-rates.

Effects of water withdrawal from G&L
A common feature for all the municipal and industrial use from the G&L river system is that the amount of water withdrawal is very low compared to the actual river flow-rates, and have generally little importance for river recipient capacity, water quality and water availability. In the G&L basin most of the hydropower development projects with regulation basins and river stretches with reduced flow rates, have been established prior to the municipal water supply plants.

However, reduced flow rates downstream hydropower dams can locally influence the recipient capacity of these stretches and give less satisfactory water quality for water supply purposes. Especially in the rural areas of the G&L basin, where many households have private wells and are not connected to municipal water supply systems, reduced flow rates from hydropower development can influence private water supply. Even small changes in ground water levels on floodplains can result in dry wells for private households in the rural areas.

Implications for hydropower development
So far river stretches with reduced flow rates from hydropower development projects have been exempted for municipal water supply purposes because most water supply plants have been planned and located more recently than the hydropower development projects. Water quality interests in Lake Mjøsa have been one of the main reasons for the refusal of the hydropower development plans in the Jotunheimen area of the G&L basin in the 1970s. The self-cleaning capacity of Lake Mjøsa was feared to be reduced by a planned transfer of water from the G&L basin and westwards. Later the further hydropower development planning in the Jotunheimen area has been concentrated on development within the G&L basin (see chapter 5 on planning and decision-making processes).

Today the standard rules for new watercourse regulation licences have special paragraphs forcing the regulation project owners to pay for measures to prevent pollution aggravation from the regulation, and paragraphs on flow schemes (ex. instructed minimum flow rates) to reduce negative impacts for public interests like municipal and private water supply.

Water Supply Interest vs. Pollution in Lake Mjøsa.
The water quality of Lake Mjøsa deteriorated dramatically during the 1970s (see chapter 3.3) and resulted in not satisfying drinking water standards. The drinking water interest was one of the main reasons for initiation of The Mjøsa Campaign in 1977. The water quality situation has improved considerably and in 1999 Lake Mjøsa is still an important source for municipal water supply (Ibrekk et al 1993).

Findings on Municipal and Industrial Water Supply
- The G&L drainage area has a total of 227 water supply plants serving 682 000 inhabitants with water from main rivers, tributary rivers, lakes and ground water resources within the basin.
- The water supply plants in the G&L basin are generally small, and only 60 plants are serving more than 1 000 inhabitants. The small plants usually have ground water as their water source.
- In the G&L basin the regulation reserviors were established prior to the municipal water supply plants and the possibilities for water withdrawal from the reservoirs have not been changed from the hydropower regulation.
- In the rural areas of the G&L basin, where many households have private wells and are not connected to municipal water supply systems, reduced flow rates from hydropower development can influence private water supply.
3.5 Recreation, Tourism and Fishing

3.5.1 Recreation and Tourism

The Glomma and Lågen watersheds are dominating landscape features. Both river courses make their way from high alpine regions with sparse settlements and populations through major valleys into the lowlands of Southeast Norway. The close proximity to a number of settlements make the watercourses highly important for local populations and visitors for recreational and tourism purposes. Outdoor recreation and tourism have a diverse history and have been performed in various forms in these watersheds for more than one hundred years. The history of tourism and outdoor recreation is even longer than the history of hydropower development, and linking the two in terms of causes and effects is a complex challenge. Since the different stages of hydropower development and construction activities are strung out over a very long period of time, it is very difficult to attribute specific effects on recreation and tourism to particular industrial actions. Many of the dam projects in the two watersheds are so old that recreation and tourism issues were not part of the concession or planning criteria. Thus, due to both the wide geographic scale of the watersheds, and the long time span, we have to assess effects of hydropower on a broad basis, and largely in a qualitative perspective.

From the perspective of tourism and recreation the two watersheds can be divided into three main sections; the upper mountainous reaches, the long intermediate section through Gudbrandsdalen and Østerdalen, and the lower reaches through the lowlands of Southeast Norway. The mountain areas comprising the headwaters of Glomma and Lågen have played a salient role for alpine recreation since the late 1800’s. Early conservation initiatives in these mountain areas partly came out of debates over use of water resources and hydropower plans. The area is characterised by rugged peaks and narrow valleys, as well as broader valleys and plains. The Norwegian Tourist Association (DNT) has marked trails and maintained lodges and huts in this region for approximately one hundred years. DNT is the only organisation with facilities inside the national parks in this area. Private corporations and lodgeowners have also run tourism facilities in this region for about equally long. Use patterns consist of a mixture of activities including mountain hiking (day trips and multi-day trips), climbing, skiing, camping, fishing, hunting, and car-based tourism. For the most part, tourism and recreation is fairly dispersed, and none of the facilities are very large or of a very high standard. Overnight facilities are found throughout the upper and middle reaches of the watershed. Several nature reserves are also found throughout the entire reach of the two watercourses.

The long intermediate sections of the rivers through the two valleys also provide a range of recreational opportunities. Most of the use here is day use associated with fishing, boating activities and shorter hikes and sightseeing along the riverbanks. Much of the use is by locals from the various communities along the rivers, but some tourism groups also use these sections of the watercourses. There is some commercial tourism activities such as fishing trips and rafting along certain parts of the rivers.

The lower parts of two rivers are particularly important for boating and day use activities. Here the slow currents and large water volumes enable the use of a range of boats, and fishing activities are also important. The landscape is less rugged and scenic from a tourism perspective than the middle and upper sections of the rivers, and the use is dominantly by local populations. Thus the activities also focus more directly on the rivercourses here. In the middle and upper reaches, the rivers to a greater extent are part of larger landscape experience as seen from the outdoor recreation and tourism interests. Both rivers have in earlier times played an important role for commercial- and partly subsistence fishing. However, most of this is now history, but elements of these traditions are maintained at certain locations where farms have specific harvesting rights. At the same time historical and traditional uses of the river have become important elements in tourism products and the images of the rivers used for marketing.
A broad assessment suggests that outdoor recreation and tourism interests in the two watersheds have been affected in different ways. However, the effects are strongly localised and unevenly distributed. From an overall perspective (i.e. on a watershed scale), tourism and recreation interests has not been heavily affected through the history of hydropower development.

In principle recreation interests and opportunities can be affected in a number of ways. Due to hydropower construction and activities, recreational activities can be either; eliminated due to lack of opportunities, change in volume or structure, displaced to other locations, change their experiential content, and/or new user groups might take advantage of changes in conditions and opportunities. Semi-structured interviews (performed by telephone) as well as analyses of documents provide some information as to the extent of these types of effects on recreation issues throughout the watershed.

The interviews indicate that there have been few direct conflicts of any real significance with recreation and tourism interests. There are few or possible no examples of distinct recreational opportunities or activities that have been completely eliminated. Fluctuations in water levels are generally not large enough to adversely affect most types of boating activities and other river related recreation directly. However, changes in water level and land use have in several cases, reduced access to riverbanks. In a few locations trails have been located due to higher water levels. This pertains particularly to the mountain areas. There are several examples of where new access opportunities have been provided through new roads related to construction activities, while these do not necessarily improve the quality of the recreational experience. There have been several claims that changes in water levels have affected fishing negatively and also reduced boating opportunities in some sections. Improved access and locations for swimming can also be identified in some cases. Furthermore, the interviews indicate that the aesthetic properties of the rivercourses and valleys have been negatively affected in many locations due to dams, powerlines, landfills and roads. Inevitably this has some influence on the quality of the recreational experience, but it is difficult to assess how much, and whether it affects activity levels and ultimately the economics of tourism. The tourism industry has traditionally not engaged in hydropower debates, and have not played and active part in the development throughout the Glomma and Lågen watersheds. An exception is the recent debate over the Øvre Otta river, a tributary to Glomma. Here the tourism industry finally voiced a formal concern and opposition to the development plans on the grounds that the proposed hydropower scheme would negatively effect the tourism experience and products in the valley.

Perhaps the most pressing problem from a recreation and tourism perspective is the reduced access to large parts of the river courses, particularly in the middle and lower sections. However, this can only to a marginal extent be attributed to hydropower activities. It is mostly caused by other land use changes, notably expansion of agriculture, industry, human settlement and infrastructure. In several municipalities, improving public access and protecting diverse riparian habitats are identified as the most pressing management needs with regard to recreation interests.

### 3.5.2 Fisheries

The length and complexity of the Glomma and Lågen watersheds constituted and still constitutes a diversity of fisheries (cfr. also chapter 3.8 annex 6). Fishery has been a major human use of the watercourse, and before the period of hydropower use, maybe the most important type of use. Historically, the commercial fishing in the lower parts of Lågen and in Mjøsa was the most important inland fishery in southern Norway. Brown trout, cisco and whitefish as well as other species were caught with a wide range of locally adapted catch methods (Eknaes 1979, Heitkøtter 1981, Rugsveen 1985). The fishery was considered highly valuable, and a complex system of fishing rights has evolved during centuries (Rugsveen 1985). This fishery is now greatly reduced due to a combination of factors including less interest for fish for consumption and hydropower development. Today, recreational fisheries is among the most popular outdoor recreation activities in Norway (Aas 1996). Around 50%
of the adult population and more than 75% of children between 10 and 16 years of age participate in recreational fishing each year.

The division of the watercourse into three main sections; the upper mountain regions, the long intermediate river sections and the lowlands of the southeast are relevant from a fisheries perspective. The differences in the fish community from north to south, east to west and from low to high altitudes are also helpful in trying to categorise the fisheries. Normally, fisheries are also divided into commercial, subsistence and recreational fisheries. All three major types are still present in the GL basin. However, recreational fisheries dominate.

The fisheries in the upper sections are primarily a fishery for salmonid fishes; mostly brown trout in the Lågen area, while other species also is important in the Glomma region, primarily grayling, whitefish, and Arctic char, in addition to brown trout. Most of the fishery is recreational, with diverse user groups including locals, domestic tourists as well as foreign anglers. Lakes, rivers and smaller streams are used for fishing. Also, what we can characterise as a subsistence fishery is common in these areas. This is primarily a lake fishery from residents, using gill nets or other catch effective gear. Brown trout is the primary target species, but also whitefish and char is fished for. Most of this fish is used for own consumption or given away to relatives and friends, some of it after conservation by means of fermentation (raking). Some lakes are used extensively for ice fishing in the winter, where char is the major target species (Nashoug and Hegge 1988).

The middle section of the system is dominated by long river sections through forested valleys. These rivers constitute very important recreational fisheries in both a national and European perspective above the cities of Elverum and Lillehammer. Especially the Glomma and Rena rivers have gained special attention from anglers and attract thousands of anglers from Norway, Sweden, Denmark and other countries each summer (Qvenild and Linløkken 1989, Vittersø 199x). Rod and line fishing for brown trout and grayling, to some extent also whitefish is the main attraction in these rivers. Remnants of the old cisco fishery still exist as a recreational or subsistence fishery in lower Lågen and upper Mjøsa.

The fishery for the large-grown brown trout in the lake Mjøsa and some of its tributaries, primarily the lower sections of the Lågen is a fishery of special interest. This trout is either fished by means of trolling out on the lake, with gill nets in the lake or with rod and line in the rivers. Despite significant focus on this fishery in the media, it attracts relatively few anglers. Low catch probability, variations depending on situational factors like runoff and weather, need for expertise and special equipment explains this relatively low number of anglers fishing for the large-growing trout (Taugbøl 1995). The gill net fishery is primarily a subsistence fishery by farmers, and not a commercial fishery. About half the annual catch of approximately 10-15 metric tonnes is estimated caught by the netsmen, and the other by trolling anglers (Taugbøl 1995).

The lower sections consist of large lakes (lakes Mjøsa and lake Øyeren) and mainly slow-flowing rivers. This part of the watershed has in general a more diverse fish fauna and more diverse types of fishing than the other parts. Several species of cyprinids, perch, pike and pikeperch dominate the fishing in this section. In addition salmon, large brown trout (see paragraph above), and grayling create more local fishing opportunities in remaining sections, with more fast-flowing water (Hegggenes, Brabrand and Saltveit 1985). These lower parts are generally in close proximity to heavy populated areas, and constitute in some certain areas what must be called urban fisheries. The lake Mjøsa is surrounded by the three cities Lillehammer, Hamar and Gjøvik. Lake Øyeren is close to some of the big suburbs of Oslo, and the big cities of Østfold (Fredrikstad and Sarpsborg) encircle the lower part of the Glomma. While these areas generally do not receive much attention from a fishery management perspective, and not gain much attention in angling magazines, the use levels can be high, and from a recreation point of view some areas are of large importance to the residents in these areas. The northern part of lake Øyeren is probably the best example. In a study from 1994, the use of the
northern part of the lake was estimated to approximately 6000 trips during a two-and-a-half month period in spring/early summer (Aas and van den Hemel 1995). Children were considered the most important group, numerically. Cyprinids and perch were their major catch. More specialised fisheries were also significant, for example fishing for pike right after spawning, and pikeperch when they enter the rivers Leira and Nitelva for spawning. Lake Øyeren is one of the relatively few lakes in Norway, which have upheld a commercial fishery the last years. This is primarily a fishery for pikeperch, pike and whitefish.

As discussed in the chapters on ecological effects and effects on recreation and tourism, the effects from hydropower development on fisheries must be assessed as diverse and complex. Generally, there is a lack of good and reliable studies of how fisheries have been affected by HPD. In addition, fisheries have gone through significant changes because of other general societal changes and other human impacts in the watersheds. As outlined in chapter 3.9, extensive use of mitigating measures has been implemented to reduce negative effects on the fish stocks. In total, this complexity makes it difficult to isolate the direct effect from HPD on fisheries from other changes. Effects on fisheries can have several reasons. In many cases, fish production is affected. In other cases, the opportunity to fish is affected. This can be the case in lakes with large fluctuations in water level, which can cause problems to access the lake by boat. Damming of previously forested areas can also lead to problems for fishing with gill nets (Aass 1987). Recreational fishing can also be negatively affected by aesthetic properties of the rivercourses by damming, powerlines, roads and land fills, low water levels and fluctuating water levels. On the other hand, positive effects also have occurred, like improved access, and creation of new fishing opportunities (damming).

Some of the impacts have had fatal or major negative effects on fisheries. Examples here are the eradication of the large brown trout fishery with traps downstream from the Hunderfossen in Lågen (Aass and Kraabøl 1999) and damming and destruction of the famous quality angling spot Bjønnhølen and other sections in the Vinstra tributary. Generally, most effects on fisheries in the basin can likely be classified as minor negative. Studies in important fishing areas like Rena and northern part of the lake Øyeren document significant complaints from anglers on effects from HPD. This is often related to concern for the fish stock or to interference on the actual fishing from fluctuating water levels. Generally, there has been an ongoing discourse between different stakeholder groups and interest groups about the effects of hydropower regulation and about the effects of the different mitigation actions taken.

Findings on Recreation, Tourism and Fishing

- Actual effects cannot be linked directed to predicted effects since the latter was never formulated explicitly due to the large geographic scale and vast time scope of the projects.

- Hydropower debates in this region have through the past century greatly influenced larger conservation and recreation issues, i. e. the designation of alpine national parks and lowland nature reserves.

- A diversity of positive and negative effects on recreation and tourism to some extent can be attributed to water regulating activities. These include improving and restricting access to the river banks, facilitating some new boating opportunities, while also reducing the quality of others due to fluctuating water levels, and some reduction in aesthetic qualities/experiences.

- On the watershed scale, recreation and tourism interests have only been moderately impacted in a negative as well as positive sense.

- Fisheries have been, and still are a major human use of the Glomma Lågen watercourse.
Fisheries have gone through major changes in the study area during the last decades. Parts of the changes can be attributed to hydropower activities, but generally in connection with other impacts and more general social changes.

In general, the regulating activities have affected fisheries in a wide variety of ways, from positive to fatal effects. On a watershed scale, the impacts are assessed to be moderately negative.

There has been an ongoing discourse between different interests about the effects of regulating activities and of important mitigating measures like stocking and fish ladders on the different resources in the basin.

### 3.6 Social Effects

#### Predicted versus actual social effects

All the G&L hydropower development projects have been predicted to result in no resettlement of people. Although the system of dams and reservoirs in the two river basins is very extensive, the total inundated land from reservoirs in the G&L basin encompasses only 45.8 km². This is an increase of 5.6% compared to the natural area of all the reservoirs before regulation. In addition most of the area inundated is high altitude forest and mountain areas. As a consequence resettlement of towns or single households from hydropower activities have not occurred in the G&L basin. In addition effects for indigenous people and ethnic minorities has not been relevant issues.

Positive social effects have been predicted from the hydropower development in the G&L basin. The effects include providing jobs both in the construction period and permanently in operation of power plants and dams, as well as distributional effects of taxes, licenses fees, owner incomes and different kinds of compensations to inhabitants and interest groups in the development areas. All the distributional economical effects are covered in more detail in section 3.8 (Regional and national effects) and chapter 4.

Some of the G&L basin hydropower development projects have been initiated to utilise unemployed workers in periods of depression and high unemployment rates. One example is the use of unemployed miners from the mining industry at Røros, to do tunnelling during the construction period at Aursunden reservoir in the early 1920s. There are also examples of hydropower developments initiated to strengthen specific regions within the G&L basin.

The Watercourse Regulation Act have from its approval in 1917 contained paragraphs on obligations for license holders to carry through social measures in the hydropower development areas. Various examples of measures are listed in The Watercourse Regulation Act. These include building of a community centre/village hall where appropriate, to cover expenses of medical help for the construction and office and their families workers during the construction period and to supply the workers and their families with satisfactory places to live.

It is likely that the hydropower developments in the two watersheds also have psychological effects related to the changes in environmental conditions. The series of dams increase the capacity to reduce flood peaks and control floods. The interviews indicate that in local communities along the watercourses this is seen as a positive effect, reducing the risk of rapidly changing water levels and potential destruction of or damage on property and livelihoods. It is well known from other studies that humans see the danger of damaging floods as one of the greatest threats of nature. Conversely, the many dam constructions through the watersheds can also be perceived as dangerous, since a breach in a dam can result in catastrophic flooding, at least locally. A dam breach has actually taken place in one
of the tributaries to River Lågen. Fortunately the accident took place on the Norwegian national day when people were out, and in spite of the considerable physical damage no one got injured.

**Findings on Social effects**

- The hydropower development in the G&L basin has resulted in no resettlement of households
- The most significant social effects of the hydropower development in G&L basin are connected to changes in local and regional economies.

### 3.7 Regional and National Effects

During the period in which hydropower in the GL region was developed, all of Norway was being “electrified”. Electric power was made available in all parts of the country, independent of the regions own production of hydropower. If we disregard wood processing installations, particularly in the lowest part of Glomma, there is little industrialisation, which can be traced directly back to the hydropower expansion in the GL region. The large industrial installations neither came about as a consequence of electrification, but were established much earlier nor based on mechanical hydropower.

If we look at the development in terms of economics and population growth, there are large regional differences within the GL region. In the south, there is a relatively great population density and economic activity. The northern part of the GL region is characterised by primary industries, low incomes and dwindling population.

In general terms, one can say that the hydropower development has not provided the GL region with an economic and population development that differs from comparable regions without hydropower development. The power development has given a few of the municipalities higher incomes than they would have had otherwise.

In the following paragraphs, we will first present some key figures for the role of the hydropower sector in Norwegian economy. Subsequent to this we will look at the taxation principles for power plants in Norway. Finally, we will make some rough estimates of the tax revenues from the power installations in the GL region and how these earnings are distributed in terms of municipalities /counties and the State.

#### 3.7.1 The hydropower sector in Norwegian economy

In 1998, the electricity supply sector accounted for 2.4 per cent of the gross domestic product in Norway. The corresponding figures for the petroleum sector was 11.5 and for manufacturing industries 13.2 per cent.

During the 1980s, employment in the hydropower sector rose each year, but dropped again at the beginning of the 1990s. In 1998 18.300 people were employed in the electricity supply sector.

The rate of return in the power supply sector has increased substantially during the past 20 years. In the 1970s, the rate of return was low, but it rose during the 1980s, partly because of an increase in the price of power to consumers other than power-intensive industry. Since the end of the 1980s, the rate of return in the power supply sector has been about the same as that in other industries.

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This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
In 1996 there were 326 utilities in the electricity supply sector including both production plants, whole sale plants, distribution plants and integrated plants. (59 production plants, 27 industrial generators, 24 wholesale plants, 93 distribution plants 106 integrated plants, 12 grid companies and 5 other plants)

More than 99 per cent of the production of electricity in Norway is water power. Norway has today about 856 power stations with a total hydropower production capacity of 27.307 MW. In addition, thermal power stations have a capacity of 265 MW. The average amount of hydropower generated in Norway is around 112 TWh (billion kilowatt hours) annually. Annual production varies a lot, depending on variation in water inflow.

Of the total Norwegian water power production in 1996 (104 TWh) 38 per cent was produced in power stations owned by central government, 6 per cent by county municipal, 12 per cent by municipal, 32 per cent by joint municipal and 12 per cent by private. Hydropower stations that are not owned by the central or local government revert to the state free of charge after normally 60 years.

3.7.2 Earnings for the G&L region

As mentioned previously, the dams in the G&L region were constructed over a long period of time and all construction was concluded many years ago. For many local communities, the construction period represented an economic time of prosperity, with growth in employment, increased tax revenues and a large demand for goods and services, from both the developers and the installation workers. Several decades have passed since the large construction projects in the G&L region were concluded and it is of limited interest to analyse the regional and local effects during the construction period so many years after the fact. We will therefore concentrate on the economic significance that the power installations have in the G&L region today.

In the G&L region today, approximately 2,100 persons are employed in the hydropower sector, that is, in all the segments of the value chain. The majority of these are connected to sale and distribution of energy, in other words, to supplying users in the G&L region with electric power. This activity can be viewed as being distinct from energy production and the dams in the G&L region. This distinction has become particularly clear after the market reform that accompanied the new Energy Act in 1991. Approximately 250 persons are employed in the production part of the hydropower sector, that is, excluded transmission, marketing and sales.

We will limit ourselves to direct earnings from the electric power activity. In other words, we will not look at indirect effects, such as where an energy enterprise and the employees in the energy enterprise purchase goods and services from other enterprises in the area. It is difficult to acquire data for such indirect effects and during the operational phase, the significance of such effects is believed to be relatively small.

The direct economic effects in the G&L region come primarily in the form of revenues to the municipalities and to a certain extent to the counties. The revenues to the private sector are small.

The revenues for municipalities come in the form of:

Taxes
License Fees
Sale of licensed energy
Owner incomes (dividends)

With the adjustments made in 1998, the main features of the new tax regulations are as such:
**Profit tax**
Taxation on the basis of annual profits for both publicly and privately owned energy enterprises. Energy enterprises shall like other industries pay tax on personal income at the rate of 28%. The distribution of taxes between the State, county and municipality is as for other enterprises, 20.75% to the State, 2.50% to the county and 4.75% to the municipalities. The tax unit is the enterprise.

**Nature resource tax**
Nature resource tax at 1.3 øre/kWh (0.00172 US$/kWh) of which 1.1 øre goes to the municipalities and 0.2 øre to the counties. The tax unit is the power installation.

**Basic interest tax**
Tax on basic interest (profits beyond normal return) for the individual power plant at 27%. The tax revenues go to the State. The tax unit is the power installation.

**Property tax**
Property tax. Here new regulations have been passed for the value stipulation of power installations. These regulations are implemented starting from the property tax year 2001. The purpose of the new regulations is to ensure that the rates to the greatest extent possible correspond with the market value. The tax unit is the power installation.

There are no available statistics on the incomes received from the energy sector by municipalities and counties. We have made some relatively rough estimates based on a range of sources. Based on this, the earnings from the power installations in the G&L region were distributed as follows in 1998:

**Table 3.7.1 Public revenues from power installations in the G&L region.**

<table>
<thead>
<tr>
<th></th>
<th>To G&amp;L region</th>
<th>Out of the G&amp;L region</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Municipalities and counties</td>
<td>the State</td>
<td></td>
</tr>
<tr>
<td>Taxes</td>
<td>278 (36.9)</td>
<td>55 (7.3)</td>
<td>333 (44.2)</td>
</tr>
<tr>
<td>License fees</td>
<td>26 (3.4)</td>
<td>5 (0.7)</td>
<td>31 (4.1)</td>
</tr>
<tr>
<td>Sale of licensed energy</td>
<td>20 (2.7)</td>
<td>0</td>
<td>20 (2.7)</td>
</tr>
<tr>
<td>Owner incomes</td>
<td>90 (11.9)*</td>
<td>60 (8.0)</td>
<td>150 (19.9)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>414 (54.9)</strong></td>
<td><strong>120 (16.0)</strong></td>
<td><strong>534 (70.9)</strong></td>
</tr>
</tbody>
</table>

*Includes revenue to both municipalities and counties.

Of accumulated incomes of NOK 534 million, a 414 million or almost 80% goes to the GL region. The large revenue entries are owner incomes and taxes. The distribution of owner incomes can be changed if the ownership is moved out of the GL region. Also profits tax will leave the GL region if the ownership of the installation is relocated. But the profit tax comprises only about 20% of the accumulated tax revenue. With the tax system that was established in 1997, the municipalities and counties are thus guaranteed a relatively large portion of the incomes even in the event of a comprehensive restructuring in the energy sector.
The total annual incomes of the municipalities in the GL region are at around NOK 12-13 billion (1.7 billion US$). Of this, energy revenues comprise a good NOK 400 million or around 3.0%. The 414 million also include revenues to the counties. If we make adjustments for this, the energy revenues for the municipal sector (municipal and counties) in the GL region will be at about 1.9% of the total incomes.

A few municipalities in the GL region have relatively large energy revenues. In these few municipalities, the revenues of the power installations make up more than 5% of the incomes. But as we will come back to later, such municipalities receive reduced subsidies from the State.

Business Development Fund

In addition to the current incomes, the municipalities have non-recurrent revenues in the form of the Business Development Fund. This was introduced in 1962, and formalised in the Water Course Act in 1969. Most of the power plants in GLB were constructed before that time. Few municipalities in the GL region have therefore an energy-financed Business Development Fund. In total, the GL-municipalities have received 29.5 MNOK (3.9 million US$) to their Business Development Funds.

Net Effects

Reduced subsidies through the income system.

A large proportion of the incomes to Norwegian municipalities comes through annual State subsidies. These subsidies are in part meant to compensate for standardized fees (fee compensation), in part compensate for low earnings (income equalization). Municipalities with large energy incomes receive lower subsidies than corresponding municipalities without energy incomes.

If we also take into consideration that the State subsidies are reduced for municipalities with large energy incomes, the net effect of the energy revenues will feasibly be at around 1.5% of the municipal sectors’ aggregate annual incomes in the GL region.

Discontinuation of subsidies to the Business Development Fund.

Most energy municipalities are rural municipalities. Rural municipalities receive annual contributions for their Business Development Fund from the Ministry of Local Government and Regional Development. Energy municipalities with their own Business Development Fund from energy development do not receive annual subsidies for a Business Development Fund from the State.

Municipal benefits, ex. from regulation of Lake Osen

The Norwegian licensing system has always included municipal benefits, as a compensation for the inconvenience that a hydro power project will make to the affected area. For the regulation of Osensjøen, Lake Osen, in the Glomma river, a new license was granted 21st May 1999, as a replacement for the old licences given 14th September 1928 and 11th June 1976. The license was granted for an unlimited period, but the conditions for the license could be revised after a period of 30 years. The lake was allowed to be regulated up 1.7 m. and down 4.9 m from normal water level. Because of aesthetic reasons, the passage of fish and pollution, there are conditions to release water to the river South Osa. For the period 1 June - 15 September the release is 6.0 m$^3$/sec, from 20th September - 31th May the release is 2.5 m$^3$/sec. Between 16th September and 20th September the release will be gradually reduced from 6.0 - 2.5 m$^3$/sec. There are also restrictions on the water level of the lake during summertime, and the water level shall from medio June - medio August be held within a variation of 70 cm. There are also restrictions to regulate the system to reduce the water in the river during flood situations.
For the increase of hydropower gained by the regulation, an annual fee per nat. hp of NOK 2.- to the state licence fee fund should be paid. Also, an annual fee of NOK 13,34 per nat. hp should be paid to the licence fee funds in the counties and the municipalities that are affected by the project. When the license was granted, an amount of NOK 8 mill. (equal to 1 mill US$) was paid to two municipalities as a business fund, to develop industry, business etc. in the affected area. The amount was paid by the company that was granted the license for the project. Special consideration has to be given to the environment during the construction period, and all damages have to be repaired after the construction period. In parts of the rivers, where the project will cause major changes of the amount of water or the water level, NVE can demand the concessionaire to construct weirs, adjust the rivercourse, cleaning up the river bed etc, to reduce the environmental impacts. There are also conditions to reduce the possible negative impact for the fish and the fish population, by captive breeding and release of the local type of fish, and to carry out other types of mitigating measures. Also conditions to take care of the outdoor life, plants- and animal species, cultural heritage etc are demanded. The concessionaire shall supply the municipalities and counties where the project is located, an amount up to 10% of the increased hydropower production to a reasonable price, and to the state up to 5% on same conditions. There are special rules for the calculation of the price for the supplied electric power. For each time these conditions are violated, a penalty of up to NOK 100.000 per day, or NOK 500.000 for each violation, can be claimed by the Ministry of Oil and Energy (OED).

Private incomes.

All dam construction projects (regulation of water levels) with a concession from the Watercourse Regulation Act are granted a permission to expropriate all necessary rights required to fulfil the project. According to this law any part is in exchange for economic compensation, obliged to relinquish ground area and rights as required in order to complete the hydropower project. In reality, the renouncing of property and associated rights is negotiated in a non-controversial manner through agreements. However, the law also contains the legal tool to expropriate if necessary, and this is stated through the concession.

Concessions granted with basis in the general Water Act for the purpose of securing public interests cannot automatically interfere with existing rights. In this case, permission to expropriate can be granted following an application if expropriation is deemed necessary for fulfilling the project. The Water Act has a specific clause for expropriation, and it also opens for expropriating water fall rights. The latter can only be acquired by public institutions (municipalities, counties, and state). However, in such cases this is commonly administered through negotiations and agreements.

Compensations from hydropower developments paid to landowners for land acquisition and expropriation are independent of the landowners’ private economical situation. The compensations are fixed from affected area/river stretch and eventually reduced possibility for business income.

Annual compensations are index-linked according to the amendments of the act in 1985.

Compensation is paid annually to landowners and holders of legal rights who are effected by regulation interventions. For the period from 1994-98 the annual compensations paid by GLB have been NOK 7-8 million (1 million US$). In 1992 the compensation was distributed among more than 3 700 receivers. The number of receivers has been reduced the recent years because it has become possible to pay annual compensations in the form of a non-recurrent fee.
Table 3.7.2 Annual compensations to landowners in the G&L basin 1994-98. Mill. NOK (US$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Mill. NOK (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>7.4 (1.05)</td>
</tr>
<tr>
<td>1995</td>
<td>7.3 (1.15)</td>
</tr>
<tr>
<td>1996</td>
<td>7.2 (1.11)</td>
</tr>
<tr>
<td>1997</td>
<td>7.0 (0.99)</td>
</tr>
<tr>
<td>1998</td>
<td>7.7 (1.02)</td>
</tr>
</tbody>
</table>

Table 3.7.3 Regional distribution of compensations to landowners in the GL-basin.

<table>
<thead>
<tr>
<th>Power plant/Reservoir</th>
<th>Number of receivers of compensations</th>
<th>Sole compensation at construction MNOK (Million US$)</th>
<th>Annual compensations to landowners in 1998 MNOK (Million US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Østerdalen (incl. Lake Fundin and Lake Storsjøen)</td>
<td>-</td>
<td>9.751 (1.468) *</td>
<td>3.060 (0.406)</td>
</tr>
<tr>
<td>Ottadalen (incl. Raudalsvatn)</td>
<td>-</td>
<td>-</td>
<td>1.340 (0.178)</td>
</tr>
<tr>
<td>Vinstravassdraget (incl. Olstappen)</td>
<td>-</td>
<td>-</td>
<td>1.622 (0.251)</td>
</tr>
<tr>
<td>Lake Mjøsa and Lake Øyeren</td>
<td>-</td>
<td>-</td>
<td>1.696 (0.225)</td>
</tr>
<tr>
<td>Sum</td>
<td>3,582 **)</td>
<td>-</td>
<td>7.718 (1.023)</td>
</tr>
</tbody>
</table>

*) The compensation concerns the development called “Østerdalsutbyggingen”, with the transfer from Fundin, Savalen and Rendalen, and represent 1966. **) The number of landowner receiving annual compensation have decrease as some have accepted a sole (one time) compensation which equals 14 times the annual compensation.

The annual compensations in 1998 were distributed as shown in figure 3.7.1.

Figure 3.7.1 Distribution of annual compensations within the G&L basin in 1998.

Findings on Regional and National Effects:

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
• The dams in the GL region were constructed over a long period of time and all construction was concluded many years ago. For many local communities, the construction period represented an economic time of prosperity, with growth in employment, increased tax revenues and a large demand for goods and services.

• In the long run, and in general terms, the hydropower development has not provided the GL region with an economic and population development which differs from comparable regions without hydropower plants.

• The power development has given a few of the municipalities higher incomes than they would have had otherwise. This has in part given the municipalities the financial basis from which to develop a larger and more costly administrative system than other municipalities of the same size, but the energy revenues have also feasibly contributed to a service offer that is better than that of other municipalities.

• In the G&L region today, approximately 2,100 persons are employed in the hydropower sector, that is, in all the segments of the value chain. The majority of these are connected to sale and distribution of energy, in other words, to supplying users in the GL region with electric power. This activity can be viewed as being distinct from energy production and the dams in the GL region. This distinction has become particularly clear after the market reform that accompanied the new Energy Act in 1991. Approximately 250 persons are employed in the production part of the hydropower sector, that is, excluded transmission, marketing and sales.

• The direct economic effects in the GL region today come primarily in the form of revenues to the municipalities and to a certain extent to the counties. The revenues to the private sector are small.

• The revenues for municipalities come in the form of:
  -Taxes
  -License Fees
  -Sale of licensed energy
  -Owner incomes (dividends)

• Of accumulated public incomes of 534 MNOK (70.9 million US$) from the energy sector in GL, a 414 million or almost 80% went to the GL region. The energy revenues amounts to about 1.9% of the total incomes in the municipal sector (municipal and counties) in the GL-region.

• A few municipalities in the GL region have relatively large energy revenues. In these few municipalities, the revenues of the power installations make up more than 5% of the incomes.

• A large proportion of the incomes to Norwegian municipalities comes through annual State subsidies. These subsidies are in part meant to compensate for standardized fees (fee compensation), in part compensate for low earnings (income equalization). Municipalities with large energy incomes receive lower subsidies than corresponding municipalities without energy incomes.

• If we also take into consideration that the State subsidies are reduced for municipalities with large energy incomes, the net effect of the energy revenues will feasibly be at around 1.5% of the municipal sectors’ aggregate annual incomes in the GL region.
3.8 Ecological Effects

Environmental impacts of hydropower projects include both negative and positive effects. In the G&L basin as well as in other hydropower development areas, a number of adverse environmental effects, direct and indirect, have been observed on terrestrial, avian and aquatic ecosystems. Other consequences of hydropower development are positive, for example the use of electricity from hydropower as an energy source instead of electricity produced from fossil fuels or from nuclear power. New techniques such as Life Cycle Analysis are being developed to assess the full chain of environment impacts for the different energy systems, however such analyses have not been included in this study.

3.8.1 Predicted and observed effects

Most of the hydropower licenses, at least in the Lågen branch, are from a period of time (i.e. before 1970) when there was little concern about ecological impacts of the projects. Thus, few investigations were undertaken to assess the situation before regulation. From about 1970 and onwards, concurrently with an increased environmental focus (e.g. foundation of the Ministry of Environmental Protection in 1972), a number of investigations have been carried out in order to assess the ecological effects of hydropower projects. However, few investigations were designed as Environmental Impact Assessments, they were basically registrations of the pre-regulation situation (Haugum 1998). Few ecological effects have thus been predicted, with the exception of effects on harvested fish populations and the fishery (Dahl 1947). Fish has been of particular interest due to the importance of recreational and to some extent subsistence fishery. Since the first regulations, compensations have been paid to the fishery right owners for damages on the fishery; the size of the compensations established by legal appraisals. Fish stocking as a mitigation measure has also been instructed from early on.

In the past two decades much attention has also been directed to remedial measures and to post-regulation studies in order to assess the actual ecological impact of the hydropower projects (Haugum 1998). An important financial source for the ecological investigations has been/is the License Fee Fund (cf. chapter 3.8). This fund has very much contributed to develop a good base of knowledge regarding ecological effects of hydropower projects in Norway (cf. Faugli et al. 1993). For the Lågen branch a summary/overview of aquatic investigations and effects are given in Hegge (1989) and Eriksen & Hegge (1994). For the Glomma branch, similar overviews are found in Svarte (1983), Qvenild & Linløkken (1989a) and Ministry of Environment (1992). In terrestrial habitats, effects of hydropower development have been studied for a much shorter period of time. The knowledge base, in the form of pre-regulation registration, is also poorer for terrestrial habitats. An indication of the knowledge bias between aquatic and terrestrial systems is the fact that licenses have begun to include specific conditions regarding amendments for fish populations, whereas conditions for terrestrial habitats most often are described in very general terms. The following presentations of effects in terrestrial and aquatic systems reflect both this bias and the short time scale of investigations.

The presentations below are specifically related to the G&L basin. A more detailed overview of general effects of hydropower development, particularly on vegetation, birds and mammals based on a number of studies mostly from Norway, are to be found in Annex 7.

Effects on vegetation

Reservoirs

Large parts of the G&L basin are in cold, dry areas with continental climate and short growing season, which means that natural vegetation recovers slowly. A large proportion of the reservoirs in the G&L basin are situated in subalpine – lower alpine regions, where revegetation in the regulation zone is very slow. Most reservoirs are regulated through both damming and draw-off (cf. Fig. 2.4.2), so the new
water line will fluctuate between former terrestrial areas and former lake bottom. Typical regulation zones with little vegetation, bare rock beds, ice-scoured and washed out substrate can be observed in several of the G&L reservoirs.

Wetlands

There are two Ramsar wetlands in the basin, Åkersvika at the outlet of Svartelva and Flakstadelva into Mjøsa and the Nordre Øyeren delta. Åkersvika is a shallow wetland in the Hamar region almost closed off from Mjøsa by road and railroad constructions. Åkersvika is a nature reserve as well as a Ramsar site. The mean depth is around 1.5 meters, ranging from 0.5 - 4 meters at normal water level in Mjøsa. The regulation of Mjøsa leaves most of the area in the inner parts of the reserve dry (above water) in late winter/spring. Large areas are then exposed to frost, desiccation and erosion. The gradual filling of Mjøsa during the growing season has led to a reduction in vegetated areas in Åkersvika (Kjellberg et al. 1994). In particular has the extent of water plants and swamp vegetation been reduced.

Nordre Øyeren delta, which is the northern end of Lake Øyeren in Glomma, is a delta formed by the flowing through of Glomma. The regulations have given a more constant water level and dampened fluctuations, including floods. The pattern of sedimentation has changed; the transport of matter stops higher up in the delta and the distribution of fine silt is more even (Akershus fylkeskommune 1997). As a result, topography in the delta is evened out and habitat diversity reduced. General narrowing of vegetation zones and increased erosion at the new water level is also observed (Akershus fylkeskommune 1997).

Alluvial plains and riparian forest

Effects on vegetation will be most pronounced in connection with large reservoirs, dammed river stretches and on river stretches with reduced water level (cf. Table 3.8.2 + Fig. 2.4.3). Both Glomma and Lågen have stretches with alluvial plains dominated by Salix-Alnus woodlands, Carex vegetation and pioneer communities. Through the regulation of water transport, with reduced water level in summer and increased water level in winter, the extent of areas that are flooded and the period of flooding have been reduced and erosion and sedimentation patterns have changed. It is the water level in the ice-free period that is most decisive with respect to vegetation. The extensive regulations in the watercourse have led to a reduction of small water bodies in the watercourse, a reduction of swamp vegetation and a reduction of stable and well-drained alluvial forest/woodland (Fremstad 1985). The most extensive floodplain-swamp vegetation types along Lågen are now found in Ringebu and Sør-Fron municipalities. The changes in water transport and flood patterns following regulations in Lågen has affected and continues to affect the zonation and succession patterns in these areas (Fremstad 1985).

Water vegetation

In the rivers Søre Osa and Glomma at Strandfossen, reduced water flow has led to a dramatic reduction in the river moss vegetation. In Søre Osa the reduction is 65-75% compared to the pre-regulation situation (Hessen et al.1992). The connection between river mosses and abundance of benthic invertebrates was also investigated. In the vegetated area number of invertebrates was 10-50 times higher compared to areas without vegetation. Thus, a reduction in vegetation may have severe impact on the invertebrate and, as a consequence, fish production. In other parts of Glomma and Lågen, few changes in water vegetation have been observed (Brandrud 1993). A more constant water level and reduction of flood conditions may also favour the growth of river mosses at the expense of other water plants. In the river Mesna, the licence specifies mandatory flooding twice yearly to eradicate overgrowth of moss.

Effects on water vegetation in reservoirs depend first and foremost on the regulation height. In the lakes Aursunden and Osensjøen (regulation height of 5.5-6m), most of the water vegetation has disappeared as a result of the regulation, i.e. critical levels for the existence of water vegetation are exceeded (Brandrud 1993). In lake Mjøsa (regulation height 3 m) vegetation in the regulated zone has

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
been reduced, while deep water vegetation are intact. In the northern part of Lake Øyeren and in Lake Løpssjøen with minor regulation heightes (1-2.5 m) an increase in water vegetation has been recorded (Brandrud 1993).

**Effects on birds**

As the largest watershed in Norway, the G&L basin also contains many important bird habitats, ranging from remote mountain and forest areas to temperate wetlands. Effects on bird life are also dependent on where effects take place; in mountain lakes, rivers or low-lying wetlands. The numerous dams and reservoirs in the G&L basin (cf. Fig. 2.4.3) has inundated substantial areas of riparian woodland, floodplains and valley bottom, which constitute important bird habitat in most of the basin. The area affected has not been quantified directly. However, the increase in water surface area following damming adds up to 46.6 km² for the 40 reservoirs. The actual area inundated is larger due to the slope. This clearly represents a substantial habitat loss.

The Lågen delta at the outlet of Lågen into Mjøsa, Åkersvika and Øyeren wetlands are all important localities for migrating and resident birds on a national and international scale. The localities are used by birds under migration both in spring and in autumn, and by resident birds throughout the year. The regular flooding pattern is an important factor forming these wetlands, and the reduction of floods following regulations has long term effects on habitat quality and for bird life. Damage to exposed mud bank habitats through ice scouring, erosion and desiccation in early spring due to the low water level, raised water level and subsequent flooding of important biotopes during the productive season and general habitat changes in vegetation zonation etc. are other important effects.

The availability of Åkersvika as foraging habitat for waders is dependent on the water level, and hence on the regulation of Mjøsa. The regulations of Mjøsa affect the birdlife in Åkersvika by changing the wetland habitat and the availability of food, in particular benthic invertebrates. Raising the water level at the time of freezing with subsequent lowering water level through the winter, increases the area affected by ice scouring and erosion on the mudbanks and vegetation (Kjellberg et al. 1994). This has negative consequences both on the availability of food (benthic invertebrates) and as nesting habitat for resident birds (Solheim 1992, Kjellberg et al. 1994). The tapping during winter, leaving larger areas above water, further damages the bird habitat by drying up the mudbanks and leading to erosion after the ice has melted and before Mjøsa fills up in spring. In the growing season, waders are favoured by a low water level, and the continuing rise of Mjøsa has detrimental effects on Åkersvika as bird habitat by flooding nests and making foraging areas unavailable (Kjellberg et al. 1994).

Similar effects can be found in Nordre Øyeren. Nordre Øyeren is an example of a delta wetland where the changes in water transport affect birdlife through general habitat effects. Reduction of floods and change of sedimentation patterns following regulation has altered the habitat dynamics of the delta. The constant water level during summer has led to the formation of erosion platforms, as erosion has been concentrated at the same level for a large part of the year (Akershus fylkeskommune 1997). The water level influences the available area of important biotopes, especially mud banks and shallow areas, which are important for many water birds, particularly waders, but also passerine birds foraging on mud flats (Akershus fylkeskommune 1997).

In mountain reservoirs, stable water levels throughout the season give the best conditions for bird populations. Some species, such as divers, only reproduce near waters with very little fluctuation (Reitan & Sandvik 1996). The regulated reservoirs therefore represent poorer bird habitat due to the direct effects on bird nesting and due to the changes in vegetation and habitat quality following regulation (see Annex 7).
River regulations affect bird life through the changes in water transport (cf. Table 3.8.2 and Fig. 2.4.3) and ice conditions. Indirect effects of regulation appear through the changes in vegetation and invertebrate fauna following changes in water regime (see Annex 7). The riparian woodland habitat, which is quite extensive in the G&L basin, is used by many species of birds, and habitat degradation or narrowing of the riparian zone will have negative effects. Direct effects include changes in ice conditions. Regulated rivers often have more ice-free areas in winter, which is favourable to e.g. ducks, whereas the increased water level in winter can be detrimental, e.g. to dippers foraging in the river. The wintering dipper forages mainly on river bottoms for insect larvae by diving. Increased capacity of the Nedre Vinstra power station, resulting in increased water discharge in daytime, gave an increased difference between lowest flow and the flow in daytime. Increased diving times (as a result of increased depth) and reduced densities of dippers have been observed on stretches of Lågen affected by the change in flow regime at Nedre Vinstra Power Station in 1989 (Kålås et al. 1996).

The extensive power line networks in the G & L basin traverse large areas of important bird habitat in alpine, subalpine and boreal forest areas. Although the Norwegian studies on bird mortality caused by power lines have been done in other parts of southern Norway (see Annex 7), large parts of the Glomma –Lågen basin have the same habitats and species and are should thus experience the same effects with respect to bird life.

**Effects on mammals**

As described in Annex 7, main effects on terrestrial mammals are habitat loss through inundation of areas and construction of dams, roads, power lines and associated structures, fragmentation and barrier effects by roads, power lines and by creating unsafe ice conditions. Of affected species, the G&L basin harbours small wild reindeer populations in the mountain regions and moose and roe deer in the forest areas. Studies of other Norwegian wild reindeer populations in relation to hydropower development, show clear changes in habitat use and density following regulations, and this has probably been an effect in the G&L basin as well. Trekking routes for moose are also likely to be affected by changing ice conditions.

Road building in connection with hydropower development has not been extensive in the G&L basin. Often, existing roads to mountain farms or for forestry purposes have been used, with some upgrading. The roads that have been built are often in more remote forest/mountain areas. No direct studies have been done to assess the effect of new roads or more extensive use of old roads in the G&L basin. However, the presence and increased use of roads in remote areas is a general ecological problem of which hydropower development is a part.

**Effects on fish and invertebrates**

Back in the 1940s, Dahl (1947) summarized the effects of watercourse regulations on fish populations: He concluded that spring and summer-spawners (i.e. pike, perch, cyprinids, grayling) in regulated waters seldom was negatively affected, on the contrary, regulations often improved the conditions for these species. From a fishery point of view, autumn spawners like brown trout, char and whitefish are far more important. Spawning and hatchery areas for these species are often destroyed or severely affected after regulation. However, the productivity of the regulated waters was, in general, supposed to be very little reduced (it could also increase). Therefore the waters could still support the same biomass of fish and the same fishery, provided stocking of hatchery reared fish to compensate for loss of natural recruitment. Later, it has become clear that this was a far too optimistic conclusion regarding effects on fish and fishery.
**Effects on fish in reservoirs**

The littoral fauna, which is the main food resource of lentic brown trout, is greatly reduced by fluctuations in water level. For instance the important food item, *Gammarus lacustris*, is completely wiped out when the annual water amplitude exceeds 5-7 m, which is the case for many reservoirs in the G&L basin (cf. Fig. 2.3.2). Planktonic fauna are less, or even positively affected by regulation, and can to some extent replace the littoral fauna as brown trout food. However, if whitefish and/or char is present, brown trout is outcompeted by these more specialized plankton feeders. No long-term studies on fish abundance and growth in order to evaluate changes in fish production before and after regulation have been conducted. However, long-term studies of brown trout yield in several reservoirs, where stocking have been conducted to compensate for recruitment loss, may give some indications of changes in the brown trout production potential following lake impoundments:

Lake Tesse (860 m a.s.l. and 1460 ha) was regulated in two steps in 1943 and 1963, and total annual water amplitude is now 12.4 m. Brown trout is the only fish species and the population is fairly intensively exploited. Annual yield during a 14-year-period (1979-1992) of regulation has varied between 850 and 3500 kg, equivalent to 0.6-2.5 kg per ha (Hesthagen 1997). Catch statistics for a 10-year-period prior to regulation (1930ies) indicate that the annual yield was about three times as high as at present. The food base for brown trout in Lake Tesse was highly damaged after regulation, as the *Gammarus lacustris* disappeared and the abundance of snails and molluscs was greatly reduced. Various planktonic crustaceans which are not affected to any great extent by fluctuations in water level are now the main food items of brown trout, but clearly do not compensate for the loss of littoral fauna.

The regulation of Lake Aursjoen (1097.5 m a.s.l. and 740 ha) in 1963 had initially only a slight effect on the allopatric population of brown trout in spite of an annual water amplitude of 12.5 m (Hesthagen et al. 1995). This is related to the occurrence of a large crustacean, *Lepidurus arcticus*, which was the main food item for brown trout, making up some 70-80% of its diet. This crustacean is an important food item for brown trout in Norwegian mountain lakes, whether regulated or unregulated (Aass 1969). *L. arcticus* is generally unaffected by water fluctuations in reservoirs. During the 1980s, the annual yield of brown trout in Lake Aursjoen was estimated to range between 1.32 and 2.43 kg per ha. This yield is probably among the largest obtained, even compared with the pre-regulation situation, and is partly related to improved access possibilities for the fishermen. However, in recent years the abundance of *L. arcticus* has been dramatically reduced, for reasons not really understood. Concurrently, yields of brown trout have also been much reduced.

In yet another reservoir, Lake Vinsteren (1031.5 m a.s.l. and 2800 ha), no apparent changes in the abundance of *L. arcticus* have occurred. This reservoir have less variations in water level, with an annual amplitude of only 4.0 m. The annual yield of brown trout between 1979 and 1993 ranged between 0.60-1.74 kg per hectare, which is probably in the same range as prior to regulation (Hesthagen & Gran 1997).

Many of the impounded lakes are also inhabited and dominated by other species than brown trout. In some cases a pre-regulation situation has been dense populations of slow-growing whitefish and char. After regulation, water level fluctuations may cause egg mortality during wintertime, resulting in reduced recruitment and better individual fish growth. This is the case for the whitefish populations in Lake Osensjøen and Lake Aursunden. Total fish production and potential yield are reduced. Compared to similar, unregulated lakes in the same area (Lake Sølensjøen and Lake Isteren), fish yield is low (< 2 kg/ha vs. 5-10 kg/ha.) (Qvenild 1981, Linløkken & Qvenild 1987, Linløkken 1990, 1992, 1993a). However, the fishery has become more attractive due to larger fish. Also the char population in Lake Savalen was dense and slow growing prior to regulation. Post-regulation growth is good, but total yield is low (Linløkken 1993b). The char population in Lake Aursunden has also been reduced after regulation, and to such extent that it is hardly exploited any more. Reduced recruitment and probably also competition from whitefish are the causes (Linløkken 1992).
To conclude, lake impoundings have in general had negative effects on the food base of brown trout, and fish production and yield has decreased, in spite of stockings. An exception is mountain lakes that sustain healthy populations of the food item *L. arcticus*, and large lakes where the brown trout are fish predator (e.g. Lake Mjosa), i.e. where the food base is unaffected. The recruitment of char and whitefish are often negatively affected by the regulation. However, if the pre-regulation populations were dense and slow growing, reduced recruitment has in some cases been positive for the fishery. In nutrient-rich, lowland lakes like Lake Oyeren, it seems that the dominance of cyprinids has further increased after regulation. It is not known that fish production by area has increased in any reservoir as a result of the regulation (where fish production has increased this is related to increased nutrient supply). Small lakes dammed up to large reservoirs can, however, hold more fish after regulation. The Fundin reservoir for instance, has developed to the most important fishing locality in the municipality of Folladal after the impoundment. On the other side; this was at the expense of a very good grouse shooting area.

After transfer of nutrient-rich water by a diversion channel from River Glomma to Lake Storsjøen, fish production in the latter has increased. Especially the whitefish has become larger and in better condition, but also the char population seems to have improved (Qvenild & Linløkken 1989a). Initially, the nutrient-rich Glomma-water caused pollution problems in the clean Lake Storsjøen, but sewage plants in River Glomma have reduced the nutrient supply to an acceptable level (Rognerud & Kjellberg 1985).

Concern has also been raised about the long-term effects of changes in hydrologic and temperature conditions and an increased sedimentation rate. Increased sedimentation and the lack/reduction of a hydrological regime that “flushes” the system may eventually destroy spawning areas and strongly reduce also those lake spawning fish species (for instance whitefish and char) that so far seems to do well in many reservoirs. So far, however, there are no documented effects on these matters.

*Effects on fish in rivers*

Changed water flow below dams/diversion tunnels, slow-flowing conditions above dams and dams as migration barriers are factors that to a very large extent have affected fish populations in the G&L rivers.

The change in water flow below a dam or diversion tunnel can be of different type. The flow regime throughout the year are sometimes very much changed (cf. Fig. 2.4.3). Some regulations in G&L imply that all waterflow in the rivers are taken by tunnel or channel into the power station, and river stretches are left totally dry. Other river stretches, affected by more recent regulations, have kept an instructed minimum water flow (cf. Table 3.8.2). In both cases, important spawning and nursery areas are often totally or partly destroyed. In some regulated river stretches (e.g. River Lågen), the winter waterflow may increase and lead to increased fish survival. Water flow in River Søre Rena, and thus the basis for fish production, has increased due to the transfer of water from River Glomma. Below the diversion tunnel, River Glomma has a minimum water flow, reducing the original fish production potential.

The slow-flowing conditions above the dams have been detrimental, especially to brown trout and grayling in River Glomma downstream Elverum. These species depends on rapids and riffles as spawning and nursery area, and below Elverum there are few such habitats left due to all the river dams (Qvenild & Linløkken 1989). The slow-flowing conditions have favoured other species like cyprinids, pike, perch and turbot.

The dams also act as migration barriers. Before the regulation dams were constructed, it was possible for fish in River Glomma to migrate several hundred kilometers, from Lake Øyeren in the south to the uppermost reaches. It is not known exactly how the original migration patterns were, but it is clear that River Glomma had god populations of large-sized brown trout and grayling with regular spawning and
feeding migrations of more than hundred kilometers (Qvenild & Linløkken 1989). After the regulation
dams were constructed, the migration patterns have been severely affected, in spite of fish ladders in the
dams. In general, the efficiency of the fish ladders seems to be low, as relatively few fish are registered
each year. The original migration patterns are probably to a large extent broken down, as most of the
marked grayling and brown trout are caught close to the fish ladder in which they were caught. This is
especially true for grayling; there are still examples of marked brown trout migrating more than 100
kilometers. The long-migrating individuals, although few, may have an important role in the terms of
exchanging and maintaining genetic diversity (Qvenild & Linløkken 1989).

Several river dams in the lower part of Glomma (below L. Øyeren) lack fish ladders. The water falls at
these dams (e.g. Vamma, see below) were probably natural migration barriers before dam
construction, except for the eel (Anguilla anguilla). The dams became an obstacle for eel migration
and are probably a bottleneck for eel production in the Glomma river system (Aage Brabrand, pers.
comm).

Outlet spawners of brown trout are particularly vulnerable to dams in outlet rivers. Access to the
spawning areas is restricted, and much of the spawning area might be located above the dam and thus
be subject to slow-flowing conditions and sedimentation. Previously, Lake Mjøsa had a large outlet
spawning brown trout population that at present is only remains of the original. Also in Lake Storsjøen
there is uncertainty whether the outlet spawners still exist.

Below power stations the water flow during winter can increase considerably, for instance in River
Lågen from about 20 to 130-150 m³ per sec. High water flow rates and ice buildup during the winter
have necessitated channelizing in certain reaches of the river, for instance at Otta. This safety effort,
resulting in a more homogenous habitat, has quite certainly reduced fish-production capacity in this
area.

Atlantic salmon in lower part of River Glomma
Atlantic salmon is found in the lowermost part of River Glomma. Annual catch is up to 1500 kg
(Ministry of Environment 1992). The dam at Vamma is the upper limit for salmon migration, and this
point was probably the upper limit also before dam construction. The main spawning and nursery area
is in River Ågårdselva, which is a parallel branch to the main river course. In optimal habitats on this
river stretch, juvenile salmon growth is extremely good due to a long growth season, high water
temperature and a surplus of food. Smoltification occurs at the age of 1-2 (Saltveit in prep.).
Uppermost, a dam diverts water between the River Ågardselva and the main course. A fish ladder
makes further migration up to Vamma feasible. Sufficient waterflow in River Ågårdselva is a
prerequisite for a self-sustaining salmon population in River Glomma. It is not known to what extent
the hydropower projects have affected the salmon population. As a mitigation measure, juvenile
salmon are stocked. In the early 1980’s there were plans to open up for salmon migration upstream
Vamma. However, the Directorate for Nature Management turned down the plans.

Effects on invertebrates
Many of the effects on fish populations described above are caused by the initial effect on
invertebrates, i.e. the food source. After regulation, the abundance of bottom-dwelling invertebrates
has in general decreased on river stretches with reduced water flow (Raddum 1993). In River Søre
Osa, the species composition also changed in favour of smaller-sized species (Garnås 1985). Below the Høyegga dam in upper part of River Glomma, bottom-dwelling invertebrate species disappeared or was strongly reduced during the low-flow winter period, but recovered during summer/autumn (Brittain et al. 1984). In the Lågen catchment area, hydropower projects have involved transfer of glacier-fed water to clear-water rivers, with possible negative effects on invertebrates (Hesthagen & Fjellheim 1987).

Peaking

Peaking implies short-time variations (often within 24 hours) in waterflow and waterlevels in reservoirs and rivers. Environmental effects can be severe. When littoral areas are frequently drained and flooded, the littoral fauna will be affected. Erosion can increase and give local and downstream effects. In the Olstappen reservoir peaking might have worsened the existing erosion problems, and in River Lågen, downstream the Nedre Vinstra power station, wintering dippers (*Cinclus cinclus*) have been affected. The changes in flow regime were introduced in 1990, and in the years 1991-1995 less than half as many birds have been observed as in 1977-1989. It is assumed that the peaking leads to greater physical obstacles for food-seeking dippers. There are also indications of long-term negative effects on the occurrence of aquatic insects as food source for the dippers (Kålås 1996).

In the River Søndre Rena there are large variations in water flow due to peaking in the Løpet power station. This is a problem for the fishermen, as the fish are very difficult to catch when water flow suddenly increases. Possible effects on the biota have not been investigated.

Red List Species

In the Red List of Norway (Directorate for nature management 1999a), there are some 700 plant and animal species associated to freshwater and wetlands. Many of these can be found within the G&L basin. To what extent the single species are threatened by hydropower projects are in general little known. A total of 55 bird species are redlisted, and approx. 15% are regarded as threatened by watercourse regulation, power lines, and other infrastructure. Two redlisted fish species, *Aspius aspius* and *Myoxocephalus quadricornis*, can be found in the G&L watercourse. The former is in the lower part of River Glomma and the latter in Lake Mjosa. None of them seems to be affected by hydropower projects. Noble crayfish (*Astacus astacus*), which is also found in the lower part of the watercourse, is probably the most exploited species on the list. The main threat of this species is the introduction of foreign crayfish species and the crayfish plague disease. Crayfish plague wiped out all the crayfish in the lower part of Glomma in 1989. The populations are now recovering after succesful reintroductions (Taugbøl 1999). It has been claimed that fluctuations in water level may severe affect the crayfish, but in general this have had little impact on crayfish in G&L, probably because the fluctuations are relatively small in most crayfish localities. One of the best crayfish localities in Norway have developed during the last few decades in the regulated Lake Einavann with an annual water amplitude of 2.3 m. The redlisted freshwater pearl mussel (*Margaritifera margaritifera*) is found in a few localities in the lower part of G&L. It is known from other areas that regulation of rivers have damaged this species, but it is not known to what extent this has happened in G&L. Otter, *Lutra lutra*, is the only redlisted mammal associated to freshwater. Previously, it might have been negatively affected by regulations, in connection with other causes, but in recent years it seems to be expanding northward in the G&L watercourse.

3.8.2 Mitigation measures

Measures to mitigate ecological effects of hydropower projects include fish stocking, habitat improvements, release of minimum water flow, and construction of fish ladders. In general, the measures are authorized in licence terms. Both in the Glomma and the Lågen branch the main
mitigation efforts have for the last 10-15 years been organized as collaboration projects between the G&L Water Management Association, power companies and the environmental authorities. These very successful projects are further described in Annex 6.1. Below is summarized the most important efforts and experiences of mitigation measures in the G&L watercourse.

**Fish stocking**

Stocking of fish (brown trout) is the traditional mitigation measure, which shall compensate for loss in recruitment, i.e., destroyed spawning and nursery habitat. As mentioned, it was previously a strong belief that stocking could counteract most of the negative effects of regulation on the brown trout populations (Dahl 1947). A prerequisite for stocking is, however, the existence of an excess food supply, and in many cases this is not fulfilled. Another issue emerging in the past 15-20 years due to new knowledge, is the great significance of the nativeness of the stocked fish. Supplementary stockings of brown trout have usually involved non-native, hatchery-reared individuals. Fish originating from the two strains in southern Norway, raised in a central hatchery, have dominated as donor populations. In recent years, the stocking policy are more turned in the direction of using native fish, and the nativeness aspect is now considered in all new license terms.

It has been claimed that many stocking programmes are carried out without any definition of objectives or evaluation of the potential or actual success (Cowx 1994). Clearly, this was the case for at least some of the brown trout stocking in the Lågen catchment area. The stocking programmes have been assessed by several marking experiments to distinguish naturally produced from hatchery reared fish, i.e. the success of the stocking effort. In the Vinsteren reservoir, it was recommended to stop the stocking of a large number of non-native fish as the effort did not increase the fish yield and the non-natives could have a negative impact on the naturally produced fish. Also in the Vinstervatna reservoir, supplementary stockings have been terminated for the same reason. In Lake Tesse, an increased number of stocked brown trout had a negative effect on fish yield. The number was reduced and resulted in higher fish yield (for further details, see Annex 6.3). In other localities like the Aursjøen reservoir, natural recruitment is very limited and fish production is almost completely dependent on stockings. Other examples are Lake Mjøsa (cf. Annex 6.2) and the Fundin reservoir, where supplementary stocking is of major importance for the brown trout fishery. However, the need for supplementary stocking has often been highly exaggerated because the natural recruitment has been higher than expected and/or because the food base (carrying capacity) have been reduced after the regulation impacts. More details on the evaluation of brown trout stocking and the significance of nativeness in the Lågen catchment area, are described in Annex 6.2.

In River Glomma the licenses for the river power plants and the transfer of water from River Glomma to the River Rena sidebranch, authorized fish stockings. After a long process starting in 1978, which involved close collaboration between G&L WMA and the environmental authorities, the stocking instruction was established in 1991. It was a compromise between the native population/local production aspect and what was practical feasible. New facilities for fish production were built and were in full operation in 1993. In an agreement between G&L WMA and a research and educational institution (the Hedmark College), the latter has got the professional and operational responsibility for the fish production in the upper part of Glomma. Fish stocked in the lower parts are produced in an older farm, owed by regulation associations and power companies. In general, stocked brown trout in the Glomma watercourse seems to have a reasonable recapture rate in e.g. Lake Storsjøen and River Sondre Rena, while there are not so good results at the low-flow stretch of River Glomma below Høyegga (where water are diverted to the Rena branch). Carrying capacity might be too low at this stretch for supplementary stockings, and there can also be other reasons for low recapture rates. It is very important to maintain long-time series of mark and recapture data in order to evaluate the stocking success and eventually adjust the stocking policy.
Habitat improvements

Habitat improvements in regulated rivers in Norway have been studied in two major research programmes headed by the Norwegian Water Resources and Energy Directorate (NVE). These were the Weir Project (1973-1983) (Mellquist 1985), and the following Biotope Adjustment Programme (1985-1995) (Eie et al. 1995). Habitat improvement efforts comprise i.a. construction of weirs, pools and stream deflectors and laying out rocks and stones in order to create a more diverse habitat for aquatic or semi-aquatic biota. Many regulation licenses, for instance in River Glomma, authorize the establishment of habitat improvements.

In river stretches with a minimum water flow, weirs are very important in order to maintain the water level in definite pool areas. It is urgent, however, that the weirs do not act as migration barriers.

Improvement efforts in large rivers and also smaller rivers much affected by floods are often very expensive, because the efforts have to be very solid and well founded in order to withstand large fluctuations in waterflow. There are examples of habitat improvements in tributaries both in the Glomma and Lågen branch which had good effects on the fish populations, but were destroyed in large floods (Taugbøl 1995, Linløkken pers. comm.).

Important spawning and nursery habitats are to a large extent lost in connection with river dams in the main rivers, and tributaries have become more important for the recruitment of fish. Often, tributaries are also affected by hydropower regulations and/or have been modified (cleared, channelized) due to log driving activities, and thus might also have needs for habitat improvement efforts. When considering cost per benefit, habitat improvements clearly have the biggest potential in the smaller tributaries. The efforts are more simple and easy to accomplish in such localities, and the effect on fish populations can be considerably. In an improved stretch of River Letjenna, a tributary to River Glomma, the brown trout population was trebled following habitat improvements (Linløkken 1997). In reservoirs in the Lågen branch, e.g. Vinsteren, there have been attempts to increase spawning and nursery areas in smaller inlet streams by facilitating the access to the streams. Also in smaller inlet rivers and streams of Lake Mjøsa, habitat improvements and access facilitating efforts have been conducted (Taugbøl 1995). The municipalities surrounding the lake have become more concerned about these habitats as spawning and nursery areas for unique populations of brown trout and grayling.

As a mitigation measure, habitat improvements have received increased attention in recent years and should always be considered as an alternative or complement to stocking.

Fish ladders

In total, there are 34 fish ladders in the G&L watercourse. This number includes all kind of ladders, both in the main rivers and tributaries (Fish ladder committee 1990). Only 26% of the ladders are considered to have a good efficiency, 41% work less well and as much as 32 % are not working at all (Table 3.8.1).

Table 3.8.1. Overview of fish ladders in the G&L watercourse

<table>
<thead>
<tr>
<th>Watercourse section</th>
<th>No. of ladders</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Lågen branch</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Glomma branch</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Below confluence</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>34</strong></td>
<td><strong>9 (26%)</strong></td>
</tr>
</tbody>
</table>

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In the main rivers, Glomma and Lågen, fish ladders are built in most river dams in order to maintain the migratory pattern of brown trout and grayling. In general, the efficiency of these 12 fish ladders are considered low, and it seems quite clear that the fish migrations are severe affected (Qvenild & Linlokken 1989). There are, however, considerable variation in efficiency between different ladders. The most important factors determining the efficiency are: 1) entrance of the fish ladder in relation to the main waterflow, and 2) waterflow in the ladder compared to dam overflow. These factors vary between different ladders and with different waterflows, and results in large annual variations in number of migrating fish. Better knowledge on how different environmental and physical factors influence the fish migration in ladders are needed in order to improve the efficiency. Lack of maintenance is also a reason why many ladders are not working (Fish ladder committee 1990).

Reviews of problems and possibilites related to fish ladders can be found in Directorate for nature management (1999) and Jungwirth et al. (1998).

### Minimum discharges

Many hydropower licenses before 1960 were issued without any instructed minimum waterflow below dams. In later licenses a minimum flow and flow scheme are normally established.

There are seven reservoirs in the G&L basin where the downstream river reach is totally dry except at bypass situations during flood periods; Savalen, Aursjø, Tesse, Heimdalsvatn, Kaldfjorden, Øyangen and Olstappen. At none of these reservoirs very long river reaches are left dry, since local runoff increasingly contributes to the river flow the further downstream you get from the reservoir. At two reservoirs the downstream river reach can be temporarily dry during the filling-up season; Elgsjø og Marsjø. At the other ten reservoirs of G&L WMA (Aursunden, Fundin, Storsjøen, Osen, Breidalsvatn, Raudalsvatn, Bygdin, Vinsteren, Mjøsa and Øyeren) there are no completely dry river reaches downstream.

At many reservoirs water is released directly to the natural outlet, without passing through any power station at all. This means that the total yearly runoff passes through the natural stream channel, but with a change in the sesonal distribution. There are two water diversions without minimum discharges; Veo-Tesse and Einunna-Savalen. There are also a few power stations without minimum discharges that may influence a significant river length between the intake and the outlet (Kuråsfossen og Skjefstadfossen). All other power plants have either sesonal minimum discharges or release water directly at the downstream side of the intake dam (Table 3.8.2).

<table>
<thead>
<tr>
<th>Reservoir Diversion</th>
<th>Minimum discharge (m³/s)</th>
<th>Reach of influence (km)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aursunden</td>
<td>8.0</td>
<td></td>
<td>Released through power station.</td>
</tr>
<tr>
<td>Elgsjø</td>
<td>-</td>
<td>4</td>
<td>Released directly to natural outlet.</td>
</tr>
<tr>
<td>Fundin</td>
<td>0.3</td>
<td></td>
<td>Released directly to natural outlet.</td>
</tr>
<tr>
<td>Marsjø</td>
<td>-</td>
<td>3</td>
<td>Released directly to natural outlet.</td>
</tr>
<tr>
<td>Savalen</td>
<td>-</td>
<td>7</td>
<td>Released through power station.</td>
</tr>
<tr>
<td>Storsjøen</td>
<td>5.0 / 7.0</td>
<td>(15)</td>
<td>Released directly to natural outlet.</td>
</tr>
<tr>
<td>Osen</td>
<td>2.5 / 6.0</td>
<td>(15)</td>
<td>Released through power station.</td>
</tr>
<tr>
<td>Breidalsvatn</td>
<td>0.3</td>
<td></td>
<td>Released through short tunnel to natural outlet.</td>
</tr>
<tr>
<td>Raudalsvatn</td>
<td>0.35</td>
<td></td>
<td>Released through short tunnel to natural outlet.</td>
</tr>
<tr>
<td>Aursjø</td>
<td>-</td>
<td>6</td>
<td>Released through power station.</td>
</tr>
<tr>
<td>Tesse</td>
<td>-</td>
<td>5</td>
<td>Released through power station.</td>
</tr>
<tr>
<td>Bygdin</td>
<td>1.25</td>
<td>(1)</td>
<td>Released through short tunnel to natural outlet.</td>
</tr>
<tr>
<td>Vinsteren</td>
<td>2.0</td>
<td>(1)</td>
<td>Released directly to natural outlet.</td>
</tr>
<tr>
<td>Heimdalsvatn</td>
<td>-</td>
<td>12</td>
<td>Released through tunnel out of catchment.</td>
</tr>
</tbody>
</table>

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The flow scheme is aimed to secure an optimal manoevring of the instructed minimum flow to get the best environmental effect. For instance in River Lågen below the Hunderfossen dam, the minimum winter waterflow is in force before the spawning period to secure that spawning do not occur in places that will be dry during winter. Far more can be done regarding optimal manoeuvring of water flow in fish ladders and on river stretches with a minimum waterflow. At minimum water flow, the Hunder trout on spawning migration are very reluctant to enter the stretch. Experiments with short-term release of water seems to have a potential for triggering the run.

Reduced water flow is often the limiting factor for migrations and carrying capacity at the regulated stretch. An increase in water flow is very costly for the power company. However, also other instructed mitigation efforts are expensive and there is a need to consider the watercourse system and possible efforts as a whole, and implement those which are most effective from a jointed ecological
and economical point of view. In the so-called Glomma and Oppland-projects (Annex 6.1) this philosophy are pronounced.

The authorizing and implementation of mitigation measures

Mitigation measures are authorized in the license terms. In old hydropower projects, environmental impacts were of little concern and mitigation measures totally absent in the license terms. From about 1965-70, as the environmental concern steadily increased, the applicants for hydropower projects had to carry out pre-regulation investigations on environmental themes. Authorization of mitigation measures like fish stocking, physical habitat improvements, fish ladders and minimum water flow started to become incorporated in the license terms. In recent years, the license terms on environmental themes have become quite extensive and appear in a standardized and very general form. The license owners are eventually instructed to implement the different mitigation measures according to more specified instructions or plans from the authorities. Pre-regulation studies have seldom predicted environmental effects and given detailed recommendations on mitigation efforts. Thus, establishment of reasonable mitigation efforts often takes a considerable period of time because there is a need for more basic knowledge on the environmental effects and how they best can be relieved. The license owners are obliged to finance necessary investigations. Therefore, mitigation measures are often implemented several years after the hydropower projects were constructed. For instance in River Glomma, many of the river dams were built in the 1970’s and fish stocking were authorized in the license terms. After several years of necessary investigations, considering fish stocking in the Glomma river system as a whole, the stocking instruction was established in 1991 (cf. Annex 6.1).

Terms in old licenses can be revised (except licenses based on the Watershed Act), and thus environmental aspects and mitigation measures be incorporated. However, changes in license terms shall not result in essential economical costs or loss in power production capacity, and only if particular reasons exist, an instructed minimum water flow can be considered. Obviously, the environmental and hydropower interests have different opinions on what are essential and particular reasons.

Findings on ecological effects and mitigation measures

- Few ecological effects have been predicted in pre-regulation studies, with the exception of effects on harvested fish populations. Previously it was supposed that regulated waters in general could support the same biomass of fish and the same fishery, provided stocking of hatchery reared fish to compensate for loss of natural recruitment. This was a far too optimistic prediction.
- An unexpected effect that has emerged due to better genetical knowledge, was the significance of nativeness and differences in adaptability and behaviour of different fish strains.
- In general, lake impounding and river regulations have had negative effects on the food base of brown trout, and fish production and yield has decreased, in spite of stocking. In some cases, the food base and hence fish production, seems to be unaffected. It is not known that long-term fish production by area has increased in any reservoir due to regulation.
- Changed water flow below dams/diversion channels, slow-flowing conditions above dams, and dams as migration barriers are factors that to a very large extent have affected fish populations in the G&L rivers.
- Measures to mitigate ecological effects of hydropower projects include fish stocking, habitat improvements, release of minimum water flow, and construction of fish ladders. In general, the measures are authorized in licence terms. There are examples of very successful mitigation measures as well as measures that have been terminated due to no or even negative effects.
- Collaboration between the environmental authorities and the hydropower interests has been very favourable with respect to biological investigations and implementation of mitigation measures.
• It is very important to consider the different mitigation measures and larger parts of the watercourse as a whole.

### 3.9 Cultural Heritage

The Glomma and Lågen rivers are lifelines of a rich and diverse human history in these regions. Salient cultural monuments and cultural heritage are linked to the river systems. Several types of cultural monuments are found along the two watercourses, and the most important categories are: logdriving constructions, sawmills and agricultural mills, mining facilities, power stations, industrial constructions linked to the river, settlement constructions, hunting-, fishing, and harvesting remnants, bridges and roads, defense constructions, and prehistoric foundations and sites.

As in other parts of Norway, most areas close to the main rivers and its tributary streams and lakes have been settled and utilized for long periods of time. This history goes back at least to the stone age, and during this time human activity have created a cultural landscape that tells the story of the mutual dependence between humans and their resource base. Within the scope of this study, the zones of cultural landscape as well as distinct relicts of former human activity or cultural monuments are of interest. Cultural monuments are in Norway often called ‘environmental resources created by humans’, as they represent valuable sources of information about living- and working conditions in earlier times. They can often be experienced and communicated within their original context, and many of the cultural monuments are functionally connected to the watercourses. Hence they can play a role in strengthening identity, attachment, and well being locally.

The requirements for documenting cultural monuments and assessing impacts related to development actions have changed greatly during this century. It is only during the past 15-20 years that cultural heritage has become a salient topic of investigation when water are exploited. Prior to 1960 any injunctions related to construction activities or running of hydropower plants came as part of the concessions. The archeological museums to some extent cooperated with the hydropower authorities (NVE) to document cultural heritage objects and values, and occasionally mitigating actions were taken during construction phases. However, it was not until the 1970’s that studies of any extent were carried out prior to implementation of hydropower projects. During the late 70’s and 80’s this was done more systematically. A challenging situation now exists since a large number of old concessions are due for renewal in the next few years. At this turn, the concession authorities have the legal basis to require new impact assessments before renewed concessions are granted.

It seems quite evident that in a number of early hydropower developments substantial amounts of prehistoric cultural relicts and monuments were lost or partly destroyed in the G&L basin. This particularly pertains to foundations and cultural layers of small settlements and harvesting techniques close to the rivers. The damming of tributary lakes and smaller rivers for logdriving probably also contributed to this. Some of this is documented, while there is clearly an array of cultural heritage attributes and impacts that not yet have been examined. Some of these may be assessed when concessions come up for renewal. Among the known examples of cultural monuments that have been lost are Stone Age settlements by lake Tesse and by Raudalen in Jotunheimen in the upper reaches of the Glomma watershed. Stone age settlements and trapping devices for moose have also been destroyed by Olstappen, bye the river Vinstri and by Mjøsa. Iron ore pits have also been damaged or destroyed in several locations. A general and widespread problem is that of erosion of sites that are located in the regulation zone. There is reason to believe that a considerable number of old foundations and other cultural monuments are situated in areas that are subject to flooding, draining, and erosion.

Other substantial impacts include the destruction of old fishing techniques in Glomma below the Hunderfossen dam. Here commercial fishing with “teiner” is completely gone after this part of the river was dammed. Old fishing spots and opportunities in the lower part of Lågen and north end of
Mjøsa have been more or less impacted by changes in water level. The population of large trout has been important for subsistence and commercial purposes for the past 500 – 600 years. Now, this population is important for recreational fishing.

Some of the old commercial and industrial activities represent salient cultural monuments in themselves. Several hydropower installations and other facilities linked to the watercourses such as small dams and mills have historical value. Examples are dams in the Glomma watershed close to Røros from the 1600’s designed to stabilize water supply to the mining town, and old power stations like Kurasfoss, Ranåsfoss, and Solbergsfoss. The era of logdriving has also left its mark on the river environments, especially along Glomma. An array of technical installations, cabins etc. is associated with this use of the rivers. Many of these are subject to general decay and considerable effort is needed to protect a representative sample for the future. However, while logdriving itself has created impacts particularly on the tributary rivers and smaller lakes, there seems to be few examples where hydropower activities in the main rivers have affected logdriving constructions much.

Findings on cultural heritage:

- Categories of cultural monuments found along the G&L rivers are logdriving constructions, sawmills and agricultural mills, mining facilities, power stations, industrial constructions linked to the river, settlement constructions, hunting-, fishing, and harvesting remnants, bridges and roads, defense constructions, and prehistoric foundations and sites.
- Studies of any extent on effects of implementation of hydropower projects on cultural heritage issues were not carried out until the 1970s.
- During the past 15-20 years cultural heritage has become a salient topic of investigation when water are exploited.
- It seems quite evident that in a number of early hydropower developments substantial amounts of prehistoric cultural relics and monuments were lost or partly destroyed in the G&L basin.

3.10 Summary of findings on Predicted, Actual and Unexpected outcomes

Table 3.10.1 Predicted, Actual, and Unexpected Outcomes of the G&L hydropower developments.

<table>
<thead>
<tr>
<th></th>
<th>Predicted</th>
<th>Actual</th>
<th>Unexpected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule</td>
<td>Determined by license</td>
<td>Variable</td>
<td>Delays in older dams affected by World War II and</td>
</tr>
<tr>
<td></td>
<td>applications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>Provided in license</td>
<td>Almost all dams change from</td>
<td>Deviation in project costs due to delays in construction and higher payment of</td>
</tr>
<tr>
<td></td>
<td>applications</td>
<td>initial planning, through</td>
<td>compensations than predicted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>licensing to final approve</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>project. Projects generally</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>were reduced through the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>licensing processes</td>
<td></td>
</tr>
<tr>
<td>Sedimentation</td>
<td>Not significant factor</td>
<td>Not significant factor</td>
<td></td>
</tr>
<tr>
<td>Project costs</td>
<td>203.6 Million NOK in 1999 currency for 4 non-focal dams</td>
<td>286.8 Million NOK in 1999 currency for 4 non-focal dams 140% increase on average</td>
<td>Deviation in project costs due to delays in construction and higher payment of compensations than predicted</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Impact</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation and irrigated agriculture</td>
<td>No impact on irrigation withdrawals from lakes and rivers</td>
<td>No impact on irrigation withdrawals from lakes and rivers</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Municipal water supply</td>
<td>No impact on municipal withdrawals from lakes and rivers</td>
<td>No impact on municipal withdrawals from lakes and rivers</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Loss of land from inundation of reservoirs. Local loss of fence-effort from</td>
<td>Effects as predicted. Effects generally are compensated and mitigated.</td>
<td>No significant unexpected effects</td>
</tr>
<tr>
<td>Hydropower generation</td>
<td>Several G&amp;L hydropower plants were initially established prior to the licensing system, have been rebuilt and upgraded step by step, and are influenced by new reservoir developments. The question of predicted production is therefore very complex and is answered by analyses of selected power plants, not on basin level</td>
<td>Mean annual G&amp;L production of 10 145 GWh from an installed effect of 2 165 MW. Production have far exceeded the predicted for the power plants analysed</td>
<td>The increase in generation from technical changes, expansion of facilities and optimisation of flows at basin level for power were not expected at the time of development of several of the power plants</td>
</tr>
<tr>
<td>Flood control</td>
<td>Dams will reduce the incidence of damaging floods in lower parts of the G&amp;L system</td>
<td>Flood peaks have been reduced by about 20%. The 1995-flood culmination level in Lake Øyeren was reduced by 1,9 m by reservoir storage.</td>
<td>Flood reduction is a subsidiary not predicted positive effect of most reservoirs</td>
</tr>
<tr>
<td>Tourism and recreation</td>
<td>Unquantified</td>
<td>Unquantified</td>
<td>Impacts on attractiveness of rivers landscapes and for recreational fishing</td>
</tr>
<tr>
<td>Social impacts</td>
<td>No resettlement for construction of facilities and inundation</td>
<td>No resettlement for construction of facilities and from inundation.</td>
<td>No significant unexpected social impacts</td>
</tr>
<tr>
<td>National development</td>
<td>Stimulation of national economy</td>
<td>Taxes paid by publicly owned power companies were 2 190 million NOK nationally in 1996. Various views on the degree of stimulation of national economy</td>
<td></td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>Negative effect on fish harvesting was the only predicted at the time of constructions (before EIAs were required). Effects have been compensated and mitigated</td>
<td>Negative impacts on fish, fisheries and aquatic biology</td>
<td>Predictions of mitigation measures effectiveness for maintaining fish stocks were too optimistic The significans of nativeness and differences in adaptability and behavior of the different fish strains</td>
</tr>
<tr>
<td>Distribution of Cost/Benefits and Impacts</td>
<td>Positive effect for employment and local economy of the development municipalities.</td>
<td>Public revenues from power installations in G&amp;L area of 534 million NOK in 1998, of which almost 80 % went to the G&amp;L region. 2350</td>
<td>Revenues from hydropower developments are unevenly distributed and the population and economic development of the total G&amp;L region is not</td>
</tr>
</tbody>
</table>

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| persons are permanently employed in the G&L area power sector. | different from regions without hydropower development |
4. Distributional Analysis

4.1 Distribution of income and taxes from production of hydropower

Weighted average end use electricity price, apart from power intensive industries and exclusive energy use taxes, was 0.34 NOK/kWh (0.052 US$) in 1996. The average price on electric energy was 0.188 NOK/kWh (0.029 US$/kWh) and the average grid rent 0.152 NOK/kWh (0.024 US$/kWh). In addition an electricity fee is levied on electricity consumption (0.0594 NOK/kWh (0.007 US$/kWh) in 1999). From 1994, manufacturing industries and mining and quarrying have been exempt from the electricity fee. The VAT rate on electricity is 23 per cent, the same as for all other goods and services subject to VAT. The three northernmost counties of Norway are exempt from VAT.

Both the electricity fee (0.0594 NOK/kWh with exemptions for manufacturing industries and mining and quarrying) and the VAT (23 per cent as for all other goods and services) are levied on consumption and are therefore equal for hydro power and thermal power and for imported electricity and electricity produced in Norway. The following sections will focus on the distribution of income from production of hydro power, and the distribution of this income on profit and taxes and on local and central authorities.

In 1996 the net sales of energy in Norway provided NOK 16 billion (2.48 billion US$) in operating income and the net sales of grid services NOK 11 billion (1.70 billion US$). The operating profit in all enterprises in electricity supply in Norway was NOK 10.4 billion (1.61 billion US$). The operating profit are mostly related to the production of electricity because the price the power utilities charge for electricity transmission not may exceed what is needed to meet investment costs, the cost of operating the grid, and a reasonable return on investments.

Up to 1996 publicly owned power stations were taxed according to special provisions in the Taxation Act. Income tax was calculated on the basis of valuation of power stations, not on their annual profits. In addition, power stations paid wealth tax to the state, and most paid property tax to the municipalities. Privately owned power companies, which account for less than 15 per cent of total production, were taxed according to the same rules as other industrial enterprises. Table 4.1 shows how much tax publicly owned power companies paid to the state, counties and municipalities in 1996.

Table 4.1 also shows the revenue from property tax that municipalities may charge from power stations, regulation dams, transmission systems including tunnels etc. It is up to the local authorities to decide whether to charge property tax or not. If they do, the tax rate must be within 2 and 7 per thousand of an appraised value.
Table 4.1  *Taxes paid by publicly owned power companies 1996. Mill. NOK (Mill US$)*

<table>
<thead>
<tr>
<th></th>
<th>State</th>
<th>Counties</th>
<th>Municipalities</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income</td>
<td>200 (31.0)</td>
<td>210 (32.5)</td>
<td>340 (52.6)</td>
<td>750 (116.1)</td>
</tr>
<tr>
<td>Wealth</td>
<td></td>
<td></td>
<td>540 (83.6)</td>
<td>540 (83.6)</td>
</tr>
<tr>
<td>Property</td>
<td></td>
<td></td>
<td>900 (139.3)</td>
<td>900 (139.3)</td>
</tr>
<tr>
<td>Total</td>
<td>200 (31.0)</td>
<td>210 (32.5)</td>
<td>1780 (275.5)</td>
<td>2190 (339.0)</td>
</tr>
</tbody>
</table>

Source: Proposition No 23 (1995-96) to the Odelsting.

From 1997 new rules for taxation of hydropower plants were introduced. Now all power companies (both privately-owned and publicly-owned) are taxed on the basis of their annual profit, according to the same rules as other industrial enterprises. In addition, the new system includes a so-called nature resource tax and a basic interest tax.

The new taxation system for energy enterprises includes:

- Profits tax
- Nature resource tax
- Basic Interest Tax
- Property Tax

According to the system, energy enterprises are to be taxed in correspondence with annual accounting profits. This implies that the calculation in per cent of revenue and capital on publicly owned energy enterprises was discontinued. The rate of taxation for municipalities, counties, and the State is to be fixed at the same rate as for other taxpayers paying tax levied on a preceding year basis. The transition from tax assessment by per cent, to taxes on the basis of annual profits of publicly owned energy enterprises involves, if perceived in isolation, the destabilisation of the earnings of energy municipalities. To counteract this, a nature resource tax was introduced, of 1.1 øre (100 øre = NOK 1.00) per kWh for municipalities and 0.2 øre per kWh for counties. The basis for taxation for the nature resource tax is actual production and is thus independent of price and cost development in the energy sector.

The nature resource tax is handled in the same fashion as that of ordinary income and capital tax with income equalisation in the income system.

The basic interest tax goes in its entirety to the State.

The changes in the taxation of energy enterprises did not affect the system for property tax nor the system for licence fees or licensed energy revenues (mentioned below).

The municipalities have the opportunity to charge property taxes on power plants. It is up to the municipality itself to determine whether it wants to impose property taxes, but the rate of taxation must be between 2 and 7 per thousand. The rate increase from year to year is limited to two units per thousand. Property tax has a relatively small significance in a national context, but for some municipalities, particularly energy municipalities, the property tax is important. Power stations, reservoirs, transmission installations including tunnels and the value of regulatory rights in connection with waterfalls are all considered property. The property tax is determined on the basis of municipal rates for the property.
The developmental municipalities receive license fees in connection with watercourse projects. The license fees for the municipality was introduced primarily for two reasons, see White paper no. 23 (1995-96) *Taxation of energy enterprises*. First of all it was intended to compensate for common interests. In practice, this means any reduction to the value of nature and the environment as a consequence of damage in connection with construction. Such damage is not subject to compensation, according to the usual expropriation regulations. Secondly, the fee is intended to give developmental municipalities a share of the added value which takes place as a result of the exploitation of natural resources. A license fee is also paid to the State. The fee to the state is fiscal in nature. By fixing the fees, one puts an emphasis on the size of the environmental disadvantages, which the development implies, as well as the profitability of the expansion. For newer licenses, the most common fee is NOK 6 (In 1998: 0.80 US$) per nature horsepower per year to the state and NOK 18-20 per nature horsepower per year to the municipalities (NOU 1998:11). The fee is index linked every fifth year. In comparison with production, the license fee in 1994 comprised an average .45 øre/kWh (0.0045 MNOK/kWh. (0.0064 US$/kWh)). The municipal earnings from license fees are not freely administered, but are bound to the municipal Business Development Fund. A special Business Development Fund can also be granted in connection with watercourse construction. Such Business Development Funds are granted directly to the municipality concerned, usually in the form of a non-recurrent fee.

Table 4.2 shows the total amounts paid to municipalities and the state in the form of licence and watercourse regulation fees in 1996.

**Table 4.2** Fees paid to municipalities and the state in 1996. Source: Ministry of Petroleum and Energy (OED) (1997).

<table>
<thead>
<tr>
<th></th>
<th>Mill. NOK (Mill US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>To the municipalities</td>
<td>408.5 (63.2)</td>
</tr>
<tr>
<td>To the state</td>
<td>98.9 (15.3)</td>
</tr>
<tr>
<td>Total</td>
<td>507.4 (78.5)</td>
</tr>
</tbody>
</table>

Developmental municipalities have earnings from the sale of licensed energy. By making natural resources available to energy development, the developmental municipality can require that up to 10% of the energy be allocated as licensed energy. The municipalities’ withdrawal of energy is limited to the energy demand for general supply. Energy intensive industry and wood processing are not included in the term general supply. The county can take the portion of the licensed energy not used for general supply. The individual municipality’s licensed energy earnings depend upon the licensed energy price, the energy market price and the scope of the licensed energy. The municipalities (and counties) decide whether to sell their proportion of the power generated to market prices or to the lower full-cost prices. In 1997, 141 municipalities reported licensed energy incomes, with an aggregate amount of MNOK 332 (47.0 million US$). Out of these 141 municipalities, there were 104 that also reported property tax.

In addition, municipalities and counties are listed as owners of a significant portion of Norwegian energy enterprises. Municipal and county owned power plants represent more than half of the total energy production in Norway. In particular, the urban municipalities own sizeable production capacity. The power plants should be able to give the owner municipalities normal capital returns, or capital...
returns corresponding that which the owner could otherwise receive in the event of alternative use of the capital. In addition, the basic interest rate on energy production gives the owners a larger return than that which is usually the case in other industries. Portions of the basic interest are, however, taxed away and in part go to the developmental municipalities, and in part to the State.

The hydropower development in the G&L basin did not result in resettlement of households and only a small fraction of the area which have been dammed were agricultural land. The flood reducing effects are considerable and this benefits all activities in the flood zone (i.e. infrastructure, settlements, industry and agriculture). However the effects on the flood vegetation is negative. The predicted effects on fisheries when viewed from the compensation and the numerous mitigation measures were considerable and the quality of fishing is reduced in the affected areas. The most severely affected areas are some of the mountain reservoirs and the migrating fish species in the Glomma river and in the lower reaches of Lågen.

The dams in the GL region were constructed over a long period of time and finished years ago. For many local communities, the construction period represented growth in employment, increased tax revenues and increased demand for goods and services. In the long run, however, the economic and population development in the GL region is similar to regions without hydropower development. Only a few of the municipalities have higher incomes than they would have had otherwise. Approximately 250 persons are employed in the production part of the hydropower sector, that is, excluded transmission, marketing and sales which are the better part of the employed persons. If all segments of the value chain are included, the employment sums up to approximately 2,100 persons. The direct economic effects in the GL region today come from revenues to the municipalities in the form of taxes, license fees, sale of licensed energy and owner incomes (dividends).

There are no available statistics on the incomes received from the energy sector by municipalities and counties. The report therefor rely on relatively rough estimates based on a range of sources which indicate that in 1998 the earnings from the power installations were distributed as shown in table 1.

**Table 4.3.** Public revenues from power installations in the G&L region. 1998.

<table>
<thead>
<tr>
<th></th>
<th>To G&amp;L region</th>
<th>Out of the G&amp;L region</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Municipalities and counties</td>
<td>the State</td>
<td></td>
</tr>
<tr>
<td><strong>Taxes</strong></td>
<td>278 (36.9)</td>
<td>55 (7.3)</td>
<td>333 (44.2)</td>
</tr>
<tr>
<td><strong>License fees</strong></td>
<td>26 (3.4)</td>
<td>5 (0.7)</td>
<td>31 (4.1)</td>
</tr>
<tr>
<td><strong>Sale of licensed energy</strong></td>
<td>20 (2.7)</td>
<td>0</td>
<td>20 (2.7)</td>
</tr>
<tr>
<td><strong>Owner incomes</strong></td>
<td>90 (11.9)*</td>
<td>60 (8.0)</td>
<td>150 (19.9)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>414 (54.9)</td>
<td>120 (16.0)</td>
<td>534 (70.9)</td>
</tr>
</tbody>
</table>

*Includes revenue to both municipalities and counties.

Of accumulated public incomes of 534 million NOK (70.9 million US$) from the energy sector in GL, a 414 million NOK or almost 80% went to the GL region. The energy revenue amounts to about 1.9%
of the total incomes in the municipal sector (municipal and counties) in the GL-region. A few municipalities in Norway does however receive a quite considerably income from the hydropower sector.

A large portion of the income to the municipalities is annual State subsidies. These subsidies are in part meant to compensate for standardized fees (fee compensation) and partly to compensate for low earnings (income equalization). Municipalities with large energy incomes receive lower subsidies than corresponding municipalities without energy incomes. If we also take into consideration that the State subsidies are reduced for municipalities with large energy incomes, the net effect of the energy revenues will feasibly be at around 1.5% of the municipal sectors’ aggregate annual incomes in the GL region. In a few municipalities, the revenues of the power installations make up more than 5% of the incomes.

4.2 Distribution matrix

The main direct outputs from the G&L basin hydropower developments have been the production of electricity and the income from taxes and fees from production and installations. Both the landowners, the basin municipalities, industries and the national populaton have benefited from the electrification and the income for the hydropower producers have been significant. Also other industries and basin municipalities have gained from the hydropower developments. A subsidary benefit for land owners and basin municipalities have been flood protection from reservoir storage. Positive indirect output have been increased employment opportunities and compensatory payments to landowners.

Project cost have been carried by the hydropower industry and by basin municipalities and counties as owners of the hydropower plants.

Main project impacts have been on ecological functions in lakes and rivers. Damage on reservoir and river fish stocks and fisheries have been negative for landowners and basin municipalities as well as for recreational users. Additional project impacts have been local negative effects for the agricultural interests. No significant impacts have occured for the irrigation interest and for the water supply interests.
Table 4.4 Distribution matrix

<table>
<thead>
<tr>
<th>Findings on distribution:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The hydropower development in the G&amp;L basin did not result in resettlement of households and only a small fraction of the area which have been dammed were agricultural land.</td>
</tr>
<tr>
<td>• The flood reducing effects are considerable and this benefits all activities in the flood zone (i.e. infrastructure, settlements, industry and agriculture).</td>
</tr>
<tr>
<td>• The predicted effects on fisheries when viewed from the compensation and the numerous mitigation measures were considerable and the quality of fishing is reduced in the affected areas. The most severely affected areas are some of the mountain reservoirs and the migrating fish species in the Glomma river and in the lower reaches of Lågen.</td>
</tr>
<tr>
<td>• Norwegian municipalities receive a large portion of their incomes through State subsidies. Particularly rural municipalities with low tax revenues receive large State subsidies.</td>
</tr>
<tr>
<td>• The direct economic effects in the GL region today come from revenues to the municipalities in the form of taxes, license fees, sale of licensed energy and owner incomes (dividends).</td>
</tr>
<tr>
<td>• The large revenue entries are owner incomes and taxes. The energy revenues for the municipal sector (municipal and counties) in the G&amp;L region are at about 1.9 % of the total incomes to the municipal sector.</td>
</tr>
</tbody>
</table>

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
5. The hydropower policy evolution, planning and decision making in Norway in 20th century with a reference to the G&L-basin

5.1 Introduction and approach

Norway is ranking 6th as a hydropower producer in the world, and in production per capita Norway is top ranking globally - and by far so. The hydropower production capacity in Norway has been developed throughout the 20th century, and the bulk of the development (more than 80% of present capacity) has taken place after the Second World War (see figure 3.1.1 on hydropower production and consumption in Norway and in the G&L basin from 1940 to 1998).

The relative quantitative importance of the hydropower production in the G&L-basin (GLB-production) has been reduced in the post-war period on a national level. In the basin itself there has been a steady growth of production in the period (see also figure 3.1.2) to the present level of about 10-12 TWh.

The opening decades of the 20th century witnessed the brake through in Norway of modern industrialism, accompanied with a considerable economic growth (Jensen 1985, Hanisch and Lange 1986, Myklebust 1991, Even Slagstad 1998). The formation of a regime for the development of the hydropower resources has been a major political issue Norwegian society throughout the 20th century. Decision making, planning and in general the apparatus applying to this field of activity, has always been considered something of national and public interest and importance (Thue 1994, 1996).

The development of a national regulatory regime may be organised into the following characteristic periods (partly based on Haagensen 1984:17):

1. A pioneer phase extending from mid 19th century to 1906 characterised by development of hydropower production technology and industrial utilisation of this resource.
2. A law and policy formation period extending from 1907 to 1919, combined with an active development activity.
3. An inactive period, extending from 1920 till the end of the 2nd world war, due to lack of financial resources for hydropower production projects.
4. A period from post 2nd world war to end of the 60es characterised by a large number of projects being undertaken, in a situation where there is almost no opposition to river regulation, dam building and so on.
5. A period of growing criticisms, especially from environmental perspectives, against hydropower development schemes, from the start of the 1970es to end of 1980es.
6. A period from the beginning of 1990's to present days characterised by several new elements. The most important is the liberalisation of the regulation regime introducing an element of free trade and competition to the industry. Of some importance is also the attention paid to global environmental policy issues through instruments like the global agreement on cutting greenhouse gasses.

The G&L-basin piecemeal development, “organic” growth (as opposed to one or a few larger installations) and integrated operation over a long time span, and the diversity of hydropower companies operating in the basin, makes it difficult to describe. In 1993 the G&L-basin had 51 power plants in operation, which in most of the cases have been upgraded and extended over the years. The basin has in total close to 200 dams of various sizes developed, upgraded and extended over the years, of which 40 are major reservoirs. The basin area is approximately 42 000 km². The distance across the
basin is at its peak approximately 400 km from north to south, and approximately 220 km from east to west.

It is beyond this presentation to give anything more than an outline of the activity and a generalised perspective on the planning and decision making in the basin. The ambition is to give a rough picture of the planning, developmental and operative activity in the basin over the period. To simplify, data on power plant planning and development have been used as the prime indicator for the activity in the basin. Some key data on reservoir development are, however, used to complete the picture.

### 5.2 The G&L-basin layout

An overview of the power stations and reservoirs in the G&L-basin is shown in figure 5.1 below. A full list of reservoirs and dams can be found in Table 2.4.1, and of power plants in Table 2.4.2.

![Figure 5.1 Glomma and Lågen basin confluence area. Main structure of the watercourses in the basin is indicated with the black "fork". Black dots show location of power stations and white squares show contemporary dams and reservoirs as of today. Some key localities are indicated to facilitate reading.](image-url)
The activity in the G&L-basin affects approximately 50 municipalities in 5 counties. The majority of the power companies are owned by public institutions (municipalities and counties). The municipalities in the basin and the power plants in the basin are shown in figure 5.2 below. As a rule of thumb, the municipality in which the power plant resides, is (or has been) involved as an owner. As a consequence of the liberalisation and de-monopolisation of the power industry in the 1990ies, there is now a major restructuring going on. This will be commented on later. A complete overview of ownership to the installations, public vs. private, and intra-basin vs. extra-basin, can be found in Table xx, page xx.

![Map of G&L-basin](image)

**Figure 5.2** Contemporary municipality borders and power stations (black dots) in the G&L-basin.

The watercourse runs through populated areas, with an increasing gradient moving from north to south and east to west in the basin. This is illustrated in figure 2.3.4.

### 5.3 Early developments in the G&L-basin

See map below, figure 5.3, for the location of the developments described in the list to follow.
The first major technical interference in the G&L-basin was the first of a series of water level manipulations of Lake Mjøsa in 1854 and Lake Øyeren in 1857-62 undertaken by the state for flood protection, logging and ship navigation measures. Later reservoir upgrading for Lake Mjøsa in 1907 and 1958-63 and Lake Øyeren in 1917-24 were hydropower motivated too.

In 1894 Lillehammer municipality, developed, to promote the electrification of the local community, the first ever local government, or municipality owned, power plant in the Mesna river, again in the G&L-basin (see map xxx). The plant has been upgraded several times since then (see later). Mesna River is a branch of Lågen, and the reservoir projects commenced there in 1910, and were carried through in several steps downstream to 1920.

In 1896 the powerful then, now dissolved, mining company in Røros local community, Røros Kobberverk (Røros Copper Mine Company) put into operation a power plant in upper Glomma, Kuråsfoss Power Plant (I). The plant produced 0.4 MW to supply an electrification of the community Røros, which was a pioneer in this respect.

In 1898 the company Borregaad A/S (Borregaard Ltd.) put its hydropower plant in production utilising about 50% of the water running through Sarpsfossen, and in 1899 the company A/S Hafslund (Hafslund Ltd.) put the rest of the water in the same waterfall into power production. These private companies, either directly or through owned companies, developed several hydropower plants in this region of the basin in this pioneer phase. Their facilities have been upgraded and expanded several times over the years. The development projects were an essential part of industrial development in the city Sarpsborg (large process industrial facilities), and promoted a general electrification of the community.

In 1903 Hafslund A/S (at that time a process industry), through their company A/S Kykkelsrud (a power company), and as part of general industrial development, started the operation of Kykkelsrud power plant situated some kilometres above the industrial sites at the town Sarpsborg.

Eidsvoll-Mathiesen Verk, a landowner and timber company (not a member of GLB) acquired the rights to regulate the Lake Hurdalssjøen running into the River Vorma, in 1905, mainly for logging purposes. The water from this regulation was given to the power plants downstream without any costs.

In 1906 the mining company at Folldal community, Folldal Verk A/S, developed and put in operation a power plant at the fall at Einunnsfoss. The plant is situated uppermost in the Gudbrandsdalen valley. The plant was expanded and upgraded in 1934. This promoted industrial mining activity and electrification of the local communities.

In 1909 Mesna Power company developed and put into operation Moelv Power Plant (the plant was upgraded in 1949 - and again in these days). This project was preceded by a reservoir development in the Moelv watercourse (branch of Lågen watercourse) in 1908. The project supported a general electrification of the local communities.

In the years 1908-1910 the company Elverum Elektrisitetsverk (Elverum Power company) constructed and put into operation Skjefstadfoss power plant. This has later been upgraded several times (see below).

In 1913 Røstefoss power plant was put into operation by Røros Elektrisitetsverk (Røros Power Company Ltd.), supporting local community and industry.
In 1914/15 a power plant at Hyttfossen in Sølna watercourse was put into operation. The power plant supported the electrification of the local community at Alvdal. The plant was develop by Lilleelvdalens Elektricitetsverk A/S (Lilleelvdalens Power company Ltd.), but was in 1948 taken over by A/L Nord-Østerdal Kraftlag (Nord-Østerdal Power company Ltd), a company owned by public authorities.

A/S Øvre Gausdal Elektrisitetsverk (Øvre Gausdal Power company Ltd, fully public owned), put into operation their plant at Holsfossen (see figure 5.3) in 1914. This is a side branch running into the Lake Mjøsa in the north. This development supported the electrification of the communities in the valley Gausdal.

Rena Kraftlag A/S (Rena Power company Ltd.), a public owned unit, developed and put into operation in 1914 a power plant at the waterfall Osfallet (see figure 5.3), supporting the electrification of the local community at Rena. It was substantially upgraded in 1946.

In 1916-1917 A/S Eidesfoss (a power company, 50% private owned and 50% owned by local authorities) put their plant at the fall at Eidefossen in production. The plant was expanded in 1920 (and again in 1951).

Vamma power plant 32 km above Sarpsfossen in the city of Sarpsborg was put in production in 1915-1919.

**Figure 5.3** Location of power stations (black dots, labels to the left) and reservoir (white squares, labels to the right) developments before 1920, corresponding to the list above

The geographical pattern of these early projects illustrates how the development was as much a rural phenomena as an urban one. The projects were small scale, locally initiated and with the purpose both
to electrify the rural communities and to promote industrial development. Both the private and public sectors (local communities) were involved in owning, planning and operation of hydropower stations. Over the years the several smaller public owned companies have come to dominate in the basin, a picture that is only changing in contemporary Norway as a result of a liberalisation of the electricity market (see below page xxx).

We should note the share volume of hydropower development activity as being substantial during the 1st World War, especially in rural municipalities. Several factors encouraged the local authorities to take on a lead role in the development of hydropower resources. One factor was the wish to promote and stimulate the local private sector in economy. The welfare obligation to secure energy supply to the households in their territory was another factor. An important event in this respect and at that time, was the rapidly rising price on other types of energy to the households. (Hovland 1987:149). The price of coal rose with 2000% during the war. The price of electricity though, only rose with something like 10-20% in the same period (Nerheim 1989:187-189). During the 1st World War the consumption of electricity rose, as could be expected, in parallel with the supply.

Throughout this period Norway had an increasingly strong financial sector supporting the development of the hydropower resources. During the war the municipalities easily acquired credit (Hovland 1987). As can be seen from the list of development projects, several municipalities exploited this opportunity to create power companies, and invest in hydropower plants. In the period 1914 to 1920 local authorities quadrupled their collected debt, and approximately half of this increase was due to investments in the hydropower sector (Nerheim 1989:208).

Autumn 1920 saw the beginning of a recession period in Norwegian economy. Export rates dropped dramatically, and the price of coal and oil normalised at a level that made them competitive with hydropower. The consumption of electricity dropped as individuals and firms cut back on their expenses (Nerheim 1989:208). It was not uncommon that the power plants owned by local authorities worked at a loss, and in fact became a heavy burden for taxpayers.

Returning to the G&L-basin, it can be concluded that it had a lead position in the early phases of the electrification of Norwegian society and economy, through the pioneer and law-making phases, into the economic recession in 1920. As to be discussed in chapter 5.5 reservoir development, water level and water flow manipulation in the G&L-basin also had a significant role in the national policy and law formation.

**5.4 The formation of a national water fall policy and a legal system**

The first state body dedicated to watercourse exploitation, was the “Canal-directionen” (The Canal State Authority - CD). CD was established as a modest office in 1804. At the turn of the 19th century Norway was in a union with Denmark and experienced a strong economic growth and a rather vigorous political development. A prime role of CD was to promote an extensive development of canals in Norway, an idea that never materialised (Vogt 1971:18). A secondary role of CD was to secure riverbanks against erosion, to promote flood protection and so on.

At the brink of the 20th century, extending to the First World War in 1914, Norway witnessed a period of extensive speculation by private financial actors in acquiring rights to utilise waterfalls. Both foreign and Norwegian companies where active. The National Assembly responded to this rapidly developing enclosure of natural resources by private economic interests in three ways:

- With the establishment in 1906 of a temporary law of license regarding utilisation and ownership of waterfalls by foreign interests (the so called “Panic Act”). Following hard political debate in the National Assembly and the Government, the Act was made permanent in 1909, and also expanded
to include non-foreign private ownership (see below). The Act requires for any company to hold ownership to waterfalls to have a license. The license was to be given for a limited period of time (normally 60-80 years), after which the ownership was to be transferred to the state without any compensation. (The issue of transferring the ownership to the state at the expiration of the license period, has over the years been a source of political and juridical controversies, but no amendment to this crucial point in waterfall legislation has so far taken place.)

- With the establishment of a relative substantial “buy-back” policy. The idea was that the Government should be active in buying the rights to waterfalls back to the State. This was a policy response entailng a period of quite intensive speculation by national and foreign private investors. This policy was effective in the period 1907-1920.
- With the reorganisation of CD to “Vassdragsvesenet” (Watercourse Authority) in 1907, with extended authority and agenda (and which in 1920 was further transformed into a Norwegian Watercourse and Energy Directorate - NVE (see below - home page http://www.nve.no - the name of NVE have changed over the years, but the present name is consistently used in this report).

### 5.5 The formation of GB

The first waterfall exploitation interest group was founded in 1903 as Glommen Brukseierforening (GB). GB organised the main private waterfall owners or holder of rights (and no other interests) in the lower part of the Glomma River (from below the river branching at Vorma). It is still operative, but its functions were taken over by GLB (see below). The rationale for the formation of GB was hydropower, not flood protection. An increasing interest in hydropower production in the lower part of the basin, resulted in a pressure from holders of the waterfall rights to increase winter water supply. This required construction of dams for water storage. GB also wished to operate Lake Mjøsa to optimise for winter water storage (GB 1938, GBL 1947:88).

In 1906 the (moderate to conservative) Government gave GB a license to regulate Lake Mjøsa according to its interests, and did so without consulting the Parliament. This led to a dispute between the Government and the Parliament on whether the Government on constitutional grounds. Could the Government grant a license without consulting the Parliament? This issue came up because the authorised regulation of Lake Mjøsa would result in a depreciation (even decommissioning) of the state owned waterfall downstream Lake Mjøsa at Sundsfossen. In the debate to follow farmers surrounding Lake Mjøsa joined side with the left wing opposition being very opposed to give these regulation rights to a private organisation like GB. Other interests than hydropower interests were excluded from GB. Farmers feared they would get no influence on operation of Lake Mjøsa (even though the CD’s intention was to give the state the supervising role in the operation of the regulation), and no economic compensation from the dis-benefits from the regulation. Left wing politicians could not accept the depreciation of state values on behalf of private capital owners and right holders. Several politicians at the time felt that the present law on water course regulations and licensing was not intended for a large scale operation like regulation of Lake Mjøsa, and that the Government had acted unwise in its relation to the Parliament.

GB initiated construction of the dam at Svanfoss under the licence granted by the Government. GB did not respond favourably to a letter from the Ministry of Labour in December 1906 asking for a stop in the work in progress (GB 1938:31). A special committee on the issue in Parliament reached a majority conclusion in June 1907, criticising the Government for not consulting the Parliament before granting GB a license. In the debate to follow it became clear that this Mjøsa-controversy could well lead to the fall of the moderate to conservative government lead by Prime Minister Christian Michelsen. Through a series of events in the year to follow the Parliament amended the legal and political procedures referring to licensing (according to the law of watercourses of 1887) reducing the autonomy of the government,

- decided on a settlement with GB contrary to the prime ministers position on this issue, and
• with a strong minority supporting the prime minister's opinion saw
• the consolidation of the left wing opposition in the Parliament, saw
• the retreat of the minister responsible for giving the license in the first place, and later saw
• the retreat of the Prime Minister himself ultimo October 1907

The formation of a new conservative government having a short life because it could not solve the political issue of licensing laws. The end result for GB was that the regulation was carried through and in 1910 had its first year of operation with GB as operative responsible.

5.6 The formation of GLB

In 1910 and 1916 two major floods occurred in the G&L-basin. This stimulated a debate in Government and the national assembly on more extensive flood protection measures. The question was put under deliberation in committees, and a need was found to get a broader representation of hydropower stakeholders in the G&L-basin.

In order to organise waterfall owners and rights holders in the whole of the G&L-basin, Glomma and Laagen Brukseierforening (GLB) - Glomma and Laagen Water Association) was formed in 1918, and took over the functions of GB (which still exists). The following is a quote from the letter of invitation to a number of owners of rights along Glomma and Lågen:

“Given the present circumstances, the questions on how to supply more electrical energy, and, in relation to this, the question of new watercourse regulations, especially regulating the lakes in Østerdalen and Gudbrandsdalen, have become pertinent. A regulation of these lakes serves a dual purpose, reducing the floods in the rivers and Lake Mjøsa and Lake Øyern, and the attainment of a larger and more regular flow of water in the winter season” (GLB 1975:8 - our translation)

GLB came to be the most important actor in the G&L-basin in the decades to come. The association took up the task of developing a large number of regulation plans.

In 1918 GLB had 10 owners. GLB have presently 21 power companies 41 falls assigned as members, managing 45 power plants and 26 reservoir and transfer facilities (a detailed list of the owners is given at http://www.glb.no/virksomhet/medl.html). Not all fall owners and reservoirs in the basin were, or are, part owners in GLB. The owners have a vote in the assembly according to the size of the falls (in natural horsepower) they had rights to.

Some of the other user interests in the watercourse has organised themselves, for the most part at a considerable later stage than GLB. These organisations operate on a sub-basin level. Among these other user organisations, there is an organisation for those who possess riparian rights around Lake Mjøsa (Mjøsen Strandeierforening) and for fishing interests in the Lågen river course (Lågen Fiskeelv).
5.7 The license laws - the conflict over policy formation continues

Licensing and river reservoir, dam and hydrological manipulation policy had become a difficult political issue. The catalyst for the political and constitutional process was Lake Mjøsa. Ultimo 1907, a new government lead by Prime Minister Gunnar Knudsen took on the task in Parliament in 1906 to establish a permanent set of license laws. The debate focused on:

- Whether the new law should include national companies in addition to foreign companies. The new Government wanted it to include all ownership, national or foreign, and this became the result.
- Whether a license should be granted for a limited period. The new Government wanted time limited licenses, and this became the result.
- Whether installations and connected rights should be transferred at no cost to the state. The new Government wanted it to be transferred at no cost to the state. (This issue was also brought before the Supreme Court, which in 1918 with 4 votes against 3 ruled that it was not in conflict with § 105 of the Constitution, which requires that full compensation shall be paid when private property is expropriated).
- Whether the people through a general parliamentary election should decide the issue. The new Government was not in favour of that.
- Whether a set of social, welfare and public infrastructure demands should be included in the licence laws. These would include public welfare buildings, social housing programmes and the establishment of co-operative organisations in local communities supporting daily life.

In 1919, the “Panic Act” was replaced by a permanent and more comprehensive law, the Watercourse Regulation Act on the utilisation of the waterfalls for (industrial) hydropower production. By now a system of licensing was established, at least as a general framework. Throughout the 1920ies there were several instances of conflict between authorities and private applicants or could-be-applicants, on the specific formulation of license terms.

The Watercourse Regulation Act required that the Government, in large and/or controversial cases, had to consult the National Assembly before granting a license. Further the Act introduced detailed regulations on the content of an application, and demands on the applicant to analyse costs and benefits of projects.

Integrated in the licensing under the Watercourse Regulation Act is the expropriation of property rights necessary to carry out the project. The landowner is entitled to full compensation for the losses the expropriation causes, plus an additional 25% of this value. In most cases, acquisition and compensation is settled in voluntary agreements between the landowners and the applicant.

5.8 The new water resource administration

In the post 1st World War period matters relating to watercourses and hydropower-production was split between 4 authorities (directorates etc.) and several ministries.

Different ministries have handled the various aspects of watercourse management over the years. The responsibility for water-resource legislation and hydropower licensing was under the Ministry of Labour until the establishment of the Ministry of Industry in 1947, and further transferred to the Ministry of Petroleum and Energy established in 1978.

The changes over the years of ministerial responsibility over matters relating to water-resource development are illustrated in figure 5.4 below.
Figure 5.4 Changes in ministerial responsibility in matters relating to water-resource development

The post 1st World War period saw several directorates or commissions involved in administration of hydropower policy:

- The Watercourse Authority, which by 1920 had grown to 110 employees. Main responsibility was hydrology and dams.
- The Electricity Commission of 1910. Responsibility for granting concessions for power lines and electrical equipment
- The Watercourse Commission of 1909. Responsibility for licensing the acquirement of waterfalls and watercourse regulations
- The Inspectorate for the Electricity Directorate
- The Waterfall Commission of 1911 (a temporary commission)
- The Electricity Supply Commission of 1919 (also a temporary commission)

This rather complex and partly ad hoc organisation, together with the general changes in ministerial responsibility, reflect the formative and turbulent situation within the energy sector in Norway. It took some years into the new century before the Norwegian political and administrative system sorted out both policy and legislation, and finally administrative and procedural aspects of hydropower production from watercourses and waterfalls. In this period there was a breakthrough of the idea that the state should finance, develop and run power plants on its own. The Parliament voted for financial resources to be spent on reservoirs and power stations. But the necessary institutional unit for an active development and operative role for the state was lacking.

A White Paper on the new administrative arrangement was presented to the Parliament in 1919, suggesting the establishment of one unit having responsibility for business assets, operations,
development, licensing and supervision. In March 1920 “Norges Vassdrags og Elektrisitetsvesen” (present name "The Norwegian Water Resources and Energy Directorate” - NVE - present name used consistently through the report) was established. One important consideration in the reorganisation was the need to strengthen planning, development and operation of state owned hydropower plants. The new NVE was a state authority managing three directorates:

- Watercourse and log driving directorate (responsible for national hydrological information, control and licensing of physical installations, preparing license processes and so on)
- Waterfall directorate (responsible for development of state owned waterfalls and the preparing the process of licensing)
- Electricity directorate (responsibility the supply, grid, distribution systems - standards, licensing, planning, running state owned facilities and so on)

This organisation was intended to build up an important and active development function in contemporary hydropower activity. The Norwegian State was after all the largest owner of water fall rights in Europe at the time (Thue 1996:47). The organisation attracted skilled hands and professionals. But due to the economic recession, things turned out different. Hydropower development on the large scale almost came to a stand still. In 1935 NVE was reorganised in order to adjust to a less active role as project developer (Thue 1996:57). The structure with a state authority managing 3 directorates was reorganised, and replaced with an NVE as “The Norwegian Water Resources and Energy Directorate” with 6 departments:

- Department for watercourses
- Department for embankments
- Department for hydrology
- Department for electricity
- Department for supervision
- Department for power stations

In 1939 NVE handled less than 10% of the total power production in Norway. It was not until after the war that this picture would change dramatically.

The Norwegian Water Resources and Energy Directorate (NVE) remained mainly unchanged until 1960, when an internal rearrangement and updating resulted the following 4 departments:

- Department for administrative, legal and economic matters
- Watercourse department handling trade, regulation and installation licences, control and supervision with physical installations and activity, and responsibility for hydrological information
- Electricity department handling issues referring to the power grid and supply infrastructure
- Department handling the operation and development of state owned hydropower plants

At the local level there was a growing tendency to build larger supply systems and water management associations. GLB is one example, and a frontrunner in this trend. From around 1920 several municipalities formed larger county-based units, among those in Akershus county, and Vestfold county.

5.9 Projects in the G&L-basin between 1920 and 1945

In 1920 the National Assembly decided to license the regulation of Lake Aursunden (see figure 5.6 below) as a state regulation, meaning that state authorities should have the responsibility to operate the installation. This was decided to give the state full control over how to handle problems following the
braking up of ice in Glomma. There was in addition found need for an expedient execution of the project to mitigate the unemployment situation in the region.

Still GLB had to finance the Aursund reservoir. Throughout the 1920ies the lack of financial resources in Norway, in combination with problems of formulating conditions for concessions acceptable to parties involved, put severe limitation on hydropower development schemes and reservoir projects as such. In the period only two more reservoir projects were embarked upon, Osensjoen (1938) and Bygdin (1928-1936) (see map next page), both with flood control as their major purpose. The license for these projects was initially given to the state, but was transferred to GLB in 1928. In addition the following power plant projects were carried out in this period:

- In 1920 Funnefoss power plant, some 5 km. upstream Glomma from Vorma was put in operation.
- There was a substantial upgrading of Borregaard power plant in Sarpsfossen in the period 1936 - 1945.
- Kvernfaller power plant was put into operation in 1936.
- In 1934 Einningfoss power plant was rebuilt and upgraded.
- In 1940 the Raua power plant was put in operation.

Figure 5.5 below shows the location of these power plants and reservoirs.

Figure 5.5 Power plants (black dots, left hand labels) and reservoir (white squares, right hand labels) developed in the period 1920-45.
As can be seen, when comparing this list of developments in the G&L-basin with the list of developments in the preceding period, the development activity was much more modest in the period from 1920 to the beginning of 2nd World War.

5.10 The era of physical development

From 1945 to the end of the 1960s was the era of physical development in Norwegian power policy. The new important factor, marking a new start for the national power policy, was the state. The state, through NVE, took on an active development and operative function, with the aim to feed the power-based melting industry and other heavy-industry projects with power. The provision of power to the process industry became a prime policy goal (Jensen 1985). In pre-war Norway industry was mainly producing its own power, but now there was a shift in policy towards the state taking over the role as a guarantor for enough electricity to the industry. This was a shift also in the sense that power for household consumption was given second priority. In the years from 1946 to 1950 the process industry increased its consumption with 84%, while the households increased its consumption with 28%, and 600,000 people were still without power supply (Thue 1996:59). The balance between the two markets stabilised in the time to come. The process industry’s share of the consumption rose to 46% in 1950. From 1970 it decreased, and is presently at 25%.

The state increased its ownership in the hydropower industry from around 10% of the total of 10 TWh in 1940, to around 23% in 1950, and to about 30% of the total 113 TWh in 1995. In the same period the part of the industry owned by the local authorities and county authorities increased from 36% to 55%, while the private owners have decreased their share from 42% to 15%. Even though there never was a nationalisation of the industry, as feared by conservative politicians in this long period of socialist majority in Parliament, the public sector as such got into ownership control of the industry in the post war period.

Taking into consideration the minor position of the state as owner and operator of installations in the G&L-basin, the development here has been quite different from the national development profile. In the period from 1945 to the end of the 60s the following projects were carried out in the G&L-basin:

- In 1936-45 the Borregaard Power Plant in Sarpsfossen was fully renovated.
- In the period of 1940-63 three power plants at Tessa was put into operation, Lower Tessa in three steps in 1940-63, Middle Tessa in 1954 and Upper Tessa in 1956 and 1963.
- In 1938 Moksa Power Plant was put into operation.
- Osfallet Power Plant was expanded and rebuilt in 1946.
- In 1949 Tyria I Power plant in the Mesna water course was put into operation, utilising the fall between Sjusjøen and Northern Mesnavatn
- In 1951-52 Eidesfossen Power Plant was upgraded In 1955 Einunna Power Plant was put into operation.
- In 1956 Skjåk I Power Plant was put into operation.
- In 1959 Tyria II Power plant in the Mesna water course was put into operation, utilizing the same water resources as Tyria I (see above)
- Upper Vinstra Power Plant was put into operation in 1959/60.
- In 1960 the Kykkelsrud-Fossumfoss Power Plant, 2,5 km above Kykkelsrudfoss, was rebuildt and expanded.
- Hunderfossen Power Plant was put into operation in 1964 and 1965.
- Harpefossen Power Plant was put into operation in 1965.
- Lower Vinstra Power Plant was put into operation in 1968.
- In 1964 Kykkelsrud Power Plant was expanded and rebuilt.
- In 1970 Vamma Power Plant 5 km above Sarpsfossen was expanded.
In 1968, the following projects were under accomplishment in the G&L-basin under GLB leadership:

- Rendalen Power Plant
- Savalen Power Plant
- Løpet Power Plant

In addition, several reservoirs were developed in this period. To mention a few (see table xx, page xx for an exhaustive list of regulations):

- Gopollen (1943)
- Djupen (1943)
- Gunnvatnet (1947)
- Vinstern (1948 / 1951)
- Rausjøen (1949)
- Olstappen (1953)
- Sjusjøen (1954)
- Øyangen (1956)
- Fundin (1966)
- Storsjøen (1940/1968)

The locations of these projects are shown in figure 5.6 below.
Figure 5.6 Power Plants (black dots - names to the left) and reservoirs (white squares - names to the right) put into operation or upgraded in the period 1945-70.

The list should well illustrate the fact that the basin is being developed piecemeal and "organic", as opposed to development based on one comprehensive development plan drawn up, financed and executed by one central authority.

With the expansion of the national grid the old supply chain between the local power plant and the local community was losing relevance, and the power plants in the G&L-basin were from the beginning of the 1970ies increasingly producing for the national grid. Local ownership to the production capacity now meant that profits from supplying to the national grid to some extent stayed in local communities see chapter xx on economy for an extensive discussion.

A list of 20 projects were in a concrete phase of planning in 1968 (as opposed to being a perceived possibility), according to the 1975 report (op. cit.). This is a long list of projects to be carried through. It does not reflect the then already established situation in national watercourse politics that the era of "uncomplicated" decisions on hydropower projects was gone. There are some clues in the report though, that the times are changing and that by now, the heat from the environmental movement was felt by the planners, contractors, developers and operators of hydropower plants and reservoirs in the
GLB system. Even though the basin was rather heavily developed over a period of close to 10 decades, GLB were now worried about future possibilities. In the official report published in 1975 from GLB covering the period from 1943-1968, there is a concluding chapter on future reservoir possibilities, were it reads:

“In the G&L-basin there are, in addition to the already developed and planned reservoirs, several other possibilities for reservoir developments. The are many reasons for why these possibilities have not been exploited, and several reasons are so strong that they for the time being makes it impossible to achieve a reasonable exploitation for hydropower purposes” (GLB 1975:235 - our translation)

Indeed, reason and the reasonable were now the issue. New ideologies, perspectives, politics and actors were brought forward and claimed one’s right.

We are entering the 70s, and the list of future regulation possibilities in addition to those 20 projects in a concrete planning phase, as seen from GLB was also long (op. cit.). The list of future reservoir development possibilities as seen by GLB contained some 30 watercourses in the basin. One of them was the Lake Gjende, were the thought on possible reservoir development was accompanied with this comment in the 1975 report:

“Lake Gjende is a national symbol unapproachable to watercourse developers like a taboo, whatever the effect of the reservoir development should be. Should one, in spite of this, dare suggest development of Lake Gjende, then that could consist of a 150.000.000 m³ sink-reservoir to be filled up within Midsummer every year” (GLB 1975:237)

A long list of possibilities as perceived by GLB in 1975, indeed. There was obviously a lot to fight over on both sides now, and GLB had no intention of backing off. All in all, in the 1975 report, and remember we are now well into the very difficult political situation that arose in Norway over the hydropower policy (to be treated below) GLB stood out as a prominent standard-bearer for more hydropower development. The rhetoric chosen by GLB, as it is found in the 1975 report, carries with it a besserwissen-mentality. Those opposing the rather expansive development schemes of GLB, are stamped as ridden by emotions, symbols and taboos, and their attitudes are singled out as a hindrance to a reasonable utilisation of hydropower resources. Positions are taken, and “enemies” are ridiculed - this is rhetorical “war”. No doubt this reflected the position taken up by the "other" side, the conservationist wing in the environmental movement.

The offensive position taken by GLB, and the pronounced frustration with the rapidly escalating volume of reports, plans, assessments and involvement’s needed to apply for a licence was not unique. The general director of The Norwegian Water Resources and Energy Directorate (NVE) at the time, Vidkun Hveding, wrote in his yearly report in 1974 the following, looking back at the way things had developed and with reference to the fact that large development projects in Jotunheimen and Saltfjellet now had been postponed:

“However, we see today that what used to be a disagreement towards the plans, and a resistance towards decisions, have developed into a resistance against the planning itself and against embarking upon a public treatment at all” (quoted from Thue 1996:81 - our translation)

In NVE the opinion was that the Parliament and the Government had backed off from the responsibility they had of taking a decision in cases where one on beforehand knew there are crossing interests. The situation was so severe, that the General Director in NVE receded from his position in protest against this situation.
GLB had already experienced some skirmish with rather scattered environmental groups in connection with the regulation plans being developed for Gjende, Sjoa water course and for Lake Bygdin around 1918 -1920. Opposing these plans were an alliance of natural scientists, of outdoors and recreation interests and some parts of the local community in the planned development area (Thue 1996:72). The conflict reached the public debate, but later faded away.

5.11 Criticism in the 60s, 70s and 80s and changes of the decision making system

Growing tension

The large and small and above all many projects, in the 50ties and 60ties, were carried through without much resistance or opposition. This also applies for the activity in the G&L-basin.

At the end of the 60ties criticism grew. Criticism focussed on several large projects (to name the most prolific ones - all outside the G&L-basin (Nea, Bykil, Femund, Aurland, Grytten) that were up for licensing in the same period (Haagensen 1984:18). Some of the projects where turned down (Femund, Bykil), others got their license (Aurland, Grytten, Nea). This period witnessed the formation of new and strengthening of old organisations sceptical to the prevailing hydropower policy and decision making system. In the development of one of these projects (Grytten), Norway also got it first project based anti-organisation, the so-called Mardøla-campaign. This resistance used both political and scientific argumentation, but also physical resistance based on non-violence ideology. The philosopher Arne Næss was one of the campaigners, and became a front figure in the ideological critique of hydropower policy.

The Mardøla-campaign was the first in a series of project based campaigns in the years to come (Projects in Femund, Aurlandsdalen, Innerdalen, and more had all their campaigns). The campaign-phenomena attracted considerable attention from the media, and added to the growing tension in Norwegian society in the late 60ties surrounding hydropower projects.

It culminated and peaked in intensity and general importance with the Alta-project, a case that dominated the hydropower policy debate for a long period. These cases had "everything" and more so than any other hydropower conflict in Norway. This applies to the political conflict and preoccupation, broad involvement and mobilisation on both sides. It applies to longevity of the conflict, media attention, the rights of the indigenous people (The Sami people), and conflict between central state and local municipalities (Parmann 1980, Haagensen and Midttun 1984, Dalland 1994) and the use of civil disobedience. The Alta-project was on several occasions brought forward to the Government and Parliament, and aspects of the decision making process were brought forward to the Supreme Court. In the “final showdown” in 1982 the government had to use a substantial police force (the number of policemen stationed at the site peaked at 600) and equipment from the army to physically remove 800-900 demonstrators chained together at the remote construction site in harsh winter conditions. This project is still highly contested, and demonstrated for all the deep divides on hydropower policy. Once again hydropower policy came to reflect differences in value systems challenging traditional party politics and indicating an erosion of the post-war consensus on the prime importance of economic growth through utilisation of natural resources over nature conservation. The project initiated a general debate on decision making system in Norwegian public life and state apparatus (Burns and Midttun 1984, Midttun, and Andersen 1984).

There is a need for balancing out the picture painted above: Not all, and not even all large hydropower projects came under heavy and well organised resistance from the environmental movement in the 70s and 80ies. Statskraftverkene (now Statkraft SF), the state owned company for developing, owning and running hydropower plants carried out two large projects in the mid 70ies (Ulla-Førre and Eidjford...
Nord with a 88 km² dam). Despite the fact that both projects had substantial environmental consequences, they were carried through without any noticeable opposition. It is beyond the scope of this report to investigate into the reasons for why some projects sparked resistance, while others got in the clear. What it does show, is that public awareness and opposition is not only a function of the size of the project or a function of the magnitude of environmental consequences - other factors must play a role to. Local support, symbolic value and the economy of political communication in society (you cannot mobilise the public for concerted political action for more than a limited number of projects at the same time), are probably some factors of importance (Haagensen 1984).

Haagensen (1984) has shown that the project-based campaigns were organised on ad hoc basis. They are characterised by improvisation, lose organisation, idealism, and small financial resources. They are typically spontaneously organised grass-roots movements that dissolve when their project-specific mission is achieved.

We have to return to this question, when discussing specifically development of the G&L-basin. What the discussion above demonstrates is that the great divide opening up in the late 60s, the 70s and the 80s was focussed around large hydro-development schemes. None of these controversies relates directly to the G&L-basin. As we shall see, these conflicts initiated a substantial reform of planning and decision making in the national hydro-policy. The G&L-basin piecemeal, low profile, mainly small-dams and modest regulation of natural lakes, did not come under the fire of environmentalists until the case with the river Øvre Otta, which is discussed in section 5.18 below.

**Some elements of the critique**

The criticism from the nature conservation movement aimed at water management and at hydropower policy as such. All parties had acknowledged hydropower as “clean” energy. The dispute early on centred around the effects many types of hydropower production schemes had on nature and society, and the “housekeeping” of energy (efficiency of production, transmission and consumption, the use of high quality energy like electricity for purposes like heating). The criticism initially aimed at three elements in Norwegian water management politics and decision-making apparatus (Raaheim 1985):

- The very decentralised and thematically fragmented system of water management politics at ministerial level. The main argument was reflecting a growing ecological awareness on rivers and lakes as holistic units incompatible with the fragmentation in policy and decision making. Water management system should, in a holistic ecological manner, address all water use affects all other water use (Albrechtsen and Moum 1984). The, more than a handful of ministries that had their specific responsibility regarding water use, and the lack of a single ministry or agent acting “holistically” on behalf of the government, promoted ecologically unsound management. The consequence of this, the critiques said, was the lack of a unified water management policy, and a bias towards hydropower production purposes in national water management politics.

- The very centralised and “technocratic” nature of the energy administration at the sub-ministry level. The Norwegian Water Resources and Energy Directorate (NVE) was the single focal point of technical, operative and prognostic knowledge, of formal and informal power, of planning, of policy formation and of having a de facto monopoly in developing argumentative and rhetorical skills in dealing with “the other side” - typically local communities and nature conservation interest (Lorange Backer 1984). Further, was given a dual responsibility, both as a responsible water resource management authority supposedly taking into consideration all aspects of water resource management, and as an agency responsible for the economy and safe supply of electricity to the national grid.

- The ideological critique of a society allegedly obsessed with economic growth depleting natural resources.
5.12 Changes in the licensing system

Three changes were made in the licensing procedures in 1969:

- Public notification of the intention to apply for a licence was introduced to improve transparency of and stakeholder participation in the process.
- A demand for more comprehensive impact assessments of both nature and society to be carried out as part of the application process.
- An obligation to propose measures and/or alternatives to avert or mitigate negative impacts on nature and society of a project.

The Watercourse Regulation Act now obliged the applicant send a notification to The Norwegian Water Resources and Energy Directorate (NVE) before initiating the planning process. The notification is published as an open invitation to parties with vested interest of specific or general nature to comment on the plan, with the aim to reduce conflicts by improving transparency through giving an early warning to all stakeholders. The notification is also the starting point for a scooping process, defining the need for more extensive assessments of environmental and societal impacts of the project.

The licensing procedures were further developed in guidelines devised by The Norwegian Water Resources and Energy Directorate (NVE) during the 1970s and 1980s, regulating in detail the content of the application, including environmental impact assessments (EIAs) and guidelines for public information duties. In 1990 the EIA procedures in the Watercourse Regulation Act and the general Watercourses Act were incorporated in the Planning and Building Act. The present flow scheme for the decision making process according to the Planning and Building Act is as shown in the figure in Annex 8.

Licenses can be granted for a limited or unlimited time period. The practice so far is that the licenses are given a time limit of 60 years for private enterprises and for an unlimited time period for publicly owned enterprises.

All licences are given on conditions that regulate the relationship between the licensee and general public interests. Some conditions follow directly from obligatory provisions in the Watercourse Regulation Act, while others are customised individually for each license based on an assessment of the project.

Provisions for revision of conditions were first made part of the Watercourse Regulation Act in 1959. The time period for revision was originally fixed at 50 years for licenses granted for an unlimited time. The provisions were not made retroactive, and in consequence only licenses granted after 1959 contain provisions in the conditions concerning revision (after 50 years).

On the basis of a legislative amendment in 1992, the interval for revisions for all licenses was changed to 30 years. This amendment was given retroactive effect, so that both time-limited and unlimited licenses can be submitted to revision 30 years after the license has been granted. With the legislative amendment, a "transitional rule" was created, which gives the authorities the right to reassess the conditions for a number of previously granted licenses with an unlimited time period, which were granted pursuant to the Watercourse Regulation Act.

The following possibilities presently exist with regard to changing the conditions of an approved license:

- When the license contains conditions concerning revision access.
- When the law permits access to revision of conditions.
• With the administration’s non-statutory access to revision. This is a form of the principle of necessity. There is accordingly no basis in the law, but it is a right on the part of the administering authority to intervene in the event of unexpected circumstances that clearly need to be addressed.

• Most flow schemes also contain a provision allowing the licensing authority to implement at any time the necessary amendments, in cases were the scheme leads to significant damage to public interest which were not considered at the time of licensing.

The licensee can at any time apply to have the license or the conditions amended.

For the time being, the authorities have handled no cases, but for several of GLB's license cases, a motion has been forwarded for the revision of conditions. In this case, the motion is first of all based on an adjustment of the flow scheme and a wish for an increase in minimum water-flow.

5.13 The Protection Plan for Watercourses

In 1960 the Parliament took initiative to establish the first comprehensive plan for hydropower development of the water resources. The background was the large number of hydropower projects being forwarded for licensing to the Parliament in post-war Norway, and a growing frustration among politicians for having to deal with these applications one by one. What was needed was some sort of a master plan or comprehensive plan as a backdrop for granting individual licenses. What the Parliament was looking for was a political development plan. What they got was something a bit different, a Protection Plan for Watercourses (Berge Larsen 1999).

The “rules” for which watercourses that should be included in the plan have been the following (Berge Larsen 1999):

• The watercourses with the areas around should be representative for the nature in the region. The protection plan should include both "typical nature" and "special nature" for a region. The plan should include a variety of watercourse sizes. Some should be located in wilderness areas.

• The plan should include watercourses in all the regions in Norway, but priority should be given to watercourses that lie close to populated areas.

• The total protected potential should not be of a size that will cost too much for the country.

• Other types of encroachments should not deplete the protection values in the localities. The authorities have in the last 10 years taken steps to better implement the last rule.

In the period 1973-93 four Protection Plans passed the National Assembly. The intention with the plans is to shield especially valuable rivers, lakes and waterfalls from hydropower development projects. This to ensure that variation of nationally “representative” watercourses and their elements can be utilised for outdoor recreation, for research and education, and as a reference for the long-term “natural” development of “pristine” watercourses. The Ministry of Petroleum and Energy and The Norwegian Water Resources and Energy Directorate (NVE) administrates the plans, an arrangement that has remained in spite of the formation of the Ministry of Environment in 1972.

Protection Plan I passed the National Assembly in 1973, giving permanent protection to 95 watercourses (or parts thereof), with total potential production capacity of 6,9 TWh, and temporary protection (10 years) to 8,1 TWh-worth of production potential. Protection Plan II was passed in 1980, adding 51 objects (2,6 TWh) to the list of watercourses permanent protection. Protection Plan IV passed the Parliament in 1993. In total 341 water courses (or parts thereof), with a potential production capacity of 35 TWh, are presently protected under this planning system against further hydropower development. However, some of these watercourses had already been subject to some hydropower development by the time the protection plan was decided. Such power plants and reservoirs could continue to run and be maintained.
A full list of the objects in the G&L-basin presently included in the Protection Plan, is given in Annex 3, table 3.2.

The protection is political, and not legal. Protection depends on a simple majority vote in the National Assembly. The decision to protect an object is to be understood as an instruction to the Government as to how a possible license application shall be concluded upon. A new vote in the National Assembly can at any time alter a status as protected object. There is an ongoing debate on whether the status as a protected object should be included in a new revision of the water resource act.

The protection plan system has been welcomed by the environmental interests, and has spurred little controversy. The Government has with authority from the Planning and Building Act set out National Guidelines for the utilisation of protected watercourses or parts thereof. These guidelines put down general limitations also on other activities than hydropower development carried out in the protected watercourses.

5.14 The National Park system

In the 70s and 80s there was a quite substantial growth in the areas protected as National Parks under the Nature Conservation Act. This has also had an impact on hydropower policy, with the consequence that several large power projects had to be abandoned (for example Veig and Dagali watercourses in the Hardangervidda national park).

There are three National Parks, and some smaller protected areas in the G&L-basin. The largest ones are located in the North-Western part of the basin. They are Jotunheimen National Park, Rondane National Park and a part of Dovre National Park. See figure 5.7 below.

![Figure 5.7 National parks in the G&L-basin](image)

5.15 The Master Plan for hydropower development projects

Around 1980, and in parallel with the process of producing Protection Plan II, the question was raised as to make a plan for the development of remaining rivers and waterfalls with a hydropower potential. The work with the first generation Master Plan commenced in 1981. The Ministry of Environment (MoE) headed the work in collaboration with the Ministry of Petroleum and Energy and NVE. This
somewhat unexpected administrative arrangement has a counterpart in the fact that the Ministry of Petroleum and Energy administers the Protection Plan for Watercourses (see above). The administrative configuration is probably partly historically conditioned by the fact that when Ministry of Environment was established in 1984 there was some forces working to give the new ministry a role as a nature resources management unit. The Master Plan for hydropower development projects fits this strategy, and may be considered one of the more successful results of this strategy, which later was abandoned.

The goal of the planning process was to present a priority grouping of hydropower projects for subsequent consideration for licensing. The emphasise on projects in the Protection plan are in contrast to the whole catchment area of the rivers evaluated in the Protection Plan system (see above). Priority should be given to projects most favourable from both an economic as well as an environmental viewpoint. A special methodology was worked out to group the projects (see below). The plan should also provide a basis for considering which watercourses should be used for other purposes than hydropower. The aims with the Master Plan are:

- to get a comprehensive or unified approach to the national watercourse development strategy,
- to get a better foundation for sector planning within other fields of activity influencing or being influenced by hydropower policy,
- to get a broad based, systematic, comprehensive and casuistic assessment of the other user interests involved in the various projects, and
- to get a more unified approach to decision making in particular projects.

The Master Plan was first accepted by Parliament in 1986. The plan has been rotated twice since then, based partly on prognoses of the national energy balance and new data on the hydropower projects. The last rotation passed the Parliament in 1993 (St meld nr 60 (1991-92)), in parallel with the adoption of Protection Plan IV. A new rotation of the Master Plan is possibly to be undertaken in 2000/2001.

The Master Plan sets out an order of priority for the consideration of individual hydropower projects on the basis of economic considerations and the degree of conflict with environmental and other user interests. The Plan is thus intended to assure that those projects which can provide the cheapest power, and which have the smallest environmental impacts, are developed first. The projects are referred to a priority list with the following categories:

- Category 1: Projects that are open for a license application, currently containing projects with a total potential of 16 TWh. It is up to the power companies to decide whether to send an application or not, based on economic considerations, supply demand and so on.
- Category 2: Projects that are not open for a license application, but who the authorities are in principle prepared to deal with at a later date. This category currently contain projects with a total potential of 9 TWh. Originally the Master Plan system contained a category 3 representing the most conflicting projects from an environmental viewpoint. Several of the projects in category III however were in rivers that were protected in the Protection Plan (see above) in 1993. The rest of the projects in category 3 were in the last revision included in category 2 (Berge Larsen 1999).

The methodology applied initially construct a value for the area before development for a selected set of user interests. These are most commonly the following:

- Nature conservation, recreation interests, fishing and wildlife (key words: geology, landscapes, botany and zoology, aesthetic experience, walking, canoeing etc., salmon, trout, science, fishing, salmon, trout, science, fishing)
- Water supply and quality
- Cultural heritage sites
- Agriculture and forestry, and reindeer husbandry
• Flood protection and erosion, ice conditions and climatology

In subsequent analytical steps the following procedure is then carried out:

• A preliminary qualitative evaluation by project of the expected impacts of the development on a wide selection the user interests, as shown in the list above.

• This is then summed up on a quasi-quantitative scale (ranging from -4 to +4) showing impacts in the master plan for the various interests project by project.

• The various impacts series are then weighted and aggregated, and arranged into a matrix that groups the collective impact "profile" by project and user interest for all the assessed projects.

• To this are then added economic indicators for development and operations costs. Taken together with data on impact profile, a preliminary ranking list is then constructed. This ranking is intended to reveal the relation between cost of development and impact profile.

• In the last step, adjustments are made for impact on certain regional economy aspects, for comments received in the hearing, size of project etc. Each project is then given a final ranking as belonging to one of the two categories described above, Category 1 and Category 2.

Being referred to Category 1 does not mean that the authorities have made an advance commitment to grant a license. Being referred to Category 1 is only a commitment to process a license application.

For Category 2 projects there are provisions in the Watercourse Regulation Act and the Water Resources Act which provide the licensing administration with the authority to postpone the processing of applications which, pursuant to the Master Plan, should not be considered for licensing at the present time.

The Master Plan was from the outset a contested tool in hydropower policy, and it remains a debatable question if the plan has had a conflict reducing function or not in the controversies over power policy issues. The opposition against The Master Plan as a tool in hydropower policies is also found within the hydropower industry and within the hydropower policy administration. As can be seen below the GLB for one, was not content with the planning process and outcome in the first Master Plan produced in 1984. The proponents of The Master Plan underscore the conflict moderating effect of the plan, the democratic qualities in the openness of the production of the plan and the comprehensive and coherent perspective it offers to resource management. There is presently a wide political acceptance in the political parties towards a favourable attitude to The Master Plan system. One should also keep in mind that the major part of the hydropower potential was developed before the Master Plan was established.

A full list of projects in the G&L-basin included in the present Master Plan, is given in Annex 3, table 3.1.

5.16 GLB and the G&L-basin through the 70s, 80s and 90s

The Protection Plan entailed the protection of 27 items in the G&L-basin (see Annex 3). This protection does not appear to spur objections in GLB on a large scale (GLB 1995:105). In this period the resources of the association was more focused on the Master Plan than the Protection Plan (GLB 1995:107).

GLB was not satisfied with the involvement in the production of the Master Plan in 1984:

“GLB tried to influence the Master Plan in an early phase, and made its statement on 25 watercourse reports with a total of 68 development alternatives within a very tight time schedule in some hectic summer months in 1985. The share volume of projects and the very limited time available made a responsible treatment hopeless and a comprehensive assessment...
within the G&L-basin impossible. GLB received the final Master Plan draft for a hearing 1st November 1984, with a deadline set to 15th of November. This resulted in GLB being unable to prepare the comments thoroughly and unable to present the comments to the board, as assumed. ... the final product did not attain the desired level of quality. ... The project therefor got a placing in the categories of the Master Plan that can appear to be at random. In stead of becoming a guiding plan for the work ahead with license processing, the Master Plan became, as pointed out by GLB, more of a development and protection plan. GLB also pointed out the unfortunate effects of assessing several of the projects with new regulation reservoirs as conflict-ridden. ... The selection of projects the Master plan was supposed to prepare for license processing would according to this proposal contain many small projects with mainly unregulated summer-power, something being assessed as not very interesting as viewed from a developer perspective.” (GLB 1995:107 - our translation)

The offensive position taken by GLB, and the pronounced frustration with the rapidly escalating volume of reports, plans, assessments and involvement’s needed to apply for a licence was not unique. Looking back at the way things had developed, and with reference to the fact that large development projects in Jotunheimen and Saltfjellet had been postponed, the General Director of NVE at the time, Vidkun Hveding, wrote the following in his 1974-Year Report:

“However, we see today that what used to be a disagreement towards the plans, and a resistance towards decisions, have developed into a resistance against the planning itself and against embarking upon a public treatment at all” (quoted from Thue 1996:81 - our translation)

In NVE the opinion was that the Parliament and the Government had backed off from the responsibility they had of taking a decision in cases where one on beforehand knew there are crossing interests. The situation was so severe, that the General Director in NVE receded from his position in protest against this situation.

In the G&L-basin the Master Plan after 1993 included 19 projects in Category 1, and 17 projects in Category 2. In 1995 GLB reports that:

“Of the category I projects, the license application for Øvre Otta is in preparation” (GLB 1995:108).

In the period 1970 and 1980 and early 1990’s, GLB, or the various owners, developed the following projects:

- Developing and starting the operation of Rendalen Power Plant in 1971.
- Skjeftadfoss II Power Plant developed and put into operation in 1972.
- Developing and putting in operation Sarp Power Plant in the period 1974-1978.
- Developing and putting into operation Kongsvinger Power Plant in 1975.
- Development and putting into operation Bingsfoss Power Plant in 1978.
- Developing and putting into operation Braskereidfoss Power Plant in 1978.
- Developing and putting into operation Strandfossen Power Plant in 1979.
- Upgrading the power plant at Eidefossen in 1980.
- Developing and putting in operation Osa Power Plant in 1981.
- Ránåsfoss Power Plant rebuilt in 1983.
- An upgrading of Viŋksjelv power plant in 1983- not a member in GLB.
- Development and operation of Mesna Power Plant in 1984
- Mørkfoss/Solbergfoss upgraded in 1985
- A major upgrading of Vamma Power Plant finished in 1995.

The location of these projects is shown in figure 5.8 below.

![Figure 5.8](image-1.png)

**Figure 5.8** Power plants (black dots with left hand labels) and reservoirs (white squares and right hand labels) developed or upgraded since 1970 in the G&L-basin.

The list of projects shows that the development and upgrading activity has not been inconsiderable in the period. Very few of these projects have, however, been entailed by conflicts of the kind that otherwise characterised the period, which makes it reasonable to assume that changes in Norwegian hydropower policy have effected planning and decision making in this period. Seen from a developer point of view, the changes made the planning and licensing process more cumbersome, in particular for large development projects which included new reservoirs and dramatic regulations of water flow. On the other hand, the changes probably made only minor changes in the *modus operandi* for a small-scale piecemeal development and operation of the type we have in the G&L-basin.

### 5.17 The liberal shift in electricity markets - consequences for planning and decision making

Norway, like other Nordic countries, is an electricity-intensive country with an abundant supply of cheap electricity. The per capita electricity consumption in Norway was approximately 25,000 KWh in 1994, more than three times the EU average (OECD 1994).

The energy sector in Norway, as in most other European countries, has been managed in a planned-economy approach, with dominant monopolistic structures.
Since the beginning of the 1990s north-western Europe has seen a shift towards liberal electricity markets. The shift has been selective and distinct differences between countries can be observed. The Norwegian market reform was introduced in 1991 (The Energy Act 1990), and was a frontrunner together with the English and Welch privatisation in 1990 (Midttun 1997). One reason for the frontrunner position for Norwegian electricity markets is probably the favourable position with the ability to produce low-cost electricity expecting to be competitive in a free-trade situation.

The basic idea in the Norwegian reform is to split up the various functions in the electricity system according consequences to be expected when exposing them to competition. Functions with natural monopoly characteristics were to be organised as regulated monopolies, while others to be exposed to competition. The latter included production and trading, the former transport, transmission and distribution (Midttun 1997:92). For a discussion on the reform, see annex 4. The reform did not fully implement a 100% free trade model, but introduced competitive elements into a cost-based supply-oriented system.

The earlier regulation regime operated with a dichotomy between market and hierarchy, with bundling of services, geographical segmentation of markets and so on. The new regulation menu is more refined. It is now possible to dissect formerly bundled services and to expose some of them to market competition and regulate the remaining parts with a more refined regime of regulatory tools. But there are important factors with a view to planning and decision making in hydropower policy the reform did not change, making important aspects of the “old” regime in operation:

- Ownership structure did not change, meaning that the main part of the system remains public.
- Licensing or concession rules did not change, which strongly disfavours privatisation.
- Transmission, production and trade functions can be integrated into the same company unit at the regional and municipal level.
- A foreign long-term contract-based trade regime was kept in place, while a pre-reform Nordic spot market for occasional power was opened up. The intention was to secure a reservoir management marked, and market for direct sales to large distributors or consumers. This marked quickly established a bilateral reference market.

The Energy Act quickly affected the information strategies in the industry toward the public and towards each other. Information on the water resources in the river basin is regarded commercially sensitive in a competitive situation. GLB, as other companies, are today much more restrictive about this kind of basic price-forming information.

We have still to see the impact of the liberal shift on planning and decision making in hydropower policy. The Norwegian Water Resources and Energy Directorate (NVE) has experienced a considerable decrease in the number of license applications since the introduction of the energy law. This is probably both due to the market situation with fairly low prices making investments in new projects difficult, and to the fact that the new regime has initiated a re-organisation within the industry temporarily giving project development a lower priority.

The rotation of both the Master Plan and the Protection Plan in 1993 did not seem to deviate significantly from the pre-liberal period. A new rotation will probably be undertaken in 2000/2001. Still, it is a fact that basic elements in the context of planning and decision-making have changed. This has altered the frame for the policy discourse between the parties in an issue that has attracted much attention and periodically represented a major conflict-line throughout the 20th century. It should be expected it to take some time before the new regime exerts a feedback on the policy making process, and before the new situation is visible to the actors at the policy arena.
5.18 A case study extending to present days: The development of the watercourse Øvre Otta (River Upper Otta)

5.18.1.1 The first development plans, alternatives and revisions

GLB had in 1948 been given a licence to regulate Breidalsvatn in Jotunheimen (see map in figure 5.9). The operation of the reservoir was made with a view to increase winter power production downstream the whole Lågen branch of the basin. The reservoir has been upgraded several times over the years. There had been some controversies with the landowners Skjåk Allmenning (a common) and Skjåk Municipality, but this had by the end of the 1980ies been settled through monetary compensations and decision made by central authorities.

GLB had in 1948 also been given a licence to regulate Raudalsvatn just to the south of Breidalsvatn. The operation of this reservoir was and is part of the same management scheme as for Breidalsvatn (see paragraph above).

With the investments made in these reservoirs (the rationale of which was primarily plants a fairly long distance downstream) and with several other resources in the area, there is a hydrological and economical potential for developing more hydropower in the eastern part of the Jotunheimen mountain area. The same was the case for the Jotunheimen mountain area to the west of the water shed. And this sets the scene for the debate on how to develop the River Øvre Otta (The Upper Otta River) with its tributaries.

In 1966 it was decided by The Norwegian Water Resources and Energy Directorate (NVE) to make a comprehensive assessment of how to develop the water resources in the Jotunheimen mountain area in the most/a more efficient manner. GLB expected the outcome of this process to be a series of project plans embracing the north-western part of the basin area (GLB 1975:240). This involved an extensive

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development of the river Øvre Otta with several side-rivers. It extended north along the west side of the river picking up all the side rivers from the centre of Lom to the river Tora.

In the G&L-basin, most of the actual projects would be situated in the municipality of Skjåk. The plans were, in 1970 and while still in a relatively early phase, presented to county and municipality administrations, and to a selection of the right owners of prime importance. The meeting gave a green light for further planning along the lines presented. In the G&L-basin this resulted in two alternatives:

- Alternative 1 had two main elements. First there was the transfer of water from Øvre Otta to an adjacent watercourse in the west, to be developed in a comprehensive projects there. This part of the project comprised in regulating all the rivers from Tora in the north to Tundra in the south. Then there was an autonomous development of one power plant regulating the resources of the watercourse Bøvra and Sjøli, both side rivers to the river Otta.
- Alternative 2: The resources in the G&L-basin should be developed within this basin, and there should be no transfer of water over the water shed to the adjacent basin in the west of Jotunheimen. Within the basin there was foreseen an extensive development and regulations of all the rivers smaller lakes from the most northern part of the basin at Torsvatn, along the west side of the basin all the way south to Bøvertunvatn.

Both alternatives involved the development of two larger reservoirs, one in Raudalsvatn and one in Breidalsvatn. Apart from this, the various alternatives were entailed by other reservoir developments specific to the alternatives. NVE-Statskraftverkene sent, in 1973, an application for a license on both of these alternatives. They were given the same standing, NVE-S’s preference being Alternative 1, and GLB’s preference being Alternative 2.

In this period, around 1975, Lake Mjøsa was threatened by eutrophication (see cap. 3.3). An extensive state financed programme to clean up the lake was undertaken. Alternative 1 meant that large amounts of water would be diverted from the Lågen water course significantly reducing the water flow in the basin and subsequently the yearly flushing of the lake in the spring flood. This would in itself worsen the condition in Lake Mjøsa, and the license applicants thus had reluctantly to pull out Alternative 1 from the process of concession granting.

Not surprisingly Alternative 2 also stirred up a lot of discussions with the environmental movements. The opposition towards new large reservoirs and regulation schemes in the Jotunheimen mountain area was fierce. In 1977, Oppland County Administration, it self a part owner of K/L Opplandskraft, one of the major players in the license applicant team, asked NVE to consider a stepwise development of the watercourse in Øvre Otta. NVE-S presented such a plan in 1978 (hereafter referred to as Alternative 2, revision 1). The idea was in the first step to develop the power plants in the plan, and at a later stage to develop the reservoirs and more extensive regulations. The plan gave mainly summer power, something the regional interests, including GLB, was dissatisfied with.

We cannot go into the details from here, but the developments in the project promotion in these initial years could be summed up as a diversion from two bearing visions in the development idea as it was originally formulated. It was launched as a comprehensive development idea of the Jotunheimen mountain area across the water shed in mid 60s. Through the late 60s and early 70s two visions was abandoned, both mainly on the environmental grounds (or at least as a result from discussions or confrontation with environmental interest groups):

- the vision of embracing the whole area in one comprehensive development plan - a sort of master plan for the area across the water shed, a grand all encompassing inter-basin development plan
- the vision of planning, licensing and developing power plants, reservoirs and regulations in one sweep - necessary to produce the precious winter power, as opposed to the summer power which at least the applicants in the region (GLB included) had less interest in.
Needless to say, this was ambitious in those days with an environmental movement on the move.

But it was not only about the environmental movement. The municipalities themselves had in mid 70s started to take a more offensive attitude towards the development interests. In GLB’s most recent major report, the following passage describes and reflects on the feeling of the change of attitude in licence processing experienced by developers in the mid 70s:

“The processing of the licence application triggered a considerable activity, and planners in NVE-S had to satisfy with information an increasing number of municipalities and interest groups that came forward. The need for information continued to grow as every new report and inquiry released by the developers was meet by new requests and demands.

Even the municipalities established a new practice. Before, they did not wish to be “influenced” in their own treatment and processing of the matters at hand, and consequently had a very limited contact with the developers. Now they often contrived to make contact with demands about negotiations on compensations and liabilities of various sorts, about specific reports from regulators and developers on the effects of regulations and effects on economic life” (GLB 1995:93, our translation)

As mentioned, the step-by-step development plan proposed in Alternative 2 revision 1, mainly gave summer power. In 1986 the regional interest groups presented a new revision of the development plan; Alternative 2 revision 2.

5.18.1.2 The Upper Otta Watercourse in the Master Plan

By now the first Master Plan was being in the final phases of preparation, and all the existing alternatives on development in the basin was presented and assessed.

The alternative with development of the Otta river with several power stations along the river assessed as most favourable, and thus

“... was in reality the idea about one large jointly run operation and all the hard work put down in this respect put an end.” (GLB 1995:95, our translation)

The parties split up, and licence applications based on the joint perspective was called back. NVE-S pulled out of the project, and the remaining regional companies did not manage to join up in a common development plan in spite of attempts.

The Master Plan 1984 placed two power stations in the upper part of the river Otta, now called the Upper Otta project, in Category 1. The rights to the falls belong to the power companies K/L Opplandskraft (80% - and an important member of GLB) and A/S Tafjord Kraftselskap (20%). GLB had already acquired a reservoir license for parts of the area, and an additional regulation license could easily enhance the production capacity in the envisaged power plants, and subsequently in all the power plants down the Lågen and later on Glomma river. The potential was substantially reduced compared to the plans originally envisaged, but was still substantial and with regulation effects well visible in the landscape.

In 1992 the developers forwarded The Norwegian Water Resources and Energy Directorate (NVE) a notice on planning activity in accordance with the Planning and Building Act (see Annex 8 for the flow scheme of the decision making process according to this act). In the last rotation of the Master Plan the Upper Otta project was moved back to Category 1.
In this process the extension of the project changed as an outcome of Master Plan processes and protection plan processes. By now a considerable part of what was originally conceived as the Upper Otta project (see above) had been protected according to The Protection Plan in 1984, and later revisions. Parts of the area had also been protected against hydropower development according as National Parks according to The Nature Protection Act. Through these processes approximately 2/3's of the technical potential of about 3 TWh had been protected before the application for a license finally was sent. This, as we shall see, was not enough to short-circuit political controversy in the licensing process, which still became quite dramatic.

The application and licensing

Early 1996, the power companies Kraftlaget Opplandskraft and Tafjord Kraftselskap (presently Tafjord Kraft AS) together with GLB, put forward a licence application for the Upper Otta project. The application comprised development and operation of the power plants Glitra and Øyberget, and transfer of several watercourses in Upper Otta to the already existing regulation reservoirs in Breidalsvatnet and Raudalsvatnet.

The project as applied for is fully located in Skjåk municipalities, while the projected transmission lines runs through the municipalities Skjåk, Lom and Vågå. The planned production of power was 1049 GWh/year. The total costs are calculated to NOK 2 billion. The more moderate and scattered step-by-step development now applied for, as compared with the original plans of a joint comprehensive all-in-one-sweep-development of The Jotunheimen Mountain Area, was still quite favourable in economic terms. Further it had interesting enhancement potentials for those who could afford to wait. And it had already passed the Parliament in the Master Plan twice.

The comments to the application can be summed up as follows (St meld nr 50 (1997-98)):

- NVE supported the licence application on the grounds that the power produced came at a very favourable economic cost, required no major new regulations, and made a substantial contribution to the national supply. NVE acknowledged the detrimental effects on the landscape and on the attractiveness for tourism and outdoor life in general caused by the reduction in water flow.
- The Ministries either had no remarks or supported the licensing of the project. This even applies to the Ministry of Environment, even though they had some minor remarks, and set some minor conditions for their support.
- The Oppland Regional County supported the project plans.
- Skjåk Municipality supported the plans, while the municipalities downstream, Lom Vågå and Skjåk, opposed them with reference to the damaging effects of the power lines (Lom, Vågå) and the negative effects on the water course below the plants (all three municipalities).
- All the NGO’s involved, Den Norske Turistforening, Friluftslivets fellesorganisasjon, and Norges Naturvernforbund, all opposed the development plans.

The Ministry of Petroleum and Energy turned down the license application in a letter to the applicants dated 23 February 1998, which reads - in extenso:

“The Ministry refers to the application dated 03.01.96 on the necessary licence for construction and operations of the power plants Glitra og Øyberget, plus various transfer of water between watercourses in the River Øvre Otta. The Ministry received the recommendation from NVE in a latter dated 10.03.97. The recommendation has been circulated for comments from the municipalities concerned other public agencies and organisations. Representatives from the Ministry have taken part in the survey in the area concerned.

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The Voksenåsen Declaration (the inaugural declaration from the Government, comment of the translator) provides the basis for the politics of the Government.

In this declaration it is stated that the Government will oppose development of the Øvre Otta watercourse.

This statement in The Voksenåsen Declaration is a follow up of the position taken by the Parliaments minority vote on permanent protection of The Øvre Otta Watercourse in connection with the handling of Protection Plan IV for watercourses, see St. prp. nr. 118 (1991-92) and Innst. S. nr. 116 (1992-93). The minority proposed in Innst. S. nr. 116 (1992-93) that the rivers Tora/Føysa (in The Øvre Otta Watercourse) should be protected under Protection Plan IV.

After having performed a comprehensive assessment the Government has concluded that the considerations towards nature and the environment must be given a decisive importance at the expense of what the development would entail in increased power supply. The Ministry views the damages and disadvantages for the common interests to exceed the benefits from the regulations and developments.

On this basis the application for a license is refused.

The Ministry draw attention to the fact that according to The Law on Watercourse Regulation § 8, gives the opportunity to demand the refusal put before the Parliament.” (Our translation)

As can be seen, the Government put more weight on the environmental issues and general public interests than any of the sector departments separately, and more so than the regional administration.

One aspect of the situation is that the government had in their inaugural document committed themselves to oppose the Øvre Otta project. This is reflected in the quote above. Still, in politics there is often a way around inaugural positions. The development plan as finally applied for was quite different from the earlier scenarios. The project for which a license was finally given was even further removed from any scenarios presented earlier. This shows there was room for manoeuvres to reconcile governmental politics and the hydropower lobby. When this did not happen, "credit" should be given to the con-development lobby.

In the period 1997 to 1999, there was, however, a very well organised resistance against the plan. It is obvious that the environmental interests had done a good job in lobbying their case, and that the developers had done a less successful job. The environmental interests had both worked through well-established NGO’s and through a dedicated campaign organisation.

The developers made it very clear that any cuts in the projects leading to a less comprehensive projects, would make it totally uneconomic - it was either the project as applied for or nothing.

5.18.1.3 The appeal to the National Assembly

The applicant made an appeal to the Parliament, based on the appropriate paragraph in the Watercourse Regulation Act.

1st June 1999 a majority in the Committee for Energy and Environment recommended partly in favour of the applicants, but made a quite substantial cut in the project (Innst S nr 200 (1998-1999)). A transfer of water from all side rivers in Billingsdalen (Tora, Føysa, Vulu, Måråe, Åfotgrove and Glitra) and a transfer tunnel to Breidalsvatn was taken out of the project. The argument for making these cuts in the project was mainly environmental. With these amendments the expected production of the

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project would be halved to 544 Gwh/year the National Assembly decided as recommended by the Committee.

A project twice included in the Master Plan had been substantially reduced, despite that the applicant beforehand had made it clear that such cuts in the project would make it uneconomically and uninteresting for the developers.

To cut that story short, the applicants have now changed their mind. These days a new application based on the Parliament's decision has been forwarded to NVE. Expected production is 525 GWh. Organisations and institutions concerned are now to be heard, and a recommendation from The Norwegian Water Resources and Energy Directorate (NVE) will be forwarded to the Ministry of Petroleum and Energy ultimo 2000 (http://www.nve.no).

5.18.1.4 Observations and conclusions on the regulatory framework

The Upper Otta project history leaves room for reflection on, among other things, the interpretation of the Master Plan and the license granting system. The project history, in all its phases, makes it plausible to say that environmental policy in a structural, dynamic and permanent way has altered the scene of planning and decision making for hydropower policy. Permanently as opposed to a mere populist fluctuation of opinions that dates back to the 80s. Structurally in the sense that new policy instruments have been designed with the Protection Plan, the Master Plan and the license granting process (described above). Dynamically in the sense that the balance between protection and development is constantly being contested. In the Upper Otta case the balance in the interpretation of the decision-making system has been shifted towards protection at the expense of development. All in all it seems fair to conclude that environmental and other interests competing with hydropower interests (environmental interests, outdoor recreation interests, tourism, agricultural interests) are given a firm position in the policy making process and in deciding on the particular projects. These competing interests even manage to amend and reform the decision making process for their benefit and “on the march”.

As a result of the Upper Otta discussions and the outcome of the decision making process, the interpretation of the Master Plan system is possibly changing. The Master Plan system still forms that basis for future hydropower planning and development activity. In fact, it would seem quite impossible these days to introduce a hydropower development project that was not in accordance with the Master Plan, and even more so if it was on collision course with the Protection Plan. But after Upper Otta, it is obvious that a position in Category I in the Master Plan is no guarantee for a positive approach from the main political parties in the Government and the Parliament in the license granting process. What this shows, is that the construction of a Protection Plan balancing a Master Plan, as conceived in the 1980s, must be understood as an historical political compromise, an “exhaust valve” in a heated situation altering the scene of hydropower policy making. Altering it, but not stabilising it for the late 1990s and beyond. The system is now being redefined, not through a formal reformulation of structural elements or process rules, but through the political and administrative practice that actually takes place in the system. This might, or might not, at a later stage demand a formal reformulation of some of the elements in today’s system. This remains to be seen. What Upper Otta shows, is that there still is a boom for interests contesting more hydropower at the expense of nature qualities, and that these interests have grown to a broader movement. What is also probably shows, it that the opposing interests mobilise whenever there are new large projects being introduced, while the kind of small scale, running river, piecemeal, “organic”, hydropower development that is a pronounced quality of the G&L-basin is low-conflict the way to go for hydropower interests.
Findings on planning and decision making processes:

- The development of a national regulatory regime may be organised into the following characteristic periods (partly based on Haagensen 1984:17):
  - A pioneer phase extending from mid 19th century to 1906 characterised by development of hydropower production technology and industrial utilisation of this resource.
  - A law and policy formation period extending from 1907 to 1919, combined with an active development activity.
  - An inactive period, extending from 1920 till the end of the 2nd world war, due to lack of financial resources for hydropower production projects.
  - A period from post 2nd world war to end of the 60ties characterised by a large number of projects being undertaken, in a situation where there is almost no opposition to river regulation, dam building and so on.
  - A period of growing criticisms, especially from environmental perspectives, against hydropower development schemes, from the start of the 1970ties to end of 1980's.
  - A period from the beginning of 1990's to present days characterised by several new elements. The most important is the liberalisation of the regulation regime introducing an element of free trade and competition to the industry. Of some importance is also the attention paid to global environmental policy issues through instruments like the global agreement on cutting greenhouse gasses.

- The first major technical interference in the G&L-basin was the first of a series of water level manipulations done by the state of Lake Mjøsa in 1854 and Lake Øyern in 1857-62 for flood protection, logging and ship navigation measures.
- Glommen Brukeierforening (GB) was founded in 1903 as as the first water user association in the G&L-basin. In order to organise waterfall owners and rights holders in the whole of the G&L-basin, Glommens og Laagens Brukeierforening (GLB) - Glommen and Laagen Water Association) was formed in 1918.
- The administration
- The license process
- Protection plans, National Parks and Master Plan for Water Resources
6. The G&L Basin Operation

The operation of the G&L basin as well as of Norwegian river basins in general has changed continuously over the last hundred years reflecting the changes in knowledge, technology and organisation, as well as changes in public decision making and integration of river operation issues in land management issues. Today the operation and management issues of the G& L basin are numerous, involving several governmental institutions with jurisdiction of different acts, different types of planning processes and monitoring, forecasting and research activities. The operation and management also include participation of non-governmental organisations and management of different water user interest by professional associations. The description of the G&L basin operation has a special emphasis on the daily and seasonal operation of the hydropower production facilities done by the G&L basin water management association (The Glommens and Laagens Water Management Association – GLB), and the associated management tasks performed by GLB.

6.1 Basin Operation and Management Issues

The G&L basin, with wide gradients in natural conditions as well as in human exploitation and use, encompasses numerous types of basin operation and management issues. Basin operation and management issues are connected both to changes in basin land use, infrastructure developments, impacts related to development of physical installations in the watercourse and management of different basin user interests. Table 6.1 gives a broad review of the main types of human impacts in the G&L basin, which parts of the basin different activities and impacts take place and the importance of the activities/impacts operation and management issues.

Table 6.1 Human impacts and basin operation/management issues in the G&l basin

<table>
<thead>
<tr>
<th>Types of human impacts / management issue</th>
<th>Areas of specific importance</th>
<th>Importance of impacts/activities in watercourse management</th>
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</thead>
<tbody>
<tr>
<td><strong>Land use changes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Middle and lower part</td>
<td>+++</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Middle and lower part</td>
<td>+++</td>
</tr>
<tr>
<td>Floodplain Cultivation</td>
<td>Middle and lower part</td>
<td>++</td>
</tr>
<tr>
<td>Forest conditions</td>
<td>Middle and lower part</td>
<td>+</td>
</tr>
<tr>
<td>Area disposals in general</td>
<td>Whole basin</td>
<td>++</td>
</tr>
<tr>
<td><strong>Infrastructure development</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main roads</td>
<td>Lower and middle part</td>
<td>+++</td>
</tr>
<tr>
<td>Forest roads</td>
<td>Whole basin</td>
<td>+</td>
</tr>
<tr>
<td>Railway</td>
<td>Gudbrandsdalen Valley, Østerdalen, Valley</td>
<td>+</td>
</tr>
<tr>
<td>Electricity transmission lines</td>
<td>Whole basin</td>
<td>+</td>
</tr>
<tr>
<td>Water supply installations</td>
<td>Middle and lower part</td>
<td>++</td>
</tr>
<tr>
<td>Sewage treatment installations</td>
<td>Whole basin – mountain areas</td>
<td>++</td>
</tr>
<tr>
<td><strong>Other impacts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropower development</td>
<td>Whole basin</td>
<td>+++</td>
</tr>
<tr>
<td>Gravel extraction</td>
<td>Middle part</td>
<td>++</td>
</tr>
<tr>
<td>Water withdrawal</td>
<td>Lower part</td>
<td>+</td>
</tr>
<tr>
<td>Flood protection measures</td>
<td>Middle and lower part</td>
<td>++</td>
</tr>
<tr>
<td>Erosion control measures</td>
<td>Middle and lower part</td>
<td>++</td>
</tr>
</tbody>
</table>
6.2 Institutional Mechanisms and Roles in Basin Operation

Public authorities involved in basin operation and management

The G&L basin represents an image of the main institutional mechanisms and roles in the Norwegian river basin operation and management system due to the size and complexity. The Norwegian public authority system contain 3 levels; the national level with ministries and directorates, the regional level with 18 counties and county governors and the local level with 437 municipalities. Most administrative tasks are organised from the 3 levels mentioned and not from river basins as units. Accordingly river basin operation and management will often include several regional and local level administrative units in addition to the national ministries and directorates. The G&L basin, which is the largest river basin in Norway, includes 5 different counties (Oppland, Hedmark, Akershus, Østfold and Sør-Trøndelag), 5 county governors and 60 municipalities. The boarders of these administrative units do not follow the basin boarders. An administration of water user interests from basin boarders can only be found for the hydropower operation through GLB, and partly for forest owner organisations due to the previous importance of log-driving activities in forestry.

The power companies operating the hydropower plants are owned either by public authorities (the State, the Counties and the Municipalities) or by the private sector. The majority of power companies in the G&L-basin are public owned. As a consequence public authorities have a stake both as hydropower utility owners, and as a part of the water management system to balance all interests.

Non-governmental associations involved in basin operation and management

Both the Non-Government Organisations (NGO’s) and the land owner associations in Norway have a similar 3 level organisation as the public authorities; a central level, a regional level often corresponding to the public authority county level, and a local municipal level.

The most important NGO’s in the G&L river basin operation and management is the farmer unions (county level and local level), the forest owners associations (basin level and local level) and different types of nature conservation associations (county level and local level). In addition NGO’s representing different kinds of river basin exploitations are involved in basin operation and management, ex. power companies (local level), Water Management Associations representing power
companies (basin level), hunters and anglers associations (county level and local level) and public interest associations (national level).

Main legislation for river basin operation and management

The legislation relevant for river basin use and management include several acts headed by different ministries and several administrative tasks are delegated to directorates, counties, county governors and municipalities. The Ministry of Petroleum and Energy (OED) has the jurisdiction for the Watercourse Regulation Act and the general Water Act regulating water use issues and permanent structural watercourse measures in Norway (The Water Act is currently for revision). The multiple use of the Norwegian watercourses necessitates the involvement of several sector-authorities and different Sector-based Acts, ex. The Pollution Act, The Nature Protection Act, The Salmonid and Freshwater Fish Act, The Act of Cultural Heritage and different forest and agricultural acts. As a result of the diversity of acts, institutions like the Ministry of Environment (MD) and the Ministry of Agriculture (LD) with their agencies and regional and local branches are important stakeholders of the water management system in addition to OED and their corresponding directorate (Norwegian Water Resources and Energy Directorate – NVE) (Table 6.2). Locally basin management is ruled partly by the municipalities according to The Planning and Building Act (Plan- og Bygningsloven).

Table 6.2 Main jurisdiction and institutions involved in river basin operation and management

<table>
<thead>
<tr>
<th>Act</th>
<th>Year of approval</th>
<th>Main jurisdictional ministry</th>
<th>Institutions with delegated authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Hydropower Regulation Act</td>
<td>1917</td>
<td>OED</td>
<td>NVE</td>
</tr>
<tr>
<td>The Watercourses Act</td>
<td>1940</td>
<td>OED, MD</td>
<td>NVE, County governors</td>
</tr>
<tr>
<td>The Energy Act</td>
<td>1990</td>
<td>OED</td>
<td>NVE</td>
</tr>
<tr>
<td>The Act on Acquirement of waterfalls, mining and other permanent property</td>
<td>1917</td>
<td>OED</td>
<td>NVE</td>
</tr>
<tr>
<td>The Nature Conservation Act</td>
<td>1970</td>
<td>MD</td>
<td>DN, County governors</td>
</tr>
<tr>
<td>The Pollution Control Act</td>
<td>1981</td>
<td>MD</td>
<td>SFT, County governors, Municipalities</td>
</tr>
<tr>
<td>The Planning and Building Act</td>
<td>1985</td>
<td>MD</td>
<td>DN, Counties, Municipalities</td>
</tr>
<tr>
<td>The Salmonid and Freshwater Fish Act</td>
<td>1992</td>
<td>MD</td>
<td>DN, County governors</td>
</tr>
<tr>
<td>The Cultural Heritage Act</td>
<td>1978</td>
<td>MD</td>
<td>The Directorate for Cultural Heritage, Counties</td>
</tr>
<tr>
<td>The Outdoor Recreation Act</td>
<td>1957</td>
<td>MD</td>
<td>DN, County Governors</td>
</tr>
<tr>
<td>The Act on use of motorized vehicles in natural areas</td>
<td>1977</td>
<td>MD</td>
<td>DN, County governors, Municipalities</td>
</tr>
<tr>
<td>The Land Act</td>
<td>1995</td>
<td>LD</td>
<td>County Governors</td>
</tr>
<tr>
<td>The Forestry Act</td>
<td>1965</td>
<td>LD</td>
<td>County Governors</td>
</tr>
</tbody>
</table>
National, regional and basin orientated planning systems

The fragmented nature of the legislation and the number of governmental institutions involved call for co-operation and co-ordination in basin management and operation and several types of planning processes and planning tools have been developed. At the basin level and for specific parts of river basins (ex. a tributary river) inter-municipal plans (action plans and watercourse plans) have been initiated to co-ordinate the multiple uses of different river sections. At the national level the call for a better integration of the individual user-interests in the licence processes for hydropower reservoirs became evident during the middle of the 1970’s. Two planning systems (The Master Plan for Water Resources and The Protection Plans for Watercourses) were introduced in order to plan further hydropower development in a manner that was assumed to be inclusive of all the interests. The Master Plan for Water Resources is a ranking system for hydropower development plans based on economic profitability and impacts for the different user-interests. The Protection Plans (I-IV) are instructions to the Norwegian Government not to give licence for regulation or hydropower development in 341 river basins. This system only targeted hydropower development and currently systems are developed to improve the management of the watercourses included in the Protection Plan. The environmental authorities currently have a project aiming to recognise various ecological values in protected watercourses (The VVV-project). The Protection Plan is administered by OED and the Master Plan by MD (see description in Chapter 5).

Within the G&L basin several watercourse plans and action plans have been implemented (table 6.3). In addition several smaller watersheds within the G&L basin have been handled in Protection Plan (I-IV) and 27 objects (i.e parts of the G&L basin) have been protected from hydropower development by these plans(Annex 3). 65 alternatives for hydropower development projects within the G&L basin have been handled by the Master Plan (Annex 3).

Table 6.3 Main Watercourse Plans and Action Plans implemented in the G&L basin

<table>
<thead>
<tr>
<th>Name of plan</th>
<th>Part of G&amp;L basin</th>
<th>Responsible institution(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Mjøsa Campaign</td>
<td>Lake Mjøsa and tributary rivers</td>
<td>Ministry of Environment</td>
</tr>
<tr>
<td>The Watercourse Plan for River Gausa</td>
<td>River Gausa</td>
<td>Gausdal and Lillehammer municipalities</td>
</tr>
<tr>
<td>The plan for multiple use of watercourses in the valley of Gudbrandsdalen</td>
<td>Lågen branch of G&amp;L</td>
<td>The County of Oppland, the County Governor of Oppland and municipalities in the valley of Gudbrandsdalen</td>
</tr>
<tr>
<td>The Watercourse Plan for River Otta</td>
<td>The Otta tributary river to river Lågen</td>
<td>The Skjåk, Lom, Vågå and Sel municipalities</td>
</tr>
<tr>
<td>The plan for multiple use of</td>
<td>The Sjoa tributary river to River Lågen</td>
<td>The Vågå and Sel municipalities</td>
</tr>
</tbody>
</table>

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
Monitoring, forecasting and data collection issues

NVE is the key institution for monitoring and data collection on hydrological conditions in Norwegian watercourses. The NVE database encompasses more than 6000 measurement points on different phases of the hydrological cycle (water levels in rivers and lakes, river flow rates, ground water levels, soil humidity, ground frost, snow depth, glacier measurements and sediment transport measurements). Most of the hydrological monitoring stations in Norway are operated and financed by the owners of the hydropower regulation facilities. In the G&L basin GLB operate and finance most of the monitoring stations supplemented by NVE. The data collected are used by GLB in basin modelling and forecasting for reservoir and flow disposal and for hydropower production strategies.

The monitoring of water quality, air quality and biological parameters is financed by the state and performed by national research institutes like Norwegian Institute for Water Research, Norwegian Institute for Air Research and Norwegian Institute for Nature Research. Several of the monitoring stations are located within the G&L basin and in addition local municipalities are monitoring water quality and biological conditions in several local watercourses (tributary rivers to Glomma and Lågen).

Table 6.4 Monitoring, data collection and modelling activities and institutions

<table>
<thead>
<tr>
<th>Monitoring, data collection and modelling issues</th>
<th>Institution(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>National Monitoring:</strong></td>
<td></td>
</tr>
<tr>
<td>Precipitation and temperature</td>
<td>DNMI</td>
</tr>
<tr>
<td>Hydrology</td>
<td>NVE, GLB</td>
</tr>
<tr>
<td>Water Quality</td>
<td>NIVA, SFT, local municipalities</td>
</tr>
<tr>
<td>Air Quality</td>
<td>NILU</td>
</tr>
<tr>
<td>Flora and Fauna</td>
<td>NINA, LFI</td>
</tr>
<tr>
<td><strong>National data base collection systems:</strong></td>
<td></td>
</tr>
<tr>
<td>Data on watercourses and drainage areas (REGINE)</td>
<td>NVE</td>
</tr>
</tbody>
</table>

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
6.3 The Glommen's and Laagen's Water Management Association – GLB

6.3.1 Organisation and objectives

Since 1917, Norwegian legislation (The Watercourse Regulation Act) has required the formation of a Water Management Association in basins with more than one industrial user of water. The Water Management Association is a sector organisation for the industry users (hydropower companies) in the basin.

For the G&L basin, Glommen Brukeierforening (GB) was established in 1906 (several years before the formation was required by law) and Glommens og Laagens Brukeierforening (GLB) was established in 1918 (see page xx in chapter 5 for the historical background). Today GB still exist, but the hydropower user interests are operated and managed by GLB. The main objectives of GLB are defined as follows:

"GLB is an independent co-operation and service institution for its members (the water fall owners) for utilisation of the water resources in G&L-basin for hydro-power production in the production facilities of the members” (GLB 1995:11)

GLB is the largest basin-level Water Management Association in Norway. GLB hold licences for a complex of 26 regulated reservoirs and watercourse diversions of small and medium size, which together provide some 3500 million m³ of storage. This is equivalent to 16 % of the yearly runoff in the G&L basin.

GLB members presently include 21 hydropower companies, running approximately 45 power plants. The owners are given a vote in the organisation according to the relative amount of the energy-production potential (measured in natural horsepower) at their disposal. The expenses for running the GLB are divided among the members according to this “relative-amount”-key. A distinction is made between general costs for running the organisation, and specific costs for running the individual reservoirs (GLB 1995:15).
GLB’s objective is thus to plan, build and operate reservoir facilities at its members’ expense and for joint utilisation of the hydropower resources in the G&L basin. GLB is not a water management association with responsibility for a total management of basin user interests, but a sector association for the hydropower interests. Only parties with legal right to utilise the energy in waterfalls within the basin may apply for membership in GLB.

Presently, GLB’s members expect the water resources in reservoirs, diversions and catchment areas to be exploited to maximise the financial performance of power stations. The interests of all members should be attended to as far as possible within the legal framework, the licences and individual agreements made during the last century.

GLB have a mediator function in case of disagreements between the members, and in minimising conflicts between the hydropower companies and other interests.

GLB have a function in representing their members’ interests in conflicts and negotiations with other river-user interests in the G&L area. Further, GLB have a law-based function as front towards the authorities in all matters relating to the development and operation of the watercourse (see below).

To sum up, GLB fulfils at least five functions:

- It is an institution co-ordinating watercourse regulation and hydropower interests towards the authorities and other «outside» interests, and is as such a policy-institution or an institution involved in policy formation on a local, regional and national scale.
- It is an institution holding rights and licences to reservoirs in the basin, and is in this capacity a legally and economically independent unit.
- It is an operative institution, having the practical and the planning responsibility for the reservoirs and the regulated discharge of the watercourse (a small number of minor reservoirs are operated outside GLB).
- It is a development institution, engaged in developing and promoting reservoir projects in the basin.
- Mitigating damage to landowners and the public in general according to licences and legislation.

As a general principle, reservoir licences are given to the water user organisation, in this case the GLB. Power plant licences are given to the various power companies along the watercourse.

Waterfall owners control GLB through the General Assembly an elected Board of Directors (figure 6.1). The GLB organisation has 4 departments; Hydrology and Operation Department, Construction, Maintenance and Dam Safety Department, Resources and Licensing Department and Finance Department.
New initiatives for dam projects have, over the years, originated from the owners. The waterfall owners' interests, and in addition the nations requirements for electric power, have been the driving force behind the establishment of new reservoirs in the basin.

In previous times (before 1990) the individual waterfall owners had a supply area where they were obliged to meet power consumption, in co-operation with central energy authorities. New projects were thus frequently promoted in collaboration with the power companies and authorities in order to achieve adequate local power coverage. In other words there were public and social considerations behind the establishment of many power plants and reservoirs, apart from the purely economical and technical considerations. The existence and growth of the regional and national grid made this local perspective less important throughout the 1970'ies and 1980'ies. Since 1990, and as an element in the liberal shift in energy policy (see page xxx) this obligation to supply local consumption, has been winded up.
6.3.2 GLB Strategy for Total Basin Operation and Energy Production

Reservoir disposition - strategic seasonal and weekly planning in the G&L basin

During the last decade power from the G&L basin has represented a yearly production value of approximately NOK 1.5 billion (see chapter 3.2.3 on economic value of production). The main goal for operation of the G&L basin is to day to utilise the reservoirs to maximise the economical value of the power production. Information on probable inflow in both short term (day-week) and long term (season) is therefore important. GLB, as the basin operator, has the responsibility to make forecasts and supply statistics as a basis for decision-making for the operation of the reservoirs, and for the production planning of the member power companies.

The energy price varies substantially during the annual cycle. However most power producer sell parts of their energy on long term agreements. In the G&L basin, up to 3 TWh is produced from reservoir water during the winter period of 5-7 months, i.e. 0.5 TWh/month. With a 5% shift in winter production to a period with a NOK 20 higher price per MWh, an additional income of NOK 5 million/year can be generated. Similarly, a “lower-than-expected” price will result in a reduced profit. Energy prices subsequently are very important for the value of production. In addition a typical feature of the G&L basin is the large proportion of unregulated flow to many of the run-of-the-river hydropower plants. The variation in production from one week to another can be as much as 50 GWh in January, 100 GWh in April and 150-170 GWh in July-September. The price assessments therefore are crucial in utilisation of reservoir water within a season, a week or a 24-hour period. The timing and amount of release is a complex operation as the same water may be utilised in as many as 15 hydropower stations, and the time lag can be considerable from the release at the reservoir to the arrival to the last downstream hydropower station.

The G&L-basin is basically developed in a piecemeal process as a running river concept. GLB has no reservoirs capable of storing as much water as the runoff from one year. Only two reservoirs have a regulation capacity of more than 80%, and for the 20 largest reservoirs the regulation level is on average 50 %. All reservoirs will usually be filled before winter and subsequently released during the winter period with the aim of a complete draw down.

The reservoirs; Aursunden, Storsjøen, Osen, Breidalsvann and Mjøsa are normally filled with less than the total spring inflow of water. Subsequently some of the spring flow can be released during fill up (so called pre-releasing). This yields the best exploitation of the power plants downstream and can provide “additional” reservoir volume for flood abatement. Generally, other user interests do not object to some pre-releasing of water from reservoirs in the summer/autumn period, but in some reservoirs, like Mjøsa, some react negatively if the reservoir is lowered by more than one metre, resulting in problems for leisure boat owners and for commercial boating tourism. However, for other reservoirs there may be reactions if the reservoir water level is kept too close to full supply level over an extended period, thereby causing wind generated erosion. In years with extreme spring inflow, almost all reservoirs in the Glomma are filled by July 1st. Pre-releasing is then very important, if snow melt and precipitation forecasts indicate a high flood probability.

All licences have instructions not to increase the natural flood discharge due to the regulation of lakes and rivers. Some licences have as well detailed instructions on a “freeboard” on “top” of the reservoirs not to be utilised until a certain date. This is to ensure a certain flood dampening volume in the reservoir.
Reservoir disposal - impact of the new Norwegian Energy Act

Information on inflow, snow, reservoir condition, power-plant revisions and the power market is important for optimisation of hydropower production, in both the short and the long term. Such information is useful both for the operation of the G&L basin and on the “surrounding world”.

Until 1992, Samkjøringen, who co-ordinated the production of Norwegian power plants from 1932 to 1992, prepared analyses and data forecasts on the domestic demand and supply. Samkjøringen initiated the development of and financed a large part of the industry’s computerised planning tools. GLB has greatly benefited from collaborating with Samkjøringen, providing basic data, simulation models, data communication and market descriptions.

After the Energy Act entered into force in 1991, the policy on the free flow of information changed. Consequently, GLB today also practices a restrictive information policy on reservoir data and water discharge. The Energy Act also introduced a new market-consciousness, which was one of the intentions of the Act. This is a major challenge for the basin operator (GLB) in its interplay with the member companies. As a basin level agency, GLB has to operate the basin in terms of overall policy and service to members, mediation between members, compliance with rules, flood management and consideration of different user interests. It should also be noted that GLB still is a forum searching optimum solutions for all parties, although the members after 1991 are competitors in a quite different and liberal energy market.

Changes in reservoir operation during the past 25 years are initially attributable to the building of new power plants and capacity upgrading of existing plants. Changes were also brought on by the Energy Act, with its provision for a liberal power market. Changes resulting from the commissioning of new reservoirs were significant until 1970, but during the last 25 years no new reservoirs of importance have been developed G&L river system. More monitoring stations and increased use of modern computing tools for forecasting runoff have also had an effect on reservoir use, as did the final closing down of log driving operations in 1985. The log driving operation included instructions in the regulation schemes on discharge and release in order to support the log transport.

Today energy is sold through Nordpool, the Nordic “marketplace” for the trade of electric energy. GLB uses Nordpool’s forward prices for establishing optimum long-term water-release strategies for the reservoirs. In the short term, the spot price is considered to provide the best basis for reservoir disposal. However as mentioned only a fraction of the energy is sold at spot prices.

A more detailed analysis of the effects of the new Energy Act is given in Annex 4.

Joint operation of reservoirs - criteria and consequences for various power plants in the river system

In the G&L basin the power plants were commissioned over a long period of time and owned by different power companies. According to the GLB’s articles of association, the power plant owners, or members, with the largest “waterfall rights” (total head) downstream a reservoir shall have comparable influence on the use of that particular reservoir, but members with lesser interests should also benefit.

In the Vinstra river system, for example, the owners of the power plants Øvre Vinstra and Nedre Vinstra previously practised an agreement lending production capacity to each other for defined periods. In recent years this agreement is not practised very much, indicating more common interests regarding the timing of production. The extra work of follow-ups and accounting is thus also avoided.
In the G&L basin it is documented that GLB’s role, as mediator between the members has been successful. Conflicts rarely arise and, at the first sign of discord, effort is made to resolve it through agreements between the parties involved.

The current operation system with one water management association and 21 members does not exploit the full economic benefit from a common operation practise. There is still some additional financial gain to be made by an even more co-ordinated operation of the reservoirs than at present. An internal committee at GLB in 1994 performed an analysis, which indicated a potential gain of NOK 25 million per year (1.3%). Although increasing the total income to the GLB-system, such a joint operation might from time to time yield less profit for some members. A system of “share of benefit” has been discussed, but the time was not yet considered ripe for this final step towards maximum output. The ongoing concentrations in fewer power companies in the GLB system will certainly bring this issue forward in the near future.

Modelling and simulations

The flow scheme provides a framework for how drainage is to be carried out. As the operator of the watercourse, GLB intends and emphasises a drainage strategy which will allow members the best possible exploitation of the resource (GLB 1995). Simultaneously, one must also take into consideration other user groups, to the extent that this does not involve exceeding the regulatory framework and does not lead to disproportionately large losses in energy production. GLB from time to time receives requests to maintain specific water levels in lakes, a specific water-flow, etc. Sometimes these requests are possible to meet, sometimes not.

When the licence for Øyeren was up for renewal, there were strong reactions voiced on the water level conditions because of a dry spring and summer (1991). Strong reactions came from users in the area and led to the authorities deciding to assess the flow scheme. Extensive scientific testing was implemented. The conclusions from these tests will, along with economic factors, and other wishes on the part of various user groups, create the basis for a new release strategy. The case is not yet concluded, but it illustrates how daily operations may be affected in ways that cannot easily be foreseen in general long-term schemes.

Data series and subsequent modelling of the water course is an important management tool to meet the various and often crossing demands in the short and long term operation of the basin, including flood issues, consequence analysis, economic simulations, operational planning, development planning. Additionally, detailed descriptions of reservoirs, basin, power stations and so forth, and reliable market forecasts are needed to produce good modelling, analysis and management strategies. An effective interplay between modelling and management thus requires a coherent and long-standing organisation as GLB.

These are a selection of data sets and the models used by GLB over the years:

- Around 1970 a simulation models (the so-called JARSIM model) was used to model the output from the river Øvre Otta development (see page xxx). This model is now terminated.
- In 1974 the in-house developed simulation program SIMPRO was implemented, enabling GLB to simulate particular development projects to maximise yield in production on a weekly basis. The model was terminated in 1985, partly because it was too cumbersome to include the whole basin.
- The HYDBAS information system established in 1976 to collect and store hydro- meteorological data. The information system has been upgraded continuously, and the HBV-model is integrated (see below). The system provides reservoir and flow prognosis in short- and long-term planning.
The rainfall runoff model HBV for three of the larger reservoirs in the GLB-basin was implemented in 1977. The inflow prognosis are taking account of the conditions in the drainage area (amount and conditions of snow, water-saturation in the various ground-elements, expected temperature conditions, rainfall and evaporation). Today the whole basin is simulated by 33 HBV-models describing the hydrological response from separate sub-basins.

VANSIMTAP is a model for long and short-term production planning in a river system with multiple reservoirs and power plants. The river system is simulated in a model where restrictions on reservoir storage, water flow and power productions can be described in detail for every reservoir and power plant in the river system. VANSIMTAP is used for determining an optimal production plan for a river system where power is exchanged to an adjacent power system. Input data for the river system as well as the adjacent system is historical inflow data, prices on alternative energy production and prices on rationing of delivered energy to the consumers. The planning method is based on making decisions at different strategic levels. The planning period lasting from months up to a year is simulated, thus making a weekly production plan for every power plant within the river system during the whole period. (VANSIMTAP 1981).

The River System Simulator (RSS) is intended to be used in consequence analysis in project planning and development in delimited areas and smaller and medium sized projects.

6.3.3 GLB involvement in management issues raised by reservoir operation licences

The different G&L licences to reservoir operations contain paragraphs on different obligations to GLB as the regulator. The obligations include to pay partly for measures performed by other institutions, and partly to fulfil the obligations by work from the GLB departments themselves.

Usually, the conditions in the licences are addressing issues like:

- Duration of the licence
- Taxes and fees to state and municipal treasuries
- Development fund to the municipalities,
- Control of detailed plans,
- Environmental constraints and mitigating issues,
- Deadline for starting construction works,
- Details on allowed manoeuvring of the reservoirs,
- Minimum flows in rivers,
- Power to special prices to the municipalities (adjusted yearly by the Ministry of Petroleum and Energy)
- Hydrological observations to be handed over to the authorities
- etc.

6.3.4 GLB involvement in other water management issues

Land use. Only in the course of the last 15-20 years have land planning issues gained significance with regard to the municipalities' overall land use for various purposes. Land areas located closest to the watercourses are of interest to a number of user groups, and therefore of particular importance.

Legally binding land planning is today being carried out in accordance with The Plan and Building Act of 1985 (see also page xxx for more information). The planning system of this act is based on a
political elected steering-body, involving a wide influence from concerned individuals and groups, with planning to take place at three levels – national, county and municipal.

Today, the modus operandi is that GLB for the most part receives for comment and consideration all plans connected to the watercourses, regardless of who is responsible for the planning. This makes it possible to clarify and inform at an early point in time with regard to GLB's rights and any possible conflicts of interest. GLB's collaboration with the 50 municipalities is established and issues-based, and conducted with the obvious fact that GLB is a hydropower interest organisation.

**Flood issues.** Flood-risk areas are to be found along River Glomma and River Lågen. The land scarcity has resulted in a number of municipalities reconsidering the use of flood-risk areas for settlement, agriculture, industry, infrastructure and transport. Some of the vulnerable areas were developed a long time ago, but there are also substantial areas that have only been developed during more recent decades. The large floods of 1967 and 1995 caused significant damage, particularly to settlements and cultivated fields (see chapter 3.3). This subsequently led to a critical review of the municipal land use policy.

GLB's hydropower reservoirs in the G&L basin have had a flood abating effect and has subsequently contributed to the reduction of possible damaging effects especially during spring floods when reservoirs are not filled to full supply levels. It is, however, a fact that there has been little focus on the elucidation and analysis of how the regulatory scheme, along with protective measures, such as embankments, etc. can be actively implemented to reduce the extent of damage to flood-risk land areas.

This was given serious attention after the flood of 1995, resulting in a public report on flood protection initiatives (NOU 1996:16). GLB played and had a vital function in performing the calculation of flood dimensions, water level increases and otherwise in procuring the relevant case studies needed for the evaluation. The report resulted in a white paper, which passed the Parliament in June 1997 (St. meld. 42 (1996-97). The process has resulted in production of flood-zone maps giving the municipalities better information on the risk involved in land use.

The flood of 1995 clearly shows that the regional Water Management Association has an important role to play during extreme floods, and that it has a large responsibility for damage prevention. The flood also showed that optimal utilization of reservoirs often depends on the possibilities of permitting deviations from normal regulation procedures. Close cooperation between the reservoir owners and the authorities is therefore very important. The primary goal has to be overall maximum damage reduction, without consideration of corporate prestige and interests. The flood of 1995 also showed that it often will be the regional Water Management Association (in the 1995-case: GLB) that has the best knowledge about the river basin and the possibilities for damage reduction.

GLB and NVE has a close co-operation on forecasting issues, but GLB does most of the forecasting. During the 1995-flood GLB had to ask NVE for several permissions, but GLB controlled the system during the flood. Power reductions when operated for flood are not compensated.

As part of this process a series of new reservoirs and operations measures were proposed in the G&L-region, which would help provide further moderation of large floods. The measures would, if effective, also help to provide significant gains in the production of energy. Interest in these measures was small, and Parliament only minimally followed-up the proposals. So far no physical measurements to increase the flood damage potential has been taken, and the power companies are not likely to apply for a licence to construct new reservoirs as long as the present situation is so anti-hydropower as it is in Norway.
Fish and fishery issues. During the last 10-15 years, the G&L Water Management Association, power companies and the environmental authorities as well as landowner representatives have co-operated on fisheries issues related to the hydropower sector. The aim of this work has been to identify the optimal use of resources to improve the conditions for fish production and angling. The work include test fishing, registration of fish migrations in fish ladders, catch statistics and date to evaluate mitigation measures, as well as implementation of various mitigation measures such as fish stocking, habitat improvement, fish ladders and minimum water flow. The experience from these projects is very positive and shows some of the benefits from an open dialogue and co-operation between the stakeholders. In this way cost-effective measures can be developed to substitute those implemented in the licence process.

Findings on Basin Operation

- The Norwegian 3 level public authority system results in a very fragmented system for main river basin operation and management.
- Inter-municipal plans (action plans and watercourse plans) have been used successfully to co-ordinate the multiple uses of different river sections in the G&L basin.
- Monitoring, modelling and forecasts are important tools for G&L basin operation and management.
- The Water Management Association (GLB) has an important role in co-ordinating the operation of the complex system of reservoirs on behalf of their members.
- GLB is a natural part for communication with other interests and co-operation on ecological issues and mitigation to improve the conditions and reduce conflict levels.
- So far the operation of the reservoirs seems to adapt step-by-step to the new Energy Act and the system of market liberalisation.
- GLB as a joint operation party has an important role in reducing flood effects and there is a considerable flood abatement effect in optimal basin operation and pre-release based on data and simulation models.
- The basin operation is not yet fully optimal from an economic view as an additional potential 1,3 % (NOK 25 million) was estimated in 1995.
7. Summary of Findings

Findings of the G&L basin case study are in the following structured according to the six key review questions for the WCD case studies:

- What were the projected vs actual benefits, costs and impacts?
- What were the unexpected benefits, costs and impacts?
- What was the distribution of actual and unexpected benefits, costs and impacts, who gained and who lost?
- Did the project(s) comply with the criteria and guidelines of the day?
- How were decisions made?
- How would this development be viewed in today’s context?

7.1 Projected versus actual benefits, costs and impacts

Benefits

The assessment of benefits, costs and impacts have been made relative to the pre-1990 overall national policy that promoted electrification as a primary means for fuelling economic development and creating public welfare locally and regionally in the G&L basin:

Undoubtedly, hydropower development has played a significant role in developing settlements, economics, infrastructure, and public services in the G&L basin. For many local communities, the long construction period represented growth in employment, increased tax revenues and increased demand for goods and services. The construction activities created important direct employment opportunities. These earnings were significant in creating family livelihoods and supporting development of municipal economies. Hydropower development projects were also initiated to support specific districts in periods of depression and high unemployment rates. The operation of the water management and hydropower system currently employ 250 persons, and including utilities providing power services employment is approximately 2100 persons. The hydropower development has also contributed to infrastructure development. The direct contribution to creating infrastructure has been modest as most of the hydropower facilities were close to existing roads. However, the development has contributed to some new and some upgrading of existing transport networks. The sector industry has also financed local infrastructure measures such as local community house, town houses and schools.

The total annual hydropower production has been 9 – 11 TWh or 1,13 to 1,63 billion NOK (159 – 253 mill US$) the last decade depending on inflow rates. The installed production capacity is 2 165 MW. The actual hydropower production for several of the power plants exceeds the projected. This is due to expansions or building of new power stations or the technical evolution (ex. new turbines, generators and controls). New reservoirs and increased reservoir capacities for winter production and optimisation of the basin operation have increased the value of the hydropower production. Total income in 1998 encompassed 534 mill. NOK ( 71 mill US$). The larger revenue entries were taxes (333 mill NOK, 44 mill US$) and public owner incomes (150 mill NOK, 20 mill US$).

Hydropower production substituted fossil fuel thermal generation emission of CO₂, SO₂ and NOₓ. Regionally, this has considerable significance for acid rain. In South Norway and Sweden aquatic and terrestrial ecosystems as well as certain infrastructure are heavily impacted by acidification from long-transported SO₂ and NOₓ.
The G&L reservoirs have a capacity of 16% of the annual runoff. Lake Mjøsa and Lake Øyeren were regulated in the 19th century primarily for flood protection. Later reservoir development was for hydropower production that could ensure earnings for full cost recovery, while flood protection was a subsidiary interest. Flood protection benefits from reservoirs is best demonstrated by the catastrophic spring flood of 1995 where peak flood levels on stretches with dense population were reduced by 1.0-1.9 m. The hydropower reservoirs have proved to reduce maximum flow rates and flood culmination levels significantly during last centuries spring floods. This has reduced flood damages both on floodplain agricultural areas, settlements and infrastructure.

**Costs and other impacts**

The G&L reservoirs analysed have been constructed with considerable cost-overruns, one as much as 180%. This is due to a combination of the time consuming licensing procedures, changes of plans (mostly reductions) during licensing procedures, changes of technology during construction period, changes of interest rates or financing environment (taxes, VAT etc.) before completion, changes in legal framework such as Labour Act, Planning and Construction Act etc. during construction period, War-time and post war obstacles (WW - I and WW - II) and variation in employment situation and competition for manpower. Due to partial lack of data and the complexity of assessing the benefit/cost of the full water and hydro-and flood protection structures in G&L, it has not been possible to calculate a rate of return on investments in the infrastructure. However, most of the investments are fully depreciated and the hydro-facilities are in several cases running well beyond their projected life-times and/or have been upgraded, making considerable earnings and providing profits and incomes for concession and fiscal taxes beyond what was expected.

There has been no resettlement of people in connection with dams and hydropower development. Land acquisition has taken place by expropriation and/or voluntarily, and compensations made at market prices and above, even in the older developments. Further, conflicts with economically significant tourism and recreational interests in the G&L basin have mainly been avoided through the processes with the national protection plan, the master plan, and licensing processes involving stakeholder consultations. These exercises have led to abandoning many of the most conflicting development plans.

Negative of hydropower development is primarily related to freshwater fisheries and to some extent to agricultural activities. Traditionally, harvesting of trout and other fish species represented an important contributions to household diets in the rural areas. Pre-regulation assessments of ecological impacts have lacked comprehensiveness, focusing mainly on fish harvesting. Negative effect on harvested fish population have been mitigated through stocking of hatchery reared fish to compensate for loss of natural recruitment. Other mitigation efforts have been habitat, release of minimum water flow and construction of fish-ladders improvements. Predictions of mitigation measures effectiveness for maintaining fish stocks have generally been over-optimistic. Lake impounding and river regulation have had negative effects on the food base of brown trout, and fish production has decreased in spite of stocking.

Results of monitoring and post-development research has disproved the assumptions that carrying capacities of regulated rivers were comparable with unregulated in terms of biomass production. The traditional mitigation with release of hatchery fish has not met expectations. The fish harvests have thus been reduced.

Negative impacts for agriculture include loss of land from reservoir inundation and loss of fence-effect in rivers with reduced flow during summer. Altered flow-rates also impact on ground water levels in some areas and at times result in dry wells for private households. Overall, the impacts on agriculture however, are limited to relatively small areas of the G&L basin. On the other hand positive flood
7.2 Unexpected costs, benefits and impacts

Many older and fully depreciated investments in the hydro-facilities lead to that several structures are running well beyond their projected life-times and/or have been upgraded, making considerable earnings and providing profits and incomes for concession and fiscal taxes beyond what was expected.

The deregulation of the energy market with the new Energy Act in 1991 was unexpected. This represents the most significant change of context for production and sale of during the development history. The energy sector has traditionally been regulated and dominated by public management. Until 1991 individual utilities had an obligation to supply customers in their licensed area. In the first half of the century local distribution networks were developed gradually and were not fully interconnected. The new situation with price competition and third-party access for all transmission lines increased the market-consciousness in the power companies significantly. Attention of utility boards and management is now increasingly directed towards competition and profitability. As a consequence the basin operator now practices a more restrictive information policy on reservoir data and water discharge.

Actual cost of the projects has been higher than the estimated cost at the time of license approval. The main reasons for the unexpected deviation are the delay of 3-5 years in the start of construction for each of the projects, and that compensation for land acquisition and to third party interests in the end became higher than estimated.

Unexpected effects on other water resource developments like irrigation and water supply have so far been ignorable.

An unexpected effect that has emerged due to better genetical knowledge of fish strains, was the significance of nativeness and differences in adaptability and behaviour of the different strains. This has changed stocking policy and caused a substantial increase in production cost for compensation stocking material.

Log-driving was an important interest in the first half of the last century, and decreased gradually until the end in the 1980ies. Most of the operation rules for the G&L reservoirs have separate paragraphs on log driving. The decline of the log-driving interest was not foreseen in the licensing process of the reservoirs and the log-driving paragraph still exist in G&L reservoir operation rules. The conditions implemented in the hydropower licenses can only be substituted in a formal revision process.

7.3 Distribution of cost, benefits and impacts (who won and who lost)

The legal tradition is based on rules protecting civil rights, including private property, common property and third party interests alike. In legislation and practice associated with water resources and hydropower development, land acquisition has been taken care of through comprehensive compensation and grievance procedures for ensuring fair treatment. Similarly, third party interests are protected through law, license covenants and the rules of operation for dams. These are to a large extent expressions of environmental and social safeguards. For instance, compulsory maintenance flow releases are a common feature in most rules of operation and so are fish stocking and other mitigation measures. Such measures are one approach safeguarding third party interests. In the G&L basin typical covenants of licenses cover maintenance flows, fish stocking, fish ladders, construction of weirs, and the developer funds the cost of these measures.

This is a working paper prepared for the World Commission on Dams as part of its information gathering activities. The views, conclusions, and recommendations in the working paper are not to be taken to represent the views of the Commission.
Electrification for households was a national objective associated with the country’s hydropower development policy. NVE had a special office for distributing subsidies to bring power to even the most remote households in the relatively sparsely populated parts.

Of the accumulated income of 534 mill. NOK in 1998 (71 mill US$), a 414 mill. NOK or almost 80 % goes to the G&L region. The total annual incomes of the municipalities in the G&L region are approximately 12-13 billion NOK (US$). Of this, energy revenues comprise a good 400 mill NOK (53 mill. US$) or 3.0 % of the total municipal incomes. The municipal income from energy revenues within the G&L basin is unevenly distributed, and a few municipalities has relatively large incomes from energy revenues (more than 5 % of total incomes). On the other hand hydropower development municipalities receive reduced subsidies from the State.

Annual fees and compulsory delivery of electricity to the local municipalities to secure local benefits from the hydropower projects was included in Norwegian legislation in 1917. This has been an important tool to distribute the benefits from the hydropower project.

### 7.4 Compliance with criteria and guidelines of the day

The present study found that GLB and the power companies owning and operating dams and hydro-installations in the G&L basin have a good record of compliance with guidelines for construction, safety, compensation, mitigation and operation as of the time licences were granted.

Conditions implemented in the hydropower licenses may not be substituted without a formal process, e.g. revision of the conditions according to the legal mechanism. Two main changes in legislation 1959 and 1992 have been crucial for the opportunity to re-evaluate old licences:

1959: Conditions in new licenses, including rules of operation may be revised after 50 years.
1992: Conditions in new licences, including rules of operation can be revised after 30 years. In addition all licenses older than 50 years may be re-evaluated and the conditions revised.

These changes gives the possibility to re-evaluate old licenses and set conditions according to present knowledge and attitude regarding environmental issues, including minimum flow and other mitigation measures.

Although GLB’s overriding objective is to optimise the operation of the river with regard to hydropower production, it is worth noting how GLB in cooperation with NGOs, municipal-, county-, and national authorities for instance has worked to optimise and direct resources budgeted for fisheries mitigation through separately licensed schemes and owners into a shared fund that would invest where the budgeted resources would provide the best results for third party interests.

### 7.5 How were decisions made?

The decision making process for water resources development in Norway has undergone a considerable evolution over time. Since early in the 20th century a requirement for licensing provided the procedures that have constituted the backbone of the decision making process:

- The first decisions before 1900 were public decisions to regulate the large natural lakes Mjøsa and Øyeren for reasons of flood management and navigation. These processes were not without controversy and involved all levels of governance including parliament.
- The next set of early decisions around 1900 to develop hydropower was made by private interests. This caused fear among leading national politicians that private and foreign interests would acquire ownership of national water resources, and led to the “Panic law” of 1907, and later to the
Watercourse Regulation Act in 1917. During the same period the Water Management Associations were formed in the G&L basin to organise basin waterfall owners.

- From 1909 the ownership to waterfalls were based on licenses. The licenses for private developers were time–bounded. Dams and hydro development under public ownership were not time-bound but still required a decision process for parliamentary approval, similar to licensing.
- From 1921 the government in a constitutional plenum granted licences based on applications. The applicant was confronted with detailed instructions on the technical content of the application, and there were demands to be met to analyse benefits and disadvantages following the project.
- 3 vital changes were made in the licensing procedures in 1969. 1) Public notification of the intention to apply for a licence was introduced to improve transparency of and stakeholder participation in the process. 2) Demand for more comprehensive impact assessments of both nature and society to be carried out as part of the application process. 3) An obligation to propose measures and/or alternatives to avert or mitigate negative impacts on nature and society of a project.
- In the 1970s and the 1980s new substantial reforms in the policy making procedures and in the administrative tools operative in the hydropower policy field took place. In 1972 the Ministry of Environment was established. In 1960 Parliament took an initiative to establish regional plans for protection of rivers and waterfalls, and around 1980 the question was raised to make a Master Plan for all the remaining hydropower development projects. One aim was to get a more unified approach to decision making in particular projects. These plans led to avoidance of (further) hydro-impacts in the river selected for protection, and thereby reduction of conflict levels.
- Public consultations around alternative large scale hydro-development of the western alpine parts of G&L that led to establishment of national parks and discarding of the comprehensive plans, in favour of environmental and recreational interests in that part of the basin.
- The Øvre Otta project got a development license in 1999 and is the only G&L basin hydropower project approved within todays context of planning and decision making.

7.6 The G&L hydropower development in today’s context

With the shift in framework conditions for production and sale of electricity and focus on cost recovery and rate of return after the deregulation in 1991, the proponents are observing risk of investments much more closely than earlier. The dilemma for hydropower developers today is the conception of how market prices will develop. The market price of electricity as it is today is too low to make most of the new potential hydropower development plans profitable, and the possible gas power developments further complicate the estimation on future market-prices. In todays context environmental impacts of further hydropower developments as well as of gas power development are considered as serious, and the choice of strategy will be a question for the Parliament.

Today the hydropower sector goes through a phase of restructuring of utilities as an adaptation to the deregulation. New investments are still done in hydropower developments in the G&L basin (ex. The Øvre Otta project) and in upgrading and refurbishment of power plants and dams. Public support for development of additional storage (new reservoirs) seems to be low in the G&L basin, and you would probably need a disastrous flood to change this attitude.

The municipalities have been in favour of hydropower development projects because of the economic benefit for local economics. During the last 10-15 years the municipalities generally have been more negative to hydropower developments within their own area. The Øvre Otta project is an exception to this trend, as the development municipality (Skjåk) has been strongly in favour of the development project. Experiences throughout Norway show that a positive attitude from local municipalities has generally been crucial for the question of license approval in hydropower development projects during the last decades.
The function of Glommens and Laagens Water Management Association (GLB) is crucial for the present integrated G&L basin hydropower management. GLB is also an important co-operator for the public authorities in other basin management issues.

During the last 20 years 65 different alternatives for further hydropower developments have been handled in The Master Plan, 27 tributaries have been protected in The Protection Plans for Watercourses and 4 areas have been protected as National Parks. Most of the reservoirs and power plants were established prior to the Master Plan and Protection Plan. However, these planning tools have been important to include environmental and local interests.

### 7.7 Timeline in G&L development

The Glomma-Lågen development project has developed as an integrated part of the industrial, bureaucratic, social and welfare development in Norway. The hydropower development includes a time span of more than a hundred years with various driving forces. As illustrated in Table 7.1, a number of events have been important for the development in the Glomma-Lågen basin. Flood protection has been a major issue. Log driving was an important factor until the termination in 1985, however there are still restrictions related to log driving on the manoeuvre regime in the basin.

**Table 7.1** Timeline of Context Events, Legislation and Important Development in the G&L basin.

<table>
<thead>
<tr>
<th>Timeline of Context Events and Legislation</th>
<th>Year</th>
<th>Timeline of Important Developments in the history of the Glomma - Lågen River Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some of the early regulations and acts in Norway from the period 1000-1200 did include issues important for the management and ownership to lakes and rivers. One regulation states that it is not allowed to use equipment, which prevent upstream migration for Atlantic salmon. Also the landowners rights in lakes and rivers were stated in these early regulations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Act on Log Driving</td>
<td>1594</td>
<td>The largest flood in history</td>
</tr>
<tr>
<td></td>
<td>1779</td>
<td></td>
</tr>
<tr>
<td>Establishment of the Canal Directorate</td>
<td>1804</td>
<td>The Canal Directorate had the responsibility for building canals, and for flood and erosion prevention</td>
</tr>
<tr>
<td></td>
<td>1854–1857</td>
<td>Regulation for flood protection in the G&amp;L Basin</td>
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<tr>
<td></td>
<td>1857–1862</td>
<td>First regulation of Lake Mjøsa</td>
</tr>
<tr>
<td></td>
<td>1862</td>
<td>First regulation of Lake Øyeren</td>
</tr>
<tr>
<td>The Act of Watercourses</td>
<td>1887</td>
<td>The first power plant Built in the river Mesna and owned by local government</td>
</tr>
<tr>
<td></td>
<td>1894</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1896</td>
<td>Several power plants built</td>
</tr>
<tr>
<td></td>
<td>1892</td>
<td>Kuråsfossen in the upper river Glomma to supply the mining town Røros</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Borregard in the lower part of river Glomma</td>
</tr>
<tr>
<td>The first Water management Association</td>
<td>1903</td>
<td>Glommen Brugseierforening was founded for the lower reaches of the Glomma river</td>
</tr>
<tr>
<td>The Panic Act</td>
<td>1906</td>
<td>Temporary law of license regarding utilisation and ownership of waterfalls by foreign interests</td>
</tr>
<tr>
<td>Canal Directorate reorganised to The Norwegian Watercourse and Electricity Authority</td>
<td>1907 and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1920</td>
<td></td>
</tr>
<tr>
<td>The Watercourse Commission</td>
<td>1909</td>
<td>Licensing of waterfall and watercourse regulation</td>
</tr>
<tr>
<td></td>
<td>1910</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1916</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1927</td>
<td>Major flood episodes during the 20th century</td>
</tr>
<tr>
<td></td>
<td></td>
<td>These floods have had various impacts on the management and the operation of the G&amp;L basin.</td>
</tr>
</tbody>
</table>

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The effects have been construction of flood protection measures, increased reservoir capacity, changes in manoeuvring practice. The floods in 1966 and 1967 resulted in measures that increased the flow capacity in the outlet of Lake Øyeren. After the 1995 flood a separate Commission on Flood Protection Measures was appointed.

<table>
<thead>
<tr>
<th>Event</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin plan for flood protection</td>
<td>1910</td>
<td>Plan for regulation of Glomma and Lågen for flood protection</td>
</tr>
<tr>
<td>The Electricity Commission</td>
<td>1910</td>
<td>Granting concessions for power lines and electrical equipment</td>
</tr>
<tr>
<td>First Norwegian Nature Protection Act</td>
<td>1910</td>
<td></td>
</tr>
<tr>
<td>The Act on Regulation of Watercourses</td>
<td>1917</td>
<td></td>
</tr>
<tr>
<td>The Act on Industrial Concession</td>
<td>1917</td>
<td></td>
</tr>
<tr>
<td>Glommen and Laagen Brugseierforening</td>
<td>1918</td>
<td></td>
</tr>
<tr>
<td>The Act of Watercourses</td>
<td>1940</td>
<td></td>
</tr>
<tr>
<td>World War II</td>
<td>1940-45</td>
<td></td>
</tr>
<tr>
<td>Revision of the licensing process</td>
<td>1969</td>
<td>Applicants had to send a notification to NVE before initiating the planning process. Other changes include more comprehensive impact assessment of both nature and society and to propose mitigation measures and alternatives for development</td>
</tr>
<tr>
<td>The National Grid</td>
<td>1971</td>
<td></td>
</tr>
<tr>
<td>The Ministry of Environment established</td>
<td>1972</td>
<td></td>
</tr>
<tr>
<td>The Act on Cultural Heritage Sites</td>
<td>1970</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>Last log driving in the G&amp;L Basin</td>
</tr>
<tr>
<td>The Protection Plans</td>
<td>1960</td>
<td>1973 Protection Plan 1 (95 watersheds, 6.9 TWh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1980 Protection Plan 2 (51 watersheds, 2.6 TWh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1993 Protection Plan 4 (in total 341 watersheds and 35 TWh)</td>
</tr>
<tr>
<td>Act on protection against pollution and on waste</td>
<td>1981</td>
<td></td>
</tr>
<tr>
<td>The Plan and Building Act</td>
<td>1985</td>
<td></td>
</tr>
<tr>
<td>The Master Plan</td>
<td>1986</td>
<td>Re...</td>
</tr>
<tr>
<td>Current</td>
<td>1990</td>
<td></td>
</tr>
<tr>
<td>The New Energy Act</td>
<td>1990</td>
<td>The Nordic Grid – Nord Pool</td>
</tr>
<tr>
<td></td>
<td>1995</td>
<td>Vesle Ofsen – major flood episode</td>
</tr>
<tr>
<td>The Øvre Otta Licensing Process</td>
<td>1999</td>
<td></td>
</tr>
</tbody>
</table>
8. Lessons Learned

A chief objective of the WCD process is to identify new knowledge from past experience with large dams. The G&L case study differs from the other WCD case studies in that the single dam focus is exchanged with an assessment of an integrated system of 40 reservoirs and 51 hydropower stations. The basin focus for lessons learned in the Glomma-Lägen context seeks to demonstrate accumulated experience representing the long time period of the development and the multitude of stakeholders in the basin. Some of the lessons are generated specifically from the G&L Case Study, whereas some are more general for the Norwegian hydropower development context.

The hydropower system of the G&L basin was developed over a time span of more than a hundred years. During this period, communities in the G&L basin and Norway as a nation took part in a transformation from a mainly rural to an urban society based on an industrial economy. During this period, development of water resources and hydropower fuelled economic development and contributed greatly to the society’s welfare development. Use of water resources influenced public debate and evolution of institutions throughout the century in the G&L basin as well as throughout the country. Experiences and lessons learned, such as from G&L, contributed to Norway becoming the first country in the world to establish a Ministry of Environment in 1972. Since then, environmental considerations and policy has increasingly been integrated into all sectors of the economy, both in public and private institutions. Public authorities have further sought to apply the subsidiarity principle in delegating responsibility for environmental and natural resources management to relevant levels of government, not the least building on the strong tradition of local government and democracy in the country.

Lesson 1: The step-by-step development history/process in the G&L basin, with alpine natural lake reservoirs and downstream powerstations, has reduced the conflicts to other user interests and sectors.

Initially, development of hydropower in Norway began with small, isolated run-of-the-river power stations supplying only a few farms, small communities or local industry. The size of the power stations increased over time and the individual power producers were gradually interconnected locally, and municipal and county power companies were established. Today all hydropower producers in Norway are connected to the main grid as well as the Nordic grid. However, about 50 per cent of the Norwegian power stations are still of less than 10 MW installed capacity. A high percentage of Norwegian hydropower reservoirs are natural lakes converted to reservoirs by lowering and heightening of the natural water level. This is also the case in the G&L-basin where only one of the major reservoirs is constructed, clearly reducing conflicts around resettlements and loss of land. Current conflicts relate to fisheries and environmental issues. Thus when a country is at the beginning of utilising its hydropower potential, it would be wise to consider several small-scale projects rather than a few megasized projects. Expansion may then come gradually according to competence, economy and social/environmental impacts.

<table>
<thead>
<tr>
<th>Issue:</th>
<th>Step-by-step development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components of project cycle:</td>
<td>Planning</td>
</tr>
<tr>
<td>Lesson:</td>
<td>The step-by-step development scheme in the G&amp;L basin with alpine natural lake reservoirs and downstream powerstations has reduced the conflicts to other user interests and sectors.</td>
</tr>
<tr>
<td>Evidence:</td>
<td>The step-by-step hydropower development took place during a period of more than 100 years. All, but one reservoir, are modified natural lakes. The water level fluctuations are small. Reservoirs with great water level amplitudes are located in remote mountainous areas.</td>
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<td></td>
<td>In the mountainous areas, nature conservation, fishing, hunting and recreation</td>
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are the key interests. In the valleys and the lower part of the watercourse flood protection of agricultural areas, infrastructure and housing are the main interests in addition to nature protection and recreation. Log driving interests were accounted for in the construction and operation of the dams. However the log driving terminated in the 1980’s.

The conflicts during the licensing process and the construction phase have been very moderate. Projects with strong opposition have not been developed as f.ex. the Jotunheimen-project. Occasional changes in ground water level in some areas, loss of land from reservoir inundation and loss of fence-effect in rivers with reduced flow during summer have been important for agriculture. Minimum flow level is another important issue. Fishery issues include effects of mitigation (stocking and fish ladders), discharge levels and patterns, and minimum flow. Locally there is concern about the transfer of R. Glomma to L. Storsjøen. Special interest is related to the migrating species (brown trout, grayling and Atlantic salmon). Human resettlement is not a problem, as no permanent residents have had to move due to construction of dams and reservoirs. Flood management is discussed in relation to the distribution of negative impacts between downstream and upstream communities. According to the Norwegian legislation, the affected land owners/farmers will be compensated either by mitigation measures or financial compensation.

The integrated system of regulation reservoirs and power plants has allowed the application of new technology to increase power production with few conflicts. Conflict levels in relation to new projects during the last 10-20 years have been substantial showing that there is an increasing awareness on the negative impacts from hydropower development and increased focus on nature protection.

Views (convergent/divergent): There are divergent views on this issue among stakeholders., but there is general agreement that the current impacts do not cause major conflicts. When licenses are revised, conflict levels tend to increase and stakeholders demand better mitigation, more money for compensation, increased minimum flow and other regulation schemes. Currently there is ongoing processes in the Vinstra tributary were local communities are very active.

Positive effects of the hydropower developments concentrate on the economic value of the hydropower production for the society and for the local municipalities and the flood protection from the hydropower reservoirs.

The negative effects typically include reduced flow rates during summer and increased flow rates during winter and the assumed negative effects for fish and fisheries. In addition, the barrier effect of dams for migratory fish species, the effect on hydropower installations on landscape aesthetics and the assumed effects on climate, nature conservation and tourism are important. Local interests are often seen as the weak part in hydropower developments. The long history of the G&L scheme and the comprehensive licensing process may complicate the caretaking of local interests.

Lesson 2: Periodic, planned re-evaluations of project operations provide a mechanism for incorporating changes in science, technology, and changes in social values and user interests into project operations.

Changes in science, technology, social values and user interests in society provide an opportunity to improve hydropower performance by applying new technology, and the power production in the G&L basin, has increased substantially. Performance can also be improved in relation to ecological, social and other user interests. Ecological effects are diverse and often unexpected, and in some of the projects the ecological effects occur long after the regulation. The legal opening for periodic
evaluation of existing licensed conditions provide a mechanism for introducing new developments in science and technology into water management operation as well as changes in political and public concerns.

<table>
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<tr>
<th>Issue:</th>
<th>Changes in science, technology, social values and user interests</th>
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<tr>
<td>Components of project cycle:</td>
<td>Management</td>
</tr>
<tr>
<td>Lesson:</td>
<td>Periodic, planned re-evaluations of project operations provide a mechanism for incorporating changes in science and technology into project operations as well as to account for changes in social values and user interests.</td>
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<tr>
<td>Evidence:</td>
<td>Hydropower production has increased by new technology. New knowledge on ecological impact and effect of mitigation has been important in developing operation schemes and mitigation measures. The ecological effects have proven to be diverse and often unexpected, and in some of the projects, the ecological effects occur long after the regulation. In Norway, private licensees must hand over power stations, regulation dams etc, in operative condition, to the State once licenses expire. New licenses are generally granted, but on revised conditions. The licensing time is unlimited for public licensees, but all license holders have to accept a possible renewal of the licensing conditions each 30 years (enacted in 1992). The legal opening for periodic evaluation of existing licensed conditions provide a mechanism for introducing new developments in science and technology into water management operation as well as changes in political and public concerns. Licenses can be granted for a limited or unlimited time period. The practice so far is that the licenses are given a time limit of 60 years for private enterprises and for an unlimited time period for publicly owned enterprises. All licences are given on conditions that they inter alia regulate the relationship between the licensee and general public interests. Some conditions follow directly from obligatory provisions in the Watercourse Regulation Act, while others are customised individually for each license based on an assessment of the project. Sustainable natural resources management is guided and safeguarded through licensing regulations and procedures Licensing legislation was introduced in Norway first as a means for ensuring that private interests did not gain permanent ownership to renewable water resources like water-falls. Licensing today entails specification of licensee rights and responsibilities, as well as requirements like environmental assessment, public consultation and time-bound review procedures for gaining permits to implement and operate dams.</td>
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The following possibilities exist to change conditions of an approved license:
- When the license contains conditions concerning revision access.
- When the law permits access to revision of conditions.
- With the administration’s non-statutory access to revision. This is a form of the principle of necessity. There is no basis in legislation, but the administrating authority has the right to intervene in the event of unexpected circumstances that clearly need to be addressed.
- In cases were the scheme leads to significant damage to public interest that were not considered at the time of licensing, most flow schemes also contain a provision allowing the licensing authority to implement at any time the necessary amendments.

The licensee can at any time apply to have the license or the conditions amended.

Views (convergent/divergent): No divergent views have been stated in the process.
Lesson 3: The Protection Plan for watercourses and the Master Plan for Water Resources have been important tools to plan hydropower development.

In 1960 the Parliament initiated the work with the first comprehensive plan for hydropower development of the water resources to handle the large number of hydropower projects being forwarded for licensing. The background was the large number of hydropower projects being forwarded for licensing to the Parliament in post-war Norway, and a growing frustration among politicians for having to deal with these applications one by one. The dilemma for the politicians was to a large extent whether to protect or to develop. A binary planning system was developed, with one set of plans for protection (The Protection Plans for Watercourses), and one set of plans for development (The Master Plan for Hydropower Development Projects). In total 341 watercourses are now protected in Norway. The Master Plan defines an order of priority for the consideration of individual hydropower projects on the basis of economic considerations and the degree of conflict with environmental and other user interests. The Plan is thus intended to assure that those projects that can provide the cheapest power, and, which have the smallest environmental impacts, are developed first. The Master Plan was first passed by Parliament in 1986. A new revision of the Master Plan is scheduled for year 2000.

| Issue: Protection Plans and Master Plans |
| Components of project cycle: Planning and licensing |
| Lesson: The Protection Plan for Watercourses and the Master Plan for Water Resources have been important tools to plan hydropower development. |
| Evidence: In the period 1973-93 four Protection Plans passed the National Assembly. The work with the first generation Master Plan commenced in 1981. In total 341 watercourses (or parts thereof representing an area of 110 000 km² and 35,1 TWh/year power potential) are now protected in Norway. In the Glommen-Laagen basin, 27 sub-basins with a potential of 4.1 TWh/year are protected. The Ministry of Petroleum and Energy and NVE administers the plans. |
| Views (convergent/divergent): The Master Plan was from the outset a contested tool in hydropower policy, and it remains an uncertain question if the plan has had a conflict reducing function or not in the public debate on power policy. One should keep in mind that the major part of the hydropower potential was developed before the Master Plan was established. The various stakeholders have divergent views on the planning system and this is particularly related to the Master Plan. Some claim that this has been a very effective and good method for planning hydropower development. Others point to what they see as weak points such as the balance between the Protection Plan and the Master Plan. The Master Plan has also been contested by the Parliament such as in The Øvre Otta project which has been changed in the licensing process, and there was also strong opposition in the Parliament, which wanted to protect this area from further hydropower development. The Master Plan in Norway was originally intended to reduce possible conflicts by ranging “all” possible future projects by economy and environmental impact. The result is much debated and the effects questioned. This also applies to the methodology and the fact that Norway now has a widely accepted Protection Plan. The Protection Plan was only intended to prevent hydropower development and other human activities (road construction, urbanisation, deforestation, agriculture etc) affecting the actual watercourse. This is a major criticism on the Protection Plan. As a result a project mapping the values in the protected watercourses is underway. |

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Lesson 4: Regional distribution of income from hydropower development in the Norway is ensured by a and dependent upon a formalised system involving compensation, taxes, license fees, sale of licensed energy and owner incomes.

Regional distribution is an important issue in Norwegian hydropower development and is recognised in the legislation. Regional distribution of income from hydropower development in the Norway is ensured by a system involving compensation, taxes, license fees, and sale of licensed energy and owner incomes. The regional distributions also include a lump sum of resources for development of local industry, as well as employment and secondary income from the increased activity during and after the construction period. Infrastructure elements such as communications (roads and telecommunications), quays, public halls, utilisation of surplus rock from excavations and underground works for roads and other construction purposes etc.

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<tr>
<th>Issue: Distribution of income</th>
<th>Components of project cycle: Management</th>
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<tr>
<td>Lesson: Regional distribution of income from hydropower development in the Norway is ensured by a and dependent upon a system involving compensation, taxes, license fees, sale of licensed energy and owner incomes.</td>
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| Evidence: | For local communities, the construction period represented growth in employment, increased tax revenues and increased demand for goods and services. However, the economic and population development in the GL region is similar to regions without hydropower development. Only a few of the municipalities have higher incomes than they would have had otherwise. Approximately 250 persons are employed in the production part of the hydropower sector, i.e. excluding transmission, marketing and sales, which represents the majority of employed persons. When including all, the total number of employment is approximately 2100. The direct economic effects in the GL region today come from revenues to the municipalities in the form of taxes, license fees, sale of licensed energy and owner incomes (dividends) as well as compensations. Of accumulated public incomes of 71 Mill US$ from the energy sector in GL, a 55 Mill US$or almost 80 per cent went to the GL region. The energy revenue amounts to about 1.9 per cent of the total incomes in the municipal sector (municipal and counties) in the GL-region. Norwegian legislation recognises the necessity to afford local communities a share of the economic profit from the hydropower development within their territory. The benefit to the local communities may be in terms of supply of power (up to 10%) from the power stations located in their territory, where the price is to be determined by the Ministry of Petroleum and Energy. In 1998 the amount of such power supply was 8.5 TWh / year.  
- A lump sum of money for development of local industry (the largest individual sum so far has been NOK 40 million).  
- Property tax (7 0/o of taxation basis)  
- Licensing fee (up to NOK 40 per Hp). Total amount on national basis in 1997 was NOK 107 million.  
- Employment and secondary income from the increased activity during and after the construction period. On national basis some 18 000 employees are estimated in hydropower utilities (production, transmission and distribution). |

| Views (convergent/divergent): | There is general agreement in Norway that the regional economic impact was substantial. The relatively low energy revenue calculated in this study have caused some discussion and a claim that the figures are too low. It is also claimed that the importance of revenue from hydropower development is higher in other regions of the country. Some of the richest municipalities in the country have a substantial income from hydropower revenues. |
Lesson 5: In the G&L basin, the combination of a moderate regulation and special flood operation procedures has high flood prevention effect.

There have been no specific goals for flood control in terms of predictions to reduce flood levels, flooded area or damage. Generally, there has been a trend towards reduced flood levels in the G&L basin during the last 150 years, mostly due to the establishment of reservoirs that permit co-ordinated flood management decisions. The basin degree of regulation increased from 4 to 16 per cent during the 20th century. In addition to the use of the reservoirs during major flood events, other protective measures in the low areas of the basin include flood banks, and since 1995 also flood hazard mapping, zoning and public information during flood periods.

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<tr>
<th>Issue: Flood protection</th>
<th>Components of project cycle: Management</th>
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<tr>
<td>Lesson: In the G&amp;L basin, the combination of a moderate regulation and special flood operation procedures has high flood prevention effect.</td>
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<td>Evidence: The G&amp;L basin have experienced several large floods during the last century with the 1995 flood as the most severe (return period of 200 years). In spite of the significant flood reduction the total estimated flood damages of the 1995 flood was 280 mill US$. Statistical analysis of long time series revealed no significant climatic trend which has influenced the floods, and modelling work showed that the establishment of reservoirs was the most significant flood reducing human activity in the basin. Calculations of flood peak attenuation of the major floods in the main rivers from 1900 to 1999 show that today’s reservoirs capacity yield considerable extra flood attenuation.</td>
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<td>Views (convergent/divergent): There is a wide spread agreement on the flood abating effects of the regulation. During the 1995 flood stakeholders in various sections of the basin claimed that the flood levels in River Glomma were reduced with approximately 1 meter, in the River Lågen and in Lake Mjøsa 0.5 meter and in Lake Øyeren 2 meters.</td>
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Lesson 6: Flexibility in the authorisation of mitigation and co-operation in the G&L basin have yielded more effective measures to compensate for negative impact from hydropower development.

During the last 10-15 years, the GLB, the individual powercompanies and the environmental authorities, as well as landowner representatives have co-operated on fish issues related to the hydropower sector. The aim of this work has been to identify the optimal use of resources to improve the conditions for fish production and angling. This includes test fishing, registration of fish migrations in fish ladders, catch statistics and data to evaluate mitigation measures, as well as implementation of various mitigation measures such as fish stocking, habitat improvement, fish ladders and minimum water flow. The experience from these projects is very positive and demonstrates some of the benefits from an open dialogue and co-operation between the stakeholders. In this way cost-effective measures can be developed to substitute those implemented in the license process.
### Issue: Mitigation measures

#### Components of project cycle: Management

#### Lesson: Flexibility in the authorisation of mitigation and co-operation in the G&L basin have yielded more effective measures for compensation.

#### Evidence: Mitigation efforts in general do not compensate ecological effects as expected during the licensing process. The mitigation measures include fish stocking, habitat improvement, fish ladders and minimum water flow levels. An intensive research activity on mitigating measurements as an alternative to monetary compensation has proven beneficial in Norway as well as in the G&L-basin. Most of the mitigation measures have changed during the period of operation and monitoring prove that the measures become more effective and more ecologically acceptable.

Efforts related to mitigation have been considerable in the basin, especially fish mitigation, and it is clearly demonstrated that mitigation measures have to develop over time in order to improve the effects. During the last decades there has been increased co-operation between the various stakeholders and the Glommen’s and Lågen’s Water Management Association, and this have resulted in a number of positive outcomes such as improved fish mitigation measures.

#### Views (convergent/divergent): There is a general consensus on the need to develop more effective and ecological sound mitigation measures. Some stakeholders feel that the measures in operation are not sufficiently comprehensive and that more efforts should focus on changing the physical characteristics of the actual regulation.

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### Lesson 7: The Glommens and Laagens Water Management Association (GLB) is an important institution in the integrated operation of the G&L basin with respect to hydropower production, flood dampening and environmental mitigating procedures.

The GLB play an important role in co-ordinating the operation of the complex system of reservoirs on behalf of their members. It is also a communication partner for other interests co-operating on ecological issues and mitigation improvements. Reservoir operations are supposed to adapt step-by-step to the new Energy Act and the system of market liberalisation. Yet, the degrees of freedom are limited due to physical and legal constraint. GLB has an important role in reducing flood damage as there is a considerable flood abatement effect in optimal basin operation. However, the basin operation is not yet optimal from an economic point of view. An additional income potential of 3,8 mill US$ was estimated in 1995. Optimising the water resources for hydropower production is the main objective of GLB. However as a consequence of the still growing number of issues within water resource development, the association also carries out other types of management work in the joint reservoir system, for example in relation to environmental issues.

#### Issue: Co-ordinated water management

#### Components of project cycle: Management and Operation

#### Lesson: The Glommens and Laagens Water Management Association (GLB) is an important and competent participant in the integrated operation of the G&L basin both with respect to hydropower (electricity) production, flood dampening and environmental mitigating procedures.

#### Evidence: The Glommens and Laagens Water Management Association (GLB) founded in 1918, operates the reservoirs as a sector organisation for the hydropower producers in the G&L basin. GLB members include 21 hydropower and industry companies. GLB hold licenses for a complex of 26 regulated reservoirs of small and medium size which together provide some 3 500 million m³ of storage, equivalent to 16 % of the runoff in the G&L basin.

The legal basis for GLB is stated in the Water Regulation Act from 1917. The basis for GLB has been confirmed during several revisions of the Act and even expanded.

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Important issues for GLB which demonstrate their importance include:

- Monitoring, modelling and forecasts are important tools for G&L basin operation and management.
- Co-ordinating the operation of the complex system of reservoirs on behalf of their members.
- Communication with other interests and co-operation on ecological issues and mitigation to improve the conditions and reduce conflict levels
- Adapt the operation of the reservoirs step-by-step to the new Energy Act and the system of market liberalisation.
- Reducing flood effects. Optimal basin operation and pre-release based on data and simulation models has considerable flood abatement effect. The GLB act as a command centre for all operations in the river basin when floods threaten or are in progress.
- Holds the licenses for the reservoirs and diversions. This arrangement reduces possible conflicts between the power companies operating the power stations in the river basin utilising the same upstream reservoirs.
- Act as a fix-point/competence centre with more consistent experience in hydropower development than the individual powercompany, which may have only one or a few development projects with decades between each one.

Views (convergent/divergent): There is consensus among stakeholders that the GLB is an important institution in the basin. However there are divergent views on the role of GLB and some claim that it is only a water user association representing the interests of the hydropower sector. However, GLB is instituted in the law and serve many important tasks for the public interest.

GLB is relatively well known by the stakeholders as the organisation representing the interests of the power companies for optimal utilisation of the hydropower resources in the G&L basin. The stakeholders also frequently mention the advantage of co-ordination through a basin association and that it makes it easier for local basin interests to have one organisation to deal with compared to 20 power companies.

Lesson 8: In the G&L basin systems for monitoring and sharing of data are needed in hydropower production, flood prevention, to illustrate compliance with current regulations and to measure social and ecological impact.

Data series and subsequent modelling of the water course is a salient management tool to meet the various and often conflicting demands in the short and long term operation of the basin, including flood issues, impact assessments, economic simulations, operational planning, and development planning. Additionally, detailed descriptions of reservoirs, basin, power stations and other technical facilities, in addition to reliable market forecasts are required to produce good modelling, analysis and management strategies.

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<th>Issue:</th>
<th>Monitoring</th>
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<td>Components of project cycle:</td>
<td>Management</td>
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<tr>
<td>Lesson:</td>
<td>In the G&amp;L basin systems for monitoring and sharing of data are needed in hydropower production, flood prevention, to illustrate compliance with current regulations and to measure social and ecological impact.</td>
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<td>Evidence:</td>
<td>NVE is the key institution for monitoring and data collection on hydrological conditions in Norwegian watercourses. The NVE database encompasses more than 6000 measurement points on different phases of the hydrological cycle (water levels in rivers and lakes, river flow rates, ground water levels, soil humidity, ground frost, snow depth, glacier measurements and sediment</td>
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Most of the hydrological monitoring stations in Norway are operated and financed by the owners of the hydropower regulation facilities. In the G&L basin GLB operate and finance most of the monitoring stations supplemented by NVE. The data collected is used by GLB in basin modelling and forecasting for reservoir and flow disposal and for hydropower production strategies.

Monitoring of water quality, air quality and biological parameters is financed by the state and performed by national research institutes like Norwegian Institute for Water Research, Norwegian Institute for Air Research and Norwegian Institute for Nature Research. Several of the monitoring stations are located within the G&L basin. In addition local municipalities monitor water quality and biological conditions in multiple local watercourses (tributary rivers to Glomma and Lågen).

The experience from the 1995 flood demonstrates the importance of monitoring. Further, the experience from the mitigation projects has clearly demonstrated the importance of the monitoring programs. The data sets are important tools in the daily operation of the reservoirs and hydropower stations.

| Views (convergent/divergent): | No divergent views can be identified. |
9. Stakeholder Views on Effects and Development Effectiveness of Hydropower Development

Stakeholder views on effects of the G&L hydropower development

The methodology for collection of stakeholder views is described in Annex 1.

The response to the questionnaire sent out to a selection of 50 stakeholder representatives were quite low, and 20 questionnaires have been returned properly answered. The reasons for the low response are probably that all the G&L hydropower development projects are more than 25 years old, and it is difficult to find persons in municipalities and NGO’s being familiar with the history of the actual development projects. In addition several of the development projects were quite uncontroversial at the time of implementation. As a consequence the engagement in the projects were quite low at the time of implementation and even lower 40 years later. Another reason may be that some of the questions were quite difficult to answer an several of the stakeholders did not feel competent to answer the questions raised, ex the question on effects on development of the area and the compliance with laws, regulations and policies. Some of the NGO’s also looked upon the question of compliance as biased, not being relevant for the G&L hydropower development projects.

Because of the low response from the stakeholder group the results from the questionnaire survey are not used quantitatively and the will probably not be representative for the whole stakeholder group. Some conclusions may however be drawn from the survey:

Positive and negative effects of the G&L hydropower development

Positive effects of the hydropower developments mentioned in the questionnaires concentrate on the economic value of the hydropower production for the society and for the local municipalities and the flood protection from the hydropower reservoirs.

The negative effects mentioned most frequently were reduced flow rates during summer and increased flow rates during winter and the negative effects of this for fish and fisheries. In addition the barriers of dams for migrating fish species, the effect on hydropower installations on landscape aesthetics and effects on climate, nature conservation and tourism were mentioned. It was also mentioned that local interests generally are the losing part in hydropower developments.

Mitigation efforts

Mitigation efforts (minimum flow rates, fish ladders, fish stocking and building of weirs) have been performed in The G&L basin, but the answers indicate that the mitigation efforts do not compensate fully the negative effects for the affected interests.

Total effect of the hydropower developments for the society

The total effect of the hydropower development projects are most frequently classified as mainly positive for the society. It is also mentioned that the classification will depend on weather it is the effect for local societies or the effect for the national society.
The influence of local communities and local interests in decisions on hydropower development

Some of the respondents claim that the G&L developments are so old that local interests have not been properly taken care of. Others claim that the licensing process is so comprehensive and democratic that local interest are well taken care of.

The compliance with laws, regulations and policies

This question is answered by very few of the respondents. The answers state that the decisions have been made in compliance with laws and regulations of the day of the decision. It is also mentioned that a couple of the development projects were approved for license during World War II, and that even though the decisions were made according to laws and regulations all the premises were set by the company applying for development license.

Lessons learned

Main lessons learned mentioned by the stakeholders:

- It is important that the hydropower development projects are owned by local companies to ensure that as much as possible of the values and incomes from the projects serve the local communities to make up for the negative effects of the developments.
- It is very difficult to predict ecological effects of hydropower developments.
- Strong economical interests in hydropower development create expectations that is hard to come up to, and the negative effects will often be evident first when it is too late. The main understanding is that hydropower development creates jobs and positive input for local economics. This is not always true, and the considerations on long term effects and the value of pristine nature is often underestimated.
- Aesthetic effects and reduction of recreational value from hydropower developments are considerably less significant than claimed in the licensing process of hydropower development projects. The experience is that both local communities and the tourism sector accept the changes surprisingly fast and uncomplicated.
- Fish mitigation efforts are more resource demanding than anticipated, but give on the other hand very positive results on fish populations even though they do not completely compensate the negative effects.
- The expectations from local municipalities on long term increased employment and incomes from hydropower developments is not fulfilled.

The Water Management Association - GLB

GLB is relatively well known by the stakeholders as the organisation representing the interests of the power companies for optimal utilisation of the hydropower resource in the G&L basin. The stakeholders also frequently mention the advantage of co-ordination through a basin association and that it makes it easier for local basin interests to have one organisation to deal with compared to 20 power companies.
Stakeholder views on development effectiveness from the 2nd stakeholder meeting

The questionnaire distributed as a part of the material for the 2nd stakeholder meeting gave very low response.

Additional contributions from stakeholders are:

Atlantic Salmon in lower Glomma

One stakeholder was concerned on the effects of hydropower regulations on the Atlantic Salmon in the lower part of the G&L river. Very few, if any, studies have been carried out to find out the effects of water regulations in the lower part of Glomma/Ågårdselva. The Salmon runs up the lower part of Glomma to Vamma. Very little is mentioned about the consequences in the lower part of Glomma due to the regulations at Vamma. The Atlantic Salmon is an endangered species and Norway has an international responsibility towards the salmon. There are many examples from River Ågårdselva (the lowest part of Glomma) where water regulations upstream have killed thousands of salmon. So far the power companies have not been very willing to improve the conditions for fish production in River Ågårdselva.

The regulation schemes

Another stakeholder was concerned about how the regulation schemes in the G&L basin should be formed today. It is necessary with a revision of the regulation schemes of existing G&L regulations to improve the possibility to use the regulations for flood protection purposes and to strengthen the environmental considerations in the regulation schemes. Today the power sector is in a phase of restructuring adapting to the new energy market. The new profit requirements makes the situation quite different from the situation when the hydropower developments in the G&L basin were executed. The basis for the developments were that each power company had an obligation to supply end user customer in their licensed area. Now this obligation is ended and the regulation framework of the established regulations should be discussed in the light of the new situation. Key words for the revisions are minimum flow rates, peaking, seasonal draw-down of reservoirs and combination of reservoir functions for hydropower and flood protection purposes.

Stakeholder views incorporated in chapter 8

Stakeholder views on lessons learned also included supplements to the lessons learned proposed in the report draft for the stakeholder meeting. The additional background material and descriptions and the suggestions from stakeholders on the wording of the lessons learned are all incorporated in the lessons learned in chapter 8 of the report.
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