Key Issue:
10-Landscape and Cultural Heritage

Climatic Zone:
Cfc: Temperate

Subject:
- Conservation of Natural and Cultural Landscape in the Project Area.

Effects:
- Preservation of beautiful landscape with amazing canyons and reduction of negative impacts from reduced rate of flow in the river basin.


Flåmsdalen valley near Aurland.
(Photo: Oslo byarkiv, photographer P.O.Breifjell)

Project Name: Aurland Hydropower Development
Country: Norway

Implementing Party & Period
- Project: Oslo Lysverker
1960 - 1984 (Preparation and Application), 1969 - 1984 (Construction),
1984 - (in Operation)
- Good Practice: Oslo Lysverker
1969 - 1984 (Construction), 1984 - (Effective)

Key Words:
Aesthetic Scenery, Underground Structures, Re-vegetation, Natural Rock Weir

Abstract:
The Aurland hydropower development project, with 5 power plants, was completed in 1984. As the Aurland Valley in Western Norway was recognized for its dramatic natural beauty, various measures to reduce the negative impact of construction on the natural and cultural landscape were taken, including re-vegetation of the disposal site and quarries, extensive use of tunnels in road construction, and small weir dams to create a more natural landscape in the river flow.

1. Outline of the Project

The Aurland hydropower development project with five power stations was completed in 1984 after fifteen years of construction work with a capacity of 840 MW, and in 1992 it still covered 30 % of the electrical power consumption in Oslo (the capital of Norway). A third unit of 250 MW has later been installed in Aurland 1, and total installed capacity is 1100 MW today. The power stations depend on the enormous energy available in the hydro system of the steep mountains in Western Norway (Fig.1-2, Table 1).
The project was accomplished by the municipality owned company “Oslo Lysverker”, and the power division from Oslo Lysverker is now transferred to “E-CO Vannkraft”. The City of Oslo still owns the major part of E-CO

Vannkraft and the installations in Aurland. The main goal for Oslo Lysverkers hydropower projects from the Second World War to the eighties were to keep up with the increase in power consumption in Oslo, to keep Oslo "self-supported" with reliable energy. According to this goal the project in Aurland was planned as a step-by-step development following the growth in power consumption in Oslo, with several subprojects completed and ready to supply power over the 15 years construction period.[1] The annual growth in power consumption in Oslo was 3-5 % between 1962 and 1979.[2]

The first plans for a large hydropower development project in Aurland as we know it today were prepared in 1944, and the legal acquirement of land and rights were done in 1946. The Aurland project were the fourth large-scale hydropower project conducted by Oslo Lysverker, and therefore benefited from the experience gained in the earlier projects (the Hol, Hemsedal and Uste/Nes projects were accomplished between Second World War and the early sixties). Growing concerns for environmental issues in the population lead to an increasingly thorough and extensive governmental process evaluating the application for concession, the process lasted from 1965 to 1969. The environmental impacts were also limited due to technical development, especially regarding tunneling and underground constructions.

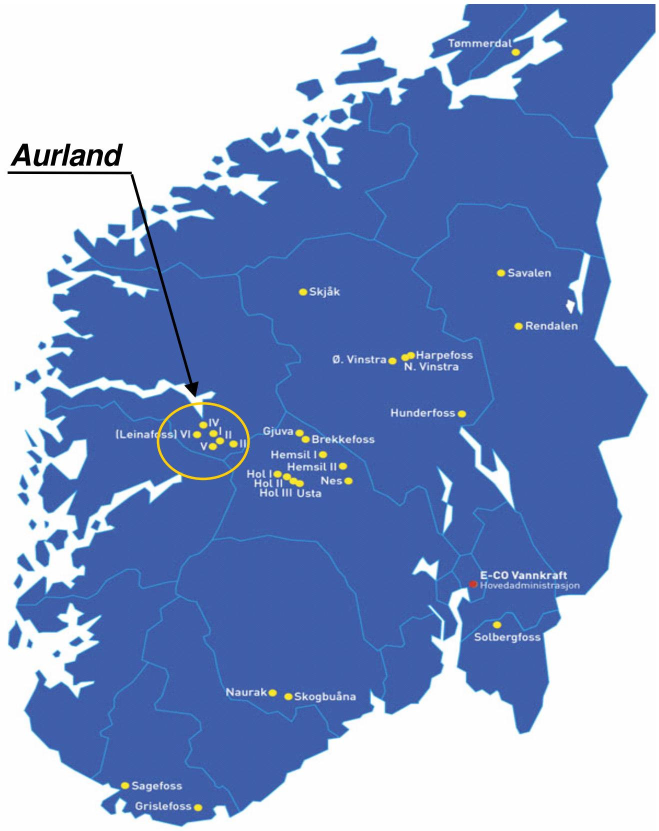

Fig.1 Location of the Project

Table 1 Characteristics of the Aurland hydropower plants (from www.oep.no)

		Aurland I	Aurland II		Aurland III	Aurland IV	Aurland V
Catchment area:	Km²	56	339	92	92	140	15
Reservoir capacity:	mill. m³	196	10	189	448	3	17
Tunnel length:	Km	3	9.864	18.794	4.03	5.718	
Head:	m	840	110	480	400	55	400
Turbine capacity:	MW	675	63	72	270	31.5	9
Mean production:	GWh	1993	186	211	350 / 281	105	24
Maximum flow:	m³/sec	96	68	15	80	79	3
Generator capacity:	MVA	3x250	2x35 / 80		2x150	35	10
Transformer voltage:	kV	420 / 15.5	380 / 66 / 9.9		420 / 15.5 / 7.75	68 / 6	68 / 4.3
Commence of construction:	Year	1969	1979		1975	1976	1980

Initial year of operation:	Year	1989	1983	1979	1980	1983

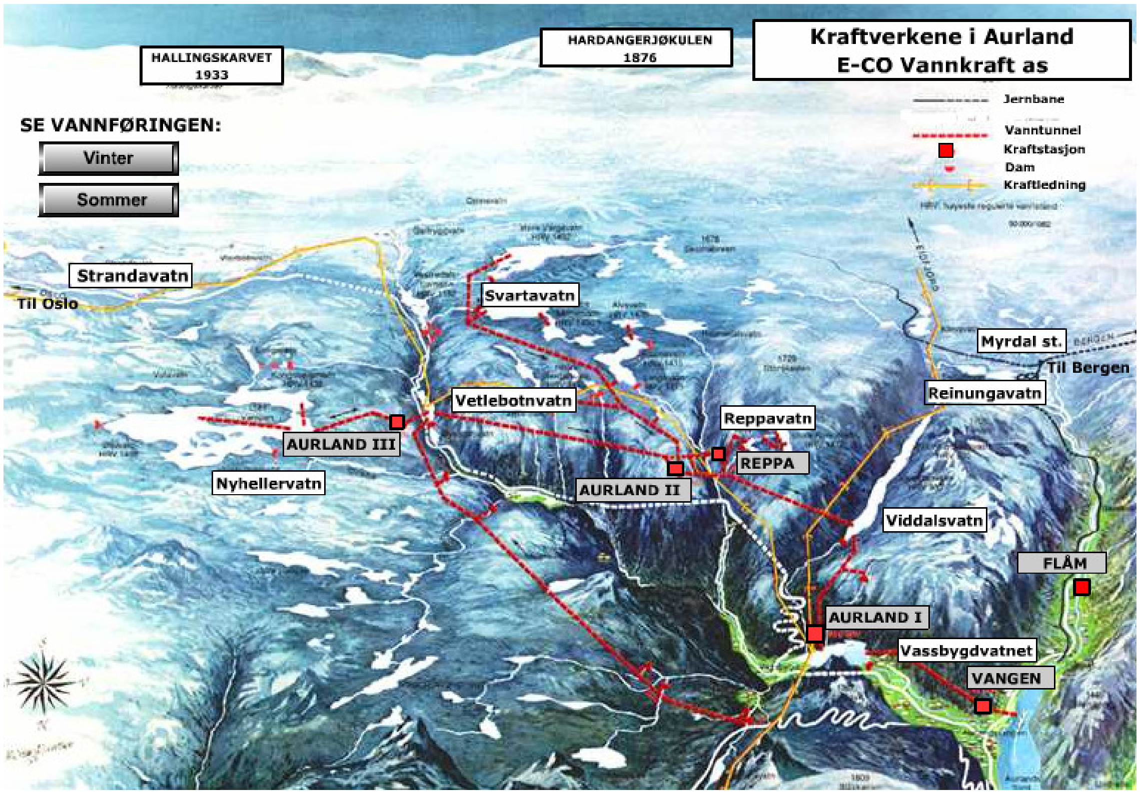

Fig.2 Project overview (from www.oep.no)


Photo. 1 Dam and reservoir, Vetlebotnvatn.
(Photo: Oslo byarkiv, photographer P. O. Breifjell)

2. Features of the Project Area

Photo. 2 River in Aurland.
(Photo: source Oslo byarkiv, photographer P.O.Breifjell)

Situated by the Aurland Fjord, connected to the famous Sognefjorden, the area is internationally recognized for its dramatic natural beauty. [3] The earlier projects in Hol, Hemsedal and Uste/Nes mainly took place in areas already extensively influenced by established tourism industry. The Aurland catchment area offered a stunning variation from virtually untouched wilderness with highland plateaus (elevation of 1300-1500 meters above sea level (m.a.s.l.) and mountains up to 1800 m.a.s.l.) and glaciers to villages alongside the river and small farms (Photo.1-2). Irreversible interventions in areas regarded by large groups of the population as wilderness that should be protected area added a new controversy to the planning process. Adjustments in the plans and compensations due to impacts in the riverbanks and lower parts of the catchment area turn out to be easier to handle than the protests from environmental activists working for preservation of natural amenities.

3. Major Impacts

Impacts from the hydropower development project affect an extensive variety issues, such as aquatic and marine ecosystems, fish stocks, ice conditions in the Aurland Fjord, terrestrial ecosystems and cultural heritage. In all development areas we must include small or large impacts for current and future aesthetic value for recreation and/or preservation, for instance with respect to electrical transmission lines. Access roads tend to increase traffic and may result in changes, regarded as good or bad depending on actual point of view, in land use. The construction activities have various impacts on the flora and fauna in and around the entire river system. [4] Tunnels for water, between reservoirs and from reservoir to the power stations, yields large amounts of rock that has to be utilized or deposed.

For the highland plateaus the major impacts relevant for this report are:

- roads, during and after construction period
- quarries for extraction of deposits
- rock deposits, near dams, tunnels etc.
- dams, intakes and reservoirs (“artificial lakes”)
- shorelines in regulating area of reservoirs

For the river, and for some aspects the Aurland Fjord, the major impacts relevant for this report are:

- aesthetic impression for people changed after the project
- changed water flow and path, for instance with tunnels from one river basin to an other
- changed water temperature
- reduced or changed flow rate
- ice conditions

4. Mitigation Measures

Long tunnels through mountains and subterranean power facilities in bedrock are distinctive characteristics for Norwegian hydropower. One advantage from this is clearly the aesthetic aspect; large parts of the installations are not visible and give no impact on the surroundings above earth. Quarries and rock deposits are disadvantages for this practice.

Rock deposits:

Using experience gained in earlier projects excessive rock material were placed in rock deposits formed by landscape architects based on local conditions. Most deposits were revegetated to faster make the rock deposit look like a natural part of the landscape. This proved efficient, and also quarries and dams were vegetated for the same reasons. Shortly and simplified described a topsoil is distributed over the rock deposit as foundation for selected vegetation based on the local flora. The selection of vegetation is adjusted to the slightly dryer conditions at the rock deposit (the rock deposit usually has increased drainage compared to the surroundings). Photo.3 shows the same area before and after revegetation.

Photo.3 Rock deposit, before and after revegetation. (Photos: P. O. Breifjell)

<u>Roads:</u>

Environmental issues have been an integrated part of road-construction in the project area. Extensive use of tunnels and assistance from landscape architects has limited the impacts (Photo.4). Ancient hiking trails can be found all over the area, and while evaluating the application for concession the Government expressed a special interest in preserving the area visible from the major hiking trail alongside the middle of the Aurland valley (the area between Aurlandsvann and Vassbygdi). The road through this part of the valley was built with three tunnels, and only a short passage (near Berdalen between Aurlandsvann and Vassbygdi) is visible from the major hiking trails in the area.

Photo.4 Road after revegetation.
(Photo: P. O. Breifjell)

<u>Ice conditions:</u>

The discharge from the power station Vangen (Aurland 5) in lowered 25 meters below sea level and has a mandatory minimum flow of 3 m^3/s during winter. Surveys have confirmed an improved ice condition due to this measure. This consequence also belongs to a different key issue and will not be further described here.

<u>Weir dams:</u>

To create a more natural visual impression of the river several weir dams (small and low dams in the river with a level regulating function) were built in the river. These weir dams give a larger surface of the river, especially in times with low water flow in the river. Together with rules on minimum flow or required discharge volumes at different times of the year this reduces the visual impacts in the river-area from water-regulating for production purposes.

A weir dam formed by rocks as shown in Photo.5 reduces the visual effect of the construction, and time has proved this to be a suitable solution for calm stretches of a river.

For more challenging conditions the weir dams had to be made of concrete, but through careful design and location the impact can be reduced (Photo.6).

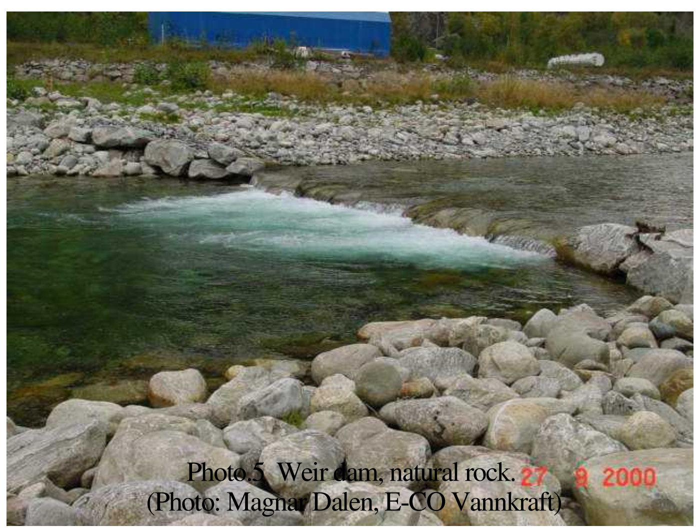

Photo.5 Weir dam, natural rock.
(Photo: Magnar Dalen, E-CO Vannkraft)

Photo.6 Weir dam, concrete. (Photo: Magnar Dalen, E-CO

5. Results of the Mitigation Measures

Rock deposits:

Rock deposits formed by landscape architects and revegetated based on local conditions looks more like a natural part of the landscape, and moderates the visual impact. Public and governmental demand for a similar approach in later projects (roads, industrial sites and large land development project) confirm the mitigation result of these measures.

Cooperation with the Ministry of Transport and local authorities has opened for positive side effects. Several deposits have been placed in assign areas where they are easy accessible and thereby made available for the Ministry of Transport to use in later road construction and similar projects within public infrastructure.

- Total volume of rock disposal : 11,400,000 m^3
  Employed for construction of roads and dams : 5,200,000 m^3
  Employed for creating rock deposits : 6,200,000 m^3
- Total area of re-vegetation : 1,600,000 m^2
  Area of re-vegetation on rock deposits : 472,000 m^2

Roads:

The chosen path for the road through the valley resulted in a reduced impact where only a short passage of the road is visible from a shortened stretch of the hiking trail in the area (Photo.7). This more expensive solution also resulted in a safer connection after the road was opened for public usage, with tunnels through areas with risk for snow avalanches.

One major positive consequence of the hydropower development for the people in Aurland is a stabile all-year road connection, which they did not have prior to the hydropower development project. The prospective possibility to achieve this reliable road-connection was one of the most important reasons for the positive attitude towards the Aurland hydropower development project among the inhabitant of Aurland. For transportation purposes during the construction period Oslo Lysverker built several roads in the area. Oslo Lysverker chose to build the main road between Aurland and Hol as a two-lane road with higher standard than required, and this road is today one of the main public roads east west in Norway. To avoid a highland plateau the project included a tunnel under the Geiteryggen. This consequence belongs to a different key issue (K13 Improvement of infrastructure) and will not be further described here.

- Length of rebuilt hiking trails : 12 km
  Yearly number of hikers through the Aurland Valley : 12,000
- Length of constructed main roads : 60 km
  Length of construction roads opened for public use : 54 km

Weir dams:
Together with rules on minimum flow at specified times of the year the weir dams have reduced the visual impacts in the river-area. The weir dam also has a positive biological effect providing shelter and breeding conditions for fish in the river.
- Number of weir dams : 34
- Increased surface of river by construction of weir dams : 982,500 m^2

Photo.7 Tunnel opening in valley Berdalen.
(Photo: P. O. Breifjell)

6. Reasons for Success

- Local groups working for improved road-connection, access to reliable electrical power and infrastructural development
- Extensive application for license, including environmental impact assessments, prior to the construction
- Economical willingness and capability to include environmental issues in planning from the start of the project

7. Outside Comments

"The Aurland hydropower development project has proved itself to be a modern installation, accomplishing present requirements for hydropower development. The project is a reference project where special mitigating measures has been taken during the entire process from construction to operation. Great efforts have been made to reduce aesthetic impacts and preserve the local landscape. Environmental and ecological considerations are also respected in operation of the installations, and visual impact is taken into consideration in water management."
Ivar Sægrov, The Norwegian Water Resources and Energy Directorate, Western Region. (www.nve.no)

8. Further Information

8.1 References

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8.2 Inquiries

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