EFFECT OF RIVER REGULATIONS ON WINTER ENVIRONMENT EXPERIENCE FROM ICELAND

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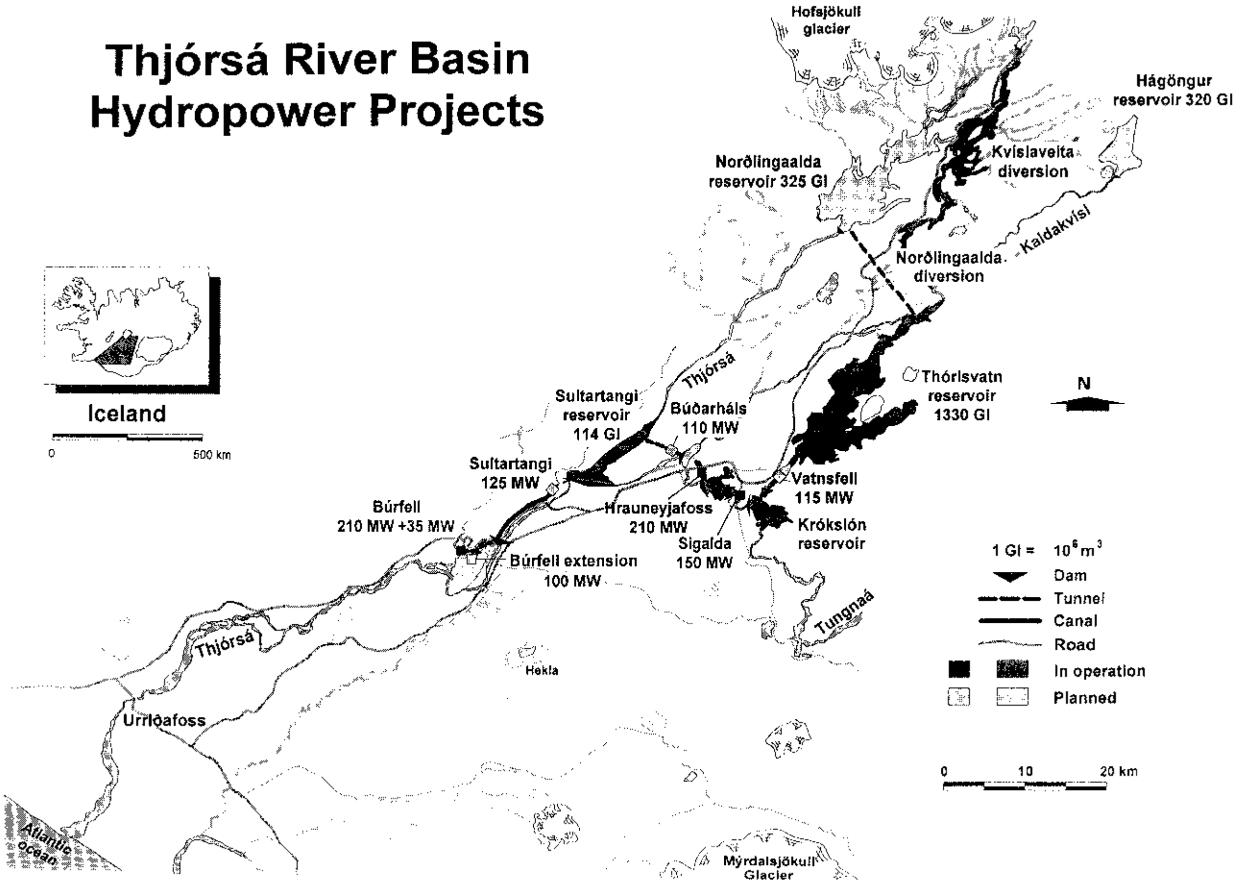
ABSTRACT

Iceland has limited natural resources, consisting almost solely of fish stocks, grassland, geothermal and hydropower resources. The hydropower is a very important resource for the island's population of 270000. The technically harnessable energy of the rivers in Iceland is estimated 60000 GWh/a. Presently about 4500 GWh/a or 15 percent has been developed. The river basins are glacierized and the power production depends heavily on regulation. The regulations have had a profound effect on winter discharge of the rivers. The major powerplants are three in the Thjórsá river basin in southern Iceland, totalling 570 MW, and one, 150 MW, on the Blanda river in northern Iceland. The normal winter discharge downstream of the Thjórsá power plants is now about 240 m^3/s compared to about 150 m^3/s before. The corresponding figures for Blanda are 25-30 m^3/s and 15-20 m^3/s respectively. The Blanda project has only been in operation for three years and effects of regulations there are being evaluated. Accordingly only the Thjórsá basin and related changes in the winter environment are outlined in the paper. At the sites of the powerplants and reservoirs there are of course very marked changes in the winter environment. With increased tourism in the wintertime it may come up that scenic values of ice formations in the rivers have declined because of the regulations. Downstream of the powerplants, the rivers flow for 40 to 50 kilometers through farmland. The regulations have had certain effects on the ice regime here and there is some concern about the consequences of the hydropower development in this respect.

Thjórsá River Basin Hydropower Projects



INTRODUCTION

The most important power resources of Iceland are ample hydro and geothermal resources. The latter are mainly used for space heating and some minor generation of electric power. The hydro resources are, and will continue for decades to be the main resource for electric power in the country. It has been estimated that the technically harnessable energy of the rivers in Iceland is equivalent to about 60000 GWh/a, and that development of about half of this energy will be economically and environmentally feasible. Since 1968 the hydroelectric power production has increased from 700 GWh/a to about 4500 GWh/a in 1994. This rapid growth is to a great extent because of establishment of power-intensive industries. The major power plants are in the Thjórsá basin in southern Iceland and at Blanda river in northern Iceland. In the Thjórsá basin there are three power plants, two 210 MW and one 150 MW, with total production capacity of about 3300 GWh/a. At Blanda there is one 150 MW plant with production capacity of about 750 GWh/a.

The development of the hydropower resources has inevitably a profound effect on the winter environment of the harnessed rivers, and especially so under the unstable Icelandic weather conditions. Concern about environmental impact was originally limited, but has been rapidly increasing and legislation on environmental impact assessment for major projects is in effect since 1994. Evaluation of environmental impact of existing hydro projects is valuable for assessment of future projects.

RIVER REGULATIONS IN THE THJORSA BASIN

The rivers and regulations in the Thjórsá basin, southern Iceland, are shown on the schematic map on page 2. The Thjórsá river and its main tributaries, the Tungná and Kaldakvísl rivers, originate in the glaciers and the summer discharge is marked by the silty glacier runoff. Direct runoff from rain and snowmelt is considerable, but this is very limited in wintertime, except during occasional warm spells. Natural wintertime runoff is however quite considerable because of groundwater inflow from lava fields and other highly permeable postglacial volcanic formations. Average discharge and typical, winter discharge, m^3/s, is as follows:

	Thjórsá at Búrfell	Tungná	Kaldakvísl
Average discharge	306	171	33
Typical winter discharge before development	150	90	17
Typical winter discharge after development	240	150	10

The uppermost regulation in the basin is a diversion of some small rivers, and ultimately part of the Thjórsá river, into Kaldakvísl river and lake Thórisvatn. The diversion consists of canals and man-made lakes and ponds. The effect on winter environment of this project seems to be negligible, except that new habitat for trout has been created.

The Kaldakvísl river is diverted into the Thórisvatn lake, which is the main reservoir of the power system with 1330 million m^3 of usable storage. The reservoir is formed by damming up the lake as well as lowering the water level by a canal leading to the Krókslón reservoir downstream. The lake was originally crystal clear, but after diversion of the Kaldakvísl river it is mixed with glacier silt and clay throughout the year. The regulation has not had any observable effect on the thermal regime of the lake. The maximum depth is about 100 meters with average depth 28 meters. The whole water mass cools down to close to zero before freeze-over in December. Break-up is usually in June. The effect of water level fluctuations on the ice cover is of minor consequences.

On the Tungná river there are two man-made reservoirs at power plants, Krókslón and Hrauneyjafoss reservoirs with volumes of 175 and 36 million m^3 respectively. Under natural conditions the Tungná river remained open most of the time throughout the winter in this area and all the way down to the confluence with Thjórsá, because of high gradients and inflow of groundwater. Heat loss from sub-zero water in the lower reaches produced considerable quantities of frazil ice. The regulated outflow from Thórisvatn reservoir has now considerable effect on the water temperature until that reservoir has cooled down. The Krókslón and Hrauneyjafoss reservoirs freeze over in October-November and water temperatures are higher than under natural conditions, resulting in less ice production, except occasionally when the Hrauneyjafoss reservoir, which is very shallow, gets supercooled before freeze-up. This may result in jamming of frazil ice and rise in stage at the river mouth to the Sultartangi reservoir downstream.

The Sultartangi reservoir at the confluence of Thjórsá and Tungná is presently used as discharge regulation and ice and sediment trap for the Búrfell run-of-river power plant 15 km downstream, but in the future this will be intake reservoir for a 125 MW power plant. With construction of the reservoir and the Búrfell plant drastic changes were made in in the winter regime of the river. The natural river channel upstream of Búrfell is a flat-bottomed 400 m wide channel with about 1 m water depth. The channel is formed by erosion of the top scoria layer on a postglacial lava flow. The lowest part of Tungná was also of this type, but actually it is more common that lava flows push the rivers to the side and the channels are between the lava and older formations. The channel upstream of Búrfell, as well as that of the lower Tungná, is so steep that it does not freeze over. Under natural conditions the open water area varied between 3 and 10 km^2 in wintertime and enormous quantities of frazil ice, about 30 million tons per year, were produced. The frazil ice accumulated in a huge ice jam, the Búrfell ice jam, in a gently sloping area downstream of where the outlet of the Búrfell power plant is now. The Búrfell plant was constructed ahead of any regulation upstream and the frazil ice was a great nuisance during the first years of operation (Mariusson et al. 1975). The regulation with the Sultartangi reservoir and remedial works (longitudinal dikes) in the channel between Sultartangi and Búrfell has resulted in radical changes in thermal regime and ice conditions. The water temperature at at the outlet of the Sultartangi reservoir has been 0,1 to 0,3°C in autumn and midwinter and the open water area upstream of Búrfell is now typically 1,5 to 2 km². Frazil ice production is limited compared to natural conditions, but strong supercooling, typical when the water temperature drops from above freezing, occurs repeatedly resulting in intense anchor ice build-up with ice dams in midwinter and anchor ice runs during daytime in late winter when global radiation begins to have effect.

From the Búrfell area the Thjórsá river flows for some 60 km through farmland to the sea. On the first 40 km there is normally open lead with slowly growing shore ice. The slope is about 0,001 (1 m/km), except for a few kilometers with steeper slope. In cold weather there is substantial dynamic ice production in this reach, frazil ice in the upstream reaches that may form pancake ice and bigger ice floes farther downstream. About 20 km from the sea the river drops 35 m over a distance of 3 km in rapids and a waterfall, Urridafoss, and from there it flows with a gentle slope, 0,0005 (0,5 m/km), to the sea. The ice from upstream accelerates the growth of ice cover in this area. When the ice cover reaches a gorge downstream of the Urridafoss waterfall, the ice discharge from upstream piles up and accumulates in an ice jam, the Urridafoss ice jam.This jam has a normal volume of about 20 million m³, ranging between 10 and 40 million m³, length 5 to 10 km and normal thickness 13 m, maximum 18 m (Rist 1962). The hydropower development and regulations upstream of Búrfell do not seem to have had much effect on the thermal regime and ice conditions in these areas. The winter discharge is higher and, what may be most important, the sediment load has diminished. Comparative observations of water levels and scouring of the river banks are very limited. Some farmers claim that scouring is increasing and the power company has made considerable investment in groynes and dikes.

From the view of power production the effect of the development on the winter environment has been beneficial, but it may be debatable if the changes in the riverscape are justified. Under natural conditions the rivers became crystal clear after prolonged periods of frost and the ice formations, run of frazil ice flocs, anchor ice islands, ice-jam build-up etc. could have been scenic attraction. At that time the area where the powerplants are now was uninhabited and there were no tourists in the wintertime. This has now changed and cross country tours in wintertime on snowmobiles and specially equipped jeeps are common. The present state of the rivers is taken for granted, but further development will most likely attract attention and eventually opposition.

REFERENCES

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Rist, Sigurjón, 1962. Þjórsárísar - Winter Ice of Thjórsá River System. Jökull 12.

DISCUSSION

David Andres

Trillium Engineering and Hydrographics Inc:

What is the tendency of the glaciers in Iceland? Are they receding or advancing? Do you have a strategy to deal with the possibility of a warming climate?

Reply:

The glaciers in Iceland were rapidly receding from the twenties until 1960-1970. Since then the glaciers have been advancing. However many of the outlet glaciers are surging glaciers and may recede even though the volume is increasing. The possible effects of a warming climate are under study by Icelandic hydrologists. Simulations for various scenarios indicate that the greenhouse effect can have substantial impact on the hydropower production in Iceland.

T.D. Prowse

NHRI, Saskatoon:

Could you please elaborate on the environmental regulations that were introduced 1994 as they relate to ice conditions?

Have any field investigations been conducted in Iceland that were specifically focussed on evaluating environmental effects of river ice, especially as related to river regulations?

Reply:

The environmental statutes do not directly address environmental impact of changes in ice conditions, but these must be evaluated as other effects, especially in connection with hydropower development and river regulations. Field investigations have certainly focussed on effects of river regulations on ice conditions, but it is not until now lately that special emphasis is placed on environmental issues.