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Hydrological information on the drainage basins of Jökulsá á Dal and Lagarfljót

Páll Jónsson,
Kristinn Einarsson,
Árni Snorrason

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Introduction

The Hydrological Service (HS) of Orkustofnun, National Energy Authority, Iceland, celebrated its 50th anniversary in 1997, but the history of hydrological surveying in Iceland can be traced back to the late 19th century. Some investigation and utilization of hydropower began in the early 20th century. Hydrological surveying and research is essential for the systematic assessment of water resources. Furthermore, it is basic to project design and operation. The discharge of rivers and level in water bodies varies with time and the variations may be on both decadal, annual, seasonal and diurnal time scales. Glaciers are an important part of Icelandic water resources, and they advance and retreat in complex interaction with climatic conditions. The variability of hydrological phenomena, both in space and on different time scales, makes it necessary to monitor them continuously at numerous locations.

The Hydrological Service tends to the needs of clients from the power industry, public authorities, and others, for reliable data on water resources by:

- Operating a hydrometric network in rivers, lakes, reservoirs and ground-water aquifers, and by monitoring glacier fluctuations, snow balance and climate at high altitudes.
- Monitoring water temperatures, sediment load and other physical and chemical properties of water.
- Bathymetry of lakes and monitoring ice cover of rivers and lakes.
- Developing and maintaining a database on hydrological data and a GIS based register of rivers, lakes and glaciers.
- Scientific processing and publication of basic hydrological data.
- Research and development in the field of water resources and hydrology.
- Cooperation with the WMO Commission of Hydrology and with sister institutes abroad.

The Hydrological Service currently (2002) operates 194 hydrological monitoring stations in Iceland on behalf of its clients, of which 125 are runoff stations. The longest unbroken runoff series with daily values in its database is of 70 years duration, but many series reach over 50 years in duration. The suspended sediment samples analyzed for concentration and grain size distribution at the sediment laboratory are more than 12,000. The regular staff of the HS numbers over 20 people, assisted by 12-15 university students during the summer season.

The hydrometric network

The hydrometric network in the Jökulsá á Dal and Lagarfljót river basins is summarized in the following table:

Station no.	River; station	Starting date of recording	Elevation m a.s.l.	Area km^2
	Jökulsá á Dal river basin			
110	Jökulsá á Dal; Hjarðarhagi	1963-05-11	150	3322
146	Hrafnkela; Vaðbrekkufoss	1969-08-26	367	183
164	*Jökulsá á Dal; Brú	1970-12-16	340	2101
215	**Hölkná; vestan Þrælaháls	1978-08-24	710	48
236	Jökulsá á Dal; Brú, Kálfseyrar	1986-10-07	341	2101
366	Reykjará, Brúarörænfum; ofan Jökulsár	1995-08-23	387	205
	Lagarfljót river basin			
7	Lögurinn; Lagarfell, brú	1967-05-02	20	2300
17	Lagarfljót; Lagarfoss	1955-10-23	13	2800
34	Bessastaðaá; Hylvað	1970-07-23	25	111
109	Jökulsá í Fljótsdal; Hóll	1962-09-06	50	558
165	***Laugará; Laugafell	1970-08-08	600	29
205	Kelduá; Kiðafellstunga	1977-05-10	100	262
206	Fellsá; Sturluflöt	1977-05-14	110	125
221	Jökulsá í Fljótsdal; Eyjabakkafoss	1981-07-22	630	296
249	Kelduá; gegnt Klúku	1990-06-05	31	440
254	Kelduá; ofan Grjótár	1991-07-03	645	62
255	Ytri-Sauðá;Sauðárvatnsós	1991-05-05	790	25

* Location near identical to station 236 ** Discontinued from 1992-10-05 *** Discontinued from 1993-11-03

The location of these gauging stations is also shown on the accompanying map of the two river basins. The starting dates given in the table refer to continuous recording of water level, but some of the stations were previously operated as staff gauges with daily or semi-daily reading of the stage. The oldest stations in the Icelandic hydrometric network are stilling wells with a float and the water level is recorded on paper, either a sheet lasting one month or on a paper roll lasting up to two years. Some of the stations are bubble gauges from A.Ott Kempten at which the water level is recorded on paper rolls lasting up to nine months. The most recent stations in the hydrometric network are pressure transducers where the water level is recorded digitally with a programmable Campbell data logger. Several of the modern stations are equipped with a telephone for transmission of data directly to a computer network at the office of the Hydrological Service in Reykjavík and their data is shown in near real time on the web.

The discharge is calculated from the water level through the rating curve that is found by making discharge measurements at different water levels. Each station is serviced by the staff of HS at least four times a year and a discharge measurement is made three times a year. The discharge measurements are usually made using current meters from A.Ott Kempten. The wading rod is used whenever possible but otherwise measurements are made from boats

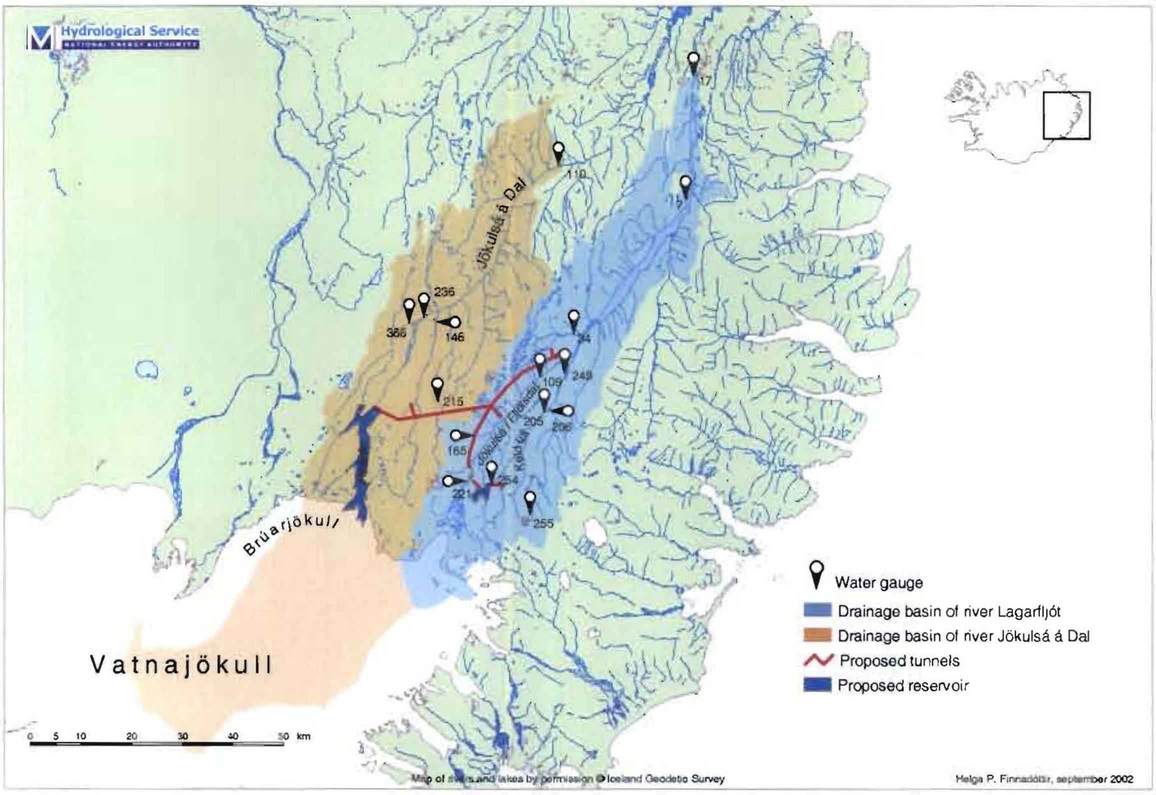

Figure 1: Jökulsá á Dal and Lagarfljót river basins, east Iceland.

or cableways. The HS has cableways available for most of the larger rivers, in particular the glacial rivers in the eastern part of the country. For some of the largest river the HS uses ADCP (Acoustic Doppler Current Profiler). It is known that current meters suspended from a cableway can overestimate the discharge and this has been confirmed by experiments comparing standars current meter measurements to measurements using ADCP.

Hydrological characteristics

Jökulsá á Dal basin

The Jökulsá á Dal river basin in east-central Iceland is one of the largest river basins in Iceland. The main contribution to its flow comes from the drainage of one of the largest outlet glaciers of Vatnajökull, Brúarjökull, which covers some 1401 km^2. The Brúarjökull is a surging glacier with recorded surges in the early 17th century and 18th century, in 1810, 1890, and the in fall of 1963. The water gauge 110 at Hjarðarhagi, was started in 1963, just prior to the most recent surge. Abnormal flows were recorded in the years after the surge. The effects of this have been studied, estimating a transient increase in discharge due to the advance which causes an increase in the ablation area, profile changes and breakup. This increase in discharge is estimated to be some 10% after the surge in 1963, lasting about 4-6 years. In addition a long term decline in discharge due to the reduced ablation area is associated with the surge and is estimated to be about 2% per year as the glaciers recedes.

The runoff from the glacier is highly dependent on temperature causing large diurnal variation in the river flow, often amounting to some 50% difference between the daily extremes. The seasonality of the flow is also pronounced with average daily low flows in winter around 10 m^3/s and average daily summer flows often above 500 m^3/s. There is also a large climatically induced variability between years with the lowest annual mean discharge of 100 m^3/s, but the highest 186 m^3/s. Long term variability is also present, both due to climatic variability as well as the periodic surges of the glacier.

The runoff from the non-glaciated areas, which are about 1921 km^2, is characterized by a pronounced snowmelt peak in late spring and early summer, but outside the melting season, the specific runoff is rather low, especially during winter when it can go as far down as 2 $l/(s \cdot km^2)$. This characteristics is well shown in the records from the station 146 in Hrafnkela, as well as in the difference between the gauges 164 and 110 on Jökulsá á Dal, but the difference in drainage area between the stations is 1221 km^2.

Floods are mainly of three types, spring floods due to snow melt, summer floods due to glacial melting and rainfall-snowmelt floods in fall and early winter. Historical information exists on extreme floods in Jökulsá á Dal in the past centuries. These are likely to be jökulhlaups, possibly associated with the surges of the glacier, but jökulhlaup associated with the surge in 1963 is the only jökulhlaup in the discharge record.

Lagarfljót basin

Jökulsá í Fljótsdal sub-basin

The Jökulsá í Fljótsdal river basin in east-central Iceland is a medium sized glacial river draining an outlet glacier of Vatnajökull, called Eyjabakkajökull. The glaciated area is about 139 km^2 of the total watershed area of 558 km^2 at the gauge 109, close to the outlet of the river into lake Lögurinn. Eyjabakkajökull is a surging glacier, with its most recent surge in 1972. The period of surges is not known, but it is considerably shorter than that of Brúarjökull. Surges cause a long term variability in the riverflow, which has to be kept in mind when planning for the future.

The runoff characteristics are very similar to those of Jökulsá á Dal, except the scale is much smaller. Proportionally larger areas are not covered with glaciers with higher specific runoff due to higher precipitation. Groundwater contributes very little to the flow, so the specific discharge is quite low during the winter season.

Floods are of three types, spring floods due to snowmelt, jökulhlaup from the marginal lake Háöldulón and rainfall-snowmelt floods during the fall and early winter. Drainage of Háöldulón can also take place as a gradual drainage, adding to the meltwater from the glacier.

Kelduá sub-basin

The Kárahnjúkar hydropower project is also based on diversions from adjacent watersheds, foremost from the watershed of Kelduá, to the south and east of Jökulsá í Fljótsdal. This river is measured in the lowlands at the gauge 205 which has been in operation since 1977. The mean discharge is 15.5 m^3/s of which about 11 m^3/s are included in the present project. Kelduá is characterized by high seasonality, with intense snowmelting in late spring and most of the summer, but very low flows during the wintertime. Extreme flooding can occur when heavy rainfall with associated snowmelt takes place in late fall or early winter, when the ground is already frozen.

Reliability of hydrometric data

It was mentioned in the section on the hydrometric network that each gauging station is serviced by the staff of HS at least four times a year and discharge measurements are made three times a year. Usually one of these measurements is made during winter conditions in order to get a measure of the low winter discharge when there is ice in the water course giving backwater effects on the water level. The other two measurements are made during normal conditions and can be used for establishing the rating curve. For the most important glacial river stations, HS makes more than three discharge measurements a year and e.g. for the station 110 in the river Jökulsá á Dal at Hjarðarhagi there have in the last three years been made up to twenty discharge measurements a year. The reason for this extensive effort is that in this particular river there is an enormous sediment transport that clearly affects the stability of the rating curve.

For each discharge measurement the standard procedure is to measure the velocity at four to five points in each of twenty verticals in the cross section. This results in between 80 and 100 velocity measurements in the cross section. The total discharge is then calculated by integrating the velocity profile in each vertical and plotting the resulting integral as a function of the position of the vertical in the river cross section. The resulting curve is then also integrated to give the total discharge. This is the most exact way of calculating the discharge from the velocity measurements.

The rating curves are established using a computer program developed at the HS to fit a three parameter power function to the measurement points. In this process great care is taken to investigate the measured water level and discharge for each discharge measurement. Furthermore the HS is very much aware of the problem of extrapolating the rating curve outside the measured range, in particular for the high flows, where one has to be very careful that the exponent of the power function does not become too high. There is also an emphasis on making discharge measurements during high flows to help in the extrapolation.

For the gauging stations in the two river basins the stability of the cross sections and the rating curves is reasonable. For some stations, e.g. 206 in Fellsá, large floods have caused changes in the cross section and thus it is necessary to do more frequent discharge measurements to establish a good rating curve. Also great sediment transport can give some instability in the rating curves. The sediment load of the river Jökulsá á Dal is extremely high, with annual mean about 6–7 million tons/year, the range about 2–12 million tons/year and the extreme of 18 million tons/year occuring right after the surge in 1963.

In connection with the establishment of the hydrological runoff models for Jökulsá á Dal, Jökulsá í Fljótsdal and Kelduá by Vatnaskil, the HS undertook a revision of the hydrometric data from the gauging stations in the river basins of these three rivers. Particular emphasis was put on the two gauging stations in Jökulsá á Dal and one of the observations made during the revision of the data from the gauging station 110 at Hjarðarhagi was that the rating curve at this gauge seems to be stable on a long term basis, but shifting between two states is observed, which is, without doubt, due to the heavy sediment load. This shift, however, is not observed for the station 236 in Jökulsá á Dal at Brú. The shift in the rating curve at Hjarðarhagi was seen to occur between years, but the frequency of discharge measurements in the period 1963–1994 was not high enough to decide if these shifts between states could occur within the year. As a consequence of this observation, it was decided by HS and Landsvirkjun to make more frequent discharge measurements during the years after 1995. A very intensive study of the rating curve has since been undertaken by HS and Vatnaskil for Landsvirkjun in the latest years and has resulted in a revised rating curve for this station.

The promising results of the revision of the hydrometric data discussed above and the very important interactions between the HS and Vatnaskil during the establishment of the runoff models has resulted in a systematic procedure for revision of hydrometric data by HS. In 1995 HS and Landsvirkjun launched a thorough revision and a systematic digitization and data base storage of the hydrological data from the Þjórsá river basin in south Iceland, where most of the largest hydropower plants in Iceland have been built. This was done in connection with the establishment of a hydrological runoff model for the Þjórsá river basin by Vatnaskil and again the interaction between Vatnaskil and HS during this process has proved to be very important for higher quality of the hydrological data.

The procedure for this revision of hydrological data has since been developed in cooperation between the Hydrological Service, Landsvirkjun and the Energy Resources Division of the National Energy Authority. From the start in 1995 up to 2002 hydrological data from several large and important river basins have been analyzed, both from river basins that have been harnessed for hydropower production and also for river basins that are at present considered from harnessing of hydropower in the future. This cooperation is continuing and the revision process will be applied where and when needed.

Operation of water level gauges can be troublesome due to the sediment transport, causing periods where the gauges are perturbed or clogged by the sediments. Long periods during winter are perturbed due to ice, which is not very important as the base-flow is low, and the HS tries to measure it during each winter.

The extreme character of Jökulsá á Dal makes it a very difficult case to study and measure. The range of flows is very large, all of which are very important for hydropower development. The sediment transport is also extreme and very variable causing problems both with rating curves as well as with the operation of the water level gauges. Ice conditions prevail during the long winter causing considerable inaccuracies in the low flow data. Every effort is and has been made to compensate for these difficulties by extra efforts in monitoring the runoff and sediment transport in the basin.

The problems described above apply only to a limited extent to the measurements in the river Jökulsá í Fljótsdal and are confined to the problems associated with the operation of water level gauges due to the sediment transport, causing periods where the gauges are perturbed or clogged by the sediments.

Discharge measurements in river Kelduá are quite difficult due to high flows and difficult terrain causing an increase in the error margin of the flow values, especially for the extreme floods. Long periods during the winter are perturbed by ice, which is not very important as the base-flow is low.