ALMENNA BYGGINGAFÉLAGIÐ H.F.
AND
VERKLEGAR FRAMKVÆMDIR H.F.

HYDROELECTRIC DEVELOPMENT
OF THE RIVER
JÖKULSÁ Á FJÖLLUM
DETTIFOSS PROJECT

REPORT

ALMENNA BYGGINGAFÉLAGIÐ H. F.
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JÖKULSÁ Á FJÖLLUM

DETTIFOSS PROJECT
Revised

Preliminary
Run-of-River Project
and
Cost Estimate

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HYDROELECTRIC DEVELOPMENT of the river JÖKULSÁ Á FJÖLLUM

DETTIFOSS PROJECT

PRELIMINARY RUN OF RIVER PROJECT AND COST ESTIMATE

1 INTRODUCTION

The State Electrical Power Works assigned the work of making a preliminary project and cost estimate of the construction part of the hydroelectric development of Jökulsá á Fjöllum to Almenna byggingafélagid h/f and Verklegar framkvæmdir h/f in the beginning of year 1958. The report was delivered in February 1959. The cost estimate was based on wage and price level in August 1958.

This report, compiled by the same firms, is a revised cost estimate of the upper project, in Jökulsá á Fjöllum called the Dettifoss Project. As before the project is worked out in conformance with the recommendations of Mr. C.K. Willey, the vice president of the Harza Engineering Co. Int. as set forth in a report of 23th October 1957.

Minor modifications of design from the former project have been made.

The purpose of this project is to work out a plan of development which can be considered near the optimum plan. Therefore only little time has been devoted to alternative arrangements.

For practical reasons a geological description of the area is disincluded here as this aspect is aptly covered in the report of Mr. Willey as well as in the detailed geological survey by Dr. Sigurdur Thorarinsson.

The development area and sites were investigated by engineers of the firm Almenna byggingafélagid h/f and Verklegar Framkvæmdir h/f in the summer of 1958 and also several times in the summer 1961.

2 TOPOGRAPHY

Jökulsá á Fjöllum is located in the North-Eastern part of Iceland (see general map of Iceland, enclosure no. 1 and topographical map of NE part of Iceland, enclosure no. 2). The source of Jökulsá is the glacier Dyngjujökull and the source of river Kreppa, its main tributary, the glacier Brúarjökull. Both these glaciers are a part of the glacier Vatnajökull. The drainage area of Jökulsá above Dettifoss is 7000 sq. km whereof 1700 sq. km are glaciers and 3000 sq. km lava. During the summer season about 60% of the discharge is glacial melt-water from Vatnajökull. The drainoff from the lava fields has a regulating effect on the flow of the river.

Jökulsá flows northwards through an even slope from an elevation of 690 m above sea level through the highlands between Midfell and Lambafjöll, past Núpaskot, where the river Skardsá flows into it, continuing through the plain of Hólsmelar where the elevation is 340 m a.s.l. The length of this route is 130 km and the head 350 m.

South of Kvíar the fall of the river becomes steeper and waterfalls and rapids are formed, where the head is about 300 m for a run of 25 km. About 3 km north of the farm Land the river branches out to the sea. The estuary of the main branch Bakkahlaup is located near to the middle of Axarfjördur.

The capacity of the development is based on a discharge of 90 m^3/sec as recommended in the report of Mr. Willey.

Discharge measurements have not been made for a sufficient period of time to enable us to determine macimum floods of the river. The greatest flood hitherto measured is about 1500 m^3/sec. In our estimate we assume that the maximum flood from normal meteorological phenomena would amount to 3000 m^3/sec. For this discharge the maximum demands for security are met.

In annals exceptional floods are recorded, the latest in year 1729. It has been assumed that such floods will not exceed 15000 m^3/sec. We have taken this danger of flood bursts in account in such a way that for a flood amounting to 7500 m^3/sec the safety margin is somewhat reduced and for a discharge of 15000 m^3/sec no major damage is expected to happen. More information about the hydrology of Jökulsá can be found in the report of Mr. Willey.

3 RUN OF RIVER PROJECT

3.1 Dettifoss Project

The general lay-out of the project is shown on drawing no. 80-08 (Enclosure 3).

3.11 Dam (see drawings nos. 80-10, 80-11b, 80-14, 80-15, 80-16 and 80-26, enclosures 5, 6, 9, 10, 11 and 12 respectively).

The dam is built up of a spillway section, sluices, an intake and a rock filled dam. The spillway is a concrete gravity dam, length 240 m, maximum height about 15 m.

The west bank of the river is rock, slightly higher in elevation than the crest of the spillway. East of the spillway a tainter gate 10x12 m is installed, then an undersluice 4x4 m and an ice sluice 8 m wide. The intake is positioned east of the ice sluice at right angles to the main dam, wherefrom the rock dam is situated on the east bank until the ground elevation has reached full height. The length of the rock filled dam is 700 m, maximum height 11 m and crest width 4.5 m. The watertight seal is a vertical soil core. The crest elevation of the rock filled dam, the intake and the sluice pillars is 342 m.

The location of the dam is about 800 m upstream of Selfoss just above rapids and islands in the river. A few comparative studies and site investigations indicate that the most economical dam site is above the rapids.

The elevation of the uncontrolled crest of the spillway has been selected 338 m. A study of the graben area did show that the elevation of the dam crest has to be considerably in excess of 340 m for utilization of it as a security spillway for glacial bursts. The capacity of spillway and sluices is 3000 m^3/sec. If the discharge reaches 7500 m^3/sec the river flows over the rock on the western bank and the water level rises to an elevation of 341.3 m.

3.12 Intake (see drawing no. 80-13, enclosure no. 8).

The number of intake openings is 5, each controlled by a tainter gate. The openings are submerged to eleminate intrusion of surface ice. Racks and stop logs are installed in front of the openings.

A shelter is constructed over the intake to house the gate machinery.

3.13 Penstock

The penstocks are vertical, steel pipe lined, grouted out to the rock. Inside dia. 2.50 m, and the maximum water velocity therefore 4.6 m/sec. Normally four are operated, the fifth one used as a spare,

3.14 Power House (see drawing no. 80-12 and 80-13, enclosure no. 7 and 8 respectively).

The underground power house is located vertically under the intake. Inside dimensions are 11.2 by 60.0 m.

The ceiling is a concrete arch construction and the walls concrete lined.

Two shafts for elevator, power house crane, air ducts, cable ducts are provided and on the surface a building for crane machinery, machine repair shops etc, is constructed. Air vents from the surge chamber are effected through one of the shafts. In the machine room 5 horizontal units are installed each 33 MVA, whereof one is operated as a spare.

Further details about the machinery are described seperately.

3.15 Outdoor switchyard

The outdoor switchyard is located on the east bank of the river behind the intake as indicated on drawing no. 80-11b (enclosure 6).

3.16 Tail Tunnel (see drawing no. 80-09, enclosure 4).

The tail tunnel is designed for free flow, 90 m^3/sec flow in the tunnel and 1500 m^3/sec discharge of the river. In great floods the tunnel will be filled. Just below the power house a surge chamber is constructed as shown on drawing no. 80-13, (enclosure no. 8).

The tail tunnel runs through lava layers of uneven thickness, mostly of columnar nature. With regard to experience gained of such tunnels in Iceland a concrete lining is considered unneccessary, as a rule. However, considerable reinforcement is considered advisable and a cost increase of 25% is included in the cost estimate for this

purpose.

The shape of the tunnel cross-section is selected with regard to our experience here of tunnels in similar rock formations. The length of the tail tunnel is 4.100 m and the cross section 69 m^2. The tailrace returns to Jökulsá about 350 m downstream from Hafragilsfoss.

4 COMMUNICATION-TRANSPORT

4.1 Harbours

The nearest harbours are Húsavík, where ships up to 3000 tons capacity, and Kópasker, where ships up to 1000 tons capacity can be unloaded. Both harbours are free from ice all year round.

In the cost estimate Húsavík is assumed to be the main import harbour and Kópasker an auxilary harbour. Kópasker is a safe harbour for 70% of the duration of the year. Transshipment to Kópasker of heavy shipments is in some instances considered more economical than reinforcement of the bridge over river Jökulsá in Axarfjördur and road transport from Húsavík.

4.2 Roads and Bridges.

The road from Húsavík lies around Tjörnes through Kelduhverfi over the bridge of Jökulsá in Axarfjördur, and up along the eastern side of the river to the project site. The distance from Húsavík to the Dettifoss Project site is 98 km. The road is a filled up earth base gravel finish road with a 4.5 m wide driveway and 1 m shoulders. A total of 8 bridges is located on this road, seven of which are short with a span from 4 - 18 m and width of driveway 3 m. The greatest bridge is over Jökulsá in Axarfjördur a suspension bridge with 116 m span and 4.2 m wide driveway. The capacity of the bridge over Jökulsá is one 9 tons truck including an 18 tons trailer. The road from Kópasker is of similar construction as the road from Húsavík. Distance 65 km from Dettifoss Project site. On this road there are also 8 bridges, none of which great, the shortest 4.0 m and the longest 27.0 m.

4.3 Airports

The nearest airports are at Kópasker, Húsavík and Akureyri respectively. The airport of Akureyri is equipped as an auxilary airport for transatlantic flight, but the airports of Húsavík and Kópasker are suitable for local flight only (DC-3).

5 CLIMATE

Experience has shown that it is feasible to carry on with construction work of hydroelectric development in Iceland all year round.

Albeit outdoor work is reduced considerably during the months December through March. However, in this period underground work and indoor work can be carried out, and opportunities to carry out outdoor work are utilized. It is also customary to carry out mass concrete placing during the winter. We have therefore assumed that the work will be organized as an all year round operation, also that necessary transport connection with Húsavík will be kept open by clearing the road when necessary or by means of snow tractors if the clearing of the road becomes too expensive during the winter.

Generally the weather is calm and cold at the project sites in wintertime, however, it has to be assumed that snow-storms will prohibit outdoor work during several days each winter.

In the following table the mean temperature of Grímsstadir á Fjöllum (elevation 380 m a. s. l.) and Húsavík is tabulated as well as the precipitation at Grímsstadir. The temperature at the Dettifoss Project site will be very close to the temperature at Grímsstadir.

TABLE I - Monthly Mean Temperatures in Húsavík and Grímsstadir and Precipitation in Grímsstadir

	Grímsstadir Temperature Centigr.	Grímsstadir Precipitation	Húsavík Temperature Centigr.
Jan.	- 4.4	26 mm	- 0.9
Febr.	- 5.1	25 "	- 1.5
March	- 3.3	20 "	- 0.3
April	- 1.3	21 "	+ 1.3
May	+ 4.0	17 "	+ 5.9
June	+ 7.7	29 "	+ 8.9
July	+ 9.6	50 "	+ 10.6
August	+ 8.7	49 "	+ 10.4
Sept.	+ 5.2	47 "	+ 7.9
Oct.	+ 0.5	31 "	+ 3.8
Nov.	+ 2.2	28 "	+ 1.3
Dec.	- 3.4	23 "	0.0

6 CONCRETE AGGREGATE

A survey covering the availability of concrete aggregate in the vicinity of the project site was carried out during the summer 1958. Numerous samples were collected and sent to The University Research Institute in Reykjavík for analysis. Ample quantity of good concrete aggregate, comprising both sand and gravel of basaltic origin is available within a reasonable distance from the project site.

In the cost estimate we have assumed that crushed rock will be used in the concrete, utilizing the blasted rock, and that sand will be collected from a distance about 8 km from the Dettifoss Project site.

If necessary and convenient, gravel can also be obtained in the same area as the sand.

It has been assumed that 250 kg/m^3 of cement will be used for the concrete in gravity dams but 300-360 kg/m^3 for other concrete work.

7 LABOUR CONDITIONS

It can be assumed that sufficient labour, both unskilled and skilled, will be available. Unskilled labourers as well as skilled labourers are organized in tradeunions.

The wage rates for unskilled labour are divided into 8 classes, but the wage rates for skilled labour are very similar for all trades.

When the cost estimate was prepared in October 1961 relevant wage rates for daytime work were as follows:

TABLE II - Basic Wages for Daytime Work

A. Unskilled labour

I.	cl.	ordinary labour	kr. 22.74	pr.	hour
II.	"	concreting, steel, hands	" 23.22	"	"
III.	"	compressor, blasting	" 23.58	"	"
IV.	"	light motorcar operation	" 24.28	"	"
V.	"	not applicable here	" 24.72	"	"
VI.	"	heavy motorcar operation, and repair work	" 26.28	"	"
VII.	"	cement work	" 26.93	"	"
VIII.	"	Operators of heavy construction machinery	" 28.00	"	"

Direct addition to the above rates.

1. Medical expense	1.0%
2. Vacation allowance	6.0%
3. Legal accident insurance	1.5%
4. Unemployment insurance	1.0%

B. Skilled Labour

Carpenters	kr. 26.86	pr.	hour
Masons	" 27.70	"	"
Mechanics	" 28.00	"	"

Direct additions are the same as for unskilled labourers, except that for carpenters an extra 6.0% employer's contribution to the carpenters' retirement fund has to be added. Rental of handtoals is included in the carpenters' wages.

Normal working week in Iceland is 48 hours. However, for work at project sites for hydroelectric developments the working week is never shorter than 60 hours. We have here assumed a 63 hours working week. In that case 12 hours are paid as overtime at a rate 60% higher than the daytime wages. All work in excess of 60 hours a week is paid at double normal rates. Shift hours for work for a longer duration than one month are paid with a 25% addition to the day-time rates. All underground work is calculated with a compensation amounting to kr. 3.20 per hour in addition to the regular rates, same for all kinds of work.

At hydroelectric development project sites work is carried out for 6 days one week and 5 days the other. After the 5 days week the employees are entitled to be transported to and from town for the 2 days weekend. In the case of the Jökulsá Project site the towns will be Akureyri and/or Húsavík.

Accomodation has to be provided for all employees. Skilled and unskilled labourers usually live four together in one room. Foremen, however, in single rooms. Engineers get apartments and probably also a few other employees. Skilled labourers are entitled to free catering, for unskilled labourers this matter has not been settled but we assume that all labourers are entitled to free catering at kr. 30,- extra a day. All expenses pertaining to kitchen and mess-hall operation are borne by the project.

8 COST ESTIMATE

8.1 Scope

The cost estimate does cover construction cost only. Preparatory and planning cost, interest banking etc. are disincluded here. The cost estimate covering installed machinery as well as mechanical and electrical equipment and accessories is also disincluded in this estimate.

This cost estimate has basically been worked out as a tender.

The official rate of exchange of the Icelandic krona is at present US $ 1,00 = 43,00.

In order to obtain a basis independent of local price level fluctuations,

official rate of exchange and changes of duties and taxes, we have in addition to the estimated cost in icelandic kr. listed a man-hour estimate covering the job and we have also listed the cost of machinery and material in dollars, as described more in detail below. All man-hours are included, from the starting of the work until its finish, including the set-up of the project site as well as erection of barracks. In addition to the work of the project units themselves, work covering unloading of material, transport, truck driving, stockkeeping, all machine and carpenter shop work etc. (including repair work of machinery and transport equipment) is included.

The man-hours have been classified into unskilled labour, skilled labour, surface work and underground work including compensation respectively; and also in shift work, (underground work and surface work without differentiation). The average pay for each category of man-hours has been calculated in such a way that the different rates of pay are taken into account as well as overtime, social additions and team leadership. Supervision, both of supervisors and engineers is not included neither are the manhours for the operation of barracks nor for clerical work.

The direct cost per man-hour was as follows in October 1961:

Unskilled labour	- Surface work - designated	V	- 31,30
" "	- Underground work	Vn	- 34,50
" "	- Shift work	Vj	- 41,00
Skilled labour	- Surface work	S	- 36,80
" "	- Underground work	Sn	- 40,00

All duties and taxes are disincluded in the $-cost for mechanical equipment and material and the prices for these commodities therefore stated cif. However, in the cost in icelandic kr. all duties and taxes are included. As stated above repair work of machinery and equipment is included in the man-hour calculation.

In October 1961 cif price for the main construction materials was as follows:

Cement	$ 19.20	per ton
Reinforcing steel	$ 111.00	" "
Lumber	$ 1.40	" cuft
Dynamite	$ 0.55	" kg

8.2 Construction Cost

In the following table III the estimated cost of the main construction units of the project is tabulated. Related construction units are taken together in such a way that the surge chamber, the shafts, the outdoor switchyard and operators housing is included in the power house unit. In the cost estimate for the dam the cost of cofferdams and of the diversion of the river is included. In the cost of accomodation all cost for barracks and mess-halls is included as well as all utilities. In the estimated cost of site setup, cost of provisory roads and bridges is included. Cost of field supervision is included in each construction unit. Administration as well as the supervisory work of the project engineers is, however, included in the overhead cost.

In addition to the estimated cost in icel. kr. the cif. cost of mechanical equipment and materials in dollars is listed. In the accommodation cost which is estimated 17,5% of paid wages, the operation cost of barracks and mess-halls is included. Transport and catering cost for skilled and unskilled labourers is also included therein.

TABLE III - DETTIFOSS PROJECT

Summary of Cost Estimate

Construction Unit	Estimated Cost Icel. Kr.		Est. Materials Cost Dollars cif
Dam	101.130.000		1.137.500
Intake	30.590.000		299.200
Tunnel	100.960.000		1.330.700
Penstock	14.740.000		157.900
Power House	56.290.000		562.600
Site Set-Up	22.000.000		405.000
Barracks	7.700.000		
TOTAL DIRECT COST	333.410.000	Note 1	3.892.900
Accommodation Cost	19.080.000	Note 2	
Overhead	48.060.000	Note 3	
Subtotal	400.550.000		
Risk and Profit 10%	40.060.000		
TOTAL CONSTRUCTION COST	440.610.000		

NOTES

1. Of this cost kr. 109.000.000 is direct labour cost.
2. Accommodation cost is estimated 17.5% of the direct labour cost (i.e. of kr. 109.000.000).
3. Overhead is estimated 20% of kr. 128.000.000 (i.e. direct labour cost plus accommodation cost) and in addition 10% of kr. 224.410.000 (i.e. total direct cost less total direct labour cost).

In the following table IV the quantities of the principial work units as well as the different classes of man-hours are listed for each construction unit of the project.

TABLE IV - DETTIFOSS PROJECT

Summary of Main Work Units and of Man-hours

Construction Unit	MAIN WORK UNITS						UNSKILLED LABOUR			SKILLED LABOUR	
	Blasting Thous cu-m	Concrete Thous cu-m	Forms Thous sq.m	Reinf Steel tons	Steel Lining tons	Grout Drilling m	Thousand man-hours Surf work V	Undg work V_n	Shft work V_j	Surf work S	Undg work S_n
Dam [x]	21.6	35.0	22.8	315	0	14000	711	0	0	120	0
Intake	8.1	5.8	8.1	138	0	0	120	0	0	57	0
Tunnel	315.0	NOT SPECIFIED IN DETAIL					40	0	706	118	0
Penstock	5.3	2.6	0	0	380	0	18	18	16	15	63
Power House	48.9	6.5	17.0	370	0	0	82	97	117	93	109
Site-Set-Up	NOT SPECIFIED IN DETAIL				0	0	95	0	0	97	0
Barracks	NOT SPECIFIED IN DETAIL				0	0	15	0	0	50	0
						TOTAL	1081	115	839	550	172
						GRAND TOTAL	2035			722	

[x] Rockfill Dam:

Rockfill	37300	m^3
Core	17200	-
Filter	6900	-

8.3 Duties and taxes

Taxes and duties on construction materials and equipment differ appreciably, depending on kind of material and type of equipment. We have calculated the average percentage of duties and taxes in accordance with the kind and quantity of the commodities, which will

be used in connection with the construction part of these project and found it to be about 36% of cif price, weight duty and sales´-tax included.

8.4 Dollar cost

The cost estimate is built up in such a way that it is comparatively simple to revise it with regard to rates of pay, prices of commodities, changes of duties and taxes as well as alteration of the rate of exchange. For ready reference a summary of the cost estimate, in accordance with the price level of October 1961 and with the exclusion of duties and taxes on construction materials and equipment has been prepared on dollar basis. The local cost is calculated in the rate of exchange 1$ = 43,00 kr.

TABLE V

Summary of Cost Estimate on Dollar Basis

Cost Item	Dettifoss Project Thous $
Materials	3.893
Direct Labour Cost	2.535
Accommodation Cost	444
Overhead	985
SUBTOTAL	7.857
Risk and Profit	786
TOTAL CONSTRUCTION COST	8.643

If duties and taxes are collected the above total would be about $ 1.600.000,- higher.

9. Final Remarks

As mentioned in the introduction the scope of this project is a part of a preliminary appraisal only, as outlined in the report of Mr. C. K. Willey.

During our work on this project we have quite naturally become aware of several alternative solutions which would perhaps prove more economical.

Where there has been some doubt about the cost of individual cost items we have preferred to be on the safe side, which in turn should mean that the estimated cost of the entire project should also be on the safe side.

Finally it may also be mentioned that by regulation it is possible to utilize considerably more power through the Dettifoss head than in this run-of-river project.
However, this aspect needs a further study.

ALMENNA BYGGINGAFÉLAGIÐ H/F	VERKLEGAR FRAMKVÆMDIR H/F
Ögmundur Jónsson (sign.)	Rögnvaldur Thorláksson (sign.)

LIST OF DRAWINGS

ENCLOSURE 1 - General Map of Iceland

" 2 - Map of the NE part of Iceland

Drawings from Verklegar framkvæmdir h/f

JÖKULSÁ Á FJÖLLUM: Dettifoss - Preliminary Project

ENCLOSURE 3 -	Dwg. No. 80-08:	General Plan of dam, tunnel and roads
" 4 -	Dwg. No. 80-09:	Longitudinal section through discharge tunnel
" 5 -	Dwg. No. 80-10:	Upstream elevation of spillway and sections through spillway and intake
" 6 -	Dwg. No. 80-11b:	Plan of dam and intake
" 7 -	Dwg. No. 80-12:	Plan of underground power house
" 8 -	Dwg. No. 80-13:	Section through intake, power house and surge chamber
" 9 -	Dwg. No. 80-14:	Tainter gate. Cross sections
" 10 -	Dwg. No. 80-15:	Icegate 3x8 m. Cross sections
" 11 -	Dwg. No. 80-16:	Undersluice. Cross sections
" 12 -	Dwg. No. 80-26:	Cross section of rock-fill dam