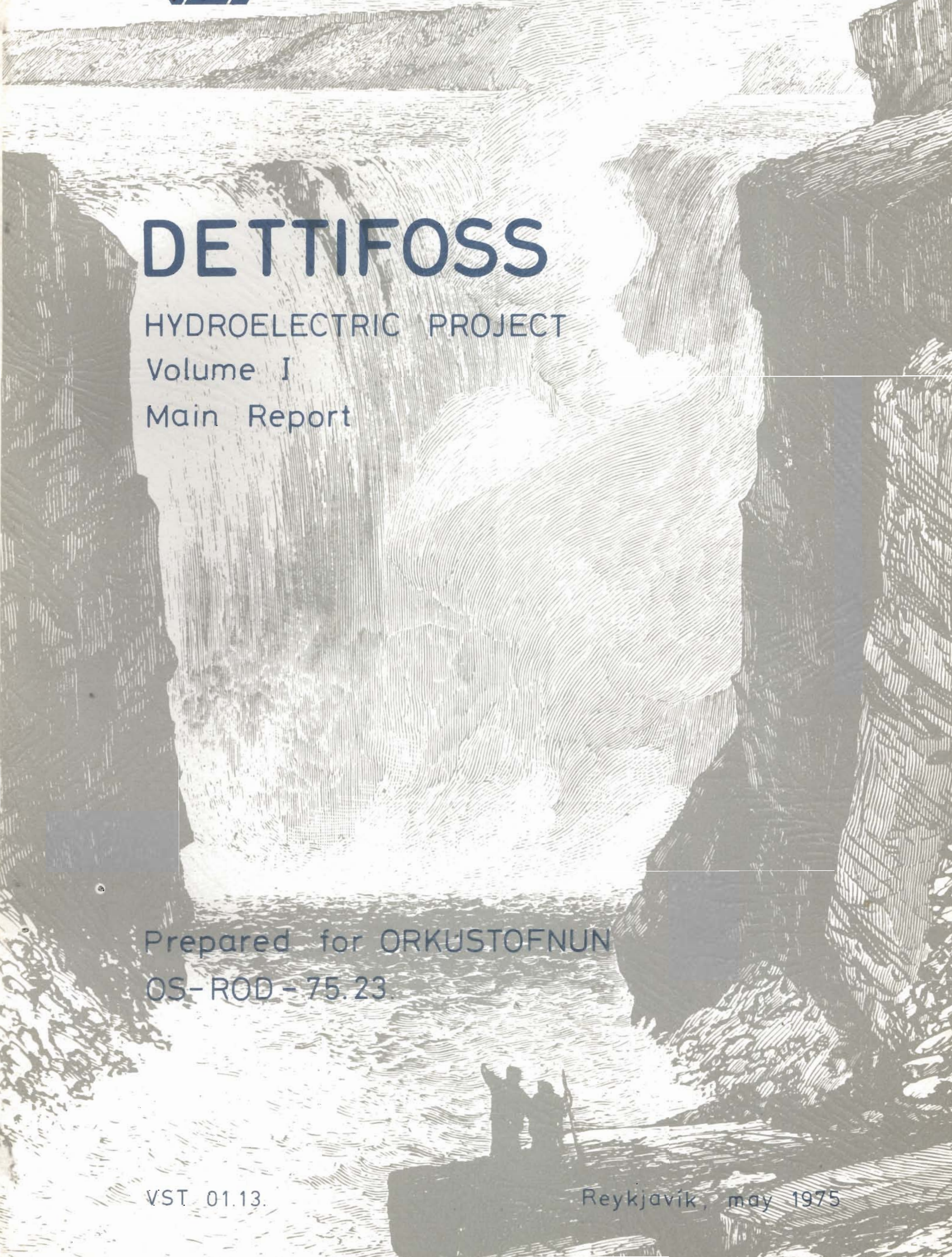
THORODDSEN & PARTNERS CONSULTING ENGINEERS
ÁRMÚLI 4 REYKJAVÍK ICELAND

DETTIFOSS

HYDROELECTRIC PROJECT

Volume I

Main Report



Prepared for ORKUSTOFNUN

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Raforkudeild

DETTIFOSS PROJECT
VOLUME I
Main Report

Prepared by
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Ármúla 4 - Reykjavík.

May 1975

GENERAL CONTENTS

SUMMARY

THORODDSEN & PARTNERS CONSULTING ENGINEERS
ÁRMÚLI 4 REYKJAVÍK ICELAND

ORKUSTOFNUN
Laugavegi 116
Reykjavík.

Your ref.	Your letter	Our ref.	Date
		01.13.	May, 1975

Gentlemen,

In 1972 you authorized us to proceed with engineering studies of development of the hydroelectric potential at the Dettifoss site in Jökulsá á Fjöllum. On the basis of a progress report submitted in January 1973 you instructed us to prepare a project planning report for approx. 160 MW development on the west bank of Jökulsá utilizing the head from a dam above Selfoss to the river downstream of Hafragilsfoss. Field investigations were carried out in the summers 1973 and 1974 and planning studies were concluded as soon as the results of field and laboratory investigations became available.

The present volume is the main report of the project planning report for a 161 MW power plant. Reports on geological and construction materials investigations and planning studies of other alternatives will be issued in separate volumes.

Surveying and field investigations in the Jökulsá Basin were started by NEA in 1954. A project planning report on a 133 MW project at Dettifoss with underground power station was prepared by the Harza Engineering Company International and submitted in January 1963. The concern for geological hazards in connection with underground structures in this area is the main reason for renewed planning at the site. In the present studies it was requested that water conductors and powerhouse should be as much in the open as feasible.

The present studies have evolved a plan of development which we consider to be technically, geologically and economically feasible. Comparison of various alternatives on both sides of the river to optimize the project were made in the aforementioned progress report of January 1973. The selected plan of devolopment is described further below and in greater detail in the body of the report.

The Jökulsá river will be dammed about ½ km upstream of the waterfall Selfoss. The dam is a rockfill dam with concrete spillway at the east end and bottom outlet in the river channel. An auxiliary dam farther upstream will restrict the reservoir from possibly permeable areas to the west. The dam will create a 26 km^2 reservoir with a total volume of about 180 gigaliters at the normal high water elevation 351,5 m a.s.l. The usable storage, between elevations 351,5 and 341,6, will be 150 Gl. This is only about 2½ % of the average annual runoff and hence the project is a run-of-river development with pondage. The power waterways are located west of the river. They consist of a 3,3 km long diversion canal with a fixed water level at 340 m a.s.l., a 370 m long underground penstock and a 150 m long tailrace canal. A diversion inlet to regulate the inflow from the reservoir to the diversion canal is located where the dam intersects the canal. In connection with the intake from the canal to the penstock there will be gated and ungated spillways and bottom outlet to flush ice and sediments from the canal. The powerhouse will be located in an open cut in the left riverbank close to Hafragilsfoss falls. The tailwater elevation for the rated plant discharge, 135 m^3/s, will be 200,8 m a.s.l. The installed generating capacity will be 161 MW in three units. The main transformers will be located close to the powerhouse and an outdoor switchyard on top of the cliff west of the powerhouse. The access road to the powerhouse will be down the east wall of the Hafragil canyon and up along the Jökulsá. An access tunnel with elevator up to the switchyard is also provided for.

The field investigations have revealed adequate quantities of suitable natural construction material either from required excavations or from deposits within reasonable haul distances. Samples of these materials were investigated by standard laboratory procedures, and the test results will be presented in a separate volume.

The dam and power features are located within or on basalt layers with interbeds. The foundations are considered to be without serious problems requiring other than routine treatment of standard nature. Tectonic faults and fissures are very pronounced in the Dettifoss area. However the proposed development is considered to evade all major faults, except in the tailrace canal and possibly under the dam and in the reservoir.

Percolation losses from the reservoir must be reckoned with, at least in the beginning. These losses are expected to be within acceptable limits and will decrease with time due to self sealing by the river's suspended load and bed load. Sedimentation of the reservoir will be the most serious problem of the project. The reservoir will be completely silted up in 20 - 40 years if nothing is done to trap sediments farther upstream. Dams for this purpose are however not included in the present study. Mapping and field investigations for the design of sediment dams have not yet been carried out.

Large floods or jökulhlaups have occurred in Jökulsá in historical times. The auxiliary dam is so designed that it would wash away if such floods would occur. The major part of the discharge would then flow to the west and down the Hraundalur graben and the powerhouse would be unaffected. Catastrophic floods, which may have happened some 2500 years ago, are not considered likely with the present extent of the Vatnajökull glacier.

Ice problems are considered to be negligible with the proposed layout of the structures and reservoir of this size.

The evaluation of environmental impact of the Dettifoss project is not within the scope of the present report. The project is partly situated within a national park and the final design and construction must of course be in close cooperation with the parts concerned.

The Dettifoss project constructed as described above has been estimated to cost 12200 Mkr. This includes taxis and duties, except on major permanent mechanical and electrical equipment, and 10% interest during construction. The unit cost of capacity is about 75800 kr. per kilowatt of rated installed capacity.

The average annual energy production which the Dettifoss project will add to the power system depends on the extent of the power system it will be connected to.

The installed generating capacity which has been assumed for the project as described here was based on studies carried out in 1971-73 of the energy production of the Dettifoss project in interconnection with the Laxá power plants.

Studies of the energy production of the Dettifoss project connected to the North-Iceland and Landsvirkjun power systems including future power plants are presently going on. With these interconnections the installed capacity would be greater than 161 MW.

However, the energy production of a 161 MW plant at Dettifoss in connection with the present North-Iceland and Landsvirkjun systems with addition of Krafla geothermal plant and Sigalda hydroelectric plant, which are now under construction, has been estimated. The addition with the Dettifoss project is estimated 1140 GWh/a.

The corresponding construction cost per energy unit is 10,7 kr/kWh/a. The unit annual cost of energy will depend on a number of financing factors as well as annual operating and maintenance expenses. The solving of the sediment problem must be taken into account either as construction cost or operating expenses.

The cost of energy generated at the Dettifoss project, according to the above figures, is attractive economically. However we would like to point out that it would be prudent to estimate other developments for the Jökulsá before any decisions on construction at Dettifoss are taken. There are indications that much more energy at similar cost may be obtained by diversion east of the river and development with higher head.

Very truly yours,
Verkfræðistofa Sigurðar Thoroddsen s.f.

Sigmundur Freysteinsson

Loftur Þorsteinsson

DETTIFOSS PROJECT

CONSTRUCTION COST SUMMARY

		Mkr.
Dams		2306
Waterways		2617
Power plant structures		733
Turbines, generators, electrical and miscellaneous equipment		2080
Access roads		205
Operators village		130
Cofferdams and care of water		60
	Subtotal	8131
Contingencies 5% of 1700 Mkr.		85
15% of 6431 "		965
	Subtotal	9181
Escalation		734
	Subtotal	9915
Engineering & supervision		992
	Subtotal	10907
Preliminary investigations		180
	Subtotal	11087
Interest during construction		1113
Project investment		12200 Mkr.

TABULATION OF SIGNIFICANT DATA

Drainage area		
Jökulsá River at Dettifoss	6500	km^2
Discharge		
Average 1940 - 1973	182	m^3/s
Maximum recorded	1550	m^3/s
Minimum recorded	37	m^3/s
Design flood (overflow spillway)	4000	m^3/s
Reservoir		
Normal maximum elevation	351,5	m a.s.l.
Normal minimum elevation	341,6	m a.s.l.
Area at normal max. el.	26	km^2
Volume at normal max. el.	180	Gl
Usable storage from el. 351,5 to 341,6	150	Gl
Elevation at design flood	354	m a.s.l.
Headwater		
Normal elevation in diversion canal	340	m a.s.l.
Tailwater		
Elevation at rated plant flow, 135 m^3/s	200,8	m a.s.l.
Elevation at design flood	215,0	m a.s.l.
Gross Head	139,2	m

Dikes

Total length (including spillway)	4,1	km
Maximum height	38	m
Length of spillway	450	m
Capacity of spillway (Res. el. 354)	4000	m^3/s
Capacity of bottom outlet (Res. el. 354)	600	m^3/s

Diversion canal

Length	3,3	km

Tailrace canal

Length	150	m

Penstock

Diameter	5,8 - 5,3	m
Length	370	m

Powerhouse

Length	55	m
Width	20	m
Height	30	m
Installed capacity	161	MW

Turbines

Number	3	
Type	Vertical, Francis	
Rating at 135,6 m net head	74800 metric	hp
Discharge at rated head, full gate	45	m^3/s
Speed	250	rpm

Generators

Number	3	
Rating	59630	kVA
Power factor	0,9	
Voltage	12	kV
Speed	250	rpm

Major quantities

Excavation	1.700.000	m^3
Fill	2.400.000	m^3
Concrete	45.000	m^3

DETAILED TABLE OF CONTENTS

I INTRODUCTION

The hydroelectric potential of Jökulsá á Fjöllum has been renowned for decades. The first estimates of the potential were made by Guðmundur Hlíðdal in 1907 and by Edvard Svanöe in 1920. Further studies were initiated by Sigurður Thoroddsen in the forties. The State Electricity Authority started surveying and geological investigations in 1954 and planning studies in the Jökulsá Basin have since then been sponsored by that Authority, which now is the National Energy Authority (NEA). Preliminary appraisals of power plants were made by Sigurður Thoroddsen in the years 1954 to 1957. Consulting engineers in the period 1957 - 1963 were Harza Engineering Company International and 1958 - 1961 the engineering firms Almenna byggingafélagið h.f. and Verklegar framkvæmdir h.f. in cooperation with Harza. The engineering studies in these years were concluded with a project planning report for the Dettifoss project, a 133 MW run-of-river project with underground powerstation. - Studies of the Jökulsá basin vere taken up again in 1966. These studies have been concerned with the basin as a whole and in connection with other basins and are still going on.

In 1972, The National Energy Authority authorized Verkfræðistofa Sigurðar Thoroddsen s.f., to make project planning studies for approx. 160 MW run-of-river project at Dettifoss. The main reason for renewed planning studies at the site was concern for geological hazard in connection with underground structures in this area and it was requested that water conductors and powerhouse should be as much in the open as feasible.

A Progress Report with comparison of alternatives was submitted to NEA in January 1973. Geological investigations were accomplished by NEA in the summers 1973 and 1974.

The alternative for the Dettifoss Project, described in the present report, was selected on basis of geological conditions as well as cost estimates for different solutions.

The Dettifoss Project is a run-of-river project with pondage. It will develop a gross head of 139 meters from a point about ½ km upstream of Selfoss to Jökulsá downstream of Hafragilsfoss. The natural fall of the river on this stretch of 4 km is about 120 m whereof 79 m are concentrated in the three waterfalls, Selfoss (9 m), Dettifoss (44 m) and Hafragilsfoss (26 m).

The project location is shown on exhibit 1 and a layout of the project is shown on exhibit 2.

The average natural flow of the Jökulsá at Dettifoss is 182 m^3/sec. The rated flow through the power station is 135 m^3/sec.

The main elements of the project are a rockfill dam with spillway and bottom outlet; a power waterway which includes a diversion canal with diversion inlet and intake structures to an underground penstock and tailrace canal; and the powerhouse and switchyard. The rated installed capacity will be 161 MW in three generating units.

II PROJECT DESCRIPTION

General

The location of the project is shown on exhibit 1 and a layout of the project on exhibit 2.

The project takes its name from the waterfall Dettifoss in the river Jökulsá á Fjöllum about 50 kilometers from the ocean. It will devolop for hydroelectric power approximately 139 meters of gross head by a diversion of the waters of Jökulsá from a point about ½ km upstream of the waterfall Selfoss to the Jökulsá canyon downstream of the waterfall Hafragilsfoss.

The Dettifoss project is a run-of-river power development with pondage. The Jökulsá river will be dammed by a rock-fill dam with concrete spillway and bottom outlet. The power waterways consist of a 3,3 km long diversion canal, a 370 m long underground penstock and a 150 m long tail-race canal. The powerhouse will be located in an open cut in the left riverbank close to Hafragilsfoss falls. The installed generating capacity will be 161 MW in three units, corresponding to a total rated discharge of 135 m^3/s.

The dam will create a 26 km^2 reservoir with a total volume of about 180 gigaliters at the normal high water elevation, 351,5 m a.s.l. The usable storage, between elevations 351,5 and 341,6 will be 150 gigaliters, which is only about 2½ % of the average annual runoff.

Access

Access to the Dettifoss project area is now east of the Jökulsá river by a gravel road extending from the main road between Northern and Eastern Iceland at a place about

1 km east of the bridge over Jökulsá river,along the river to the region Axarfjörður. This road is shown on exhibit 1.

A new access road has to be constructed west of the Jökulsá river from the main road to the project area. This road will be alongside the reservoir and diversion canal and down the east wall of Hafragil canyon to the powerhouse area in the Jökulsá canyon, with spurs to the diversion intake and the power intake and the switchyard.

The road down the canyons has to great extent to be blasted as a cut in the rock walls. This part of the road will frequently be unpassable in wintertime because of snow and therefore an access tunnel from an entrance hall at the switchyard to the powerhouse is provided for. This will be the main access after construction.

The access roads will be six meters wide with a maximum grade of 10 percent.

Dams

The location of the dams, the main dam and an auxiliary dam, is shown on exhibit 4. To create a reservoir an earth fill dam will be located a short distance upstream of Selfoss falls and an auxiliary dam at higher ground along the Hraundalur graben. The crest height of the dams will be at elevation 356 thus allowing for a normal reservoir elevation of 351,5 and a maximum elevation of 354. An uncontrolled concrete spillway, 450 meters long with a crest height at elevation 351,5 is provided for near the right abutment of the dam. A one hundred meter long section of the auxiliary dam will be constructed as a fuse plug section so designed that it can be washed away in the event of extreme floods or in emergency.

In case of catastrophic flood the whole auxiliary dam will be washed away as well. The auxiliary dam will be founded on lava at about elevation 345.

A bottom outlet will be located where the main dam crosses the riverbed. The total length of the main dam (spillway included) will be about 2,9 kilometers and of the auxiliary dam about 1,2 km. The maximum height of the main dam will be 38 m and that of the auxiliary dam 12 m.

The design of the dams is shown on exhibit 5. They are fill structures with an impervious central core of moraine separated from the rock shells on both sides by a single-zone filter. The moraine for the core will be taken from the nearby hills west of the damsite. Rock material for the shells will come from excavation for the diversion canal. Filter material is found in alluvial deposits about 3 km south of the damsite. Riprap is available either from the canal excavation or local boulders. The core trench will be excavated to sound rock, which will be cleaned thoroughly and sealed with a slush grout slurry. The dams are founded on basalt and the foundation will for the most part be provided with a grout curtain.

Reservoir

A plan of the reservoir is shown on exhibit 2 and area - volume curves on exhibit 3. The reservoir area at the normal operating level of 351,5 will be about 26 km^2 and the total volume about 180 Gigaliters.

The usable storage is 150 Gigaliters, between reservoir levels 351,5 and 341,6. This is only about $2\frac{1}{2}$ % of the average annual runoff. The main function of the reservoir is protection against ice troubles and it will be very effective for that purpose. The 150 Gl storage will also increase the power production somewhat.

Losses from the reservoir will mainly be leakage and deep percolation losses. These losses are expected to be within acceptable limits and will decrease with time due to self sealing by the river´s suspended load and bed load.

Sedimentation in the reservoir will be a real problem. The sediments carried by the river would completely fill the reservoir in 20 - 40 years if nothing is done to remedy this. The most effective way to prolong the life of the reservoir would be to build dams to trap sediments higher up in the river. The dam of the Dettifoss project is provided with a bottom outlet and flushing of sediments to some extent is also a possibility, but this has not proved to be practical for reservoirs of this size at other projects.

The problem of ice, leakage and sediments are discussed more fully in chapters III and IV.

Spillway and Bottom Outlet

The overflow spillway will, as above stated, be located near the right abutment of the main dam. This location is chosen as the most economic place for the spillway. The length of it is 450 meters, based on optimal studies of the spillway and dam costs. The spillway will be an uncontrolled overflow spillway constructed as a concrete gravity dam (exh. 5). The crest elevation will be 351,5 m a.s.l. and the spillway will pass a discharge of 4000 m^3/s with a water level in the reservoir at 354 m a.s.l.

The fuse plug in the auxiliary dam to meet unforeseen larger floods was mentioned above.

The dissipation of the energy of the spillway discharge will be no problem because of the soild rock bed in the whole area on the right river bank, and no special efforts will be needed to prevent erosion. The spillway discharges will flow back to the Jökulsá river channel 300 - 400 m upstream of Dettifoss and also farther upstream for larger floods. A training dike will be constructed to divert the spillway flows into the river upstream of Dettifoss.

A rating curve is shown on exhibit 3 for the spillway and the bottom outlet, the latter will pass a discharge of about 600 m^3/s in addition to the overflow spillway.

The foundation of the spillway will be provided with a grout curtain. Further, drains will be provided for, downstream of the grout curtain.

The bottom outlet will be under the main dam where the dam crosses the river. The outlet is a concrete structure with two water conductors, 3,8 m wide by 4,2 m high each. The outflow will be controlled by radial gates at the downstream end. Emergency gates will be upstream of the radial gates.

Diversion Inlet

The diversion inlet structure is located in the diversion canal at the end of the main dam as shown on exhibit 4.

The main functions of this structure are following: Firstly, it will provide a way of keeping the water level in the diversion canal constant while the water level in the reservoir can fluctuate. Secondly, it will provide a way of shutting off all flow into the diversion canal if it should become necessary. Thirdly, it will provide a shear wall to prevent floating ice from entering the diversion canal. The construction is shown on exhibit 9.

The flow from the reservoir to the diversion canal is controlled by a radial gate of a height of 5 meters and a width of 6 meters. The gate is operated by a hydraulic cylinder and will be remotely controlled. Above this gate is a house for the hydraulic hoist and control system.

On the upstream side of the inlet structure there is a wheeled gate of height 6,7 meters and width 6 meters. This gate will only be used when the radial gate needs reparation and in case of emergency. It will be operated by a mobile crane and only under water pressure on both sides.

Diversion Canal

The diversion canal will convey the water from the reservoir to the power intake. Plan, profile and sections of the canal is shown on exhibit 7. The water level elevation in the canal will be 340 m a.s.l. which is as high as the topography permits without excessive dikes on the canal sides. The design flow velocity at rated discharge is 0,55 m/s. This velocity will allow for forming of an ice cover during freezing periods.

The canal will be about 3,300 meters long and 20 meters wide at the bottom. The bottom slope will be 0,001 from elevation 330 at the diversion structure to el. 327 at the intake. The canal sides will have slopes 1 horizontal to 4 vertical in rock and 2 to 1 in the overburden. A 3 m berm will be at the contact between rock and overburden.

The canal is mostly formed by excavation except at the downstream end where it is partly formed by dikes. The excavation is mostly in basalt layers but in places in overburden, mostly hard moraine. The basalt layers are made up of vertical pillars, which themselves are impervious. Leakage may though occur through the contacts between the pillars, but this is not serious and the suspended load in the water will seal these contacts. Horizontal contacts between different layers are on the other hand usually pervious and might be source for leakage from the canal. Those areas will have to be sealed with a concrete membrane of some kind, which is taken into account in the cost estimate.

The excavated rock will be used in the shell of the dams and dikes.

The dikes forming the downstream end of the canal will be conventional earth fill dams with an impervious central core founded on sludge grout and grout curtains will be provided for. The elevation of the crest of the dikes is 343 m a.s.l.

Intake Structures

The intake structures consist of the following concrete structures: the intake to the penstock, skimmer wall, gated spillway with bottom outlet, an ungated overflow spillway and retaining walls to connect the structures to the canal dikes. The intake and the spillways are gravity structures. All the structures will be founded on solid rock. Grout curtains and drains will be provided for as necessary. The structures are shown on exhibit 10.

The intake connects the diversion canal to the penstock. It extends from the canal bottom at elevation 327 to the deck at elevation 342,2 m above the water level in the canal. The intake is provided with trashracks designed for a velocity of 0,9 m/s on their gross area. The intake gate will be a remotely controlled wheeled gate 8 meters wide by 6,3 meters high. Slots for a bulkhead gate are upstream of the intake gate. The bulkhead gate and the trashracks will be operated with a mobile crane. The hydraulic cylinder for the intake gate and the gate control equipment will be in a gate house standing on the deck of the intake.

The skimmer wall extends from the right side of the intake obliquely up to the left bank of the diversion canal, forming a small pond in front of the intake. The functions of the skimmer wall are to prevent ice from piling up on the trashracks during freeze-up and break-up, and, in combination with the bottom outlet, to reduce sediment transport to the intake. The wall has 8 submerged openings; the average water velocity through the openings is 0,5 m/s. The top of the openings is at elevation 338 except for the two openings closest to the gated spillway where it is 337, thus allowing for 2, resp. 3, meters depth. The bottom of the openings will be at elevation 330 allowing for a 3 - 4 meters threshold.

The gated spillway is to the right of the intake, vertical to the skimmer wall. The gate is a radial gate 6 m wide by 4 m high. The function of this spillway is to flush ice or trash that may pile up against the skimmer wall. A bottom outlet with a 4 m wide by 3,5 m high radial gate is under the spillway and discharging to the same channel. The diversion canal bottom has a slope of 0,001 towards the intake structures, and by lowering the water level there will be a possibility of cleaning out sediments in the canal through the bottom outlet.

A 38 meters long uncontrolled overflow spillway connects the gated spillway structure and the right bank dike of the diversion canal. The crest elevation of the spillway is 340,2. or 0,2 m above the water level in the canal. This spillway is intended to secure against overflow from the diversion canal, especially if the control of the diversion inlet fails and the inflow to the canal becomes much larger than the flow to the station.

The discharge from the intake spillways and bottom outlet will be directed down to the canyon and into the Jökulsá river some 400 m upstream of Hafragilsfoss falls. A canal with a pedestrian bridge to accomodate tourist traffic will be provided for where the discharge enters the Jökulsá river.

Penstock

The penstock, (exh. 7 and 8) conveys the water from the intake to branch outlets to the three turbines. The total length of the penstock is about 370 m. It is a tunnel with circular section; down from the intake it is a vertical shaft which bends over to a horizontal tunnel with bottom elevation 210 and about 130 m from the powerhouse it slopes down to match the elevation of the distributor, 200 m a.s.l. The vertical shaft and a part of the horizontal section is concrete lined, closer to the powerhouse the penstock is lined with steel embedded in concrete. The concrete lined part has an inside diameter of 5,8 m and the steel lined part 5,3 m. The diameter of the branch outlets to the turbines, which also are embedded in concrete, is 3,0 m.

The tunnel will be located in basaltic formations, see further in the chapter on geology.

Tailrace Canal

The tailrace canal will extend from the powerhouse to a recess in the left bank of the Jökulsá river downstream of the Hafragilsfoss fall, as shown on exhibits 8 and 11.

The canal will be 150 meters long, excavated to a depth sufficient to obtain a tailwater elevation of 200,8 for the rated discharge of 135 cubic meters per second, the water depth at this discharge will be about 4,5 meters. The bottom width will be minimum 25 meters and the slopes of the walls will be 1 V on 0,25 H.

The materials encountered in the canal excavation will be almost entirely of solid rock.

Powerhouse

General

The powerhouse will contain the main generating equipment and auxiliaries. It will be a surface indoor type and located in a cut in the left bank of the Jökulsá river about 100 meters upstream of the Hafragilsfoss waterfall, and at the base of an 80 meters high cliff. The powerhouse substructure and superstructure will be of reinforced concrete construction including three generating units, and an erection bay, as shown on exhibits 11, 12 and 13. The powerhouse will be founded on basaltic formations, as determined from two drill-holes near the powerhouse site. This rock seems to be very tight and uniform without any big faults at the site.

As shown on exhibit 12 the depth of the excavation will be about 50 meters and the roof of the machine hall will be at elevation 222 and thus about 20 meters under the surroundings.

Drainage ditches will be provided around the powerhouse to collect and drain the surface run-off. Underground collector pipes will be placed around the powerhouse to receive the groundwater infiltration.

Structures

The powerhouse is of a conventional type in general planning, proportioning, and structural arrangement.

It will have three floor levels; the turbine floor at elevation 202; the generator floor at elevation 206, generator hall and erection bay at elevation 210. The first floor will have galleries located upstream of the turbines at elevation 196,4 in order to make an access to the inlet valves. A longitudinal cable gallery will be located downstream of the generators at elevation 206. Stairways will be provided between the floors at convenient locations.

Plans and sections of the powerhouse are shown on exhibits 12 and 13.

Above the powerhouse building at elevation 244 a service building will be located, the total area of it will be about 550 square meters. This service building is connected to the powerhouse by a transfer building located at the west end of the erection bay. It consists of a vertical gallery of about 100 square meters and an entrance hall at elevation 244. The transfer building will be provided with a crane going out over the vertical section in order to make the transport of material and equipment down to the powerhouse. The transfer building and the service building are shown on exhibits 12 and 13.

Equipment

The three hydraulic turbines will be vertical shaft, Francis type with steel spiral cases and elbow type draft tubes. Each turbine will develop 74.800 metric horsepower at the rated speed of 250 rpm under the rated net head of 135,6 meters.

The turbine discharge at rated conditions will be about 45 m^3/s. The turbine distributor centerline is tentatively set at elevation 200 meters. Each turbine will be provided with a butterfly inlet valve with a diameter of 3 meters. The valves, located within the powerhouse, will connect each unit branch pipe with the turbine spiral case inlet. Individual valves will be provided for emergency protection of each turbine and to permit shutting off individual turbines for maintenance.

The generators will be vertical shaft type directly connected to the turbines. Each generator will be rated 59,630 kVA at 0,9 power factor, three phase, 50 Hz, 250 rpm. At this time it has been assumed that the generator voltage will be 12 kV.

The powerhouse crane will be an electrically operated overhead travelling bridge crane. Another crane, of the same type, will be in the transfer building.

The powerhouse electrical and mechanical equipment will include such miscellaneous mechanical equipment as valves, gates, crane, pumps, heating and ventilating system, compressed air system, raw and potable water systems, sanitary system, fire protection system, and drainage and unwatering systems; such accessory electrical equipment as low tension power cables, low tension switchgear, station service equipment, control and protection equipment; and other equipment that is normally associated with a powerhouse of this type.

The control room, machine and electric shop, emergency diesel generator and miscellaneous equipment will be in the service building. The station service transformer will be located outside the transfer building.

Transformers and Switchyard

The main transformers will be located along the access to the transfer building. A cable duct will connect the transformers and the powerhouse, as shown on exhibit 13. The transformers will be connected by overhead transmission lines to the switchyard located at elevation 336 on the rim of the canyon west of the powerhouse. The number of outgoing lines is not known at this time, but it is presently assumed the switchyard will be 55 by 85 meters. An entrance hall to the access tunnel to the service building is located close to the switchyard. The control cables between the powerhouse and the switchyard will be carried in the access tunnel.

Operators' Village

The location and layout of the operators' village has not been decided upon finally. A lump sum for the cost of about 10 houses for operators and maintenance workers has been included in the cost estimates.

III HYDROLOGY

The Basin

The Jökulsá á Fjöllum originates in Dyngjujökull and Kverkjökull, outlet glaciers of Vatnajökull, at about elevation 800 m a.s.l. Its main tributary, Kreppa river, originates in Brúarjökull, outlet glacier of Vatnajökull, at similar altitude. The Jökulsá flows from Vatnajökull in a general northerly direction to the Axarfjörður bay.

The length of the Jökulsá is 206 km and its drainage basin has an area of 7750 km^2 (NEA, Vatnasvið Íslands, 1969). The drainage area upstream of the Dettifoss damsite is about 6500 km^2. The drainage area on Vatnajökull glacier is somewhat uncertain, it has been estimated from 1400 to 1700 km^2.

The drainage area is situated within a young volcanic belt. The bedrock consists mainly of three types: interglacial basalts, subglacially formed palagonite tuffs and breccias and postglacial basalt- lava flows. A large portion of the watershed is covered with lava and volcanic deposits and has little surface runoff. The remainder is mostly covered with moraines or eolian loess and is relatively impervious.

The Jökulsá is predominantly a glacial river, but with some characteristics of spring-fed rivers and direct runoff rivers.

The Jökulsá flows with a moderate grade from the glaciers for about 150 km to Selfoss waterfall. Then it drops about 180 m in 12 km in a series of rapids and the waterfalls Selfoss, Dettifoss, Hafragilsfoss, Réttarfoss and

Vígabergsfoss. Downstream of Vígabergsfoss the grade is 7 to 8 m/km for 13 - 14 km and then there is a gradual flattening of the grade until the coastal plain is reached.

Climate

One meteorological station is located in the basin, Grímsstaðir, at elevation 384 m a.s.l. (see exhibit 1). This station has been in operation since 1907. Another station in the basin, Möðrudalur, was in operation from 1944 to 1964. Average monthly climatological data from Grímsstaðir are given in Table III - 1.

The precipitation at Grímsstaðir, and probably in most of the basin north of Vatnajökull, is very low. On Vatnajökull the precipitation increases very rapidly to the south and may perhaps reach 3000 mm/year at the southern end of the basin. There is some evidence that the potential water balance for most of the basin north of Vatnajökull is negative (Markús Á. Einarsson: Evaporation and potential evapotranspiration in Iceland, 1972).

TABLE III - 1

Climatological Data for Grímsstaðir. Monthly averages.

	Precipitation, mm		Mean temp., °C	
		1931-60	1901-30	1931-60
Jan.		26	-5,6	-4,8
Febr.		26	-4,9	-4,8
March		21	-4,5	-3,1
Apr.		21	-1,7	-1,1
May		15	2,1	3,7
June		28	7,1	7,2
July		49	9,6	8,9
Aug.		49	7,2	8,0
Sept.		43	4,2	5,4
Oct.		34	0,1	0,9
Nov.		26	-3,6	-1,8
Dec.		28	-4,9	-3,6
Year		366	0,5	1,2

Streamflow

Gage height and streamflow records for the Jökulsá are collected and prepared by the Hydrological Survey of the National Energy Authority.

Continuous records of gage height and streamflow for a station at Ferjubakki (vhm 20), about 30 km downstream of Dettifoss, are available since Nov. 1938. A water stage recorder was installed in Oct. 1955, but prior to that the stage observations were from a staff gage.

A stage recorder at the bridge near Grímsstaðir (vhm 102), about 25 km upstream of Dettifoss, has been in operation since August 1965.

Two stage recorders are higher up in the basin, in the Jökulsá at Upptyppingar (vhm 162) and in Kreppa at Kreppu-tunga (vhm 163). These recorders were installed in July 1972.

The flow at the Dettifoss damsite has been computed by NEA by subtracting from the flow at Ferjubakki gaging station a constant amount of 21 m^3/s. This value was determined from simultaneous discharge measurements. The inflow between the damsite and the gaging station consists primarily of discharge from springs and a constant adjustment is therefore justified.

The average annual runoff of the Jökulsá at Dettifoss for the years 1940 - 1973 was 5740 Gl/year, corresponding to the average flow of 182 m^3/s. A flow duration curve is shown on exhibit 3.

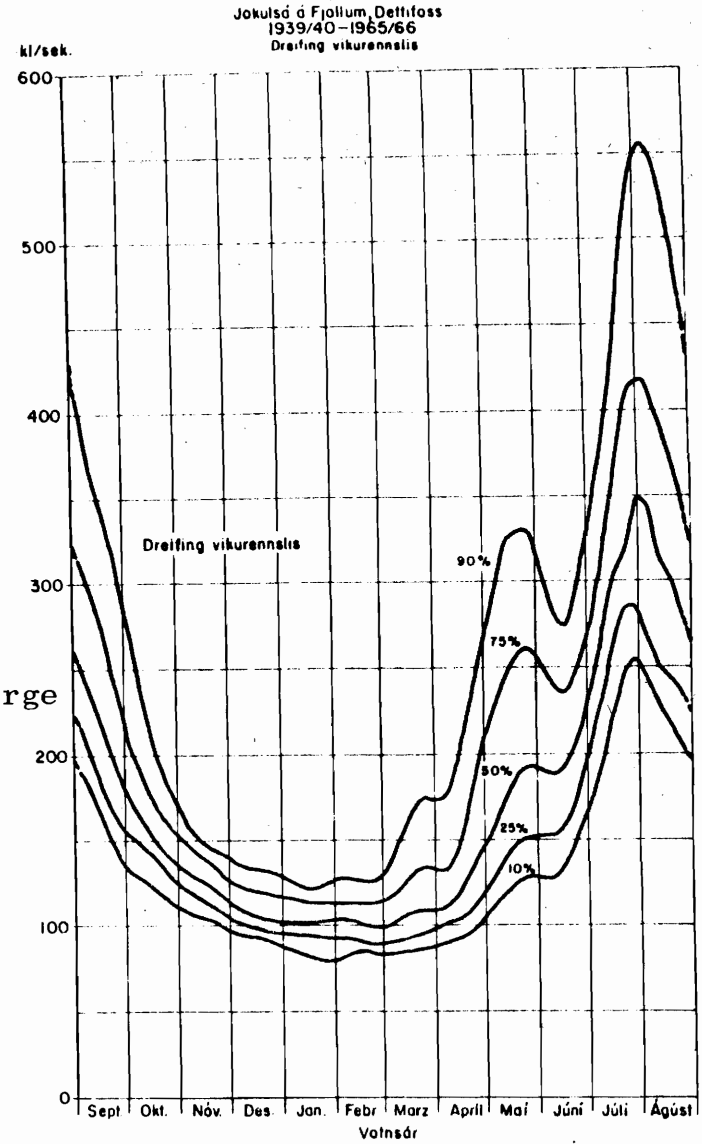
A statistical evaluation of the seasonal variations of the flow is shown on Diagram III - 1 (Sigurjón Rist & Helgi

Sigvaldason: Langtímamælingar vatnsfalla, Orkumál 18, 1968). The spring floods and glacier melt in summer are very pronounced. The winter flow has the characteristics of spring-fed rivers.

DIAGRAM III - 1

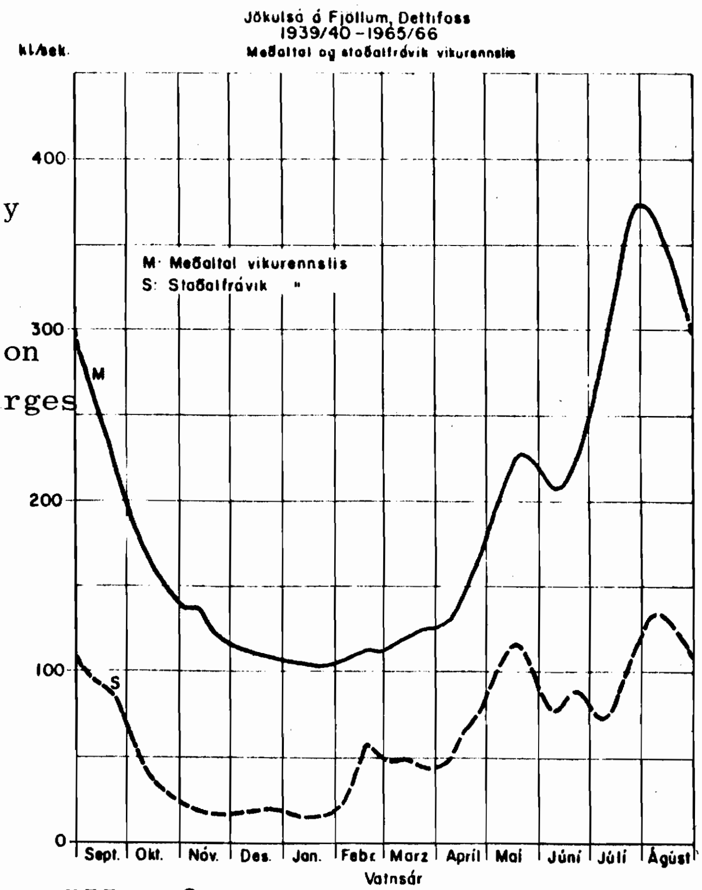
Jökulsá á Fjöllum
Dettifoss

Variation of discharge
Weekly averages



M: Average of weekly discharges

S: Standard deviation of weekly discharges



Floods

The maximum annual discharges for the observation period at Dettifoss are given in Table III - 2. The flood of record, 1550 m^3/s, occurred in June 1949.

The probable maximum flood from rain and snowmelt has been roughly estimated about 4000 m^3/s (Harza Engineering Company International: Dettifoss Project, Vol. I, 1963). The empirical approach gives a maximum flood of similiar size.

Numerous jökulhlaups have occurred in the Jökulsá in historical times (Sigurður Þórarinsson: Jökulhlaup og eldgos á jökulvatnasvæði Jökulsár á Fjöllum, Náttúrufræðingurinn 1950). The largest floods occurred in the period 1655 - 1729 and they are belived to have been caused by volcanic activity in Dyngjujökull. The discharge of these floods is not known, but in Sigurður Þórarinsson´s opinion it is unlikely that any of these floods had a maximum discharge higher than 15.000 m^3/s (Sigurður Þórarinsson: Some geological problems involved in the hydro- electric development of the Jökulsá á Fjöllum, Iceland, 1959).

TABLE III - 2

Jökulsá á Fjöllum, Dettifoss.
Maximum Annual Discharges.

Year	HaQ, m^3/s	Year	HaQ, m^3/s
1939	636	1959	601
40	707	60	466
41	785	61	404
42	942	62	537
43	636	63	478
44	568	64	455
45	823	65	478
46	785	66	472
47	1020	67	496
48	601	68	404
49	1550	69	460
50	785	70	472
51	636	71	383
52	942	72	532
53	863	73	378
54	508		
55	863		
56	399		
57	526		
58	508		

Some geologists are of the opinion that the canyons of Jökulsá were formed in one or more catastrophic floods with a maximum discharge of 0,4 - 0,5 million m^3/s, some 2500 years ago (Haukur Tómasson: Hamfarahlaup í Jökulsá á Fjöllum, Náttúrufræðingurinn 1973; Sigurvin Elíasson: Eldsumbrot í Jökulsárgljúfrum, Náttúrufræðingurinn 1974). The origin of these floods would have been in a big ice dammed lake in Vatnajökull; the glacier may at that time have had a very different extent from what is now.

Catastrophic floods are not taken into account in the design of the spillways for the Dettifoss Project. They are not likely to happen as a possible origin for such floods is not known of. In the case of large jökulhlaups the auxiliary dam would be washed away and the water would flow down Hraundalur and Hafragil and to Jökulsá about 1 km downstream of the powerhouse and also to lower areas west of Hraundalur. Together with the concrete spillway a discharge of 15000 m^3/s would easily pass without exceeding the design high water level of the reservoir, 354 m a.s.l. The 450 m long concrete spillway will pass 4000 m^3/s, or about the maximum probable flood from rain and snowmelt, without overtopping of the auxiliary dam.

A rating curve for the Jökulsá at the outlet from the powerhouse is shown on exhibit 3. This is based on a few observed points for discharges from 200 to 300 m^3/s and assumed bottom elevation of the control section. The control is upstream of Hafragil and the effect of a large flood down Hafragil has not been studied in detail. However the canyon downstream of Hafragil is much wider and a flood down Hafragil would probably not affect the water level at the station when the spillway discharge is maximum.

Installation of a water stage recorder downstream of Hafragilsfoss and observation of river profiles at various discharges is warranted prior to final design of the powerhouse.

Sediment Transport and Sediment Problems

Samples of suspended sediments in the Jökulsá have been collected by the National Energy Authority. Fortyfive samples were collected at the Ferjubakki gaging station in the years 1956 - 1961 (Skýrsla um aurburðarrannsóknir fram til 1970, 2. hefti, Orkustofnun 1974). The first sample at the Grímsstaðir gaging station was taken in 1953 but most of the samples there have been collected after 1962. In the years 1963 - 1970 128 samples were collected at Grímsstaðir (Skýrsla um aurburðarrannsóknir fram til 1970, 1. hefti, Orkustofnun 1973). An estimate of the suspended load at Dettifoss for the years 1963 - 1970 has been made at NEA. The main results are given in Table III - 3.

TABLE III - 3

Jökulsá á Fjöllum, Dettifoss
Suspended sediments
Calculated yearly sums, million metric tons

Year	Total	Coarse	Fine	MaQ, m^3/s
1963	6,9	5,3	1,9	160
1964	5,0	3,3	1,5	160
1965	8,9	6,5	2,4	178
1966	7,8	5,9	2,0	162
1967	4,9	3,5	1,4	155
1968	6,4	4,5	1,8	166
1969	7,3	5,4	1,9	164
1970	7,0	5,9	1,7	153
Average	6,8	5,0	1,8	162

The boundary between coarse and fine sediments is at grain size 0,02 mm. The average discharge 1963-70 was considerably less than the long - term average and no floods over 500 m^3/s occurred in this period.

The bed load of the Jökulsá at Dettifoss has not been estimated. By comparison with estimates from the Thjórsá River it may be guessed to be some 20% of the suspended load.

The reservoir of the Dettifoss Project will certainly fill up rather quickly with sediments if nothing is done to trap sediments farther upstream. Dredging or flushing sediments through the bottom outlet of the dam will hardly be practical. The coarse suspended load and the bed load will be deposited in the reservoir but the fine suspended load will for a large part pass through the reservoir. A rough estimate of the volume of the sediments that will be deposited in the reservoir is 5 to 10 Gl/year. This means that the reservoir will be completely silted up after 18 - 36 years. This shows that permeable dams or dikes to trap sediments farther upstream must be built, preferable as soon as the project is completed.

Ice Conditions and Ice Problems

A description of the ice conditions of the Jökulsá has been given by S. Rist (Jökulsá á Fjöllum; Virkjun við Dettifoss; Ísaspá, Orkustofnun 1975). About 20 km stretch of the Jökulsá upstream of the Dettifoss reservoir is a very active zone in freezing weather. The reservoir will cool down to 0^{o} C soon after the cold sets in autumn. An idea on the ice conditions of the Dettifoss reservoir can be formed on basis of ice observations at Lake Mývatn, which is at elevation 277 m a.s.l. some 35 km southwest of Dettifoss (Sigurjón Rist: Mývatnsísar. Hafísinn 1969).

Some dates on the ice cover of Lake Mývatn are given in Table III - 4.

TABLE III - 4

Ice cover of Lake Mývatn
36 years observations

	First day	Median	Last day
Beginning of freeze-up	Sept. 29	Oct. 28	Nov. 30
Freeze-up date	Oct. 6	Nov. 5	Dec. 6
Beginning of break-up	Apr. 6	May 14	June 21

The Dettifoss Reservoir will freeze over in October - November and be ice covered through the winter, in most years until May. The diversion canal of the project is designed with low flow velocity and will freeze over even sooner than the reservoir because of less wave action. Troubles in the freeze-up period due to frazil ice and ice on trashracks etc. under adverse weather conditions can happen at any hydro - power station in Iceland but there is no reason to believe that such troubles will be frequent at the Dettifoss project.

Ice jams can build up in the upstream end of the reservoir and the ice may progress up the river with a considerable rise in stage. This is however not different from the present natural conditions; up to 5 m rise in stage has been observed at the Grímsstaðir bridge. - Ice jams in the tailrace from the power station are not to be expected. Under natural conditions the river in the canyons downstream of Hafragilsfoss remains open except for a few ice bridges.

IV ENGINEERING GEOLOGY

General

The geology of the project area as regards power development has been under study since 1953. Studies have been made by Prof. Sigurður Thorarinsson (1) (2) by The State Electricity Authority´s (SEA´s) geologists (3) and by The National Energy Authority´s (NEA´s) geologists since 1967, which in the years 1973 - 1974 have carried out comprehensive investigations.

The geological investigation in the general area over this last period have included diamond core drilling, borro soundings, seismic survey, digging of test pits among other, which together with the walls of the Dettifossgljúfur gorge give generally adequate information for planning purpose. The details of these field investigations are presented in a separate report (4).

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(1) Sig. Þórarinsson: Jarðfræðileg greinargerð í sambandi við álitsgerð um virkjunarmöguleika í Jökulsá á Fjöllum. March 1954.

(2) Sigurður Thorarinsson: Some geological problems involved in the hydroelectric development of the Jökulsá á Fjöllum, Iceland. January 1959.

(3) The State Electricity Authority: Project Planning Report. Volume II. Dettifoss Project. Geology. March 1963.

(4) Oddur Sigurðsson, Snorri Zóphóníasson, Laufey Hannesdóttir, Sveinn Þorgrímsson og Páll Ingólfsson: Dettifossvirkjun. Jarðfræðiskýrsla. 1975.

The prominent bedrock formations in the Project area proper are of volanic origin which have been accumulating during the latest stage of glaciation and continued until very recently The rock types met with are mainly a) Interglacial basalts and b) Postglacial basalt lava.

The interglacial rocks consists mainly of basaltic lava flows with intercalated sedimentary layers of different origin, such as ash, eolean - and water transported material. The basalt layers are almost horizontal and have solidified into a coarse vertical columnar structure. The columns are frequently 2 m diam. and may be found of up to 3 m diameter. The thickness of the layers varies from ab. 5 m up to ab. 45 m. The basalts are rather coarsegrained but for the uppermost layer on either side of the river south of Selfoss which is rather fine grained basalt.

The sedimentary layers in between the basalt layers vary both in thickness and structure. They are weakly semented and some of them are very permeable and the lowest two layers seem to be the main aquiferes in the canyon feeding small springs south of and bigger ones north of Hafragilsfoss waterfall.

The basalts on either side of the river south of the Dettifoss falls are overlain by morainal deposits but those deposits have been eroded away by former big floods and are not to be found nearest to the river.

The postglacial lava overlies the basalt between Dettifoss falls and the Hafragil canyon and on the left to the project area a graben named Hraundalur lies parallel to the Dettifoss canyon - . The above mentioned floods have in places between Dettifoss and Hafragilsfoss falls also eroded those lavas away.

The lava and the basalts are again covered with both alluvial and eolean deposits which though are generally thin but for limited areas, where a certain thickness prevails.

The recent geologic investigations have shown that the geology of the Dettifoss project is generally favourable and contains no serious or unusual problems. It has been pointed out that the project is situated within an active volcanic zone with active tectonic movements. Precision levelling since 1971 has however not disclosed any vertical movements within the project site. Major earthquakes in the project area have not been recorded. Evaluation of the risk of volcanic eruptions is outside the scope of this report.

Geology in Relationship to the Structures.

Geological maps of the project area and geological sections are shown on exhibits 15, 16 and 17.

Many faults are evident in the project area and its neighbourhood as may be expected in an active volcanic region, with fissures and dykes. As the dykes seem to have the effect to lead the groundwater and dam for the aquiferous layers and as there is certain risk that the motion of the faults may be going on, a consideration has been given to this matter by choice of locations for the structures, which are located in between the main fault and dyke belts east of the Hraundalur graben and west of the Sveinagjá graben.

The dam with spillway and the diversion structure will be founded on the uppermost layers of the basalt series across the river and a stretch on both sides ending with the abutments founded on moraine.

An auxiliary dam with a fuse plug is founded on postglacial lava originating in the Hraundalur graben. The dam's abutments will be founded on moraine.

The foundation of the dam and its concrete structures will have an adequate bearing strength. The over 3300 m long diversion canal is located along side and east of the Hraundalur graben. Its bottom is all the way but for the last ab. 300 m nearest to the intake structure, in the basalt layers. Those ab. 300 m are in the Sveinahraun postglacial lava.

The location of the canal is such that the canal is formed by excavation with some low dikes in places, the height of these dikes will though nowhere exceed ab. 5 m and are highest on the last 300 m.

The geological units encountered with at the canal sides are the different basalt layers: A_0, A_1, A_3, A_4 and B. In between these layers interbeds will be met with, both morainal, on a short stretch, breccias and alluvial materials.

The basalt layers are relatively impervious but some measures will be taken to diminish leakage through the interbeds and where the canal lies in the postglacial lava it will have to be lined to some extent.

The intake structure will be founded on the postglacial lava, which has an adequate bearing strength.

The penstock begins as a vertical section from the intake and passes over to a near horizontal section to the power-house.

The vertical section will pass trough the postglacial lava in the uppermost few meters and then eleven different layers of basalts and their contacts. The horizontal section will pass through one or two different basalt layers which though presently cannot be definitively stated as information hereon is not available. It is to be expected that some leakage will be encountered with from the contacts between the basalt layers but it should not be excessive as only small springs issue from the wall of the canyon on the stretch here in question.

The powerhouse and tilrace canal will be in excavation in seven basalt layers. The foundation of the powerhouse will be of adquate bearing strength. What above was stated on the leakage in the penstock excavation applies here too.

The reservoir covers about 26 km^2. The reservoir bottom consists mostly of the present riverbed and alluvial deposits. Close to the dam the bottom is basalt layers and moraines. At two places the reservoir is on postglacial lava in small areas. The reservoir will be perched over the regional groundwater table and accordingly some seepage is to be reckoned with. The dams will be protected with grout curtains and slush grout lining under the core. If percolation problems arise, these will most likely be confined to fissures and contacts between basalt layers. Such exposures within the reservoir will be located when the reservoir is progressively filled, then provided with filters, seals and protective cover against erosion. The postglacial lavas within the reservoir are not considered to cause percolation problems. The fine sediments carried by the Jökulsá will, within a short time, infiltrate the alluvial deposits and joints in the basalt layers and thus reduce percolation and leakage.

Natural Construction Materials

Adequate natural construction materials of suitable quality and quantity are available within reasonable hauling distance of the project structures.

The locations of these deposits are shown on exhibit 18. The investigation and test results on the materials is discussed more fully in a separate report (Jökulsá á Fjöllum. Virkjun við Dettifoss. Byggingarefnarannsóknir 1973).

Impermeable material for the dam cores and seals is available in morainal deposits east of Hraundalur close to the left abutment of the main dam (Area M).

Suitable filter material is available in the alluvial deposits located on the left bank of the river about 3 km upstream of the dam site (Area K). This material can most likely also be used as concrete aggregate.

Suitable shell material will mainly come from required excavation for the diversion canal but material from the above mentioned alluvial deposit may also be used.

Rip rap for protection of the dam will come from required excavation or by collecting boulders which are scattered over the area.

A possible source of concrete aggregates is about 3 km upstream of the damsite (Area K), as mentioned above. Another possible source of concrete aggregates is the Grænalág esker, Sandhryggur, some 10 km southwest of the project.

V ENVIRONMENTAL IMPACT

It is not within the scope of the present report to give a detailed evaluation of the environmental impact of the Dettifoss project. An environmental impact statement must be prepared in cooperation with the parties concerned and potential environmental problems and claims discussed and settled before any decisions on construction are taken.

The Dettifoss project, excluding the dams, reservoir and uppernmost part of the diversion canal, is situated within a national park. Man - made structures that affect the scenery in a national park are of course always subject to objections. The median discharge of the waterfalls Dettifoss and Hafragilsfoss will be 100 to 200 m^3/s in the tourist season after the construction of the project instead of 200 - 300 m^3/s under natural conditions.

The project area including the reservoir site is uninhabited and with little vegetation. The loss of grazing land will be negligible and there are no fishing interests in the Jökulsá in this area.

VI PROJECT COSTS

Cost estimates for construction of the Dettifoss Project have been made based on the design and layouts described in chapter II.

The cost estimates are based on calculated average bid prices as of late May 1975. For the main items that affect unit prices of civil works the following rates and prices have been used.

Labor (4th rate, daytime)	250	kr/h
Construction equipment		
Bulldozer, Cat D9G	13050	kr/h
" with ripper	15300	kr/h
Payloader, 5,5 cu. y.	8050	kr/h
Truck, 15t	2980	kr/h
Crawler drill with compressor	9150	kr/h
Mobile crane, 10t	2230	kr/h
Construction materials		
Cement	10160	kr/t
Dynamite	300	kr/kg
Reinforcing steel	100	kr/kg
Timber, 25 x 150 mm	139	kr/m

Import duties and sales tax are included in the above costs as appropriate.

Estimates of the cost of major items of equipment such as turbines, governors, generators, transformers and main electrical and mechanical equipment are based on direct quotations from manufacturers supplemented with data available from other projects.

Duties and taxis are not included in the cost of major permanent electrical and mechanical equipment.

A detailed cost estimate for the project is presented on the following pages. The total estimated project investment is 12200 million kronur.

DETTIFOSS PROJECT

COST ESTIMATE MAY 1975

SUMMARY

		Mkr.
Dams		2306
Waterways		2617
Power plant structures		733
Turbines, generators, electrical and miscellaneous equipment		2080
Access roads		205
Operators village		130
Cofferdams and care of water		60
	Subtotal	8131
Contingencies 5% of 1700 Mkr.		85
15% of 6431 "		965
	Subtotal	9181
Escalation		734
	Subtotal	9915
Engineering & supervision		992
	Subtotal	10907
Preliminary investigations		180
	Subtotal	11087
Interest during construction		1113
Project investment		12200

DETTIFOSS PROJECT

COST ESTIMATE

MAY 1975

	Unit	Quantity	Unit price kr.	Amount kr.
DAMS				
Rockfill Dams.				
Excavation overburden	m^3	50.000	200	10.000.000
Foundation preparation and grouting			l.s	350.000.000
Impervious core	m^3	466.000	500	233.000.000
Filters	m^3	315.000	450	141.750.000
Rockfill	m^3	1.197.000	590	706.230.000
Riprap	m^3	202.000	1700	343.400.000
Miscellaneous			l.s	20.620.000
Subtotal Rockfill Dams				1.805.000.000
Overflow Spillway				
Excavation overburden	m^3	5.000	200	1.000.000
Foundation preparation, grouting and drains			l.s	35.000.000
Concrete	m^3	7.300	12800	93.440.000
Formwork, straight	m^2	3.900	3600	14.040.000
" , curved	m^2	2.600	6100	15.860.000
Reinforcing steel	kg	54.000	185	9.990.000
Water stops	m	180	3000	540.000
Miscellaneous			l.s	1.130.000
Subtotal Overflow Spillway				171.000.000
Bottom Outlet				
Excavation unclassified	m^3	3.000	900	2.700.000

	Unit	Quantity	Unit Price kr.	Amount kr.
Foundation preparation			l.s	3.000.000
Concrete	m^3	8.000	12800	102.400.000
Formwork, straight	m^2	6.600	3600	23.760.000
Formwork, curved	m^2	60	6200	372.000
Reinforcing steel	kg	230.000	180	41.400.000
Gates, guides and hoists			l.s	95.000.000
Miscellaneous			l.s	4.368.000
Subtotal Bottom Outlet				273.000.000
Training Dike				
Rockfill	m^3	30.000	1900	57.000.000
Subtotal Training Dike				57.000.000
SUBTOTAL DAMS				2.306.000.000
WATERWAYS				
Diversion Canal				
Excavation unclassified	m^3	290.000	400	116.000.000
Excavation rock	m^3	1.050.000	1100	1.155.000.000
Dikes	m^3	140.000	550	77.000.000
Grouting and canal lining			l.s	90.000.000
Miscellaneous			l.s	2.000.000
Subtotal Diversion Canal				1.440.000.000

	Unit	Quantity	Unit Price kr.	Amount kr.
Diversion Inlet				
Excavation unclassified	m^3	8.500	400	3.400.000
Excavation rock	m^3	10.000	1100	11.000.000
Foundation preparation			l.s.	1.500.000
Concrete	m^3	3.000	12800	38.400.000
Formwork, straight	m^2	3.500	3600	12.600.000
Formwork, curved	m^2	200	6100	1.220.000
Reinforcing steel	kg	60.000	190	11.400.000
Gates, guides and hoists			l.s.	80.000.000
Architectural & Miscellaneous			l.s.	5.480.000
Subtotal Diversion Inlet				165.000.000
Intake Structures				
Excavation rock	m^3	16.000	1100	17.600.000
Foundation preparation			l.s.	2.000.000
Concrete	m^3	7.500	12800	96.000.000
Formwork, straight	m^2	8.500	3600	30.600.000
Formwork, curved	m^2	900	6100	5.490.000
Reinforcing steel	kg	250.000	190	47.500.000
Gates, guides and hoists			l.s.	85.000.000
Trashracks			l.s.	60.000.000
Architectural & miscellaneous			l.s.	5.810.000
Subtotal Intake Structures				350.000.000

	Unit	Quantity	Unit Price kr.	Amount kr.
Penstock				
Tunnel excavation	m^3	11.000	2300	25.300.000
Formwork, curved	m^2	3.500	6200	21.700.000
Concrete	m^3	5.000	18000	90.000.000
Reinforcing steel	kg	280.000	275	77.000.000
Steel lining	kg	600.000	360	216.000.000
Subtotal Penstock				430.000.000
Tailrace				
Excavation, rock	m^3	185.000	1200	222.000.000
Draft tube gates, guides and hoist			l.s.	10.000.000
Subtotal Tailrace				232.000.000
SUBTOTAL WATERWAYS				2.617.000.000
POWER PLANT STRUCTURES				
Powerhouse				
Excavation overburden	m^3	3.200	270	864.000
Excavation rock	m^3	67.000	1200	80.400.000
Concrete	m^3	12.800	12800	163.840.000
Formwork straight	m^2	20.600	3600	74.160.000
Formwork curved	m^2	460	6100	2.806.000
Reinforcing steel	kg	860.000	185	159.100.000

	Unit	Quantity	Unit Price kr.	Amount kr.
Architectural treatment			l.s.	75.000.000
Miscellaneous metalwork			l.s.	12.000.000
Plumbing, heating, vent-ilating and lighting			l.s.	60.000.000
Station yard			l.s.	1.830.000
Subtotal Powerhouse				630.000.000
Access Tunnel				
Tunnel excavation	m^3	5.100	2800	14.280.000
Concrete	m^3	1.000	18000	18.000.000
Formwork straight	m^2	2.600	3600	9.360.000
Formwork curved	m^2	1.200	6100	7.320.000
Stairs & elevator	l.s.			30.000.000
Access hall	l.s.			10.040.000
Subtotal Access Tunnel				89.000.000
Switchyard				
Excavation, unclassified	m^3	1.000	900	900.000
Fill	m^3	15.000	500	7.500.000
Miscellaneous construction grading, surface & fence			l.s.	5.600.000
Subtotal Switchyard				14.000.000
SUBTOTAL POWER PLANT STRUCTURES				733.000.000

	Unit	Quantity	Unit Price kr.	Amount kr.
TURBINES, GENERATORS, ELECTRICAL & MISCELLANEOUS EQUIPMENT				
3 turbines, governors & valves			l.s.	845.000.000
3 generators			l.s.	660.000.000
3 transformators			l.s.	195.000.000
Accessory electrical equipment			l.s.	125.000.000
Miscellaneous power plant equ.			l.s.	135.000.000
Switchyard equipment			l.s.	120.000.000
SUBTOTAL TURBINES, GENERATORS, ELECTRICAL AND MISELLANEOUS EQUIPMENT				2.080.000.000
SUBTOTAL ACCESS ROADS			l.s.	205.000.000
SUBTOTAL OPERATORS VILLAGE			l.s.	130.000.000
SUBTOTAL COFFERDAMS AND CARE OF WATER (All Structures)			l.s.	60.000.000

VII PROJECT CONSTRUCTION

In order to provide a reliable basis for estimating project cost some assumptions with respect to the construction of the Dettifoss project have to be taken into account. Some of the more important assumptions which were made are presented at least in general terms.

The project civil engineering construction is expected to be without difficulties that could not be overcome by Icelandic contractors as regards skill to perform the work.

The project´s spread-out nature means that consideration might be given at the time of bidding to split civil engineering construction of the work into several segments in order to expedite the work, such as:

1. Road work
2. Erection of camps
3. Erection of operators village
4. All excavation and dike construction including bottom outlet, diversion structure and the intake structure
5. The powerhouse with penstocks, access tunnel and tailrace canal
6. Concrete manufacture
7. Gates, trashracks
8. Any combination of the above

The field investigations conducted in 1974 and previously developed the availability of suitable natural construction materials in adequate quantity within reasonable hauling distances. These include impervious core materials, filter and rock fill materials, riprap etc.

A bar graph construction schedule was prepared and is shown as exhibit 19. This graph is based on the designs and the above construction assumptions. Details of the construction procedures assumed to accomplish this schedule are discussed in greater detail hereinafter. Actual procedures including sequences used by the ultimate contractors, may, of course, differ from these assumptions but should not tend to increase costs or construction time.

The result shown in the schedule is a construction time for the project extending for four years which in part is due to the hard weather conditions at the site, which make work in the open almost unpossible during midwinter.

Construction Procedure

Owing to the difficult weather condition and almost total lack of access road to the site a quick start of the construction will not be possible. The first year will mostly go to construct an access road, a camp and to the move in. The construction of the operators village which will consist of one family houses is also reckoned with as the village will be useful during construction.

Of the construction proper only a relatively small portion will be performed the first year, mainly diverting the river, beginning of the excavation for the diversion canal and else some preparatory work for the next year's work.

This initial work mentioned above ought to start not earlier nor later than in April.

The river diversion work will consist of coffer dams across the river both upstream and downstream of the bottom outlet and a training dike from the upstream dam to confine the flow past the features in the river channel on the right bank of the river. A temporary bridge has to be built across this waterway or across the river downstream in the Selfoss fall region. The last stage of the dam construction will be the closing of the diversion. This will be performed by building a second cofferdam which will be part of the main dam. The water will then pass through the bottom outlet. As the bottom outlet is of limited capacity the time for this closure has to be chosen when the riverflow is relatively small viz. during the fall, August-October. Removal of the cofferdams will not be neccessary but for the downstream dam across the river. The material in the cofferdams will total about 85000 cubic meters.

It will be neccessary to begin excavations in several places more or less concurrently. The most important parts for early construction are the dam, the diversion canal with structures and not least the powerhouse with tailrace, which represent the major features requiring the longest time. The excavation of the diversion canal will proceed generally as to best fit the utilization of the excavated material, which will comprise shell material in the dam. It may be necessary to stock-pile some of the excavated material.

The aggregate processing plant will be established at the borrowarea, which is about 3 km upstream of the main dam. A processing of the aggregate will be needed. It is not to be expected that the water from the river can be used for washing the aggregate so drilling for water must be reckoned with. The same applies to potable water for the camp and operators village.

The powerhouse excavation will be carried out in connection with the excavation for the tailrace canal as the excavated material from the powerhouse will be hauled out through the tailrace canal. As soon as possible the excavation for the horizontal parts of the tunnel for the penstock and the access will be started. The vertical parts will be excavated from beneath.

The powerhouse concreting will start as soon as the excavation in the upstream end has proceeded to grade. Thereafter the powerhouse concreting can proceed coincidentally with the excavation of the downstream end and the tailrace canal. The erection and assembling of the powerunits will proceed after the superstructure of the house is in place and the powerhouse cranes erected.

The concreting of the different structures, the bottom-outlet, the spillway, the diversion inlet and the intake structures and the tunnels for the penstocks will be started as soon as the excavation is completed and mostly in the second year session.

Erection of the main electrical and mechanical equipment will take place in the third and fourth year.

The operation of the project will start in late fall of the fourth year according to the construction shedule.

VIII POWER PRODUCTION

The average annual energy production which the Dettifoss project will add to the power system depends on the extent of the power system it will be connected to.

The installed generating capacity which has been assumed for the project as described here was based on studies carried out in 1971-73 of the energy production of the Dettifoss project in interconnection with the Laxá power plants (Helgi Sigvaldason & Gunnar Ámundason: Aðgerðarrannsóknir á samrekstri virkjana í Laxá í Suður-Þingeyjarsýslu og Jökulsá á Fjöllum, Orkustofnun, Sept. 1971; Verkfræðistofa Sigurðar Thoroddsen s.f.: Jökulsá á Fjöllum, Framvinduskýrsla, Orkustofnun, janúar 1973). These studies were revised in 1974 including studies of interconnection with the Landsvirkjun power system (Helgi Sigvaldason & Gunnar Ámundason: Aðgerðarrannsóknir á samrekstri virkjana, á Norður- og Suðurlandi, Orkustofnun, Febrúar 1974).

The main result of the latter studies were as follows:

1. The Dettifoss Project interconnected to the Laxá power plants.
   Added energy production: 1180 GWh/a. Energy production of the total system: 1315 GWh/a, whereof 197 GWh/a were assumed for power consuming industries.

2. The Dettifoss project interconnected to the Laxá plants and the Landsvirkjun plants Sog, Búrfell and Sigalda. Added energy production with the Dettifoss project: 1235 GWh/a. Energy production of the total system: 4350 GWh/a, whereof 75% or 3262 GWh/a were assumed for power consuming industries.

The necessary capacity of the Dettifoss project in connection with the Laxá plants was estimated 156 MW in these studies, but the necessary capacity of the project when connected to Landsvirkjun´s power system was not investigated.

The above referenced results are now more or less obsolete. Studies on energy production of the Dettifoss project connected to the North-Iceland and Landsvirkjun power systems with power plants that are presently under construction and future plants are now going on.

Results for a 161 MW plant at Dettifoss connected to the present North-Iceland and Landsvirkjun power systems with addition of Krafla geothermal plant and Sigalda hydroelectric plant, which are now under construction, are already available. The additional annual energy production with the Dettifoss project is estimated 1140 GWh/a. The energy production of the total system including Dettifoss is estimated 4900 GWh/a, divided as 75% for power consuming industries and 25% as general load.

Results of the power studies that are now under way, and which will include estimates of the energy production of the Dettifoss Project for various reservoir sizes and installed capacity, will be presentes in a separate report.

LIST OF EXHIBITS

Exhibit 1

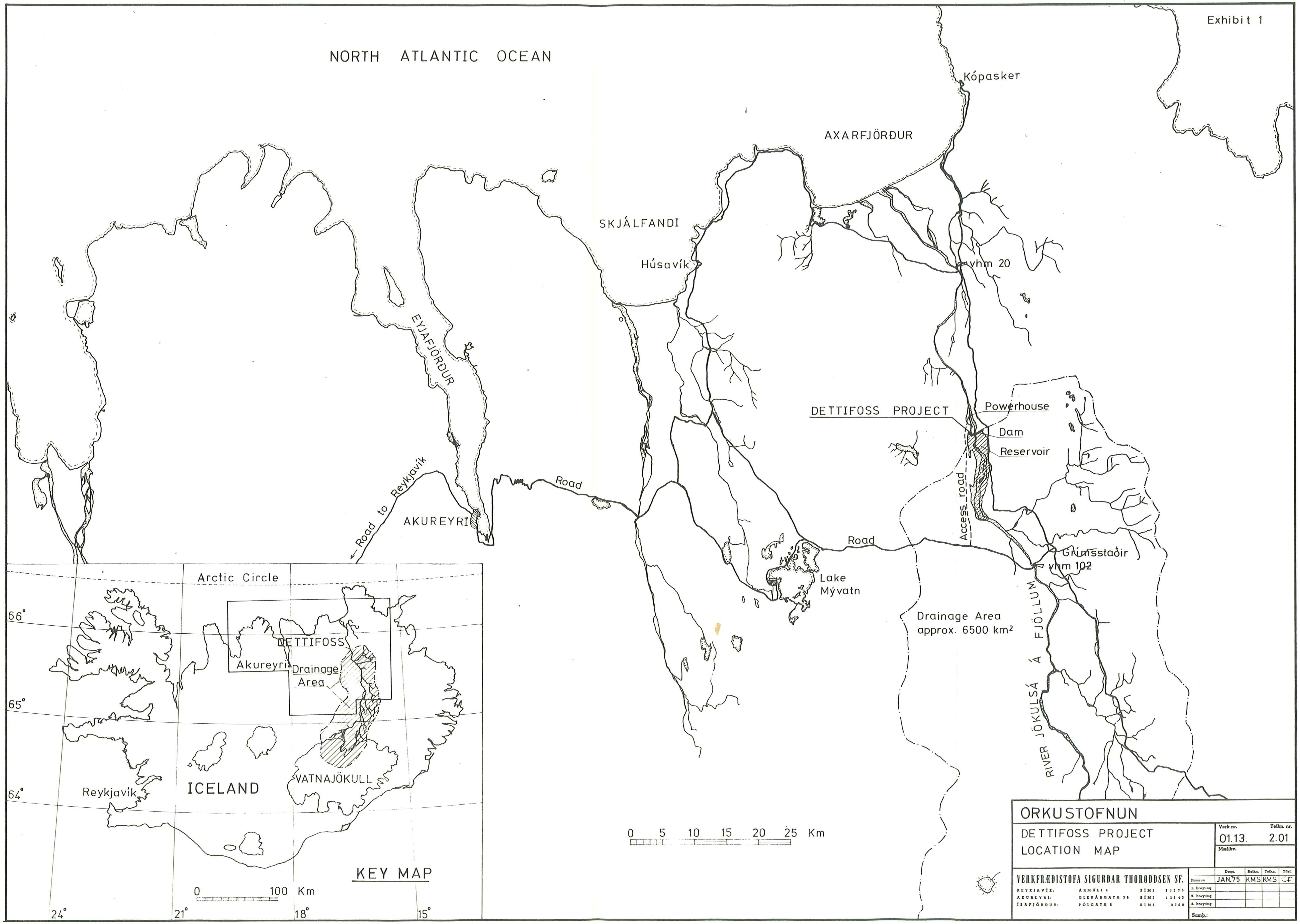
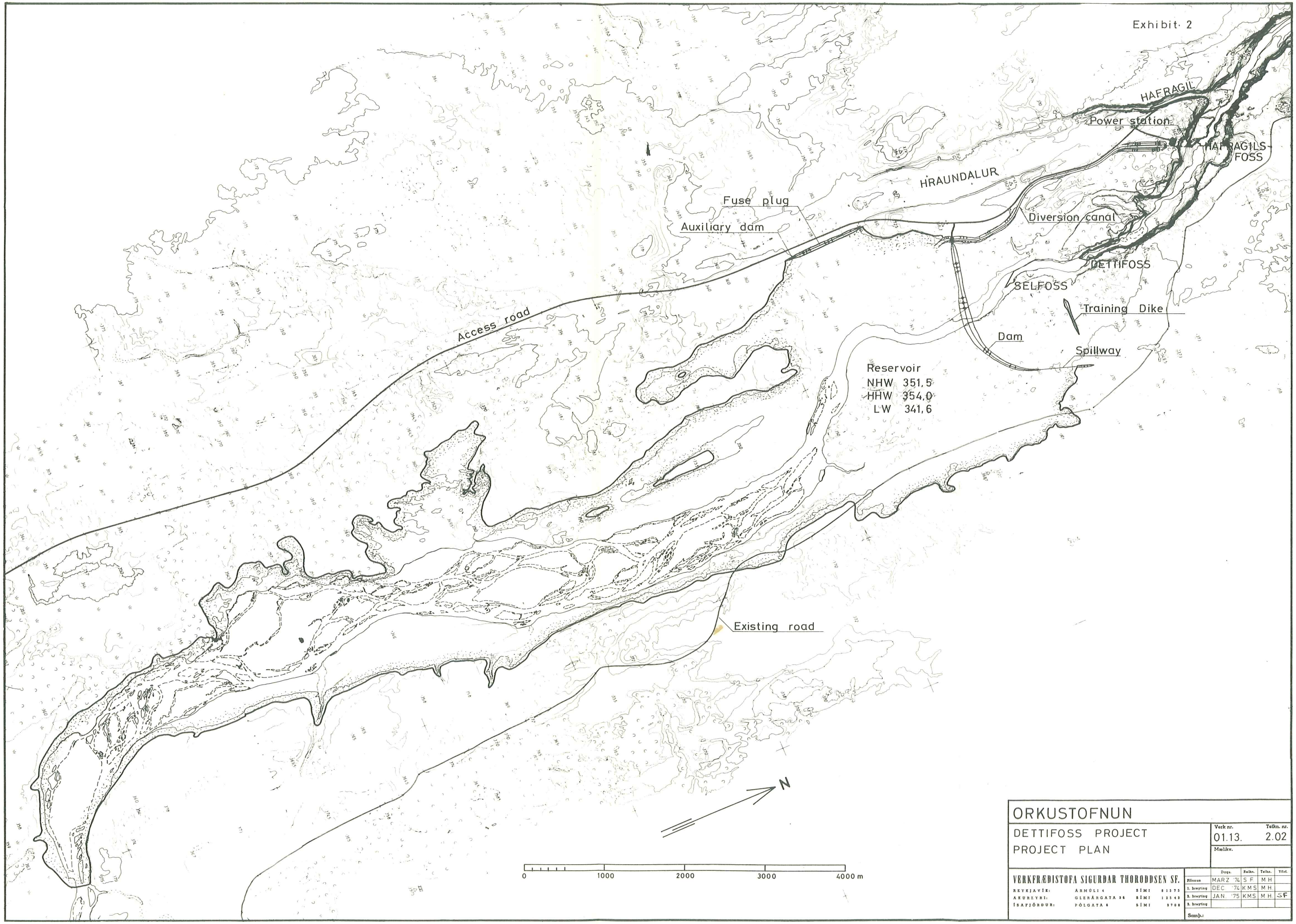

NORTH ATLANTIC OCEAN
Kópasker
AXARFJÖRÐUR
SKJÁLFANDI
Húsavík
vhm 20
EYJAFJÖRÐUR
DETTIFOSS PROJECT
Powerhouse
Dam
Reservoir
Access road
Road
Road to Reykjavík
AKUREYRI
Road
Lake Mývatn
Grímsstaðir
vhm 102
Drainage Area approx. 6500 km²
RIVER JÖKULSÁ Á FJÖLLUM
0 5 10 15 20 25 Km
Arctic Circle
66°
65°
64°
DETTIFOSS
Akureyri
Drainage Area
VATNAJÖKULL
Reykjavík
ICELAND
KEY MAP
0 100 Km
24°
21°
18°
15°
ORKUSTOFNUN
DETTIFOSS PROJECT
LOCATION MAP
01.13.
2.01
JAN.75
KMS
KMS
VERKFRÆDISTOFA SIGURDAR THORODDSEN SF.

Exhibit 2



ORKUSTOFNUN

DETTIFOSS PROJECT
PROJECT PLAN

Verk nr. 01.13.
Telkn. nr. 2.02
Mælikv.

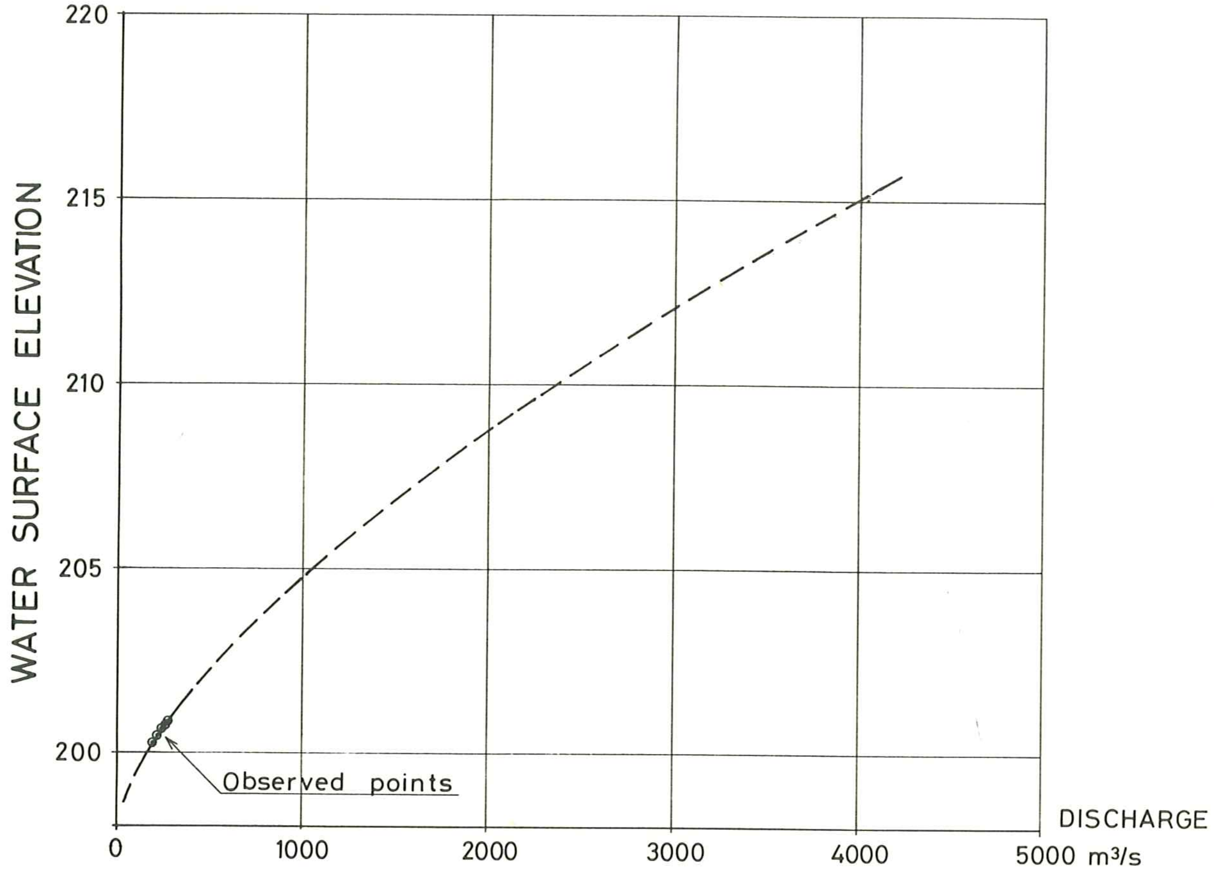
VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.

REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575
AKUREYRI: GLERÁRGATA 36 SÍMI 12543
ÍSAFJÖRÐUR: PÓLGATA 6 SÍMI 3708

	Dags.	Reikn.	Teikn.	Yfirl.
Hönnun	MARZ '74	S F	M H	
1. breyting	DEC '74	K M S	M H	
2. breyting	JAN. '75	K M S	M H	SF
3. breyting				

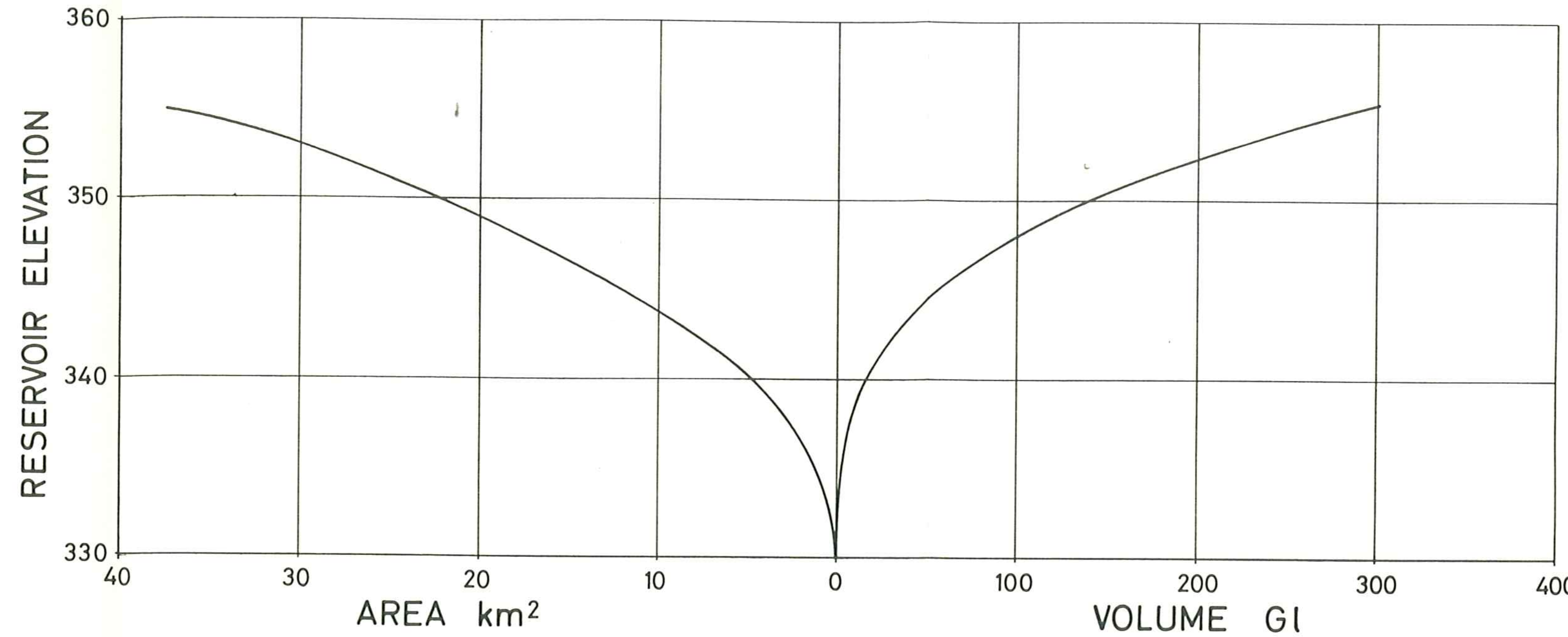
Samþ.:

Exhibit 3

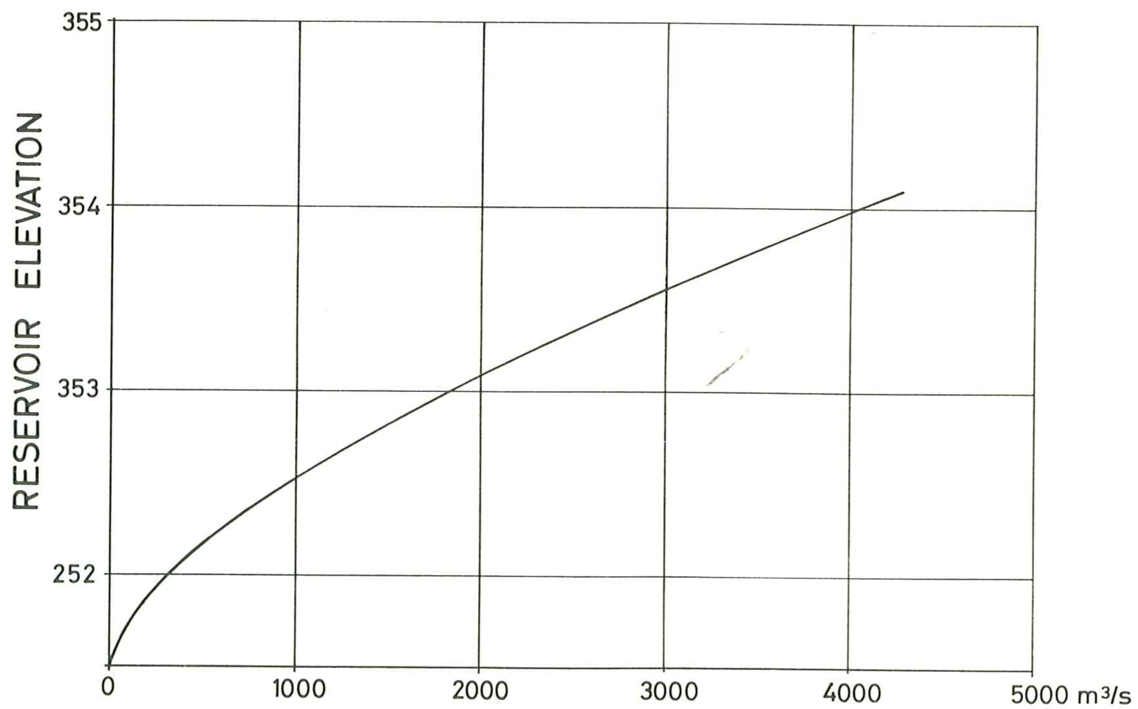


JÖKULSÁ BELOW HAFRAGILSFOSS

RATING CURVE

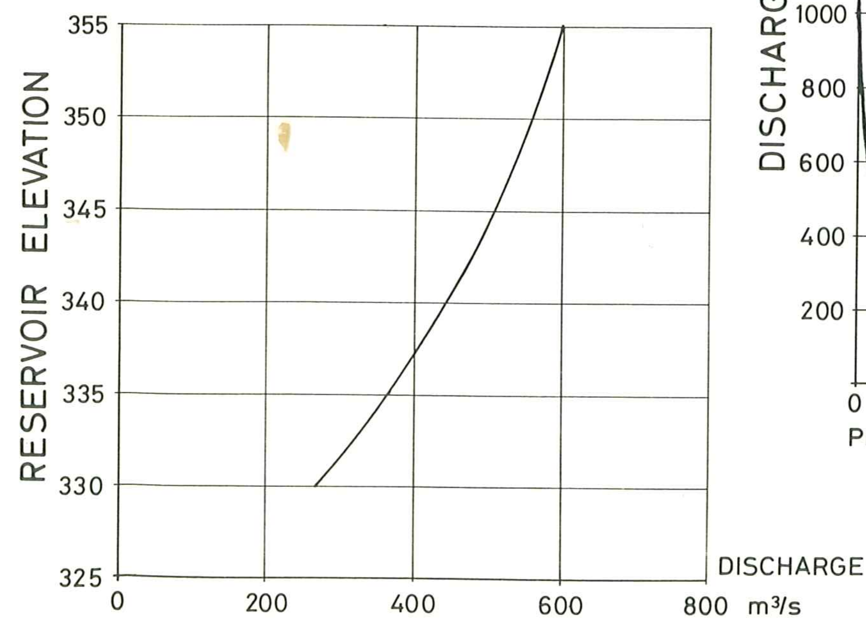


RESERVOIR AREA-VOLUME CURVE



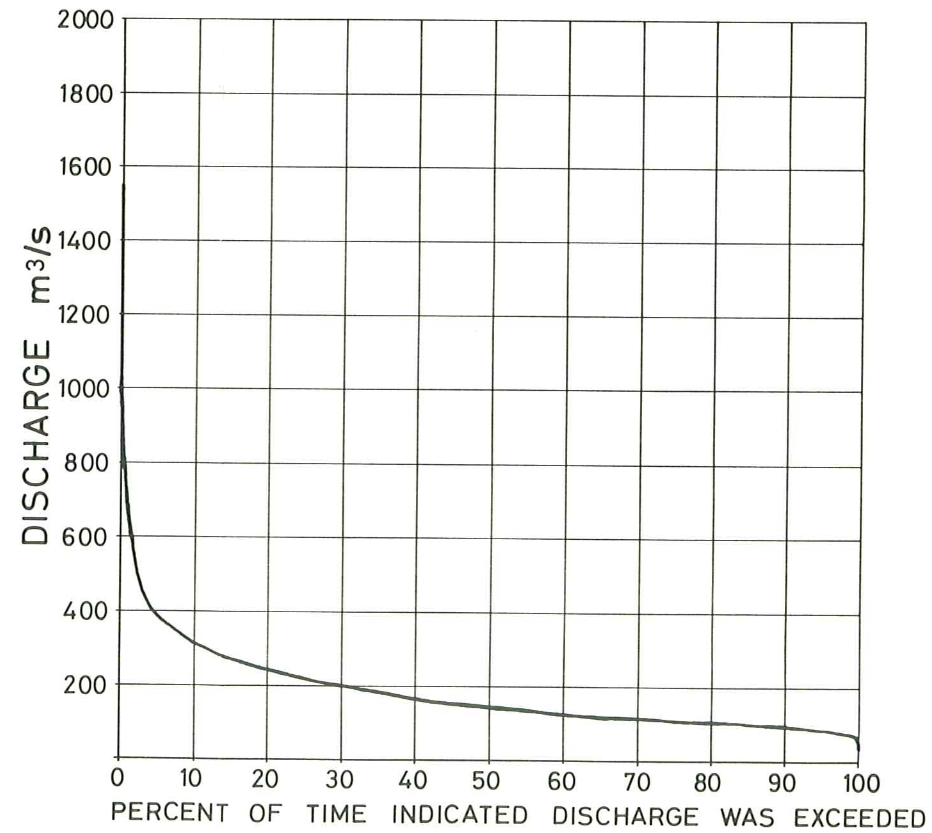
SPILLWAY

RATING CURVE



BOTTOM OUTLET

RATING CURVE



FLOW DURATION CURVE

ORKUSTOFNUN	
DETTIFOSS PROJECT HYDRAULIC DATA	Verk nr. 01.13. Teikn. nr. 2.03 Mælikv.
VERKFRÆDISTOFA SIGURDAR THORODDSEN SF. REYKJAVÍK: ÁRMÚLI 4 AKUREYRI: GLERÁRGATA 36 ÍSAFJÖRDUR: PÓLGATA 1	Dags. JAN. '75 SF/KMS SF 1. breyting 2. breyting 3. breyting Samþ.:

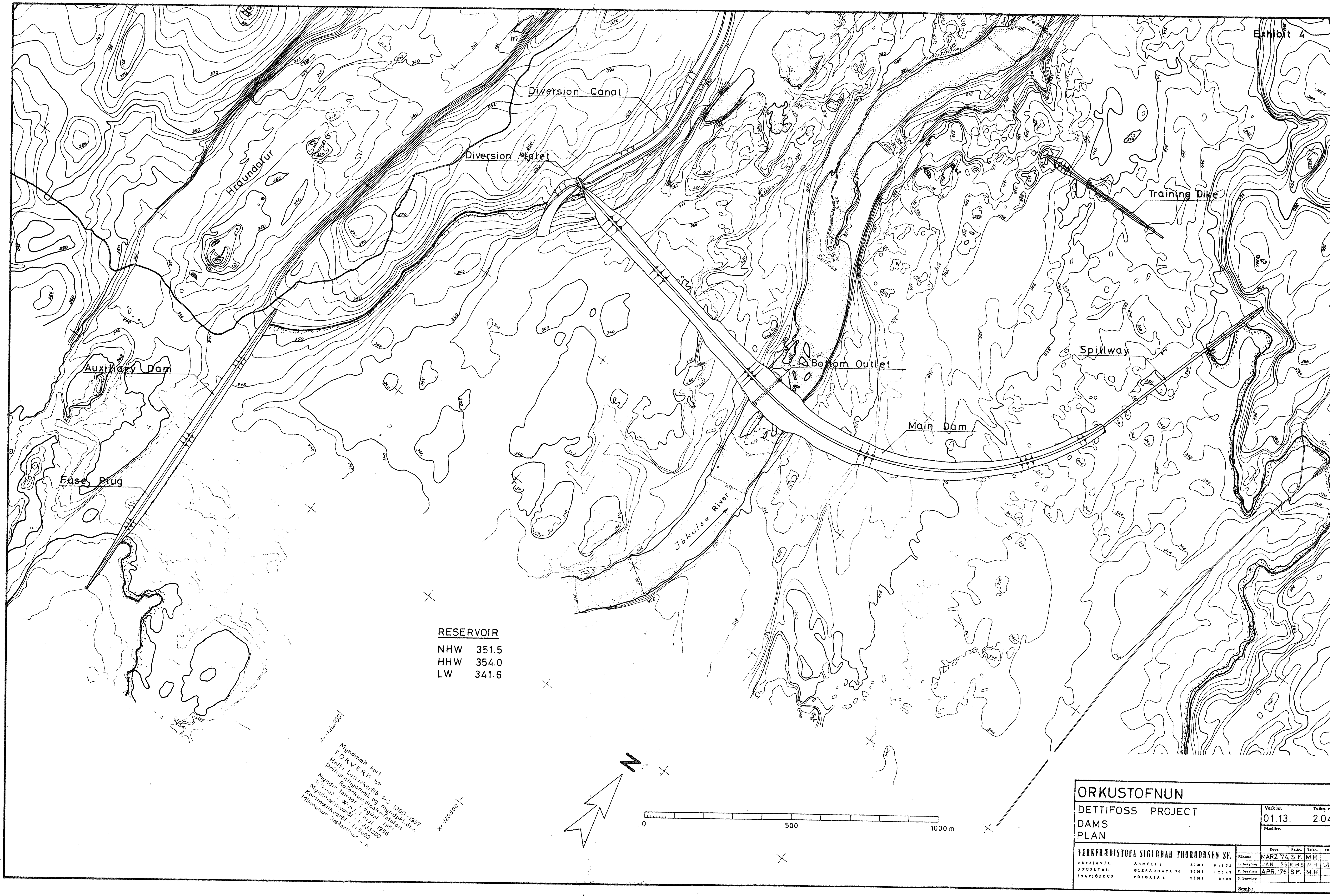
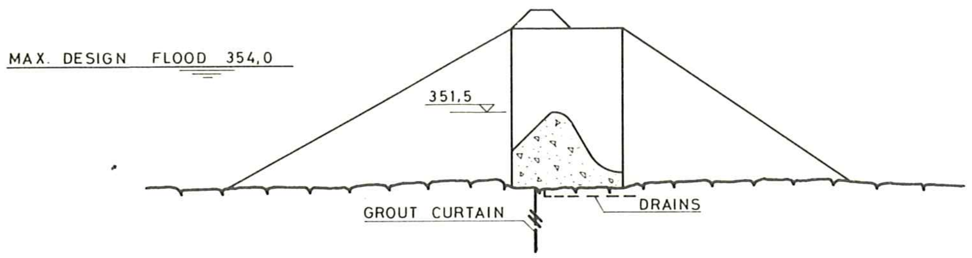
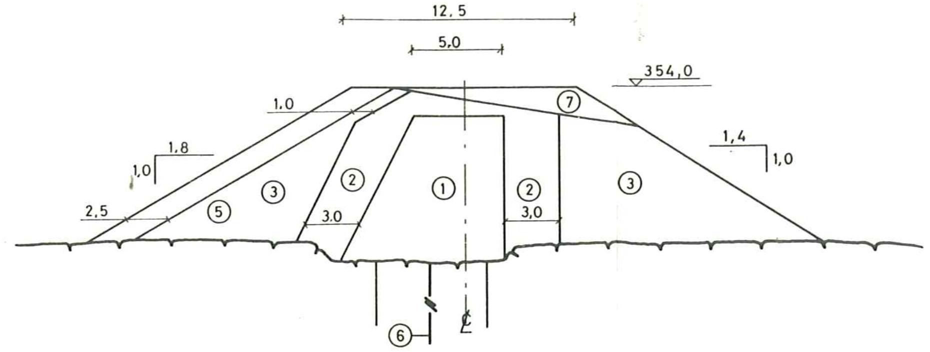


Exhibit 4
Diversion Canal
Diversion Inlet
Hraundalur
Training Dike
Selfoss
Spillway
Auxiliary Dam
Bottom Outlet
Main Dam
Fuse Plug
Jökulsá River
RESERVOIR
NHW 351.5
HHW 354.0
LW 341.6
N
0
500
1000 m
ORKUSTOFNUN
DETTIFOSS PROJECT
DAMS
PLAN
Verk nr. 01.13.
Teikn. nr. 2.04
Mælikv.
VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.
REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575
AKUREYRI: GLERÁRGATA 36 SÍMI 12543
ÍSAFJÖRÐUR: PÓLGATA 6 SÍMI 3708
Dags. Reikn. Teikn. Yfirf.
Hönnun MARZ '74 S.F. M.H.
1. breyting JAN '75 K.M.S. M.H.
2. breyting APR. '75 S.F. M.H.
3. breyting
Samþ.:



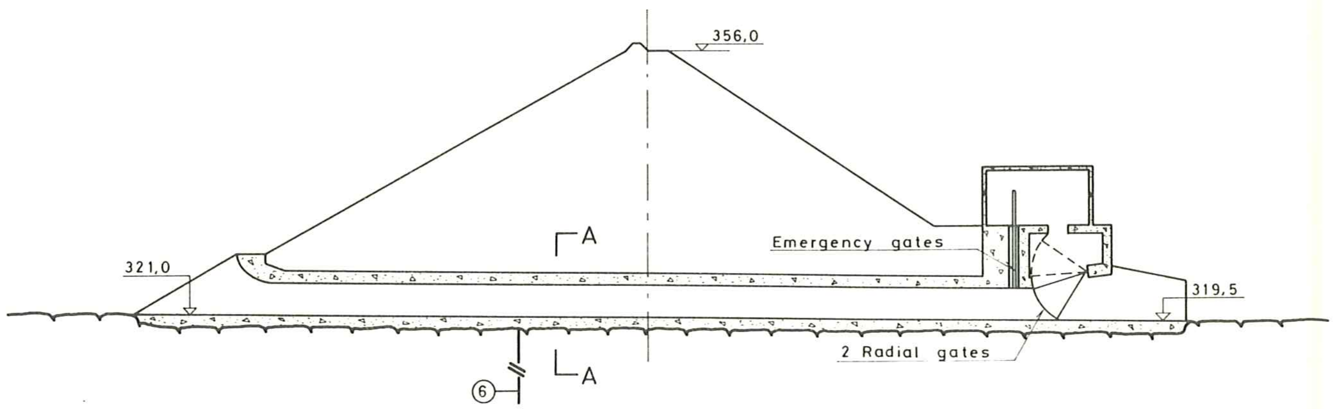
SPILLWAY SECTION

0 5 10 15 20 25 m



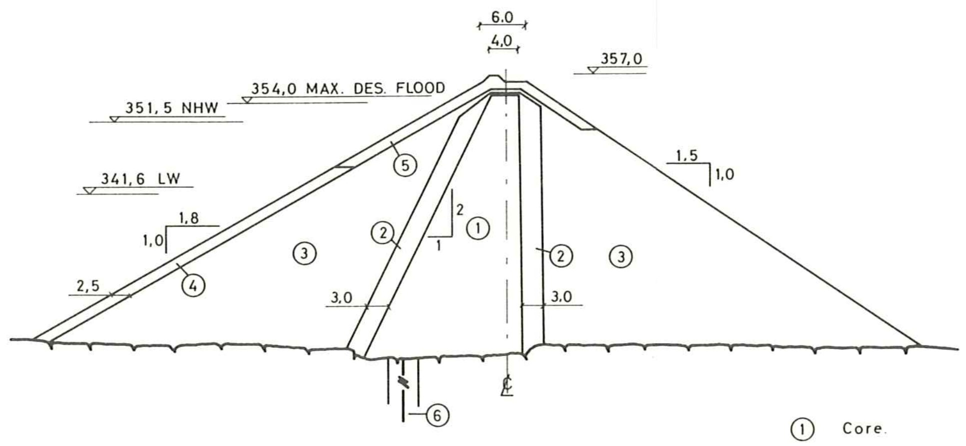
AUXILIARY DAM - FUSE PLUG SECTION

0 5 10 15 20 m



BOTTOM OUTLET

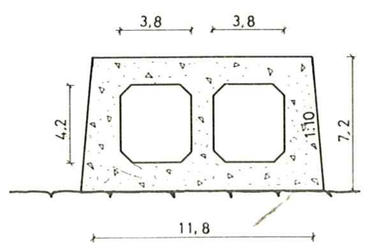
0 10 20 30 40 50 60 70 80 m



MAIN DAM

0 10 20 30 40 50 m

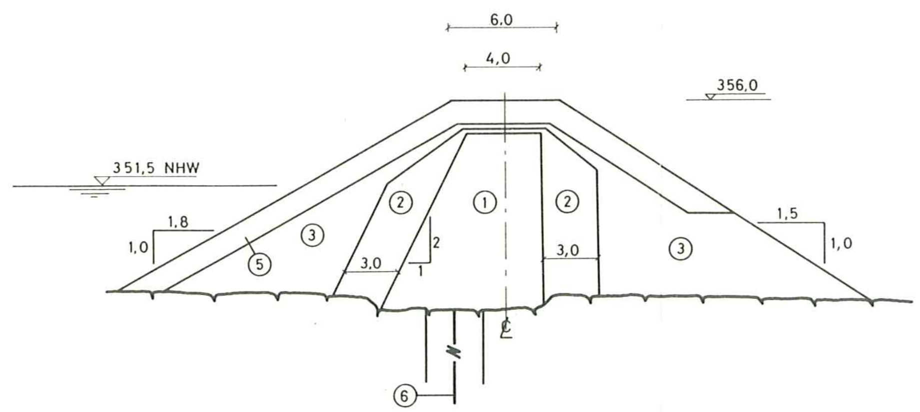
1. Core.
2. Filter.
3. Rock- and gravel fill.
4. Rip rap, boulders ≥ 0,2 m³.
5. —″— —″— ≥ 0,35 m³.
6. Grout curtain.
7. Boulders & gravel ≤ 15 kg.



SECTION A-A

0 5 10 15 20 25 m

Dimensions in meters.
Elevations in m.a.s.l.

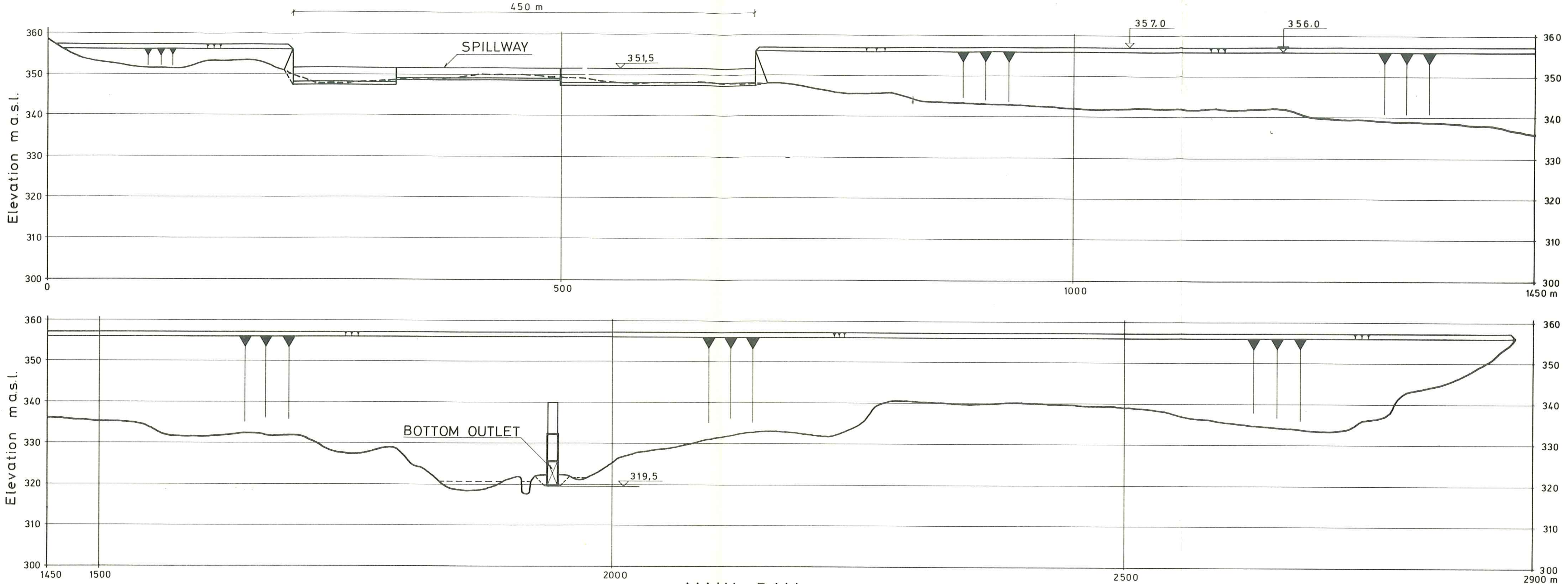


AUXILIARY DAM - GENERAL SECTION

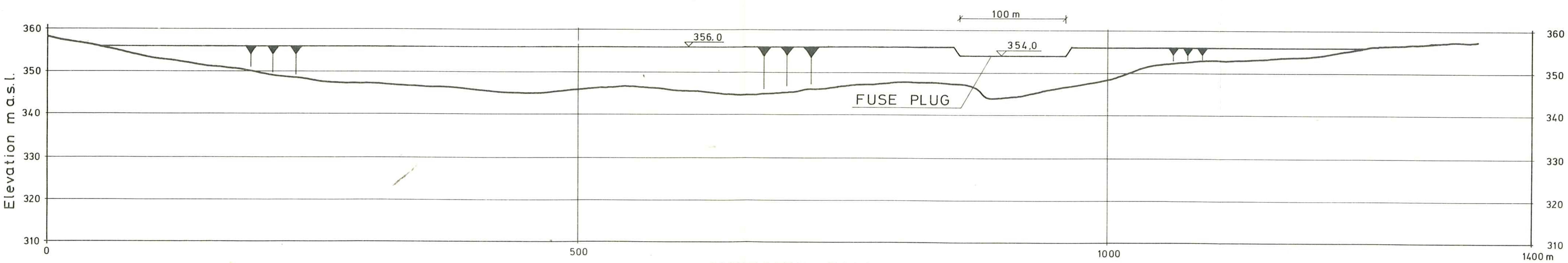
0 5 10 15 20 m

ORKUSTOFNUN		
DETTIFOSS PROJECT DAMS AND BOTTOM OUTLET SECTIONS	Verk nr. 01.13.	Teikn. nr. 2.05
	Mælikv.	

VERKFRÆDISTOFA SIGURDAR THORODDSEN SF.		Dags.	Reikn.	Teikn.	Yfirf.
REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575	Hönnun	DEC '74	KMS	PRP	
AKUREYRI: GLERÁRGATA 34 SÍMI 12543	1. breyting	JAN. '75	KMS	M.H.	JF
ÍSAFJÖRDUR: PÓLGATA 4 SÍMI 3708	2. breyting				
	3. breyting				
	Samþ.:				



MAIN DAM

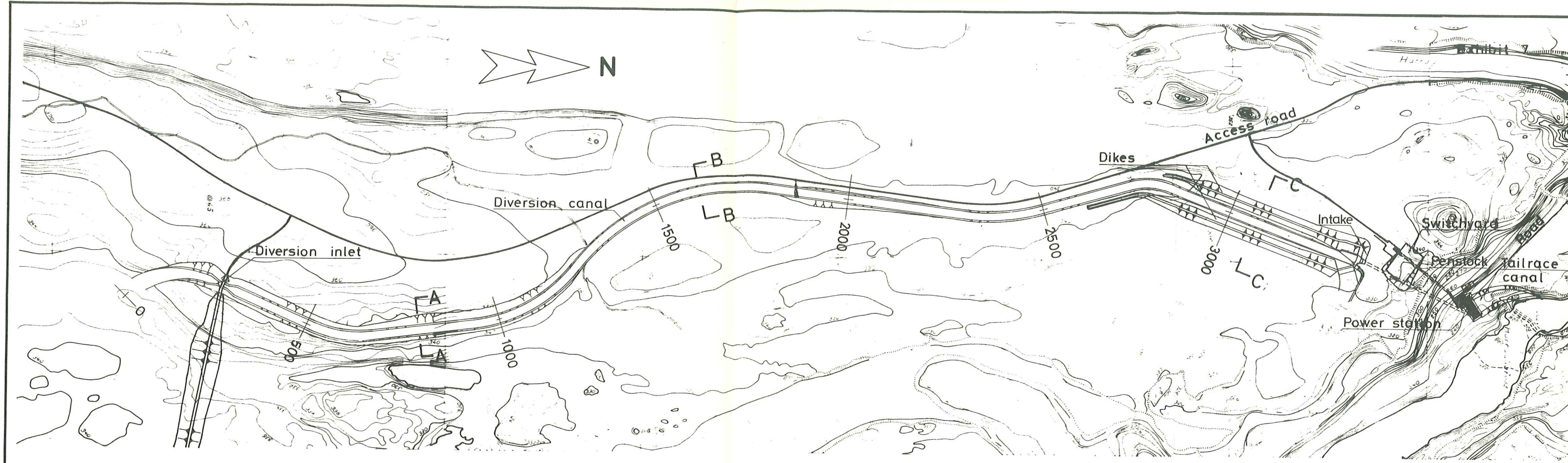


AUXILIARY DAM

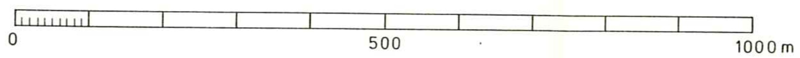
ORKUSTOFNUN	
DETTIFOSS PROJECT DAMS AND SPILLWAY DOWNSTREAM VIEW	Verk nr. 01.13. Teikn. nr. 2.06 Mælikv.

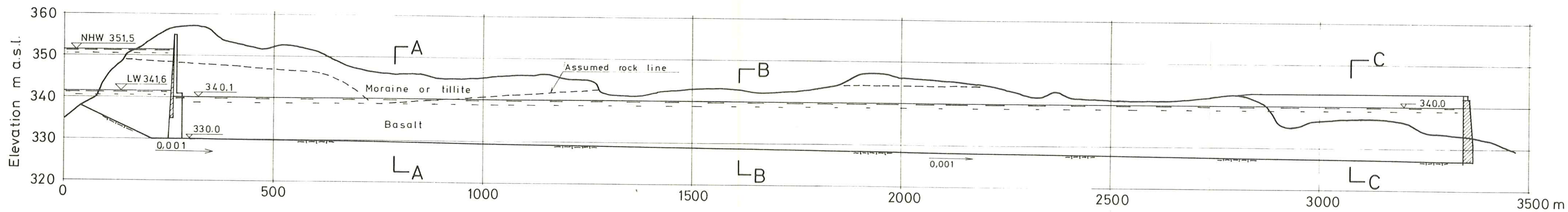
VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.
REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575
AKUREYRI: GLERÁRGATA 36 SÍMI 12543
ÍSAFJÖRÐUR: PÓLGATA 6 SÍMI 3708

	Dags.	Reikn.	Teikn.	Yfirl.
Hönnun	DEC. '74	K.M.S.	M.H.	
1. breyting	JAN. '75	K.M.S.	M.H.	SF
2. breyting				
3. breyting				
Samþ.:				



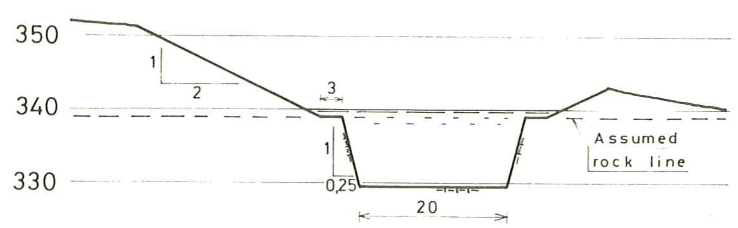
PLAN



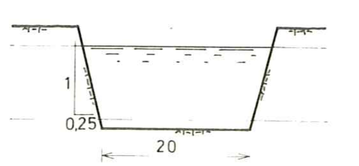


PROFILE

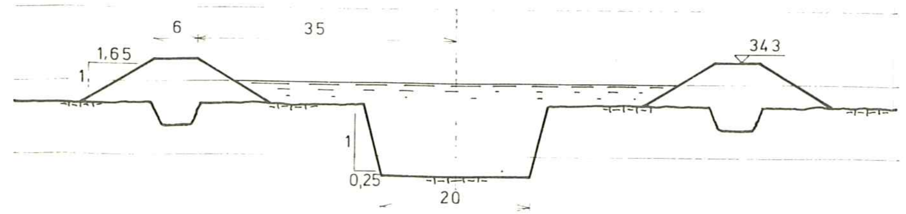
Dimensions in meters.
Elevations in m.a.s.l.



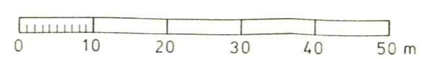
SECTION A-A



SECTION B-B



SECTION C-C



ORKUSTOFNUN

DETTIFOSS PROJECT
POWER WATERWAYS PLAN
DIVERSION CANAL PROFILE AND SECTIONS

Verk nr.	Teikn. nr.
01.13.	2.07

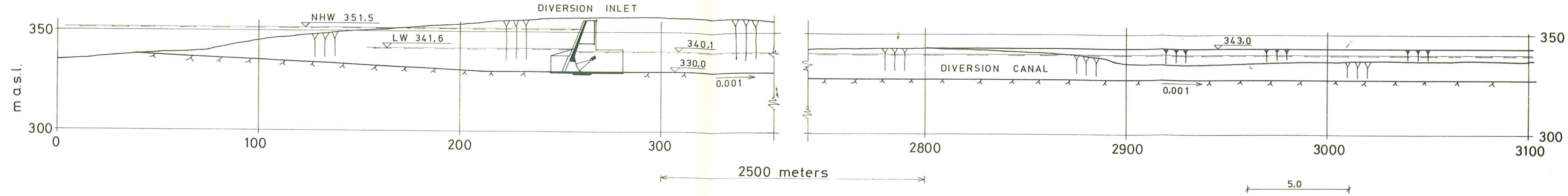
Mælikv.

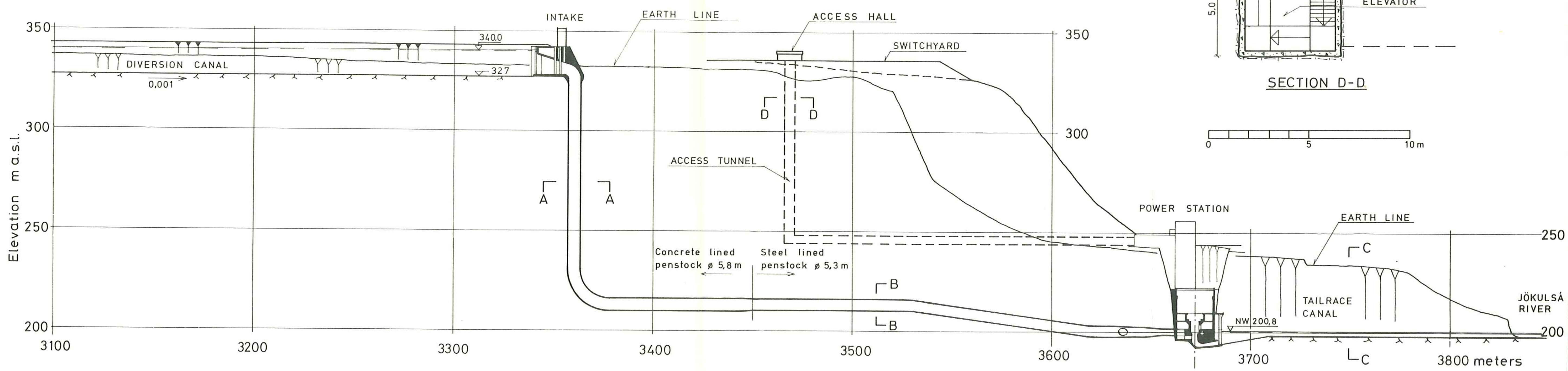
VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.

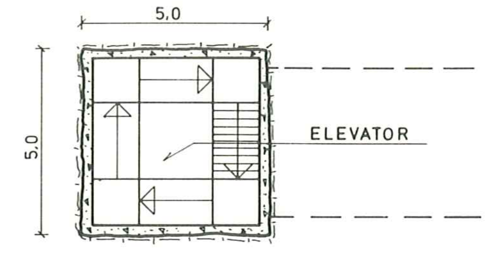
REYKJAVÍK:	ÁRMÚLI 4	SÍMI	81575
AKUREYRI:	GLERÁRGATA 36	SÍMI	12543
ÍSAFJÖRÐUR:	PÓLGATA 6	SÍMI	3708

	Dags.	Reikn.	Teikn.	Yfirl.
Hönnun	FEB. '74	S.F.	S.F/M.H.	
1. breyting	JAN '75	KMS	M.H.	
2. breyting	APR. '75		M.H.	
3. breyting				

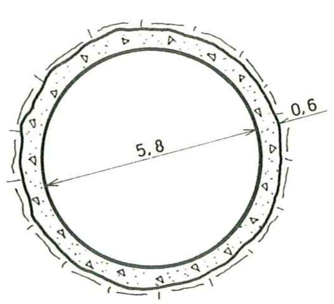
Samþ.:



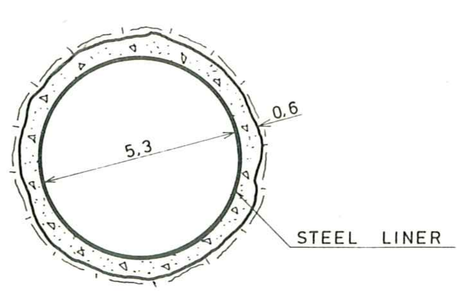




SECTION D-D

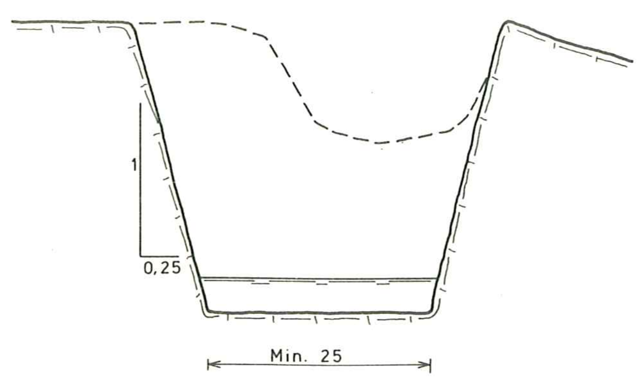


SECTION A-A



SECTION B-B

0 5 10 m



SECTION C-C

0 10 20 30 m

Dimensions in meters.
Elevation m a.s.l.
Diversion canal: see drawing no. 01.13.2.07.

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DETTIFOSS PROJECT
POWER WATERWAYS
PROFILE AND SECTIONS

Verk nr. 01.13. Teikn. nr. 2.08

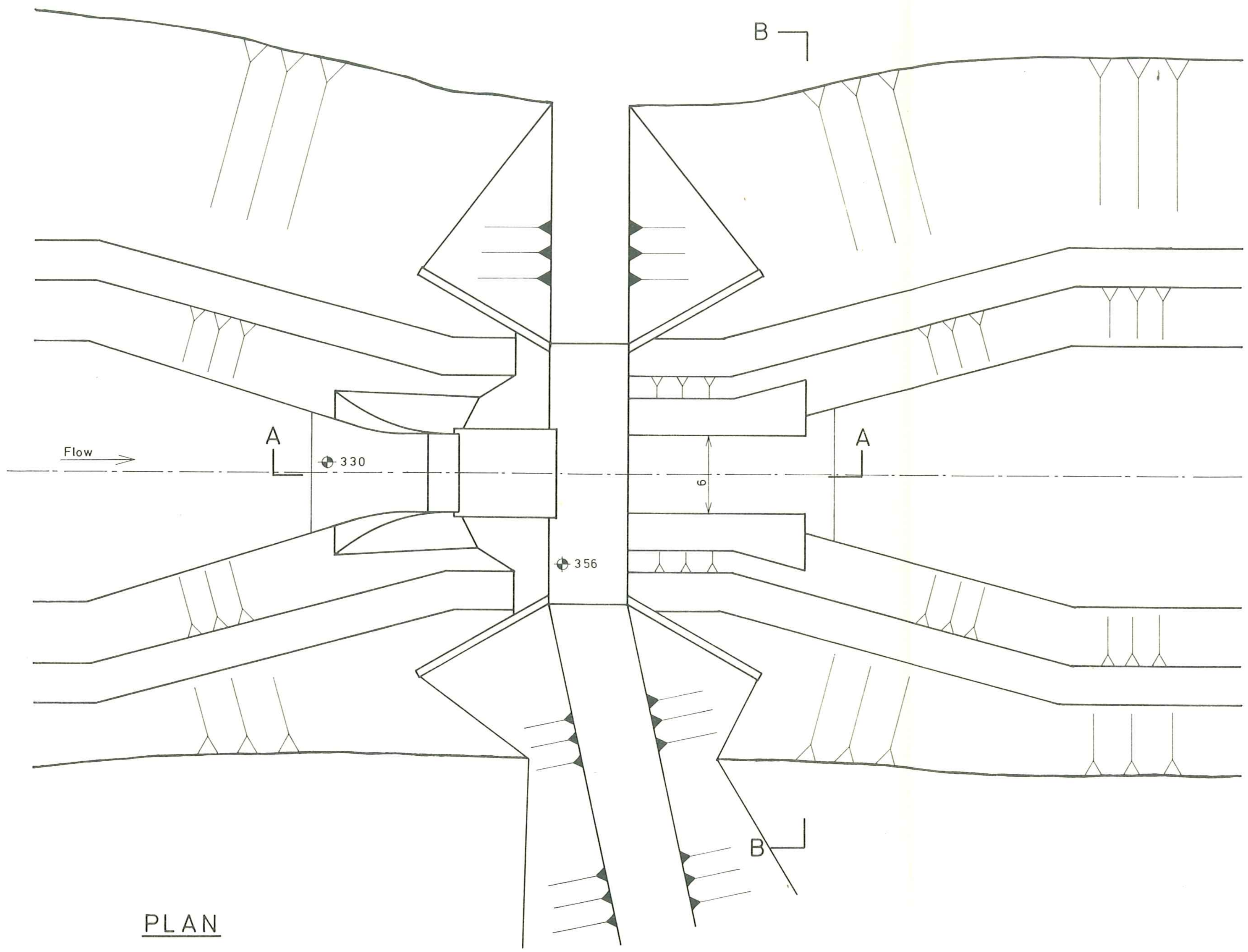
Mælikv.

VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.
REYKJAVÍK: ÁRMÚLI 4 SÍMI 84499
AKUREYRI: GLERÁRGATA 36 SÍMI 21548
ÍSAFJÖRÐUR: PÓLGATA 5 SÍMI 3708

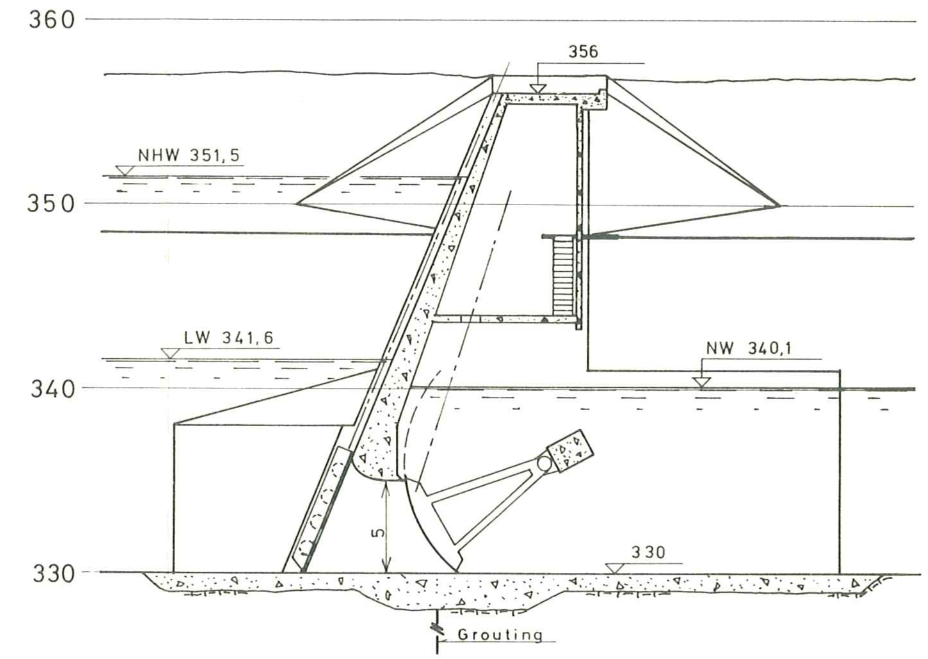
	Dags.	Reikn.	Teikn.	Yfirf.
Hönnun	April 74	S.F.	M.H.	
1. breyting	DEC. 74	K.M.S.	M.H.	
2. breyting	JAN. 75	K.M.S.	M.H.	S.F.
3. breyting				
4. breyting				

Samþ.:

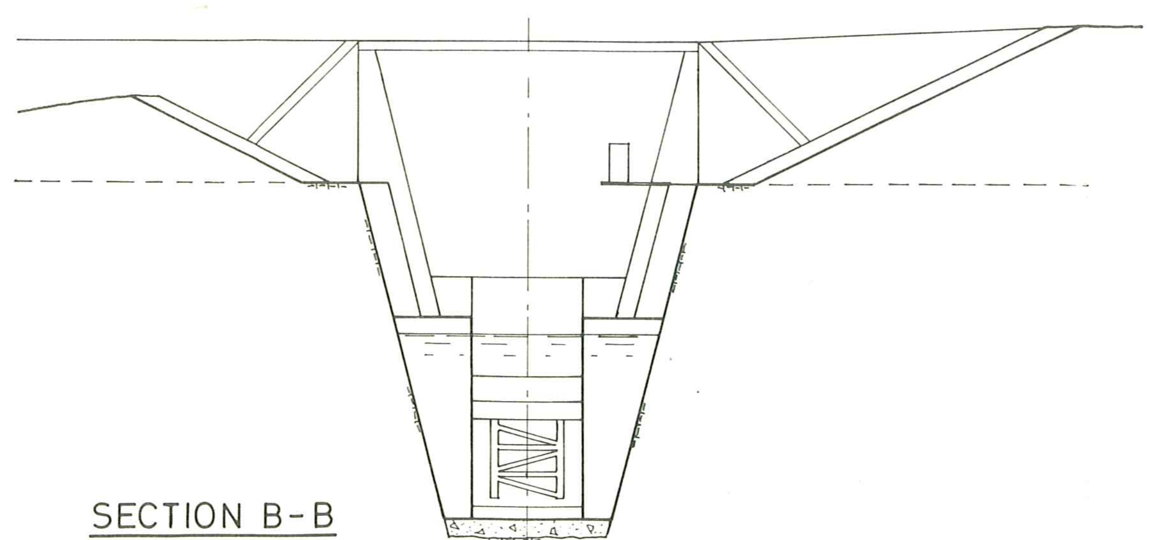
Exhibit 9



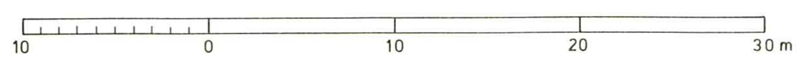
PLAN



SECTION A-A



SECTION B-B



Dimensions in meters.
Elevations in m.a.s.l.

ORKUSTOFNUN

DETTIFOSS PROJECT
DIVERSION INLET

Verk nr.	Teikn. nr.
01. 13.	2.09

Mælikv.

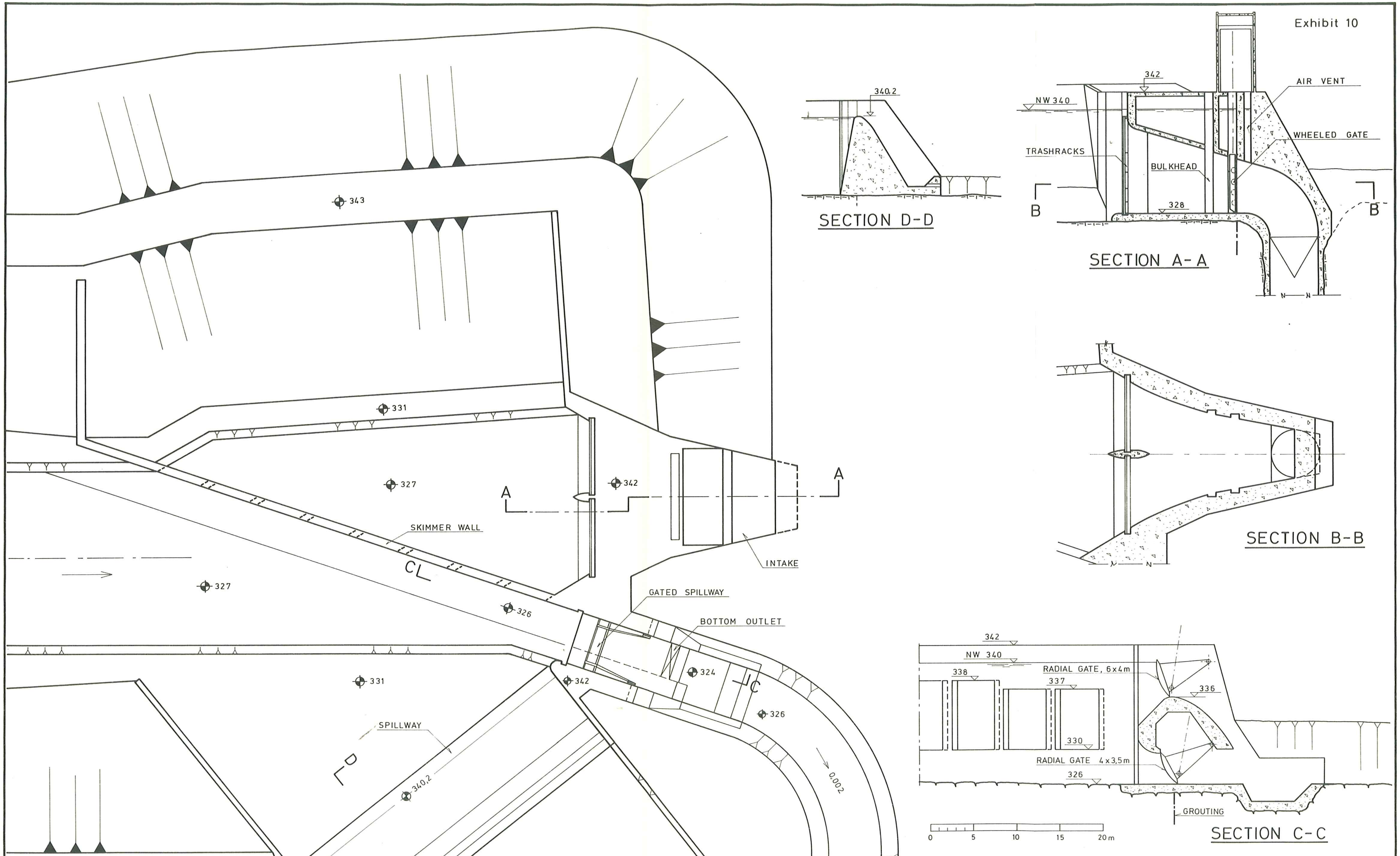
VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.

REYKJAVÍK:	ÁRMÚLI 4	SÍMI	81575
AKUREYRI:	GLERÁRGATA 36	SÍMI	12543
ÍSAFJÖRÐUR:	PÓLGATA 8	SÍMI	3708

	Dags.	Reikn.	Teikn.	Yfirl.
Hönnun	FEB. '74	S.F.	SF/MH.	
1. breyting	DES. '74	KMS.	KMS.	
2. breyting	JAN. '75	K.M.S.	M.H.	SF
3. breyting				

Samþ.:

Exhibit 10



ORKUSTOFNUN

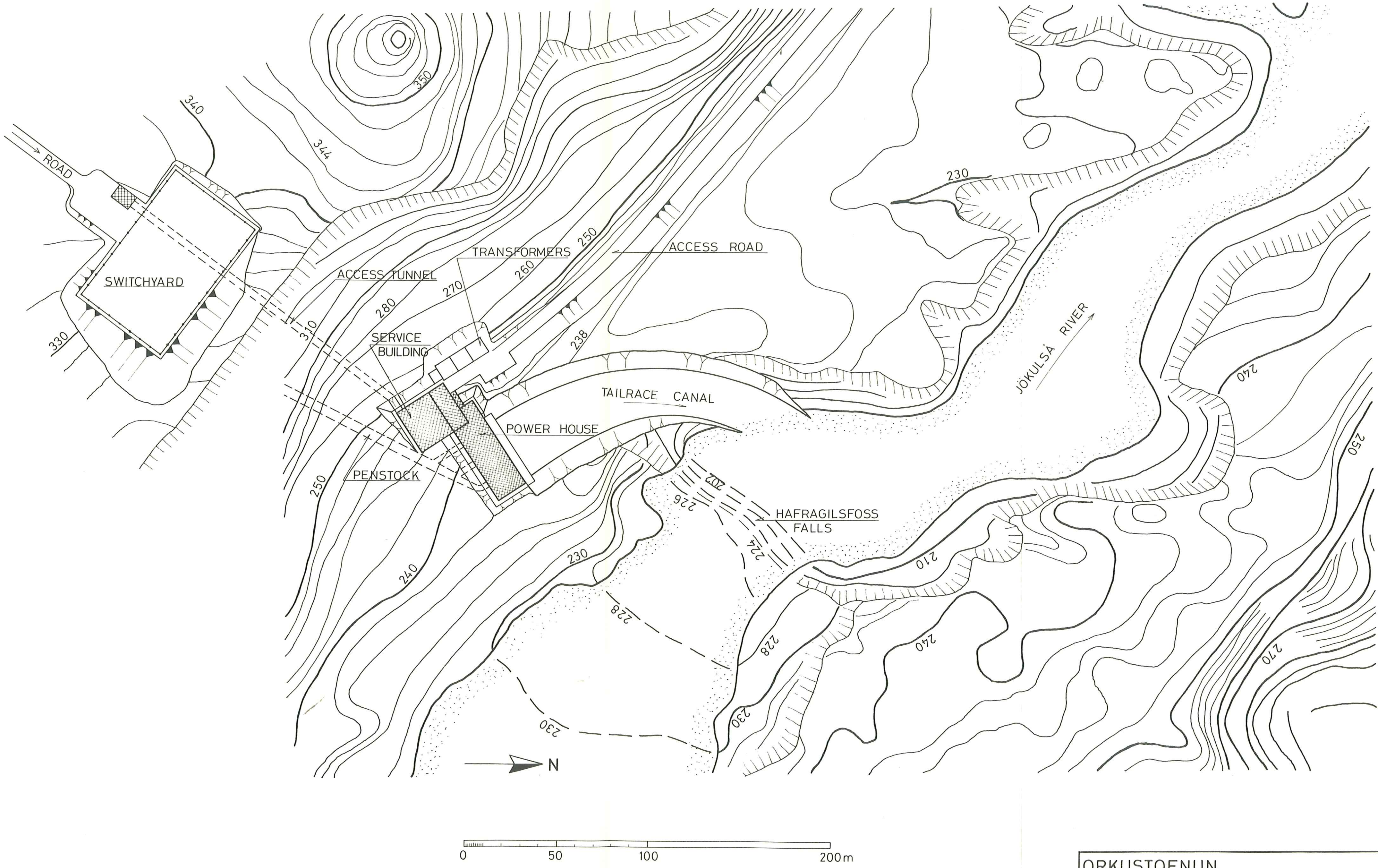
DETTIFOSS PROJECT
INTAKE STRUCTURES

Verk nr. 01.13.
Teikn. nr. 2.10
Mælikv.

VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.
REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575
AKUREYRI: GLERÁRGATA 36 SÍMI 12543
ÍSAFJÖRÐUR: PÓLGATA 6 SÍMI 3708

	Dags.	Reikn.	Teikn.	Yfirf.
Hönnun	FEB '74	S F	M H	
1. breyting	DEC '74	K M S	M H	
2. breyting	JAN '75	K M S	M H	SF
3. breyting				

Samþ.:



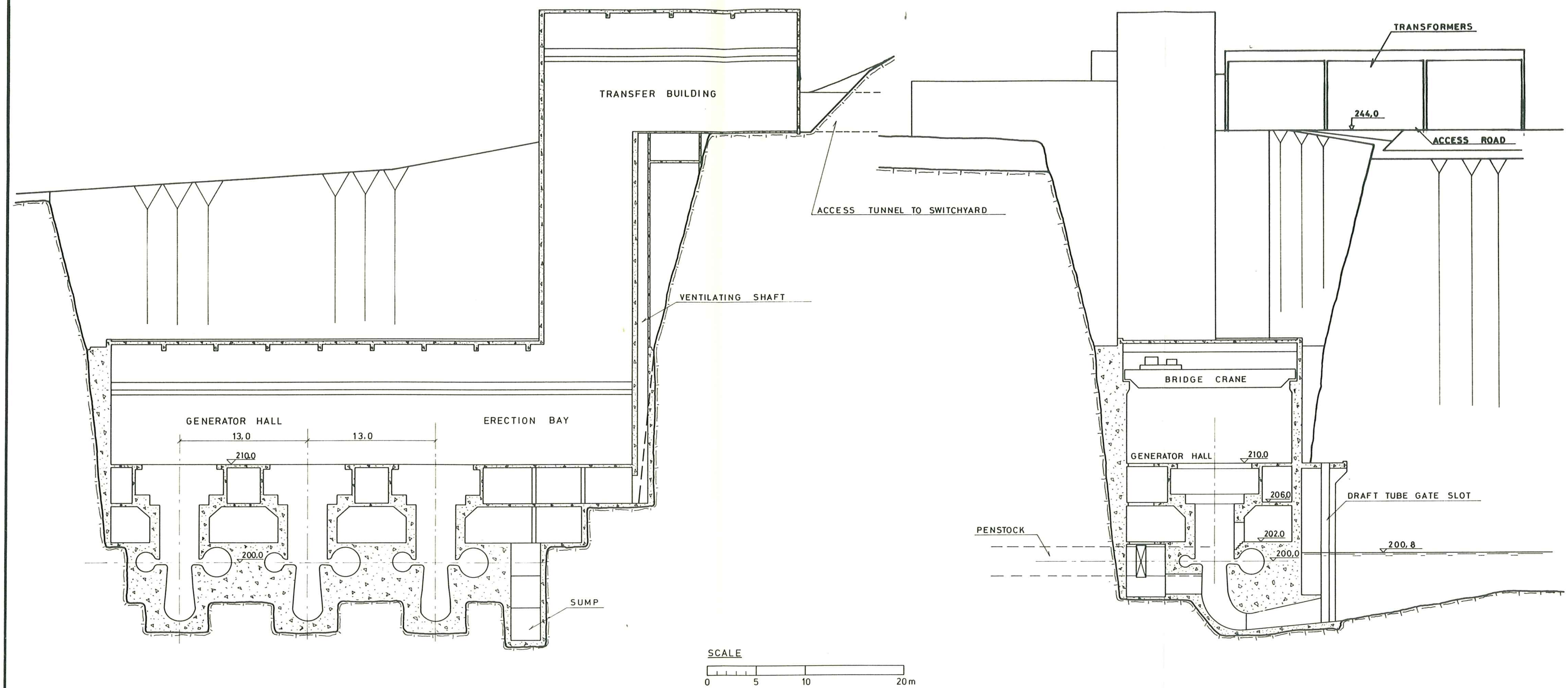
Elevations in m.a.s.l.

ORKUSTOFNUN	
DETTIFOSS PROJECT POWER STATION LAYOUT	Verk nr. 01.13. Teikn. nr. 2.11 Mælikv.

VERKFRÆDISTOFA SIGURDAR THORODDSEN SF.

				Dags.	Reikn.	Teikn.	Yfirf.
REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575			Hönnun	Mai '74	S.F.	M.H.	
AKUREYRI: GLERÁRGATA 36 SÍMI 12543			1. breyting	DEC. '74	K.M.S.	M.H.	
ÍSAFJÖRDUR: PÓLGATA 4 SÍMI 3708			2. breyting	JAN '75	K.M.S.	M.H.	S.F.
			3. breyting				
			Samþ.:				

Exhibit 12



Dimensions in meters
Elevations in m.a.s.l.

LONGITUDINAL SECTION

TRANSVERSE SECTION

ORKUSTOFNUN

DETTIFOSS PROJECT
POWERHOUSE
SECTIONS

Verk nr. 01.13. Teikn. nr. 2.12
Mælikv.

VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.

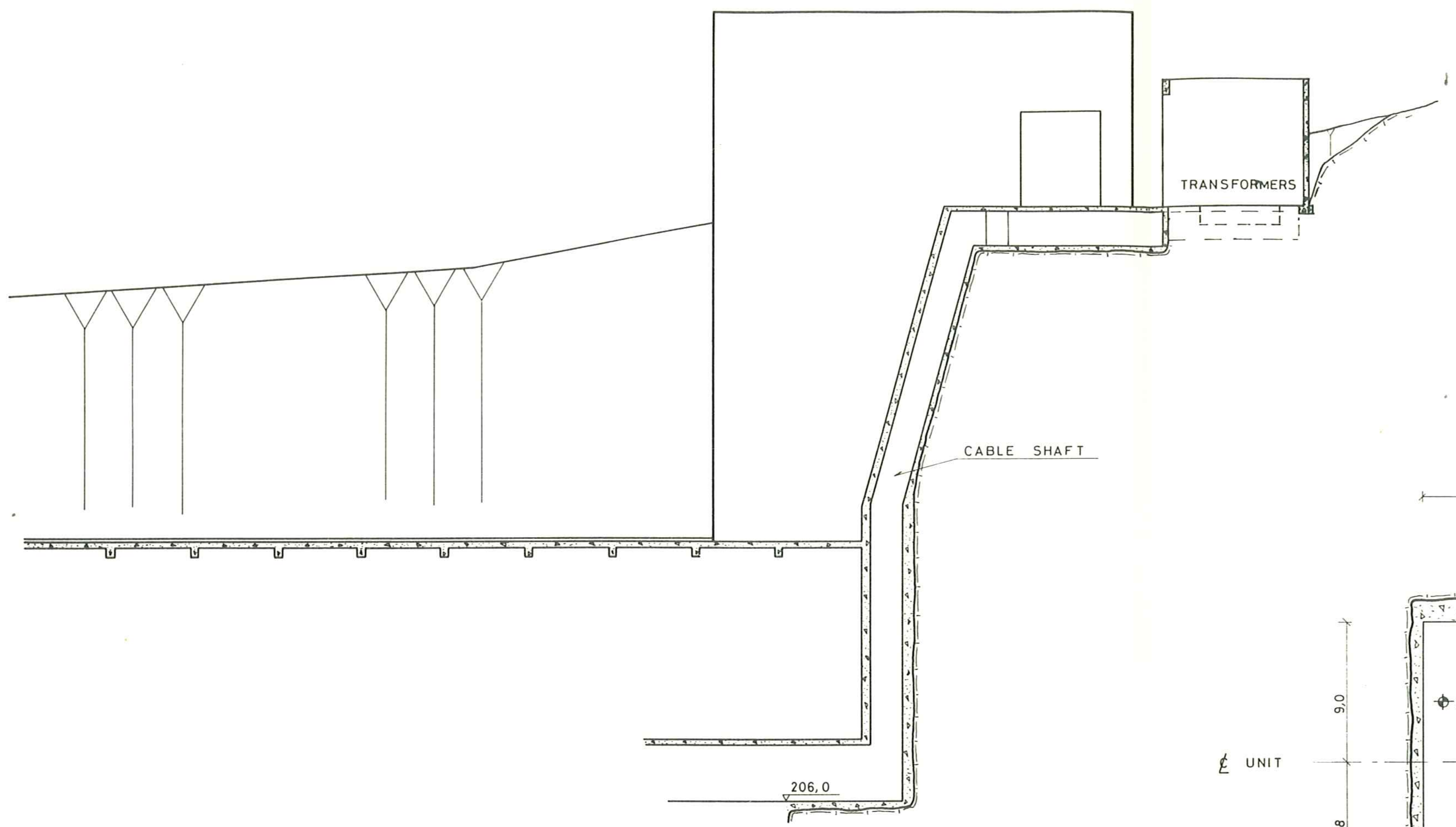
REYKJAVÍK:	ÁRMÚLI 4	SÍMI 81575
AKUREYRI:	GLERÁRGATA 36	SÍMI 12543
ÍSAFJÖRÐUR:	PÓLGATA 8	SÍMI 3708

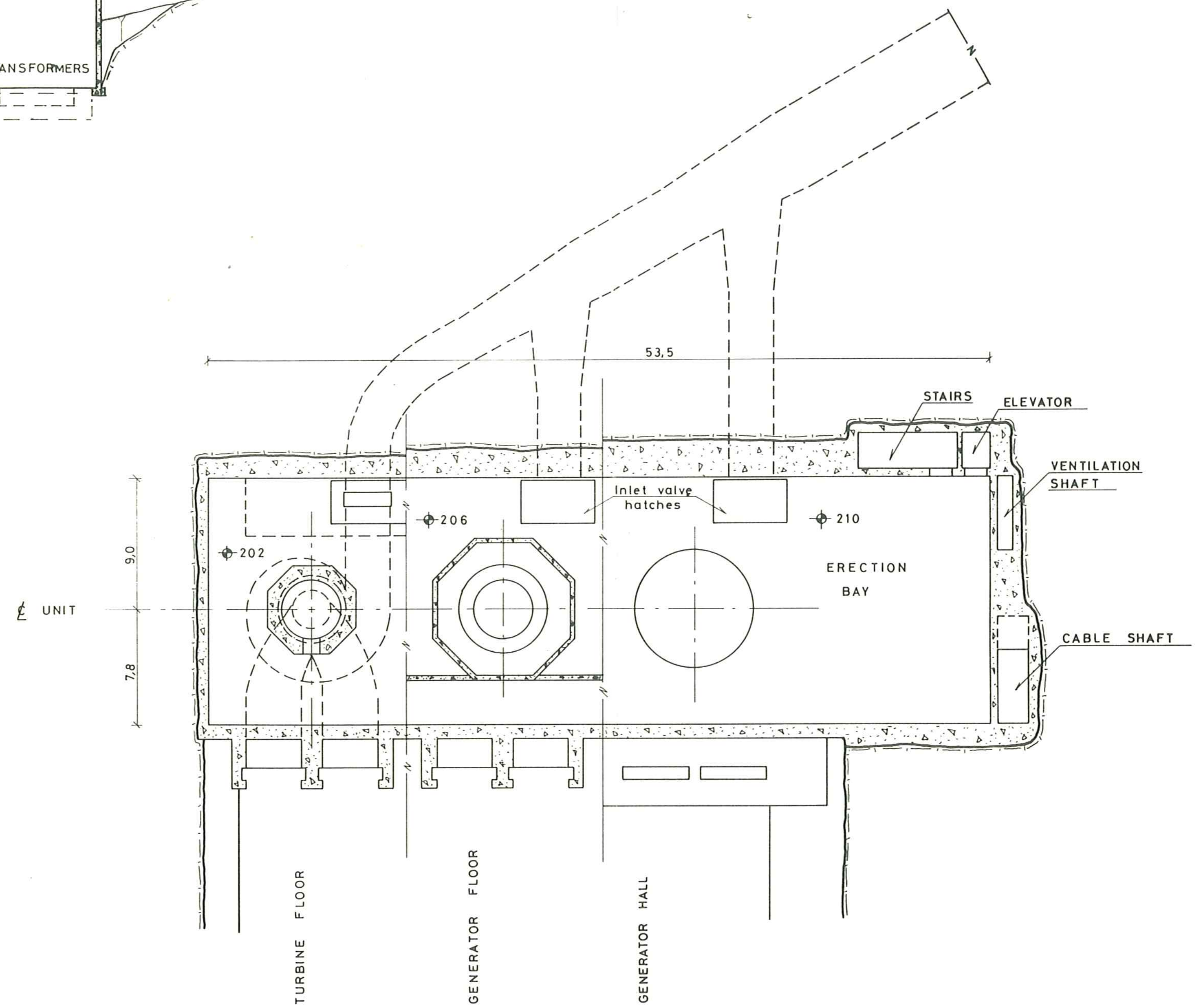
	Dags.	Reikn.	Teikn.	Yfirl.
Hönnun	Apr. '74	S.F.	M.H.	
1. breyting	DEC. '74	K.M.S.	M.H.	
2. breyting	JAN. '75	K.M.S.	M.H.	SF
3. breyting				

Samþ.:

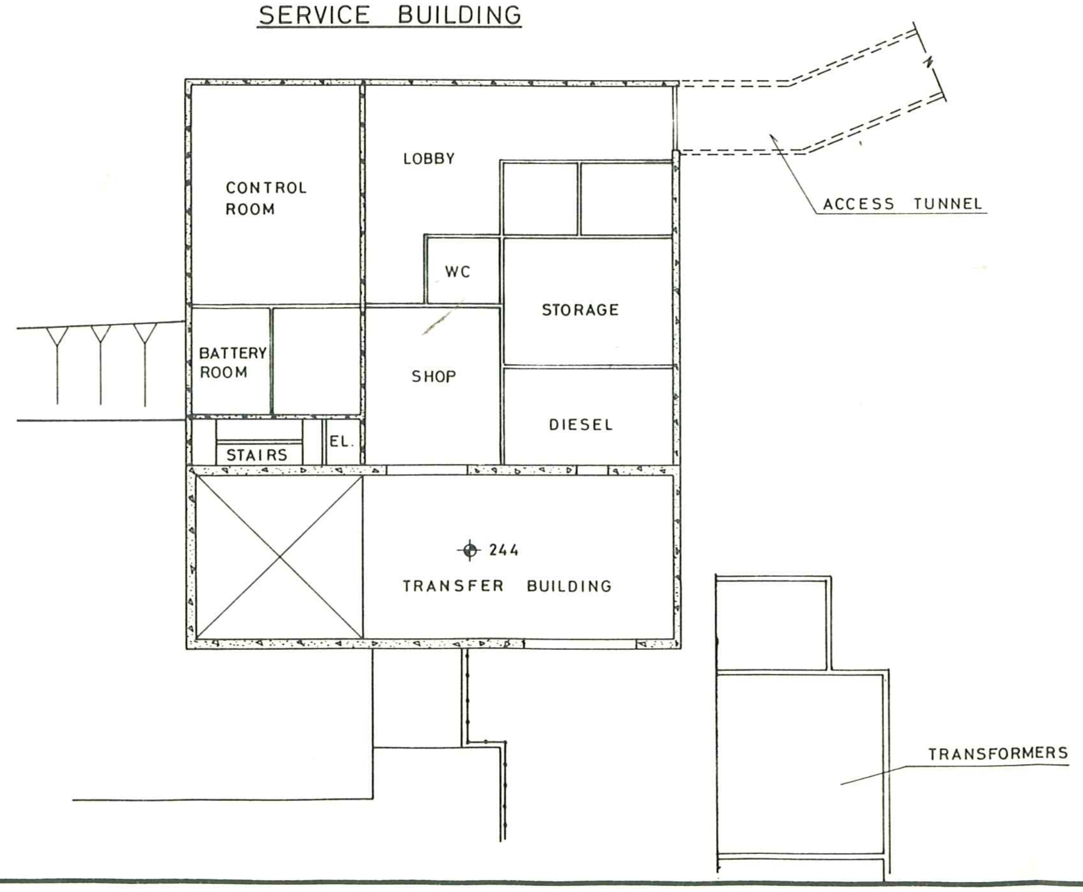
Exhibit 13

CABLE SHAFT AND TRANSFORMERS SECTION





SERVICE BUILDING



SCALE

0 5 10 15 20

Elevations in m.a.s.l.

Dimensions in meters

ORKUSTOFNUN

DETTIFOSS PROJECT
POWER HOUSE
PLAN AND SECTIONS

Verk nr.	Teikn. nr.
01.13.	2.13
Mælikv.	

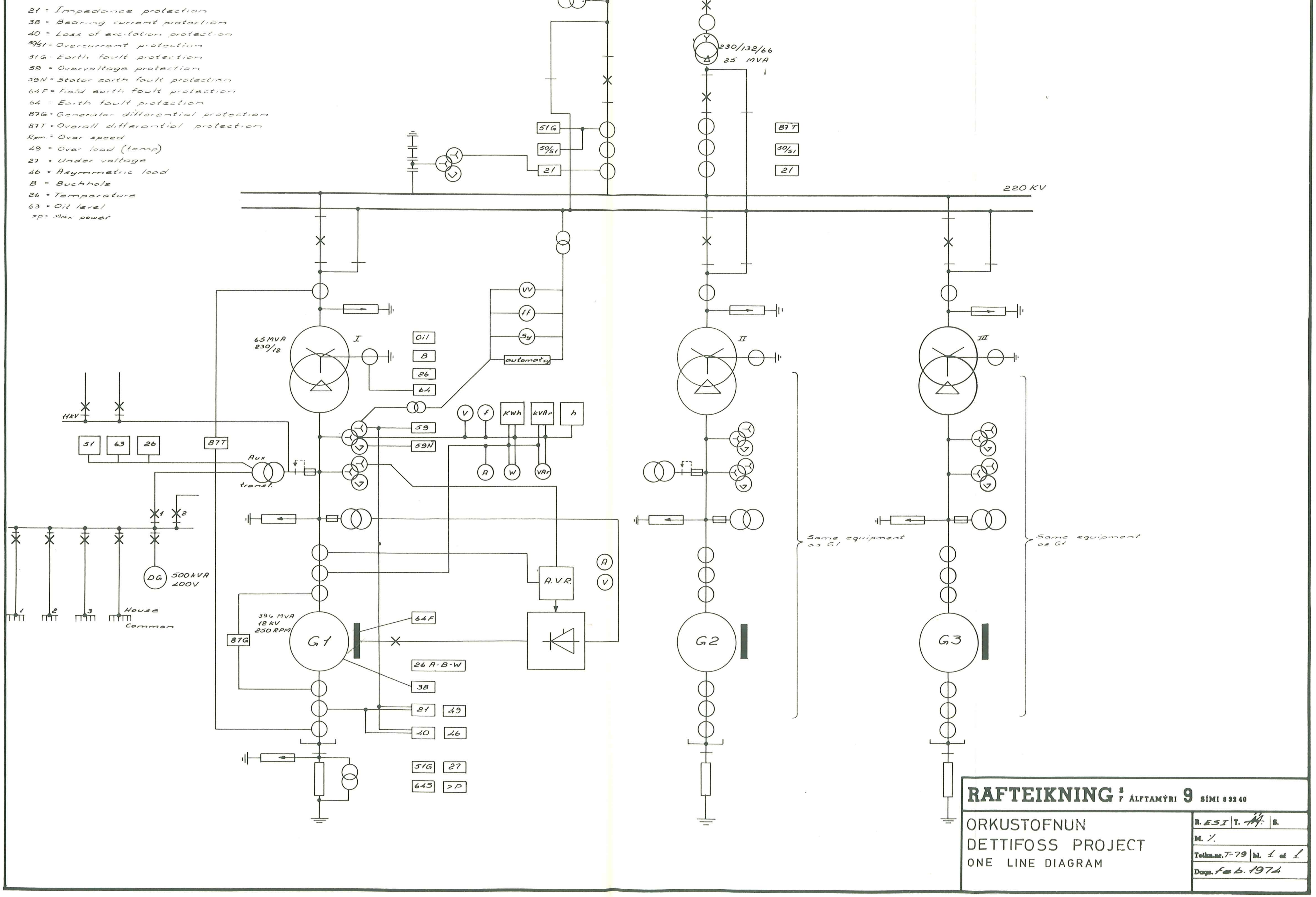
VERKFRÆDISTOFA SIGURDAR THORODDSEN SF.

REYKJAVÍK:	ÁRMÚLI 4	SÍMI	81575
AKUREYRI:	GLERÁRGATA 36	SÍMI	12543
ÍSAFJÖRDUR:	PÓLGATA 6	SÍMI	3708

	Dags.	Reikn.	Teikn.	Yfirf.
Hönnun	APR. '74	S.F.	M.H.	
1. breyting	DEC. '74	K.M.S.	M.H.	
2. breyting	JAN. '75	K.M.S.	M.H.	SF
3. breyting				

Samþ.:

Exhibit 14



21 = Impedance protection
38 = Bearing current protection
40 = Loss of excitation protection
50/51 = Overcurrent protection
51G = Earth fault protection
59 = Overvoltage protection
59N = Stator earth fault protection
64F = Field earth fault protection
64 = Earth fault protection
87G = Generator differential protection
87T = Overall differantial protection
Rpm. = Over speed
49 = Over load (temp)
27 = Under voltage
46 = Asymmetric load
B = Buchholz
26 = Temperature
63 = Oil level
>P = Max power
230/132/66
25 MVA
51G
50/51
21
87T
220 KV
VV
ff
Sy
automatsy
65 MVA
230/12
I
II
III
Oil
B
26
64
11kV
51
63
26
87T
Aux
transf.
59
59N
V
f
KWh
kVAr
h
A
W
VAr
500kVA
400V
DG
A.V.R.
House
Common
59.6 MVA
12 kV
250 RPM
G1
G2
G3
87G
64F
26 A-B-W
38
21
49
40
46
51G
27
64S
>P
Same equipment as G1
RAFTEIKNING s/f ÁLFTAMÝRI 9 SÍMI 83240
ORKUSTOFNUN
DETTIFOSS PROJECT
ONE LINE DIAGRAM
T-79
bl. 1 af 1
Dags. feb. 1974

Exhibit 15

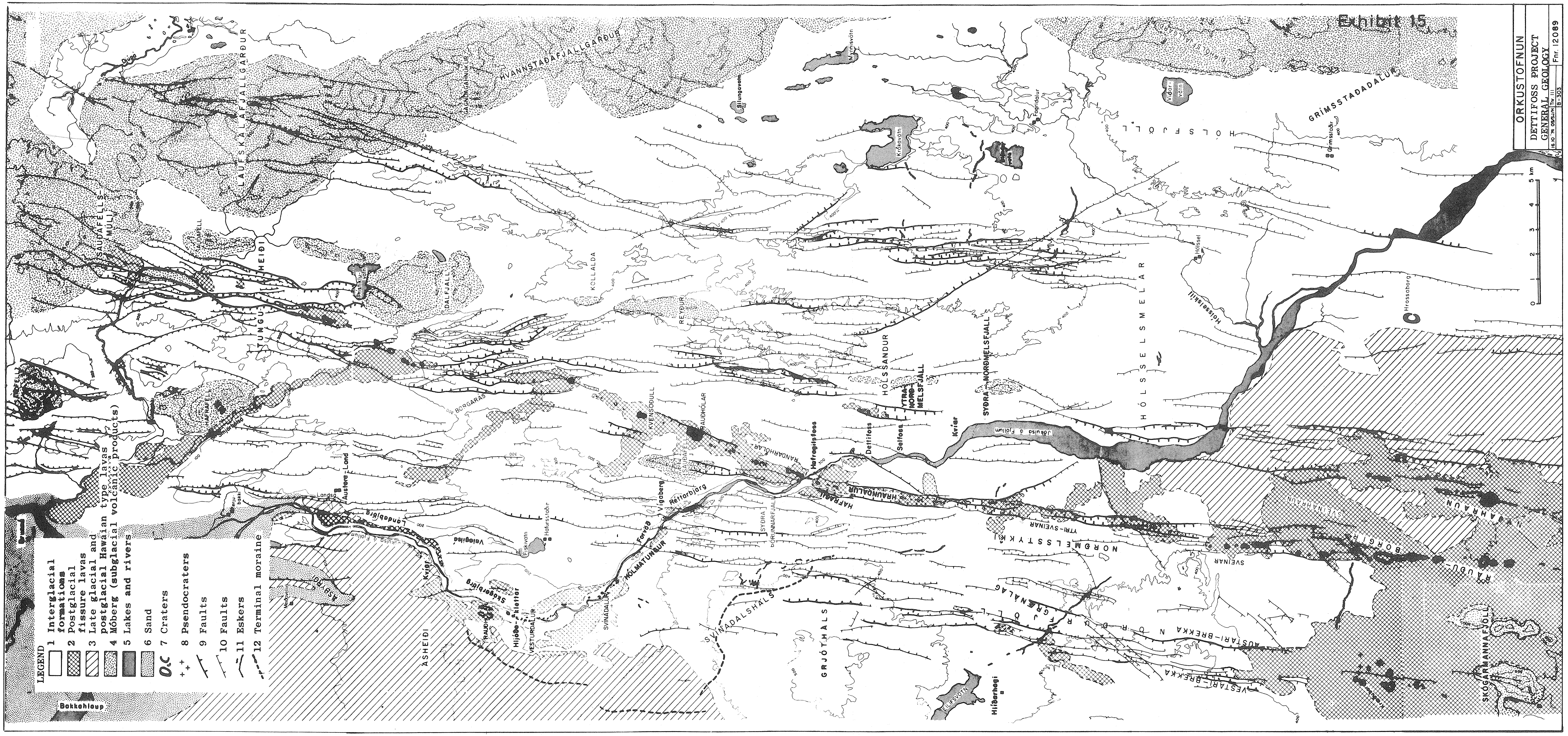
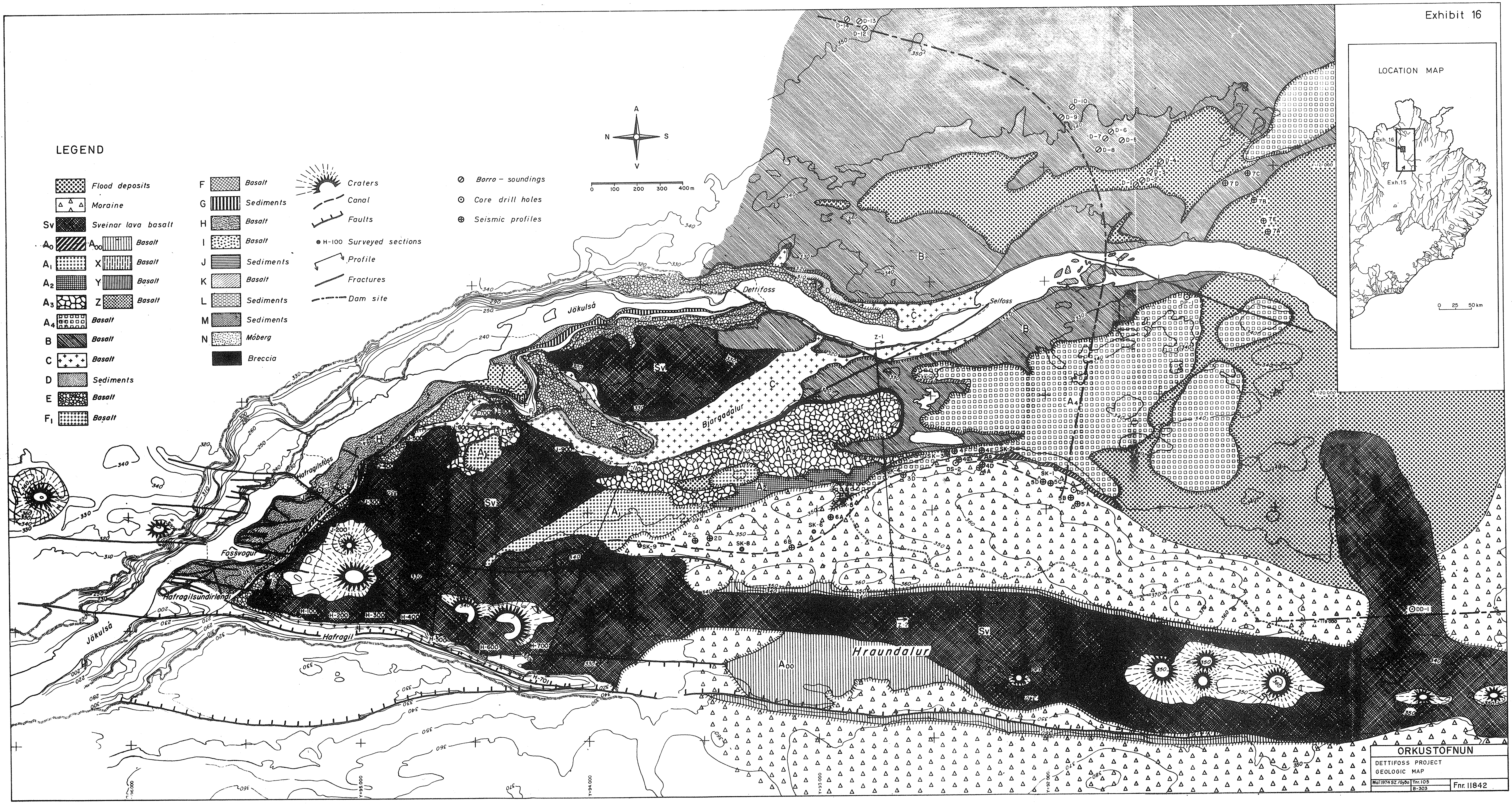
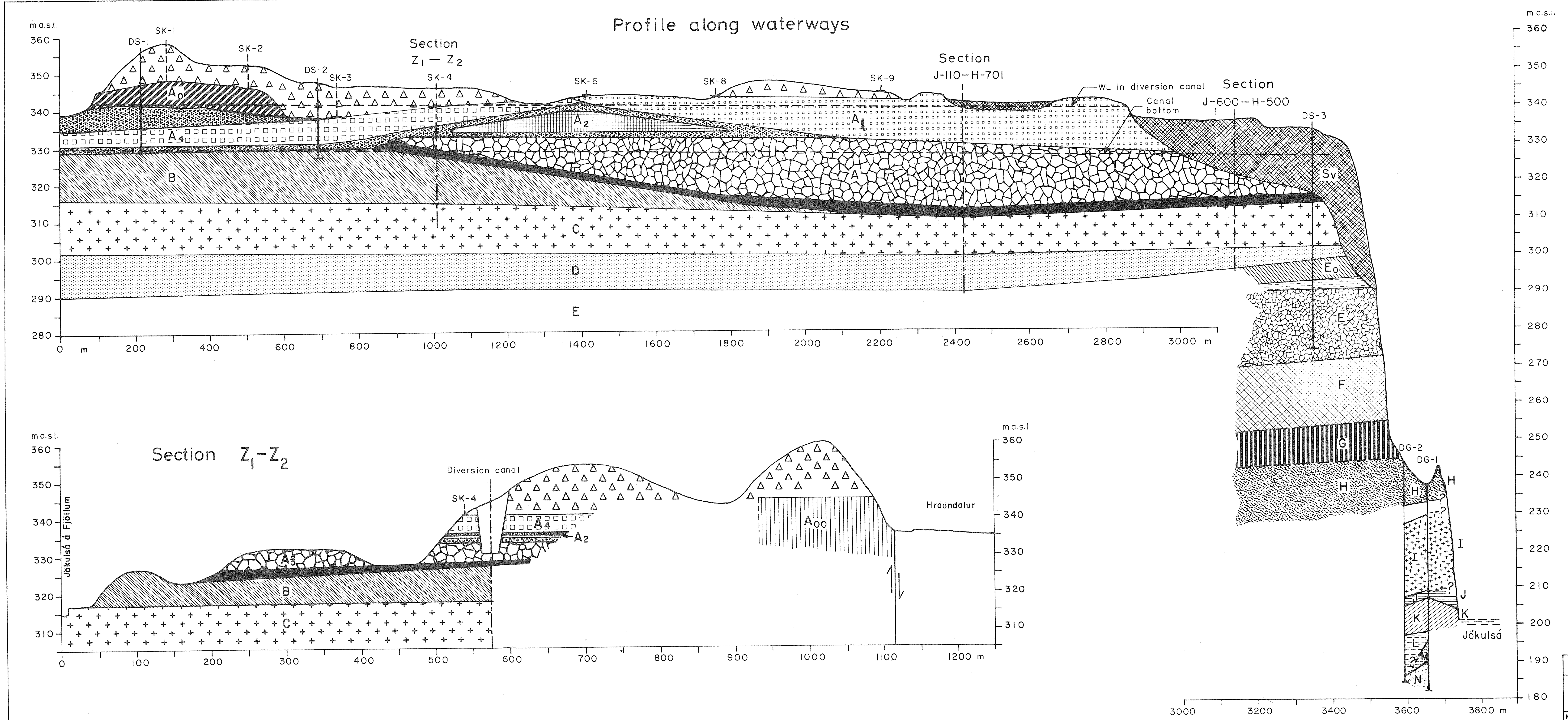

ORKUSTOFNUN
DETTIFOSS PROJECT
GENERAL GEOLOGY
Fnr. 12089
LEGEND
1 Interglacial formations
2 Postglacial fissure lavas
3 Late glacial and postglacial Hawaian type lavas
4 Móberg (subglacial volcanic products)
5 Lakes and rivers
6 Sand
7 Craters
8 Pseudocraters
9 Faults
10 Faults
11 Eskers
12 Terminal moraine
0 1 2 3 4 5 km
HVANNSTAÐAFJALLGARÐUR
LAUFSKÁLAFJALLGARÐUR
SAUÐAFELLSMÚLI
TUNGUHEIÐI
DALFJALL
KOLLALDA
REYÐUR
HÓLSSANDUR
HÓLSSELSMELAR
HÓLSFJÖLL
GRÍMSSTAÐADALUR
Grímsstaðir
Hólssel
Hrossaborg
SYÐRA-NORÐMELSFJALL
YTRA-NORÐMELSFJALL
Dettifoss
Selfoss
Hafragilsfoss
Jökulsá á Fjöllum
HRAUNDALUR
RANDARHÓLAR
RAUÐHÓLAR
KVENSÖDULL
BORGARÁS
HAFRAFELL
Hafragil
Réttarbjarg
Vígaberg
Forvöð
HÓLMATUNGUR
Landsbjörg
Ásbyrgi
Skógarbjörg
Hljóðaklettar
VESTURDALUR
ÁSHEIÐI
SVÍNADALSHÁLS
GRJÓTHÁLS
NORÐMELSSTYKKI
YTRI-SVEINAR
SVEINAR
SVEINAHRAUN
RAUÐUBORGIR
NORÐURFJÖLL
AUSTARI-BREKKA
VESTARI-BREKKA
SKÓGARMANNAFJÖLL
Krókavatn
Bakkahlaup
Víðirhóll

Exhibit 16


LEGEND
Flood deposits
Moraine
Sv Sveinar lava basalt
A0 A00 Basalt
A1 X Basalt
A2 Y Basalt
A3 Z Basalt
A4 Basalt
B Basalt
C Basalt
D Sediments
E Basalt
F1 Basalt
F Basalt
G Sediments
H Basalt
I Basalt
J Sediments
K Basalt
L Sediments
M Sediments
N Móberg
Breccia
Craters
Canal
Faults
H-100 Surveyed sections
Profile
Fractures
Dam site
Borro - soundings
Core drill holes
Seismic profiles
A
N
S
V
0 100 200 300 400 m
LOCATION MAP
Exh. 16
Exh. 15
0 25 50 km
Dettifoss
Selfoss
Jökulsá
Bjargadalur
Hafragilsfoss
Fossvogur
Hafragilsundirlendi
Hafragil
Hraundalur
ORKUSTOFNUN
DETTIFOSS PROJECT
GEOLOGIC MAP
Fnr. 11842
B-303



ORKUSTOFNUN

DETTIFOSS PRJOECT

GEOLOGICAL SECTIONS

Maí 1974 S.Z./Gyða	Tnr. 109 B-303	Fnr. 11846

Exhibit 18

ORKUSTOFNUN

DETTIFOSS PROJECT
LOCATION OF TEST PITS

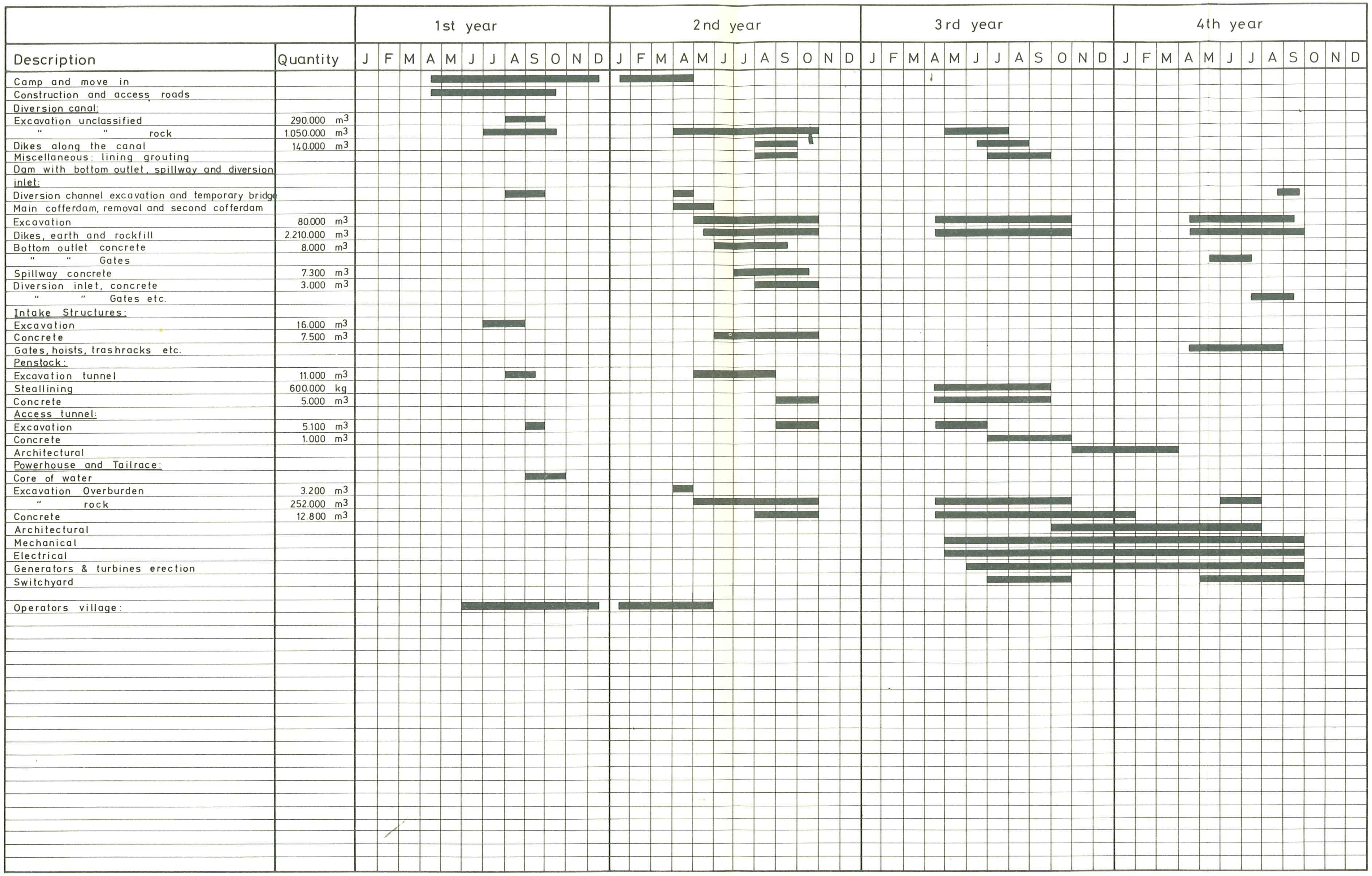
Verk nr. 01.13. Teikn. nr. 2.14

Mælikv.

VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.

Dags. APR. '75 M.H.

Exhibit 19



ORKUSTOFNUN

DETTIFOSS PROJECT
CONSTRUCTION SCHEDULE

Verk nr. 01.13. Teikn. nr. 2.15

Mælikv.

VERKFRÆÐISTOFA SIGURÐAR THORODDSEN SF.

REYKJAVÍK: ÁRMÚLI 4 SÍMI 81575
AKUREYRI: GLERÁRGATA 36 SÍMI 12543
ÍSAFJÖRÐUR: PÓLGATA 6 SÍMI 3708

	Dags.	Reikn.	Teikn.	Yfirf.
Hönnun	JUNE '75	S.Th.	M.H.	
1. breyting				
2. breyting				
3. breyting				

Samþ.: