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APPRAISAL REPORT
ON
BURFELL PROJECT.

THJORSA RIVER - ICELAND

For

THE STATE ELECTRICITY AUTHORITY
REYKJAVIK, ICELAND

by

HARZA ENGINEERING COMPANY INTERNATIONAL

March, 1962

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SUMMARY OF REPORT

The State Electricity Authority
P.O. Box 40
REYKJAVIK
Iceland

Subject: Burfell Project
Appraisal Report

Gentlemen:

We take pleasure in presenting our Appraisal Report on the Burfell Project located on the Thjorsa River in Southwest Iceland. This Report deals with our appraisal of a development at the "Upper Site" and compares with our study, presented in our "Summary Report", dated November 4, 1961, at the site now designated the "Lower Site". The fall in the Thjorsa River as it flows in a hemicycle around the mountain, Burfell, would be developed for power at either alternative site on a run-of-river basis. The development concept and the cost estimates presented are on comparable bases.

Development at the Upper Site, presented in this Report, would utilize at best efficiency 145 cubic meters per second (cms) of flow through a gross head of about 120 meters and produce about 156,000 kilowatts of rated power. The detailed studies, presented in the main body of the Report, are on the basis of developing that amount of power with six units of 26 megawatts each. The same amount of power, approximately, can be developed by five units of 31 megawatts each with a cost savings of about two percent. Our studies thereof are presented in Appendix A, hereto. We also present in the Appendix our studies of incremental installation with either the five-unit or six-unit plant. Any final selection of unit size and incremental installation would be based on overall economics taking into consideration expected system load growth.

Our estimate of Total Construction Cost for the six-unit Burfell Project, including transmission to Reykjavik with a tie to the existing system, is \$ 26,530,000. This amount includes allowances for omissions and contingencies, escalation, and such indirect costs as continued preliminary

investigations, engineering, supervision of construction, and owner overhead. It does not, however, include any allowance for any appropriate import duties and taxes. Our estimate of Total Capital Requirements is \$ 31,670,000. This amount was determined by adding to the estimated Total Construction Cost estimated amounts for interest during construction, working capital, and one year of interest reserve.

The flow of 145 cms or more is estimated to be available at least 90 percent of the time. Energy deficiencies during the remaining 10 percent of the time would need to be offset by load restrictions, energy from other sources, or upstream storage. The relatively small amount of energy, amounting to about two percent of the total, may be provided by an initial partial development of upstream storage located in the lake, Thorisvatn. This storage development is discussed in Appendix B, hereto, but the costs and benefits have not been included with the Burfell Project.

The delivered annual primary energy from the Burfell Project was estimated to be 1180 million kilowatt-hours (kwh). This estimate was based on utilization of flows up to 145 cms. It includes allowances for all losses, 98 percent utilization, and energy deficiencies during extremely low flow periods. Some high-grade secondary energy would also be available but has not been evaluated. The peaking capability of the Project to Reykjavik would be about 160,000 kilowatts.

Our estimates for annual cost include operation and maintenance, reserves, water rights, and debt service. Debt service will depend on ultimate financing terms, currently unknown. Our estimate for unit energy costs are based on: (1) the sale of the annual delivered primary energy of 1180 million kwh. (2) annual costs other than debt service of \$775,000, and (3) a range of level debt service expressed as a percent of Total Capital Requirements. On this basis our estimate of unit primary energy costs varies on a nearly straight line relationship from 2.0 mills U.S. for five percent to 2.8 mills U.S. for eight percent of the debt service expressed as noted above.

Similar estimates of annual cost and of unit primary energy costs are presented in Appendix A for the five-unit plant and for incremented unit installation in both the six-unit and five-unit plants. No studies were made for incremental installation of the Lower Site.

Comparison of costs between the two Sites shows an economic advantage in favor of the Upper Site. The estimated Total Construction Cost and Total Capital Requirements would each be about ten percent greater for the Upper Site. However, the increased head results in an increase of about 19 percent in average annual primary energy delivered to Reykjavik. The unit cost of delivered primary energy would be about one-tenth mill U.S. less for the Upper Site than for the Lower Site.

The Upper Site has additional advantages over the Lower Site. The larger head-water pond provides intangible advantages with respect to decreasing iceing problems and increasing silt storage. It also provides far greater daily pondage which could be useful during low flow periods. It is now anticipated that rock conditions may be somewhat superior for the underground construction at the Upper Site. Further, the tunnel route for the Upper Site is near enough to the surface to permit exploration prior to undertaking construction while the tunnel for the Lower Site is deep within the mountain, Burfell. Thus, construction and cost contingency risks tend to be reduced.

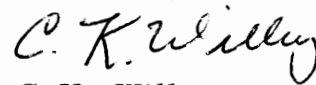
Accordingly, we recommend that future studies and investigations be concentrated exclusively on furthering the plan for development of the Upper Site. The field investigation would include topographic, route, and geologic mapping; hydraulic and hydrographic measurements and surveys; overburden probings; diamond core drillings; investigation shafts and tunnels; and the reconnaissance, sampling, and testing of natural construction materials. We estimate that these investigations can be accomplished substantially by concentrated effort in one summer season.

As information from the field investigations become available, office studies to evolve a definite Project Plan could begin, and be aimed for completion by late fall. The planning studies and the results of the field investigations would be incorporated in a Project Planning Report. This Report would be suitable for Final power marketing negotiations and Financing. It would also serve as a basis for detailed design. However we do not now expect that further investigations and studies will affect adversely the Project economics as presented in this Appraisal Report.

It is our opinion that the development at the Burfell Upper Site represents an economical and logical hydroelectric potential for initial large block of firm power and energy. The basic concept of the plan presented within the Appraisal Report would fit within the scope of ~~comprehensive~~ resources development of the Thjorsa River Basin. Further, the basic plan would accommodate readily future enlargement of the potential at Burfell as upstream storage is provided to regulate the flow.

We very much appreciate the opportunity to provide the engineering service, represented by this Appraisal Report, to you.

Very truly yours,

A handwritten signature in cursive script, reading "C. K. Willey".

C. K. Willey

TABULATION OF SIGNIFICANT DATA

Drainage Area	6375 sq. km.
Average Discharge	334 cms
Design Flood Capacity	9000 cms
Normal Headwater Elevation	242 m (m. s. l.)
Normal Tailwater Elevation	122 m
Penstock Diameter	2.6 m
Powerstation Type	Underground
Generators	
Number	six
Type	Vertical-Shaft, Hydraulic Turbine Driven
Rating	29,000 kva
Power Factor	0.9
Voltage	13.8 kv.
Phases	Three
Cycles/second	50
Speed	375 rpm
Low Tension Leads	Non-draining
Turbines	
Number	six
Type	Francis
Rating a 116 m. net head	42,500 metric h. p.
Discharge at rated head, best gate	24.25 cms
Speed	375 rpm
Transformers	
Number	six
Type	Outdoor Three-Phase, OA/FA
Rating	32,000 kva
Voltage	13.8/230 kv
Main Transmission Line	
Length	105 km
Voltage	230 kv
Construction	woodpole

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APPRAISAL REPORT
ON
BURFELL PROJECT - UPPER ALTERNATIVE
THJORSA RIVER - ICELAND.

GENERAL LOCATION

The Burfell Project - Upper Alternative will develop essentially the same reach of the Thjorsa River as the Lower Alternative described in our report on that site dated November 4, 1961. It will be located on the middle section of the river in Southwest Iceland as shown on Exhibit 1. The Thjorsa River, together with its principal tributary, the Tungnaá, originates at the glaciers, Hofsjokull and Vatnajokull, and flows southwesterly to the North Atlantic Ocean. The drainage area upstream of the site is about 6375 square kilometers. The project as presented herein will develop about 118 meters of gross head by a diversion north of the mountain, Burfell, into the Fossa River about two kilometers upstream of its confluence with the Thjorsa. The relative locations of the two alternatives studied are shown on the Key Plan on Exhibit 3. Transmission facilities, shown on Exhibit 4, would extend to near Reykjavík, the country's principal and capital city. The location of the Burfell Project with respect to other proposed power and storage projects on the Thjorsa and Hvita Rivers is shown on Exhibit 1. Detail data with respect to these proposed projects are shown on Exhibit 2. This general master plan of development is described more fully in the report by the Harza Engineering Company International, entitled, "Advisory Report - Hydroelectric Power Resources - Hvita and Thjorsa River System - Southwest Iceland", dated March, 1960. It is important to point out that the presently proposed plan for the Burfell Project differs from the plan presented therein in that no initial storage is provided. The present plan is limited to a run-of-river development which permits the future provision of a storage dam and reservoir. Also included as Appendix B hereto is a discussion relative to a possible limited initial development of emergency and holdover storage at the lake, Thorisvatn.

DESCRIPTION OF PRODUCTION FACILITIES

The general layout of the Burfell Project - Upper Alternative is shown on Exhibit 3. It will consist of : (1) a diversion weir and spillway across the Thjorsa River, about four kilometers upstream from the low waterfall, Trollkonufoss. A contiguous intake structure on the right (west) bank of the river will connect with (2) a diversion canal leading westward to (3) a headrace pond formed by a dike across the stream, Bjarnalækur ; (4) an inlet canal connecting the pond with (5) the power intake and sluice structure located on the divide between the Thjorsa and the Fossa Basins near the saddle between Skalarfell and Samstadamuli, two smaller mountains north of Burfell (6) vertical pressure shafts (penstocks) leading from the intake to (7) an underground power station ; (8) a tailtunnel and a short channel terminating in the Fossa River about two kilometers upstream of its confluence with the Thjorsa ; (9) a switchyard ; (10) access facilities and an operators village.

The plan is generally similar to the Lower Alternative, but will develop about 16 meters more net head and will have the advantage of a larger and deeper headrace pond. There are other variations of this general alternative that have not yet been studied and investigated. The final selection would be on the basis of improved geologic conditions and economic advantages. These are not

now considered to be very great relative to the presently proposed plan.

The six-unit plant with all units installed initially is presented in the main body of this Report. There is presented in Appendix A, hereto, a discussion relative to a five-unit plant of approximately the same installed capacity. Also presented is a discussion of incremental unit installation.

1. Dam, Spillway and Diversion Structure.

The location of the dam, spillway and intake structure is shown on Exhibit 5. A general plan, together with typical sections of the structures, is shown on Exhibit 6. The design details are quite similar to those for the same structures of the Lower Alternative.

The Thjórsá River flows in this section on the surface of postglacial lava which has filled the valley between the slopes of Hekla to the east and Búrfell, Skeljafell and Stangarfell to the west. The lava plain is at the damsite several kilometers wide and bordered by the upper branches of the two smaller streams, Ytri-Rangá on the east and Bjarnalaekur on the west. These two streams are generally below the grade of the Thjórsá which has been kept in its present channel by more recent sediments. There is no evidence that the Thjórsá even during great floods has ever flowed, even in part, into the marginal streams. High flood discharges, however, are, in part, diverted through the Rauda Gap to the Fossá. It may be desirable to prevent such diversion after the Búrfell Project is constructed, but no cost estimates for the required facilities, expected to be nominal, are included herein. The river bed at the damsite is on a grade of about 4 meters per kilometer, gradually increasing to about 6 meters farther downstream towards Tröllkonufoss. These slopes result in high velocities, estimated at up to six meters per second during floods.

All of the diversion structures will be founded on the Thjórsá lava which appears entirely competent. The main spillway will consist of a free overflow concrete weir only three to four meters high up to a crest elevation of 242 meters. The weir will extend across the entire river and will raise the natural water surface only about two meters. Two tainter gate bays will be located to the right of the weir and adjacent to the diversion intake structure. Each will contain a tainter gate, 12 meters wide by 4 meters high, operated by an individual hoist located at the deck level, elevation 249 meters. Operation will be by remote control from the powerstation. The gate sill is set at elevation 238.5, the approximate present river bottom. Inasmuch as it is expected that the Thjórsá will, by sedimentation, establish a new grade upstream of the weir, the principal purpose of the gated section is to sluice sediment and ice from front of the diversion intake structure. Minor flow regulation will also be permitted. The spillway structure will be designed to have little backwater effect upstream during high floods.

A gravity retaining wall at the left end of the weir will serve as a terminus of the left bank rockfill dike. This dike will extend in an upstream direction to high rock and be graded in conformity with the expected water surface profile for the design flood of 9,000 cubic meters per second (cms). A freeboard allowance is provided. The rockfill dike will have a central impervious core protected by graded filters.

The diversion intake structure will be located along the right bank of the river upstream from the gated spillway. It will contain thirteen low level ports for entry of water into the diversion canal. Each port will be 10 meters wide by 1.5 meters high. The continuous wall above the ports will serve as a "shear" wall to guide floating ice towards the spillway and prevent its entry into the canal. The top of the wall will be graded upwards in an upstream direction generally parallel with the expected water surface during a moderate flood. The base of the ports will be approximately one meter above the present riverbed and will be likewise graded to correspond with the expected normal water surface level. The structure will be of reinforced concrete construction except

for the base slab which will be of mass concrete. A curved concrete gravity retaining wall terminating in a short rockfill dike, both located beyond the upstream end of the diversion structure, will prevent all but great floods from entering the diversion canal and the headrace pond.

2. Diversion Canal.

The diversion canal will extend from the diversion intake structure westward for about one kilometer into a depression drained by the stream Bjarnalaekur. A profile and section of the canal is shown on Exhibit 5. A 200 meter long transition section will be excavated beyond the diversion intake leading into the 20 meter wide canal at elevation 235.5 meters. The canal will be constructed with a slight slope towards the depression. At normal operating conditions, the velocity will be about 0.9 meters per second for a flow of 145 cms. The excavation will be almost entirely in Thjorsá lava.

3. Bjarnalaekur Dike and Outlet Structure.

A rockfill dike will extend from the downstream end of the diversion structure to the northeast slopes of Skálarfell, crossing the Bjarnalaekur at about elevation 225 meters. The dike will have a crest at elevation 249 and be of a design as shown on Exhibit 5. It will provide a pond in the depression to the north with a surface area of about one square kilometer at the normal and usual minimum pool elevation of 242 meters. An outlet has been provided through the dike at Bjarnalaekur. Details of this structure are shown on Exhibit 7. It will consist of a reinforced concrete culvert four meters wide and three meters high with a gate structure at the entrance and a stilling basin at the outlet. A wheel gate, four by four meters, will normally be in closed position. The gate will be operated by a fixed frame hoist on a deck at elevation 249 meters. Access to the deck is provided by a bridge from the crest of the dike. The hydraulic capacity of the outlet will be about equal to the total turbine capacity in the power-station.

4. Inlet Canal.

The inlet canal will connect the Bjarnalaekur Pond with the power intake. It will be about one kilometer in length and be of the same crosssection as the diversion canal. The bottom will be at about elevation 235 meters with a slight grade toward the intake. The canal will be widened and deepened in front of the intake to ensure low approach velocities under all operating conditions. The rock excavated from both headrace canals will be used in the construction of the dikes. The present estimates show that nearly all of the rock excavation in the canals can be utilized as shell material in the embankments.

5. Power Intake and Sluice Structure.

The plan and sections of the power intake and the sluice structure are shown on Exhibit 7. The intake will consist of six contiguous and identical bays, one for each pressure shaft. The bays are in a straight line and oriented at an angle of about 45 degrees to the direction of the inlet canal. The sluice structure is located in a channel that leads from the left side of the forebay to the outlet on the west slope of the divide.

The intake will form the entrance to the vertical pressure shafts and will be provided with removable trashracks and emergency gates. Concrete construction will be utilized. The sill is placed at elevation 234 meters, or about two meters above the bottom of the forebay. The 5.5 meter high trashracks will thus be submerged about two meters at minimum operating levels. Removal of the trashracks will permit insertion of stoplogs to close the openings. A movable hoist will be positioned on the intake deck at elevation 249 for handling of the trashracks and stoplogs. The tainter gates, designed for emergency closure, will be 3.5 meters wide by 4 meters high and will be operated by individual hoists

placed on the intake deck. The transition from the trashrack openings to the pressure shafts will be designed to minimize hydraulic losses.

The sluice structure will be designed to permit passing debris and ice over a weir at elevation 240.5 meters and sediment through an undersluice with the sill at elevation 232.0 meters, two meters lower than the intake sill. Both openings are to be six meters wide. A wheeled gate will provide control for the undersluice. The wheeled crest gate will be of the spilt-leaf type with each leaf three meters high. A movable-trolley fixed-frame hoist located at deck level will operate all gates, using a lifting beam. The hydraulic capacity of the openings will be about equal to the total turbine capacity in the powerstation. The water from the sluices will be discharged down the west slopes of Skálarfell and into the Fossá River.

The left sidewall of the sluice structure will serve as the abutment for a low rockfill dike crossing the saddle towards Skálarfell.

6. Pressure Shafts.

Six vertical pressure shafts will connect each turbine in the powerstation with the intake above. A profile of the pressure shafts is shown on Exhibit 3. All shafts will be of the same inside diameter, 2.6 meters, and will be steel lined throughout. The space between the excavation and the liner is to be filled with concrete. Ninety degree bends will connect the lower part of the vertical shafts with short horizontal sections leading into the powerstation at turbine level. Reducer sections will be provided inside the powerstation immediately, upstream of the spiral casing. The total length of each shaft including the horizontal portion will be about 130 meters.

7. Powerstation.

The powerstation will be located almost directly below the intake and under about 100 meters of rock cover, as shown in plan and profiles on Exhibit 3 and 8. Details of the generator hall and appurtenant structures are shown on Exhibit 9. A single drillhole in the vicinity of the powerstation indicates that the rock will be suitable for the planned construction.

As presently planned, the generator hall will house six units of a vertical setting. It will be 14 meters wide and 78 meters long between curtain walls, including the erection bay at the south end. A control and service bay of 16 meters length and equal width will be located at the north end. A short tunnel from the control bay will lead to a vertical access and cable shaft that will daylight near the intake and the switchyard located on the surface above. The shaft will, in addition to a stairway and an elevator, also house the low tension cables and a ventilation duct which will be connected by a separate tunnel to exhaust fans located on the top floor of the control building. Fresh air will be drawn in through the main access tunnel by fans located in a separate room at the south end of the powerstation. The main access tunnel will be about 750 meters long, sloping down towards the powerstation at a grade of 7.3 percent. The six meter wide floor will be concrete paved. The walls and the roof will be lined only where necessary.

The roof in the generator hall will be concrete lined throughout and will be provided with a suspended drip ceiling. An overhead bridge crane will be supported by concrete columns and beams along the entire length of the generator hall. The turbine will be set at elevation 118, or four meters below minimum tailwater, in order to permit the economy of high specific speed. The draft tubes will be constructed at a slight angle with the powerstation to improve the hydraulic conditions at the outlet into a surge chamber to be excavated downstream of and parallel to the generator hall.

A draft tube gate structure will be provided within the surge chamber. The gates will be handled by a monorail hoist suspended from the roof to the chamber.

Access to the draft tube deck and venting of the surge chamber will be by a 100 meter long tunnel connecting with the access tunnel.

8. Tailrace.

The tailrace is located as shown on Exhibit 8. It will be in tunnel from the south end of the surge chamber to the portal, a distance of about 1775 meters. A short open channel will be excavated from the portal to the Fossá River. The tunnel will be 6.5 meters wide and 8.75 meters high and is planned to be concrete lined throughout. The water will be flowing with a free surface under normal operating conditions. A concrete portal structure with stoplog slots will be provided at the downstream end of the tunnel. Excavated rock will be used to provide dike protection on the south side of the canal against discharges from the sluice structure.

9. Switchyard.

The switchyard will be located directly above the powerstation and behind the intake as shown on Exhibit 8. The cables from the powerstation will enter at the north end of the switchyard area. The main power transformers will be located in the yard.

10. Access and Operators Village.

A trail exists on the east side of the Thjórsá River in the vicinity of Búrfell. This trail connects to the main population areas of Southwest Iceland. Improvements of this trail and portions of the connecting road net will be required. A connection to this road could be made as shown on the Key Plan on Exhibit 3. This would involve a bridge across a narrow section of the Thjórsá River at the south end of Búrfell. The main access road to the Project Site will, from the bridge, extend northerly on the west side of Búrfell, to the access tunnel portal. A road to the intake and switchyard area will branch out from this road about one kilometer south of the portal. Access to the dikes and diversion structures on the right bank of the Thjórsá will be by means of a road from the intake area along the north slopes of Skálarfell and across the Bjarnalaekur dike. Alternatively, the main access road could enter from the west, with much smaller bridges required for crossing the Sandá and Fossá Rivers. The road to the diversion structures on the left bank will be located entirely on the east side of the Thjórsá, connecting with the existing trail and road to Reykjavík.

An operators village will be constructed in the area near the access tunnel portal. The lack of a settled community in this area makes such a village necessary.

11. Main Station Equipment.

The present plans provide for an installation of six units. The generators will be of the vertical-shaft, hydraulic turbine-driven type rated 29,000 kva, 0.9 power factor, 13.8 kv, three-phase, 50 cycles.

The six turbines will each be of the Francis type sized for a maximum output of 42,500 metric horsepower at 116 meters net head. The speed of the units has been tentatively selected at 375 rpm. Each of the six outdoor main three-phase transformers will be of the OA/FA type rated at 32,000 kva, 13.8/230 kv. The low tension leads from the generators will be non-draining cables. Eight air blast circuit breakers will be located in the switchyard. Power breakers are provided for at the receiving end in addition to a 96,000 kva tie to the Sog System.

A one-line diagram for the Production Facilities is included as Exhibit 10, while the plan and a one-line diagram for the ties to the load centers at Reykjavík is shown on Exhibit 11.

TRANSMISSION

A single circuit 230 kv line of wood pole construction will transmit the power from the Búrfell switchyard to the load center at Eidi near Reykjavík. The line would pass the Sog hydroelectric plants. A 138 kv tie with the existing system will be provided to the Ellidaár substation in Reykjavík. The length of the transmission lines following the route shown on Exhibit 4 is estimated at 105 kilometers for the 230 kv line and 5.5 kilometers for the 138 kv tie.

POWER AND ENERGY

1. Stream Flow.

This upper Alternative of the Búrfell Project as presented herein has been sized to utilize a flow of 145 cms with the turbines operating at best efficiency. This is the same assumption as was made for the Lower Alternative in November 1961 as the difference in drainage areas is negligible. This flow without regulation is estimated to be available about 90 percent of the time. The average flow of the river has been estimated at 334 cms. About 160 cms could be utilized by operating the turbines at full gate operation.

2. Primary Energy.

The primary energy of the Búrfell Project - Upper Alternative has been considered as that produced from a flow up to 145 cms as available. Some load curtailment or energy from other sources would be required during the approximately ten percent of the time when flows may be slightly less than 145 cms. The estimate of annual primary energy delivered to the load center at high tension after allowance for all losses and a utilization factor of 98 percent amounts to 1180 million kilowatt-hours. As discussed in Appendix B, hereto, it may be economically feasible to firm the available flow to 145 cms with a limited initial development of storage at Thorisvatn. This firming would increase the amount of primary energy by about two percent. Some secondary energy would be available by turbine operation between best gate and full gate when flows are available, but this has not been evaluated.

3. Peaking Capability.

It is expected that the plant can deliver to the load center peaking power up to 160,000 kilowatts. This might be reduced slightly during periods of high tailwater, including encroachment resulting from ice jams downstream.

PROJECT COST

1. Capital Costs.

A cost estimate has been prepared for the Búrfell Project-Upper Alternative as described above on the same basis as for the Lower Alternative, estimated in November 1961. The estimates presented in a summary form, are included as Exhibit 12. The estimate was prepared as the result of a detailed quantity survey based on the drawings referred to above, except for major equipment items discussed hereinafter. The unit prices used were the same as those established for the Lower Alternative for similar types of work, and refer therefore to the 1961 price level. These unit prices did not include import duties and taxes where otherwise applicable on imported material and equipment, including construction equipment. The only item of profit considered was that to the general construction contractor or contractors.

The estimated cost for permanent equipment is based on that of Western European manufacture. These prices were based on quotations or on recent bid prices for similar equipment from well-known manufacturers. Again import duties and taxes were not included.

A contingencies and omissions allowance of 20 percent was added to the estimated subtotal of direct costs for the production and transmission plants. This allowance is considered reasonable for an appraisal estimate in view of the limited topographic and geologic information available, and the minor amount of subsurface investigations.

An escalation allowance of five percent was added to the estimated subtotal including contingencies. This allowance is considered reasonable in view of : (1) recent economic history, (2) frequent practice of equipment manufacturers and; (3) the fact that the estimate is based on 1961 labor and material prices.

The addition of the escalation allowance resulted in establishing the estimated total direct costs. An allowance of eight percent of the total direct costs was applied to allow for such indirect costs as design engineering, supervision of construction, and owner overhead. A further allowance of \$ 500,000 was made to cover the estimated cost for preliminary planning basic to design and for field investigations which are yet to be undertaken. This addition gave an estimated total construction cost of \$ 26,530,000.

Financing terms are, at present, not established. Therefore, an allowance of ten percent was made to cover interest during construction for the approximately three-year construction period. This allowance is considered reasonable.

Capitalization of working capital in the amount of two percent and a reserve of one year's interest (based on six percent coupon rate) was also made. The former is required for operation purposes. The latter provides an allowance for delays in either completion of construction or receipt of power revenue, and is a relatively common practice for financing of this type. If this interest reserve is not needed ultimately, it would be reserved for debt service.

2. Annual Costs.

The principal item of annual cost will be the expense of interest and amortization of the capital debt (debt service) This cost will not be known until such time as the financing terms may be established.

The annual cost for operation and maintenance has been estimated at \$ 450,000 including both the production and transmission systems. No item for insurance premiums has been included in the annual costs. For most usual coverage for projects of this type, the annual costs are usually relatively small.

The return on the value of water rights has been included as an annual cost. This is considered to be the fair return on the value of such rights, which are not now known definitely.

The estimate for Reserves has been taken as about one percent of the estimated total construction cost. This Reserve is required to be established to cover expenses of an extraordinary nature not otherwise covered by promptly paid insurance or normal maintenance. It could be used, for example : (1) to replace equipment failures beyond the guarantee period, (2) for expenses prior to insurance recovery, (3) for rewinding of generators, (4) for other major replacements to structures or equipment in whole or in part, (5) for assessed consequential damages or costs, (6) for delays or failures in revenue collection, and (7) for other unforeseen costs.

The estimated annual costs other than debt service are as follows :

1. Operation and Maintenance	\$ 450,000
2. Reserves and Water Rights	<u>\$ 325,000</u>
Total	\$ 775,000

3. Primary Energy Costs.

In the evaluation of unit energy costs, no consideration has been given to income from the sale of any secondary energy, but all delivered primary energy, as defined above, amounting to an estimated 1180 million kilowatthours per year, has been considered as sold.

Inasmuch as the financing terms have not been established, it has been necessary to present an estimate of the unit cost of energy as a graph for a range of annual debt service expressed as a percentage of the total capital requirements of \$ 31,670,000 over a range from five to nine percent. This graph is shown on Exhibit 13. The other definitely estimated annual costs amounting to \$ 775,000 have, of course, been included in determining the unit energy costs as a fixed amount not varying with debt service. However, no allowance for profit has been included in this evaluation. It is also important to point out that allowance has been made in the capital requirements for any import duties and taxes which might be appropriate.

ACKNOWLEDGEMENTS.

We wish to extend our sincere appreciation to the Icelandic entities and individuals who have so ably assisted in the basic studies and data which have made this summary report possible. These include the State Electricity Authority ; the Icelandic engineering firms of Verklegar framkvæmdir H/F and Almenna Byggingarfelagid H/F; Messers, Jakob Gislason, Eiríkur Briem, Árni Snævarr Ögmundur Jónsson, Rögnvaldur Thorláksson ; and many others. Permission to use drawings prepared by Rarik and by the other engineering firms is especially appreciated.

APPENDIX A
ECONOMICS OF A FIVE-UNIT PLANT AND
OF INCREMENTAL UNIT INSTALLATIONS.

GENERAL

This Appendix deals with the economics of alternative power installations at the Upper Site of the Burfell Project on the Thjorsa River in Southwest Iceland. Studies are presented for : (1) An alternative five-unit plant of 155 megawatt (Mw) ultimate capacity, and (2) initial installations of lesser capacity than the ultimate for the alternatives, including the six-unit plant presented in the main body of this Report.

PROJECT LAYOUT

The project layout and the structural design of each component were, for all alternatives, assumed to be generally as described in the main body of this Report. Certain modifications were, however, required as a result of changes in (1) unit size, and (2) initial installations. These modifications are described briefly below :

1. Change in Unit Size. The rated capacity of each unit will be increased by about 20 percent in the case of a five-unit plant of 155-Mw ultimate capacity as compared to the unit size of the six-unit plant. The rated capacity of the generators will increase from 26 Mw to 31 Mw. The size of the intake, penstocks, unit bays and draft tubes will be increased as a consequence. The penstocks will, for example, increase from 2.6 meters to 2.85 meters, and the length of each unit bay will increase from 10.0 meters to 11.0 meters. The number of bays in the intake and the powerstation and also the number of penstocks will be reduced from six to five. The diversion structures, the headrace and the tailrace will be unchanged since the station's rated hydraulic capacity will be the same, 145 cubic meters per second (cms).
2. Provisions for Future Units. A minimum of provisions were considered to be made for the installation of the future units. The future intake bays would be skeleton structures with only the front portion supported by the side walls fully completed. The intake openings would be closed by temporary bulkheads positioned in the future trash-rack slots. The emergency tainter gates and the deck over them would not be installed. The penstocks would be fully excavated but left unlined on the assumption that leakage would not be serious.

Installation of units were assumed to start at the control bay end of the powerstation and proceed progressively towards the erection bay. The future unit bays would be provided with minimum facilities for satisfactory operation of the powerstation. The roof arch, side walls and the entire support structure for the bridge crane would be completed, in addition to longitudinal galleries as required. A walkway and temporary floor would be provided at generator floor level. The draft tubes would be completed fully between the downstream wall of the powerstation and the surge chamber. The draft tube gate structure would also be completed to provide support for temporary bulkheads to close the draft tube openings into the surge chamber. Electrical and mechanical equipment in the powerstation and switchyard would, in general, be provided only as necessary for the units in operation. The diversion structures, the headrace, canals, and the tailrace would all be constructed to full ultimate capacity in the initial stage.

CAPITAL COSTS

The capital costs have been estimated for 3, 4 og 5-unit initial installations of the 5-unit plant and for 3, 4, 5 and 6-unit initial installations of the six-unit plant. The estimates are based on the layout and the design presented in the main body of the Report, modified in each case as outlined above. The basic estimate for each of the two alternative plants refers to the ultimate installation. These estimates are shown in summary form on Exhibit 14, sheets 1 and 2. The estimate for the six-unit plant is identical with Exhibit 12, of the main Report.

The costs for projects not fully installed initially were determined by subtracting from the fully installed cost an amount estimated for installation of a single complete unit multiplied by the appropriate number of future units. This required an estimate for the incremental cost of installing one unit in a bay for which minimum provisions only were previously available. These estimates for both unit sizes (26 and 31 Mw) are included as Exhibit 14, Shetts 3 and 4. This estimating technique is considered satisfactory for the present purposes. More detailed analyses may, however, show that the installation of future units may cost more than shown by the estimated determined as above inasmuch as higher unit rates can be expected because of relatively much smaller quantities. This factor would tend to increase the ultimate cost of the plant as compared to a comparable plant fully installed initially.

Our estimated capital requirements for the various alternatives and stages of development are given in the following Table 1 :

TABLE I.

	Total Capital Requirements in US \$.
<u>Six-unit Plant - 156 Mw.</u>	
<u>Initial Capacity</u>	
Three Units - 78 Mw	25,850.000
Four Units - 104 "	27.790.000
Five Units - 130 "	29.730.000
Six Units - 156 "	31.670.000
<u>Five-Unit Plant - 155 Mw</u>	
<u>Initial Capacity</u>	
Three Units - 93 Mw	26.610.000
Four Units - 124 "	28.830.000
Five Units - 155 "	31.050.000

The above requirements do not include import duties and taxes which might be appropriate.

ANNUAL COSTS

The annual costs for operation and maintenance will not be in direct proportion to the installed capacity in the case of incremental development of one specific plant. The portion of the total cost required for operation and maintenance of the dam, roads, transmission line, powerstation and appurtenant structures will be independent of the installation and therefore be practically constant. We have estimated that this fixed annual operation and maintenance cost will

amount to \$ 87,000. All other operation and maintenance costs have been estimated on the basis of varying with total installed capacity in each case.

The value of Water Rights and the income required for necessary Reserves have been included as annual costs. They were estimated on the basis outlined in the main body of the Report.

The estimated annual costs other than debt service are shown in Table 2 below for the various alternatives considered :

TABLE 2.

Six-Unit Plant - 156 Mw

	Number of Initial Units			
	<u>3 Units</u>	<u>4 Units</u>	<u>5 Units</u>	<u>6 Units</u>
O & M	\$ 310,000	\$ 360,000	\$ 410,000	\$ 450,000
Reserves & W.R. 's	<u>\$ 270,000</u>	<u>\$ 290,000</u>	<u>\$ 310,000</u>	<u>\$ 325,000</u>
Total	\$ 580,000	\$ 650,000	\$ 720,000	\$ 775,000

Five-Unit Plant - 155 Mw

	Number of Initial Units		
	<u>3 Units</u>	<u>4 Units</u>	<u>5 Units</u>
O & M	\$ 340,000	\$ 400,000	\$ 450,000
Reserves & W.R. 's	<u>275,000</u>	<u>300,000</u>	<u>320,000</u>
Total	\$ 615,000	\$ 700,000	\$ 770,000

The annual expenses for interest and amortization of capital debt (debt service) will not be known until such time as the financing terms may be established. These expenses were therefore estimated for a probable range of annual debt service. The results will be discussed hereinafter in the section on Primary Energy Costs.

POWER AND ENERGY

1. Peaking Capability

The estimates of the peaking power in megawatts delivered to Reykjavík are as follows :

	Number of Initial Units			
	<u>3 Units</u>	<u>4 Units</u>	<u>5 Units</u>	<u>6 Units</u>
156 Mw-Six- Unit Plant	80	107	133	160
155 Mw-Five-Unit Plant	96	128	160	"

All estimates are based on the initial provision of a single circuit 230 Kv transmission line on wood pole construction from Burfell.

2. Primary Energy. The annual primary energy has been considered as that produced from available river flows by rated turbine flows of 24.25 cms for the 26 Mw units and 29 cms for the 31 Mw units. Some

load curtailment or energy from other sources would be required for installations larger than about 100 Mw at times when the river flows will be less than the total plant flow capability. Such curtailment would be required for about ten percent of the time with ultimate development of either plant. The estimated amounts of annual primary energy delivered to the load center at the high tension side after allowance for all losses and a utilization factor of 98 percent are tabulated below :

Annual Primary Energy in Million Kilowatt Hours.

	<u>Number of Initial Units</u>			
	<u>3 Units</u>	<u>4 Units</u>	<u>5 Units</u>	<u>6 Units.</u>
156 Mw-Six-Unit Plant	605	805	1000	1180
155 Mw-Five-Unit Plant	725	960	1180	-

Some secondary energy would be available by turbine operation between best gate and full gate, but this has not been evaluated.

PRIMARY ENERGY COST.

In the evaluation of unit energy costs no consideration has been given to income from sale of any secondary energy, but all delivered primary energy as defined above has been considered sold. The estimates of unit costs of energy are shown in the form of graphs for a range of annual debt service expressed as a percentage of the Total Capital Requirements, inasmuch as the financing terms have not been established. The graphs are all shown on Exhibit 15. The fixed annual charges for operation, maintenance, water rights and reserves have been included as fixed amounts not varying, with the debt service. However, no allowance for profit has been included in the evaluation. It should be also noted that import duties and taxes are not included in the capital requirements.

APPENDIX B

THORISVATN STORAGE

GENERAL

The development of seasonal storage at the natural lake, Thorisvatn, was discussed in the Advisory Report on "Hydroelectric Power Resources - Hvita and Thjorsa River Systems - Southwest Iceland" by the Harza Engineering Company International, dated March 1960. The Advisory Report envisioned the diversion of the Kaldakvisl into the Tungnaa above Tungnaarkrokur via Thorisvatn, with the lake drawn down about 27 meters for seasonal and holdover storage. That proposed plan of development is shown on Exhibit 1. The location of Thorisvatn with respect to the Burfell Project is shown on Exhibit 16.

Thorisvatn has a surface area of about 70 square kilometers and is nearly constant at elevation 571. Storage in the upper 10 meters of Thorisvatn averages about 63.45 million cubic meters per meter. The lake is fed almost entirely by underground springs issuing from porous lava to the east. Thus there may be a considerable underground storage in addition to the above ground storage. The surface outlet of Thorisvatn is northward via the Thorisos to the Kaldakvisl. There is also some leakage westward, estimated to be between 7 and 10 cubic meters per second (cms). The average flow of the Thorisos is about 14 cms and is rather constant, seldom dropping below 10 cms. These discharges, naturally regulated, reach Burfell. - An initial partial development of storage at Thorisvatn, without diversion of the Kaldakvisl, is technically feasible. Such a development may be economical as emergency and holdover storage to firm flows at Burfell during the periods when the natural flow drops below the primary energy requirement of 145 cms. Alternatives for such development are discussed hereinafter.

STORAGE REQUIREMENTS

Flow records are available for the Thjorsa River at Urridafoss, where the drainage area is about 13 percent greater than at Burfell, since April 1946. A gage was established near Burfell in the fall of 1959. A study of these flow records for the overlapping period of the water year 1960-61 indicates that the average flow at Burfell is about 89 percent that of Urridafoss or very nearly the drainage area relationship. However, the percentage drops as low as about 84 during low flow periods. A relationship of about 80 percent was adopted on a conservative basis for extreme low flow periods for comparison of Burfell with Urridafoss.

The Urridafoss daily flow records from April 1946 through December 1961 were studied for periods less than 180 cms (145 cms/0.80). This study revealed that flows of less than that amount were found to occur every year within the winter period from November through April. The low flow periods were of two basic types: (1) short periods resulting from severe frost, (Type 1), and (2) longer periods resulting from general drought conditions (Type 2). The Type 1 periods were relatively short, extending up to about three weeks, with an average of about one week. In some winters there were as many as eight such periods, with the average being about four. However, intervening higher flow periods would permit substantial replenishment of storage withdrawn from Thorisvatn. In general, they present no problem with respect to either storage quantity available or withdrawal rate from Thorisvatn.

There were two Type 2 periods within the 14 complete winters studied, one in 1951 and other in 1957. The former was by far the more severe.

It extended from February 13 to May 1. Further, the stream flow decreased more or less gradually and did not begin to increase until about the last ten days of the period. The cumulative flow deficiency below a flow of 180 cms for this period was about 360 million cubic meters at Urridafoss or about 290 million cubic meters at Burfell on the basis of the assumed 80 percent relationship. This amount of surface storage would be available in the top 4.5 meters of Thorisvatn.

The flow at Urridafoss towards the end of the 1951 dry period dropped to about 85 cms which, converted to Burfell, would be 68 cms. Thus, to assure a flow of 145 cms to Burfell the storage release rate would need to be about 77 cms. Further, this rate would need to be possible near the end of the drawdown period when the lake would be at near minimum levels. At these levels the existing contribution of Thorisvatn to Burfell through the Thorisos may have been nearly completely eliminated thus requiring an additional discharge capacity, estimated at 13 cms, when the lake would be at minimum levels. The total capacity of the outlet works would then become 90 cms.

DEVELOPMENT ALTERNATIVES

There exists three relatively short potential routes for facilities to withdraw storage from Thorisvatn on an initial basis prior to accomplishment of the fuller development discussed in the Advisory Report. These routes are: (1) along the general course of Thorisos, (2) through the Rjupnadalur with an inlet in the lake about 6 kilometers southwest of the existing outlet to the Thorisos, and (3) through the low divide following the northwest base of the mountain, Vatnsfell, near the southern end of the lake. The first two routes would return the water to Kaldakvisl. The Vatnsfell route would place Thorisvatn water into the Tungnaa above Tungnaarkrokur, although a small fill dam might be required near the west end of a small depression located about one-half the distance to the Tungnaa in order to prevent the water from seeking a route to the Kaldakvisl. The Vatnsfell route appears to be the most attractive on the basis of the limited available information. The Thorisos route would be more expensive than the other two. The Rjupnadalur route may be comparable in cost to the Vatnsfell route and should be studied further. The Vatnsfell route has been selected for detailed study at this time. It has the advantage of placing Thorisvatn water in the Tungnaa above Tungnaarkrokur where it may enhance the appropriate proposed Tungnaa developments in advance of a fuller development of Thorisvatn.

VATNSFELL OUTLET FACILITIES

The Vatnsfell outlet facilities would consist of an excavated open canal with a control works near the downstream end. A short discharge canal beyond the control works would release the water to follow natural water courses to the Tungnaa. A plan and section of the outlet facilities is shown on Exhibit 16.

The canals were designed for a base width of 6 meters in order to facilitate the use of large construction equipment for those portions to be excavated in the dry. A rock groin would parallel the canal on the north side within the lake to serve as a working platform for a dragline excavating the canal. It would also serve to retard silting of the canal by wind-driven currents within the lake. Rock for the groin construction could come from required rock excavations or from a large talus deposit on the south end of the mountain, Vatnsfell. The depth of overburden along the canal route is unknown; therefore the excavation has been assumed to be largely in rock and provided with 1/2 to 1 sideslopes. Overburden probings and rock drillings are required along the general route for more advanced design studies.

The approach canal grade would be dropped about six meters immediately in front of the control structure in order to provide adequate head and freeboard on the outlet sluice.

The requirement to discharge about 90 cms with the lake at minimum levels resulted in placing the inlet end of the canal four meters below the minimum lake level, and placing the bottom of the canal on a slope of 0,0025 (1/4%). There would thus be a considerable volume of storage available below the minimum level required to achieve this discharge rate, but the discharge rate would gradually decrease as the lake level dropped towards the elevation of the inlet end of the canal.

The outlet structure would be largely of mass concrete as shown on the section of Exhibit 16. The wheeled-service gate would be operated by a hydraulic cylinder located at deck level in the control house. A fixed-hoist operated bulkhead gate would be provided for the upstream slot. Oil-fired heating would be provided for the control house and for heating of gate guides and seals. No A.C. electric power supply is contemplated.

Operation of the outlet gate would be by remote control from Burfell, possibly by a battery-operated electric motor to drive the hydraulic pump for the cylinder. Telemark installations would be required to permit determination at Burfell of lake levels and gate openings at Thorisvatn.

PROJECT COSTS

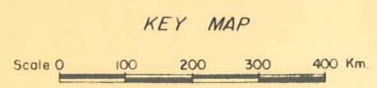
The project costs have been estimated for a range of drawdown in Thorisvatn up to ten meters under the condition of providing a release rate of 90 cms. The direct costs were estimated on the same basis as for the Burfell Project. To these totals were added indirect costs, amounting to 36 percent of the estimated direct cost, on a identical basis with the Burfell Project estimate to determine estimated Total Construction Costs. No allowances were made for import duties and taxes. Additions have not been made for working capital, interest during construction or capitalized reserves.

A graph has been prepared and is presented as Exhibit 17 which relates estimated total construction costs to available storage in Thorisvatn. Two curves are shown. The lower curve indicates the costs required to provide 90 cms discharge with any given amount of storage withdrawn. The upper curve indicates the total storage available corresponding to this release rate requirement. Thus, the storage between the two curves could be available at reduced discharge rates thereafter. For example, the estimated construction costs for a 90 cms rate and the storage requirement noted above of 290,000,000 cm would be about \$ 1,300,000. The remaining storage in Thorisvatn down to the bottom of the outlet canal would then be about 260 million cubic meters.

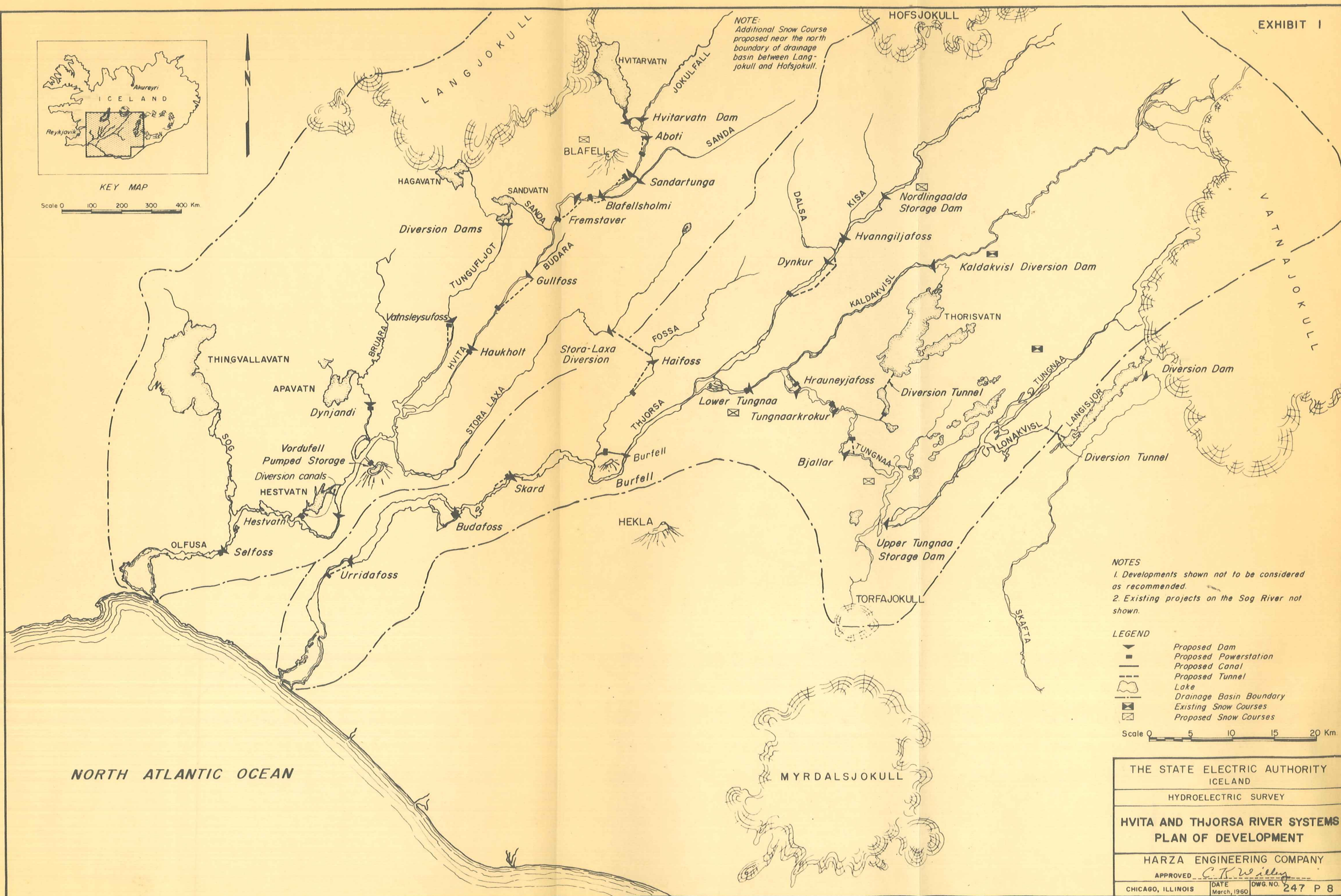
No attempt has been made to evaluate the cost of storage at Thorisvatn as it relates to the economics of firming the energy output at Burfell. This would require much more detailed study whenever the loads for that Project become established. The appraisal made herein indicates that a limited initial storage at Thorisvatn may be attractive and should be studied further.

EXHIBIT INDEX.

<u>Exhibit No.</u>	<u>Title.</u>
<u>Main Report.</u>	
1	Hvítá and Thjórsá River Systems- Plan of Development
2	Hvítá and Thjórsá River Systems- Project Data
3	General Plan and Profile
4	Existing and Proposed Transmission Grid
5	Diversion Structures and Headrace Canals
6	Diversion Structures
7	Power Intake and Bjarnarlaekur Outlet Structure
8	Power Station and Tailrace-General Layout
9	Power Station Plan and Sections
10	One-Line Diagram
11	Transmission Ties at Reykjavík
12	Cost Estimate - Summary
13	Estimated Cost of Firm Energy
<u>Appendix A</u>	
14	Cost Estimate - Summary (four sheets)
15	Cost of Energy
<u>Appendix B.</u>	
16	Thórisvatn - Outlet Facilities- Plan & Sections
17	Thórisvatn-Estimated Cost of Storage



NOTE:
Additional Snow Course
proposed near the north
boundary of drainage
basin between Lang-
jokull and Hofsjokull.











NOTES

1. Developments shown not to be considered as recommended.

2 Existing projects on the Sag River not shown.

LEGEND

	<i>Proposed Dam</i>
	<i>Proposed Powerstation</i>
	<i>Proposed Canal</i>
	<i>Proposed Tunnel</i>
	<i>Lake</i>
	<i>Drainage Basin Boundary</i>
	<i>Existing Snow Courses</i>
	<i>Proposed Snow Courses</i>

Scale 0 5 10 15 20 Km

THE STATE ELECTRIC AUTHORITY
ICELAND

HYDROELECTRIC SURVEY

HVITA AND THJORSA RIVER SYSTEMS PLAN OF DEVELOPMENT

HARZA ENGINEERING COMPANY

APPROVED C. K. Willey

CHICAGO, ILLINOIS	DATE March, 1960	DWG. NO. 247 P 8
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PROJECT	HEADWATER ELEVATION Meters	TAILWATER ELEVATION Meters	GROSS HEAD Meters	LENGTH OF WATER CONDUCTOR Kilometers	STORAGE VOLUME Million M ³	RESERVOIR DRAWDOWN Meters	NET HEAD - Meters		AVERAGE FLOW Kl/s	STATION FLOW CAPACITY ⁽³⁾ Kiloliters per Second		STATION OUTPUT CAPACITY ⁽⁴⁾ Kilowatts		GROSS AVERAGE ANNUAL ENERGY ⁽⁵⁾ Million Kwh
							@ STATION FLOW CAPACITY ⁽¹⁾	@ AVERAGE FLOW ⁽²⁾		BASE LOAD PLANT	PEAKING PLANT	BASE LOAD PLANT	PEAKING PLANT	
HVITA RIVER BASIN	HVITA RIVER													
	Hvitavátn Storage	435	—	—	800	14	—	—	77 ⁽⁶⁾					
	Blafell													
	Aboti II	420	385	35	2.0	—	32.0	33.0	77	110	—	30,000	—	180
	Sandartunga IIIA	385	325	60	3.5	—	55.0	56.5	102	145	—	65,000	—	400
	Blafellsholmi	325	287	38	1.0	—	36.5	37.0	102	145	—	45,000	—	260
	Fremstaver	287	252	35	4.0	—	32.0	33.0	102	145	—	40,000	—	240
	Gullfoss	242	114	128	7.0	—	117.5	121.0	140 ⁽⁷⁾	—	280	—	270,000	1120 ⁽¹²⁾
	Haukholt	114	77	37	—	—	37.0	37.0	145 ⁽⁷⁾	210	—	65,000	—	370
	Hestvatn	50	33	17	2.0	—	15.5	16.0	262	375	—	50,000	—	290
	Selfoss	14	7	7	—	—	7.0	7.0	386	550	—	30,000	—	190
	BRUARA RIVER													
	Apavatn Storage	60	—	—	50	5	—	—	—					
THJORSA RIVER BASIN	Dynjandi	60	50	10			9.0	9.0	66	100	—	7,000	—	40
	TUNGUFLJOT RIVER													
	Vatnsleysufoss	96	56	40	5.0	—	32.5	35.0	25 ⁽⁸⁾	35	—	9,000	—	60
	THJORSA RIVER													
	Nordlingaalda Storage	590	—	—	1200	15	—	—	99					
	Hvanngiljafoss	515	490	25	—	—	25.0	25.0	110	160	—	35,000	—	190
	Dynkur	490	305	185	8.0	—	173.0	177.0	125	—	250	—	360,000	1600
	Burfell	260	121	139	2.5	1000	130.0	131.5	334	—	670	—	710,000	3100
	Skard	121	85	36	2.0	—	33.0	34.0	365	520	—	140,000	—	870
	Budafoss	80	66	14	—	—	14.0	14.0	365	520	—	60,000	—	360
	Urridafoss	46	11	35	2.5	—	31.0	32.5	377	540	—	140,000	—	850
	KALDAKVISL RIVER													
	Thorisvatn Storage	571	—	—	1500	27	—	—	45 - 50					
FOSSA RIVER	TUNGNAA RIVER													
	Langisjor Storage	660	—	—	500	20	—	—	15					
	Bjollar	565	505	60	3.0	200	51.5	53.0	95 ⁽⁹⁾	135	—	55,000	—	350
	Tungnaarkrokur	500	425	75	1.5	200	68.0	68.5	160 ⁽¹⁰⁾	230	—	130,000	—	770
	Hrauneyjafoss	425	325	100	3.0	—	95.5	97.0	169 ⁽¹⁰⁾	240	—	190,000	—	1100
	Lower Tungnaa	325	300	25	—	—	25.0	25.0	202 ⁽¹⁰⁾	290	—	60,000	—	350
	Haifoss	500	260	240	2.5	100	233.0	234.5	6.5 ⁽¹¹⁾	—	25	—	70,000	110
	SUB-TOTAL HVITA RIVER BASIN				850							341,000	270,000	3150
	SUB-TOTAL THJORSA RIVER BASIN				4700							810,000	1,140,000	9650
	TOTAL ALL DEVELOPMENTS				5550							2,561,000		12,800

REFERENCE NOTES

- Represents gross head reduced by 25% of reservoir drawdown plus friction losses in water conductors amounting to 1.5 m/km for tunnels and 0.75 m/km for canals.
- Same as (1) except friction losses amount to 1.0 and 0.5 m/km for tunnels and canals, respectively.
- Base load and peaking based on 70% and 50% capacity factors, respectively; referred to average flow; except at Haifoss where 25% capacity factor is assumed.
- Station capacity computed from formula: $Kw = 8.2 Q_s H_s$ where Q_s = Station flow capacity and H_s = Net head at station capacity
- Annual energy computed from formula: $Kwh = 8.4 (8760) Q_a H_a$ where Q_a = Average flow x water utilization factor, 0.95 and H_a = Net head at average flow

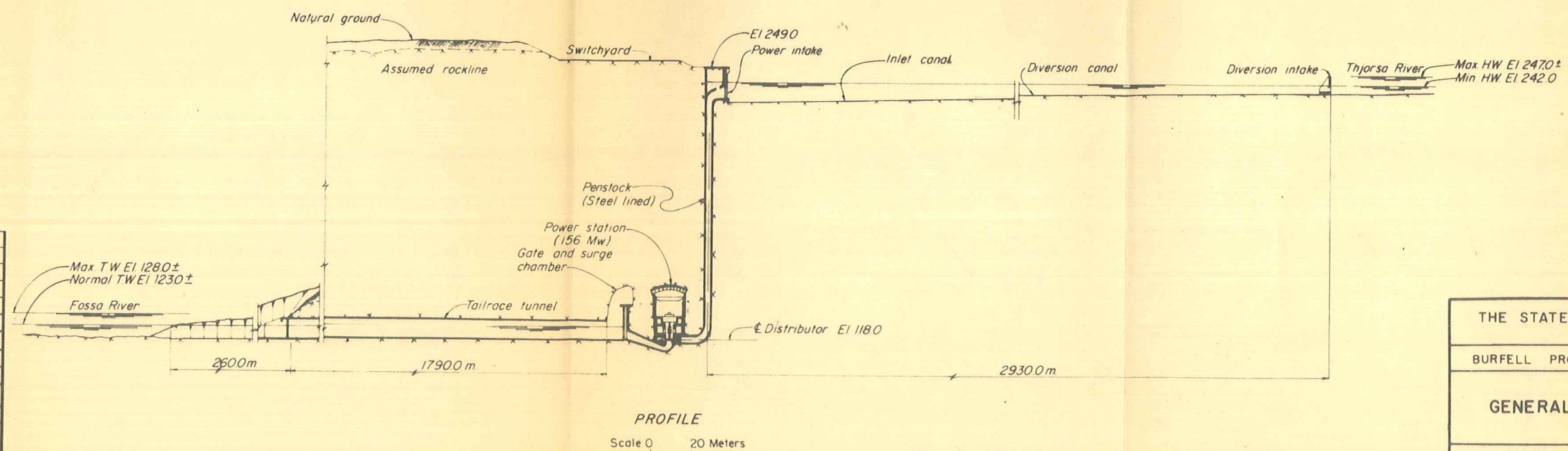
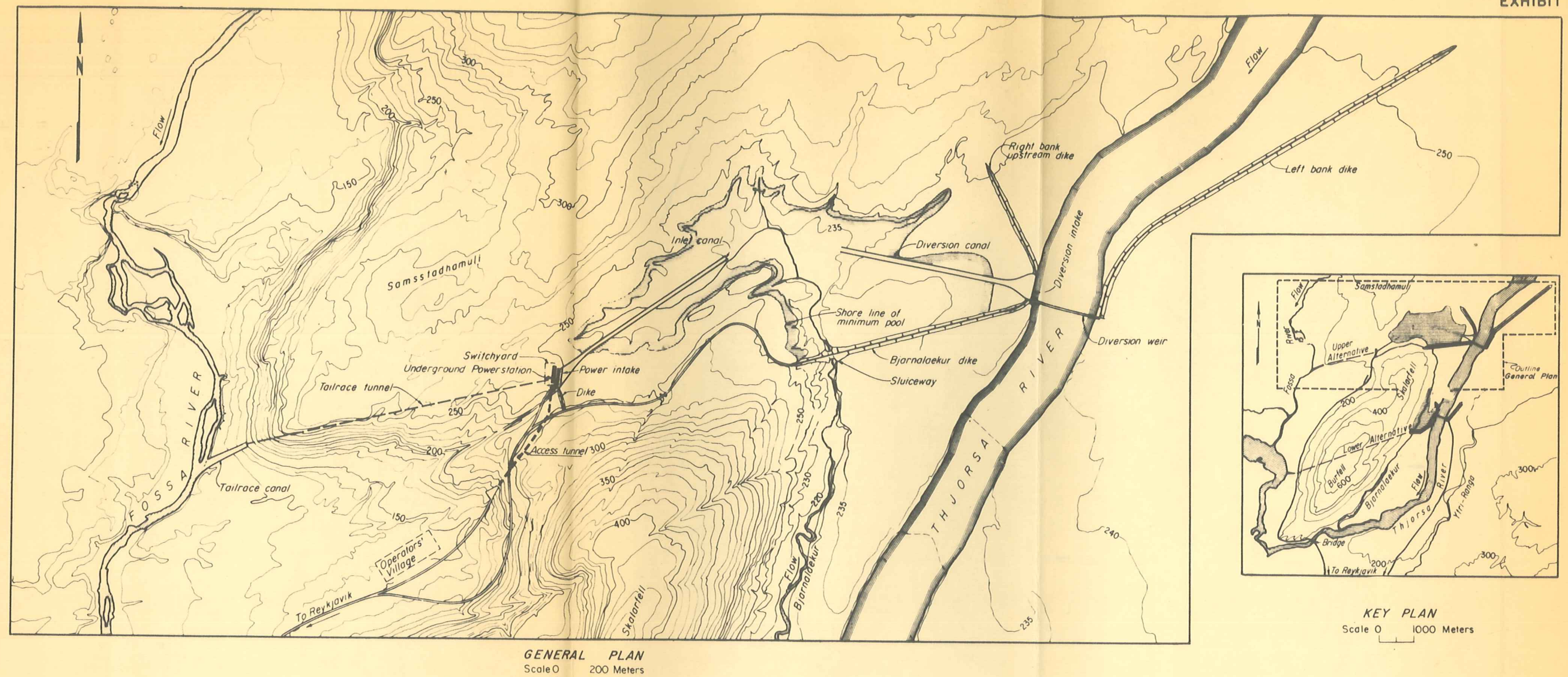
GENERAL NOTE

Data tabulated above is preliminary only and should not be considered as our recommended development for each project.

DATE	NO	DISTRIBUTION
PRINTS		
BY	DATE	CHKD. DATE
OWN.		
DEPT.		
CIVIL		
MECH.		
ELECT.		
PLAN.		
STAFF		

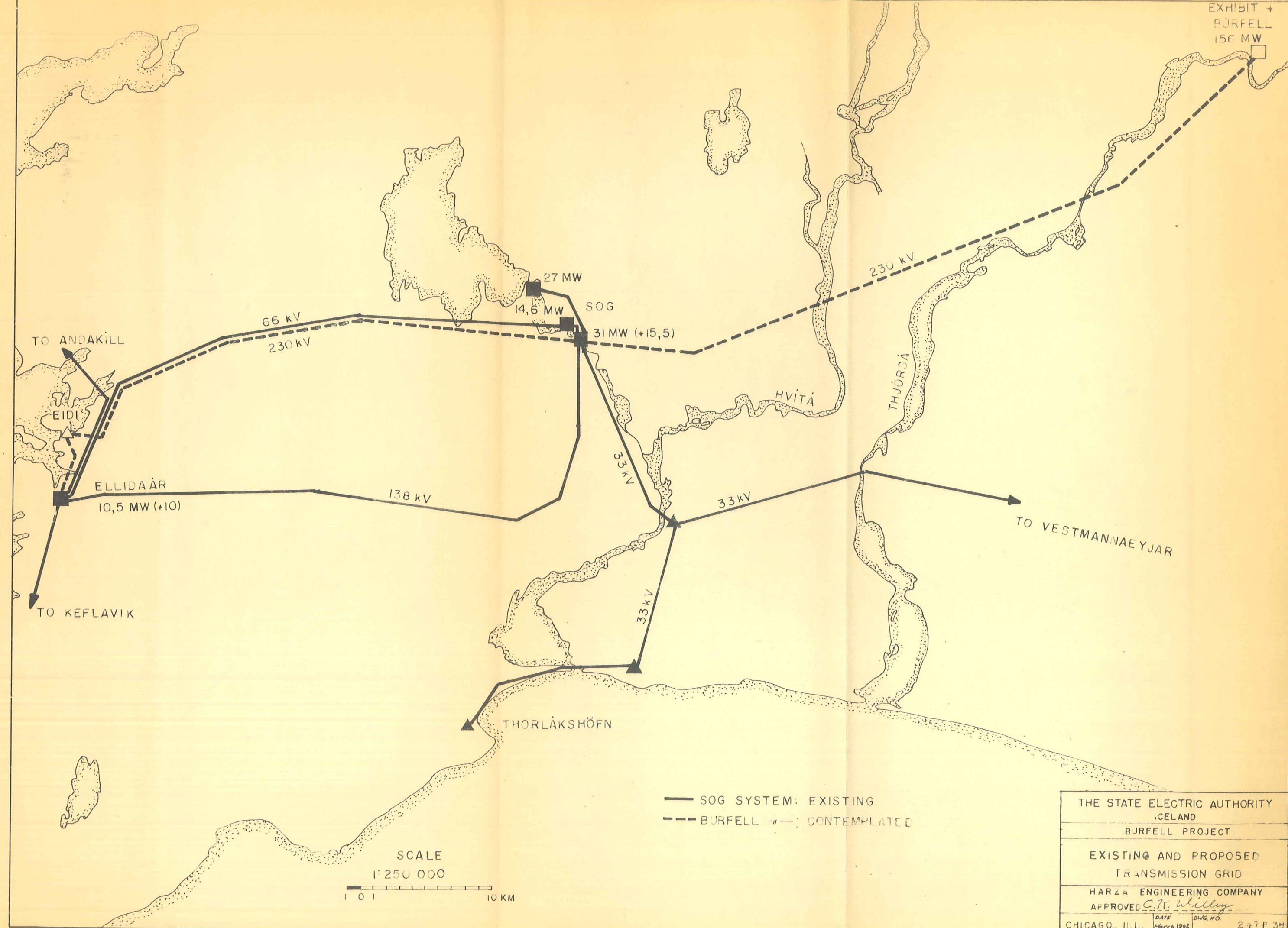
THE STATE ELECTRICITY AUTHORITY ICELAND	
HYDROELECTRIC SURVEY	
HVITA AND THJORSA RIVER SYSTEMS PROJECT DATA	
HARZA ENGINEERING COMPANY	
APPROVED <i>[Signature]</i>	DATE <i>[Signature]</i>
CHICAGO, ILLINOIS	DWG. NO. 247 P 13

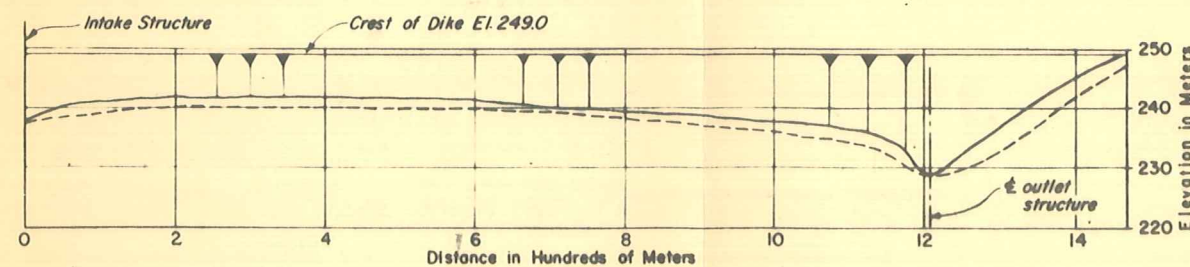
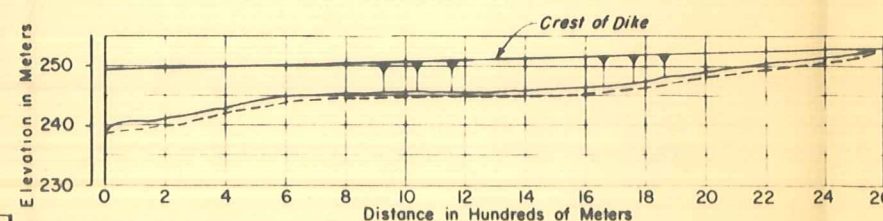
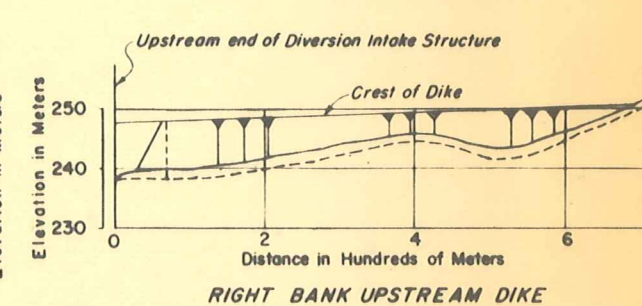
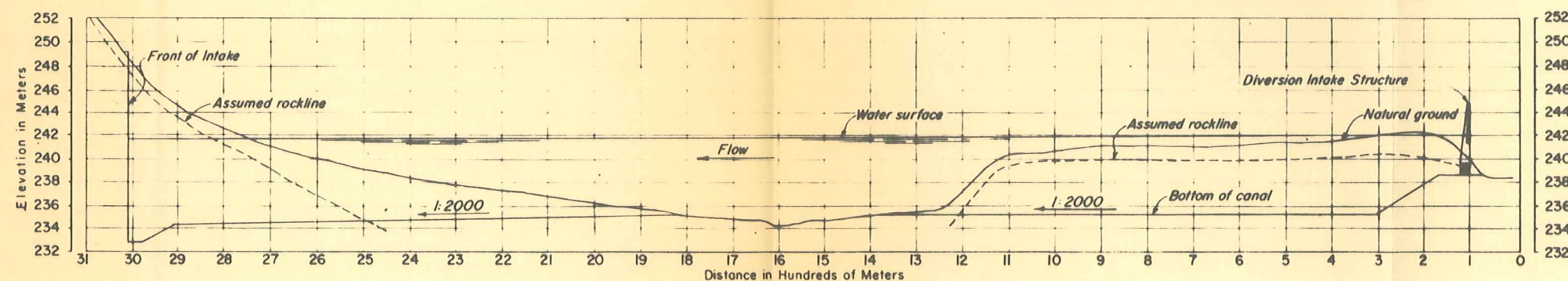
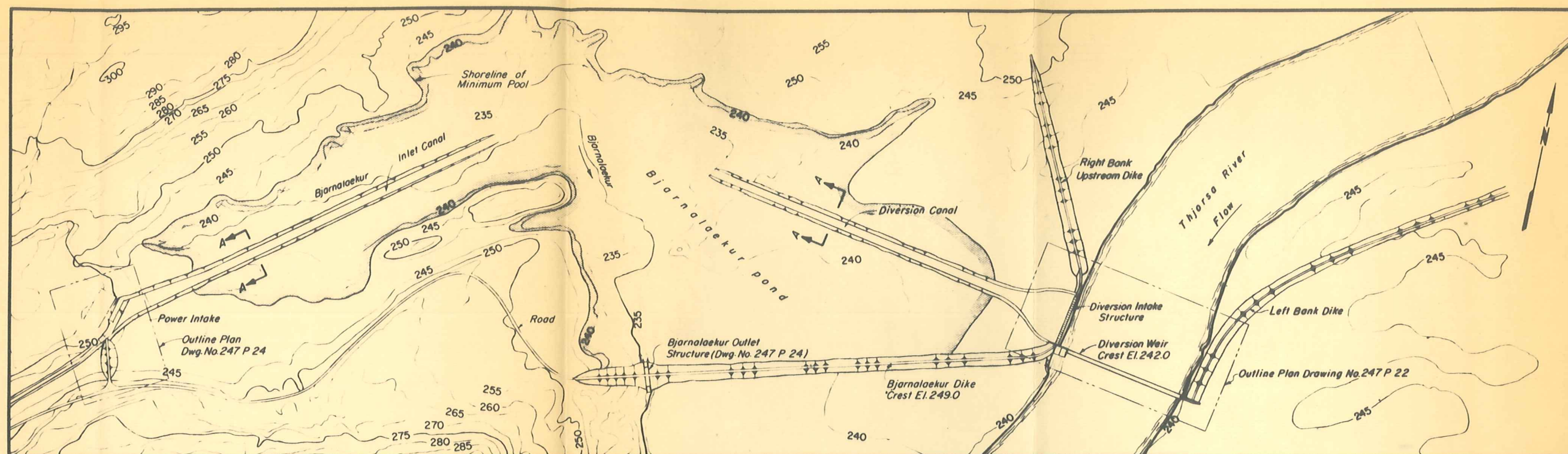
REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.



DATE	NO	DISTRIBUTION			
PRINTS					
	BY	DATE	CHKD.	DATE	
DRAWN					
DWEN.	AC	Feb 62			
DEPT.	GROUP LEADER		SECT. HEAD	DEPT. HEAD	
CIVIL					
MECH.					
ELECT.					
PLAN.		AAE			
STAFF				CHLWHR	

THE STATE ELECTRICITY AUTHORITY ICELAND		
BURFELL	PROJECT	UPPER ALTERNATIVE
GENERAL PLAN AND PROFILE		
HARZA ENGINEERING COMPANY		
APPROVED <i>[Signature]</i>		
CHICAGO, ILLINOIS	DATE March 1962	DWG. NO. 247 P 20

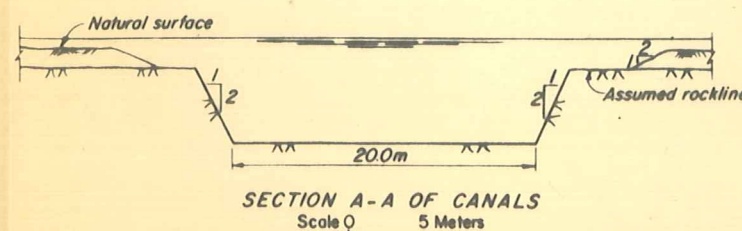
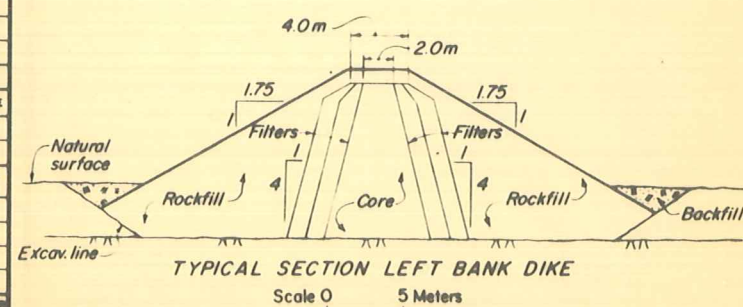




NOTE:

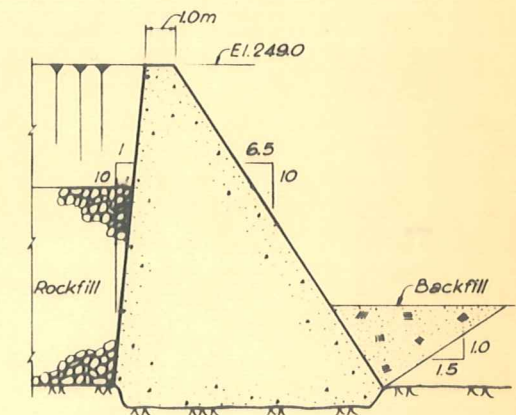
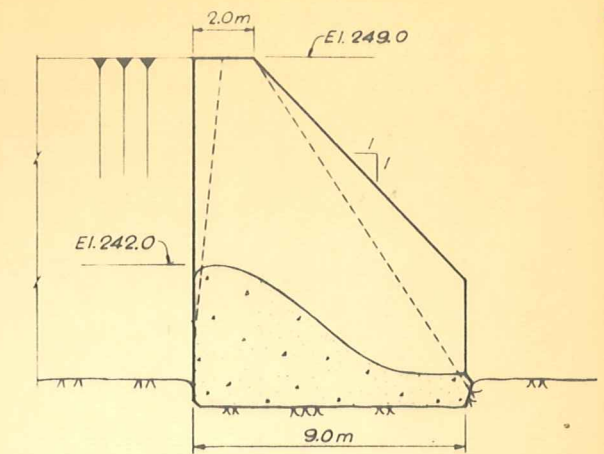
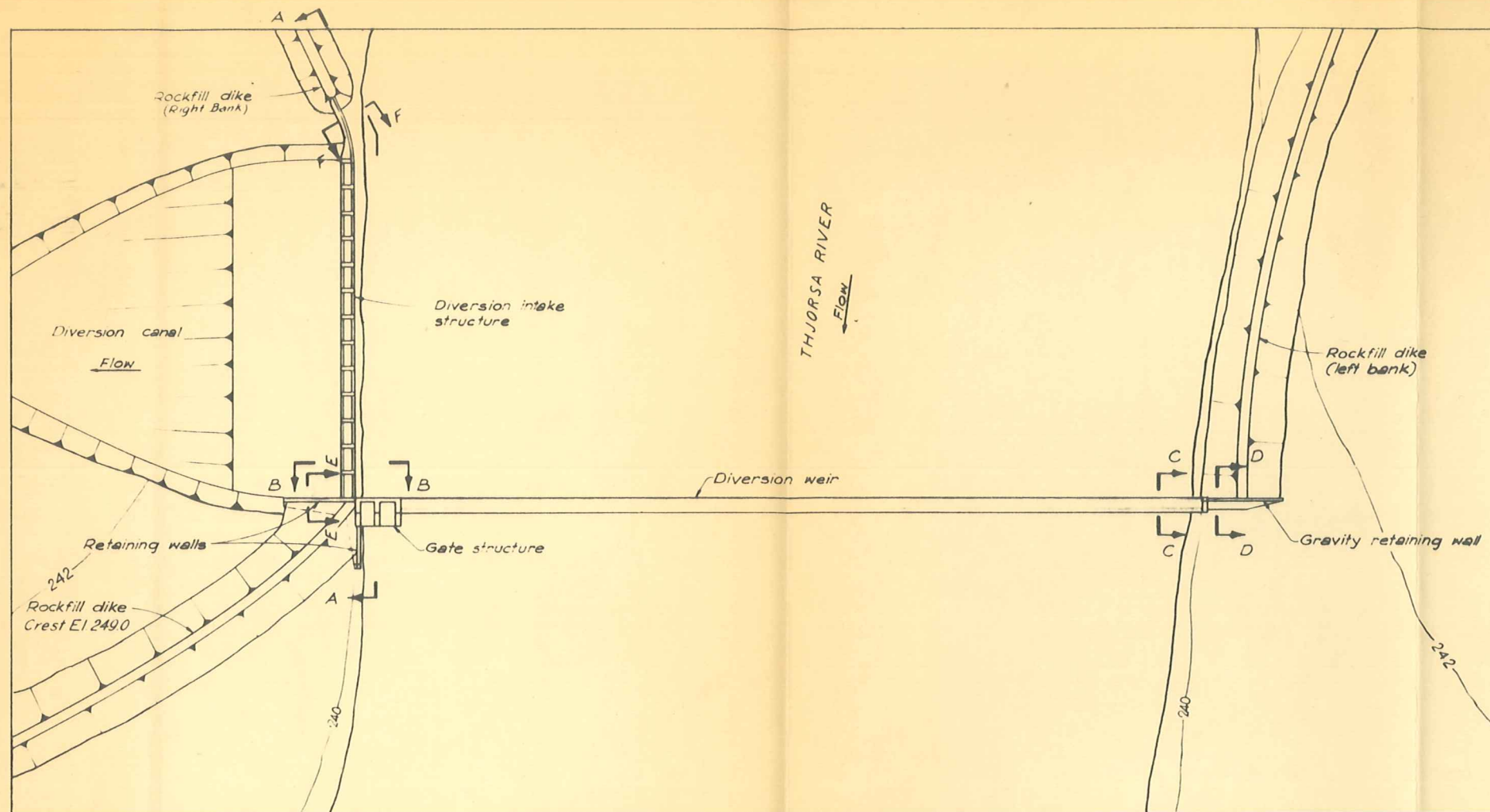
For plan of complete project see drawing No. 247 P 20

DATE	NO	DISTRIBUTION		
PRINTS				
	BY	DATE	CHKD.	DATE
DESIGN				
DRAWN	VET	1/2/74		
DEPT.	GROUP	SECT.	DEPT.	
	LEADER	HEAD	HEAD	
CIVIL				
MECH.				
ELECT				
PLAN.		AKK		
STAFF			CHENON	

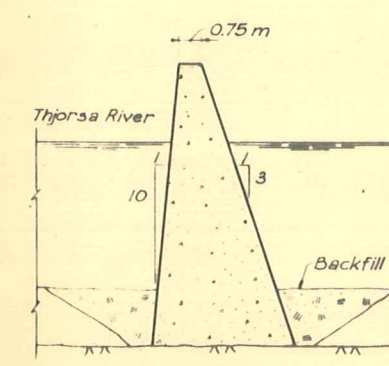
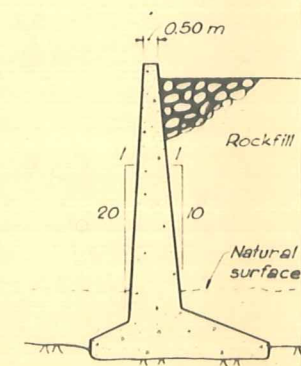
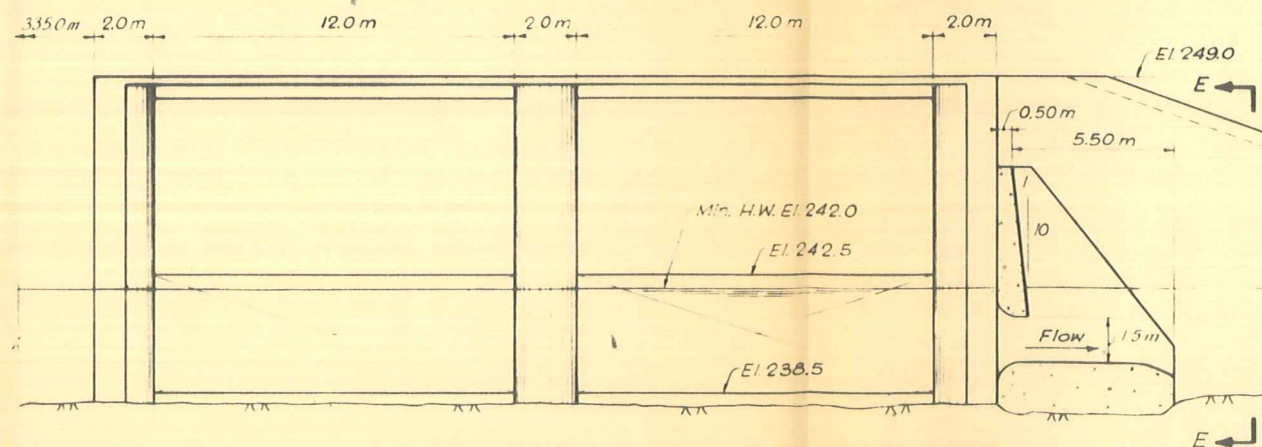
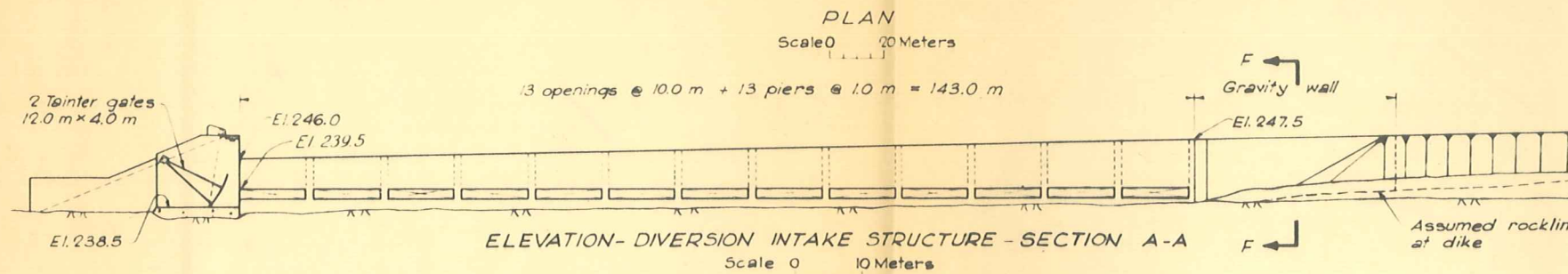


THE STATE ELECTRICITY AUTHORITY	
ICELAND	
BURFELL PROJECT	UPPER ALTERNATIVE
DIVERSION STRUCTURES AND HEADRACE CANALS	
HARZA ENGINEERING COMPANY	
APPROVED: <i>[Signature]</i>	
CHICAGO, ILLINOIS	DATE: March, 1982
DWG. NO.	247 P 21

REV.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.



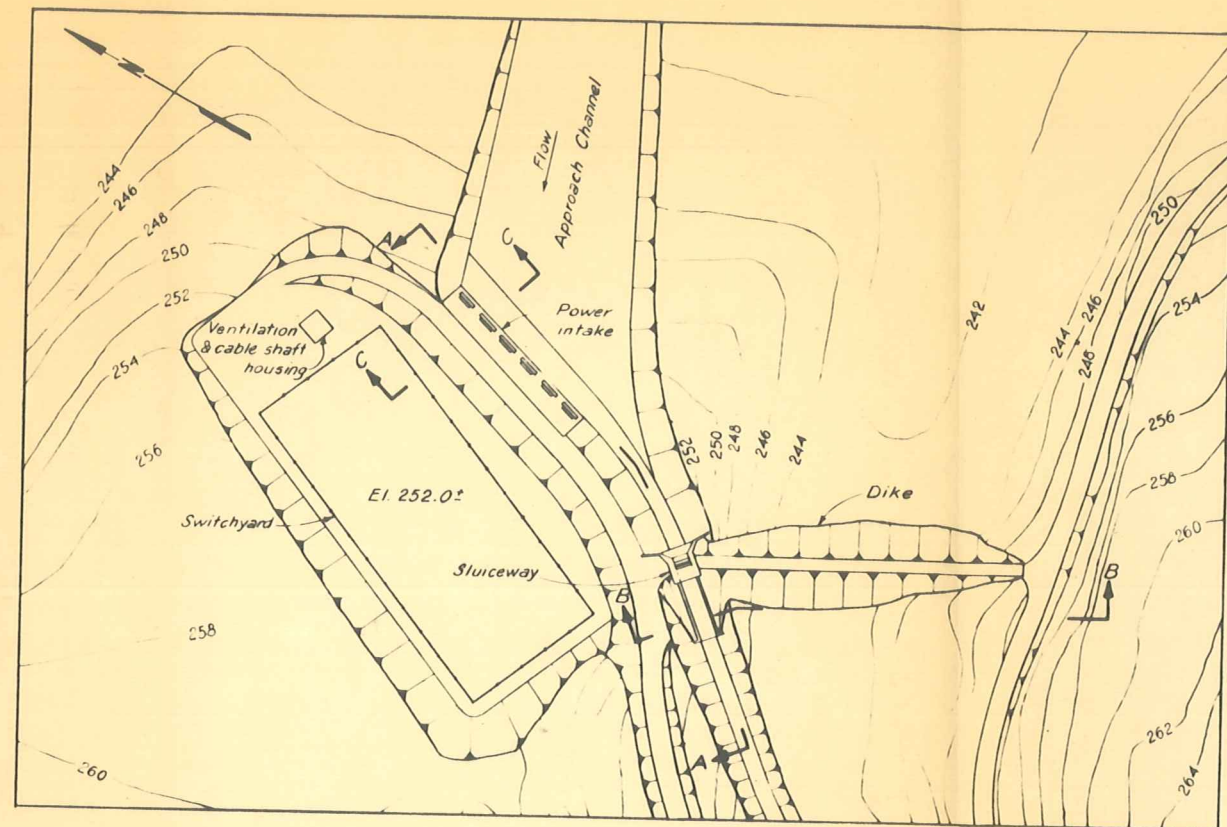
NOTE:
For location of structures see drawings 247P 20 and 247P 21



DATE	NO	DISTRIBUTION
PRINTS		
BY	DATE	CHKD. DATE
DOCK		
DWK	VET.	
DEPT.	GROUP	SECT.
CIVIL	LEADER	HEAD
MECH.		
ELECT.		
PLAN.	AKK	
STAFF		CHENON

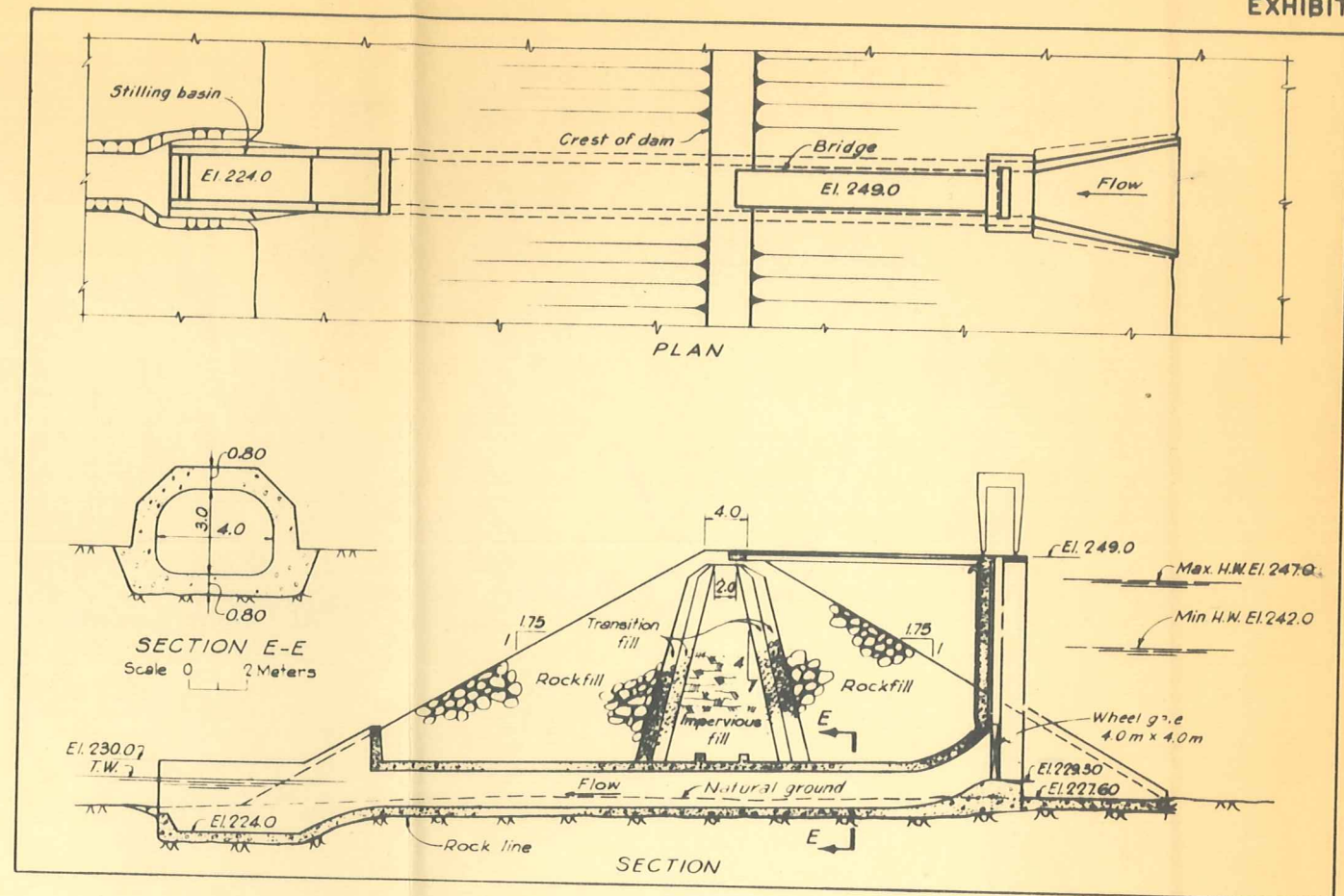
THE STATE ELECTRICITY AUTHORITY ICELAND	
BURFELL PROJECT	UPPER ALTERNATIVE
DIVERSION STRUCTURES	
HARZA ENGINEERING COMPANY	
APPROVED: <i>[Signature]</i>	
CHICAGO, ILLINOIS	DATE: March, 1962
DWG. NO. 247 P 22	

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPR.



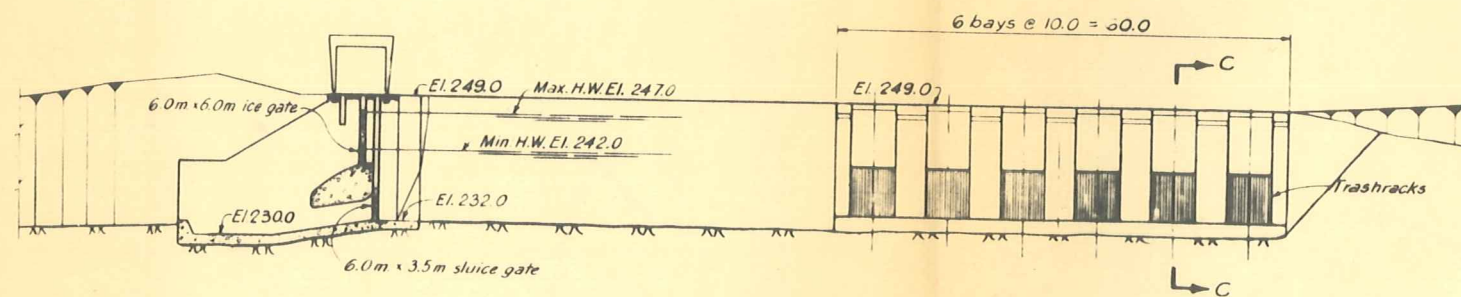
PLAN - POWER INTAKE

Scale 0 20Meters



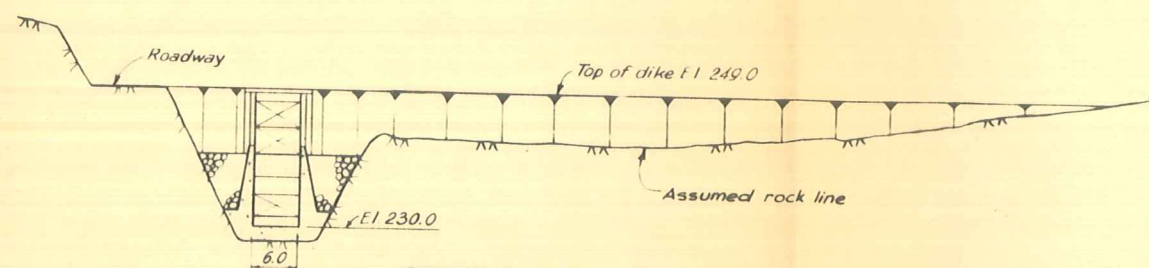
BJARNALAEKUR OUTLET STRUCTURE

Scale 0 5 10 Meters



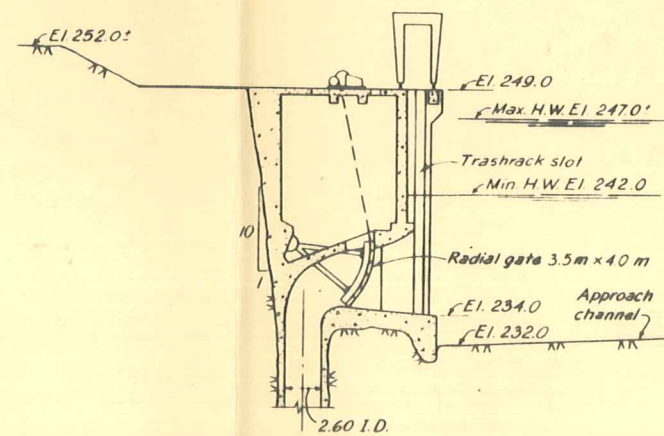
SECTION A-A

Scale 0 10Meters



SECTION B-B

Scale 0 10Meters



SECTION C-C

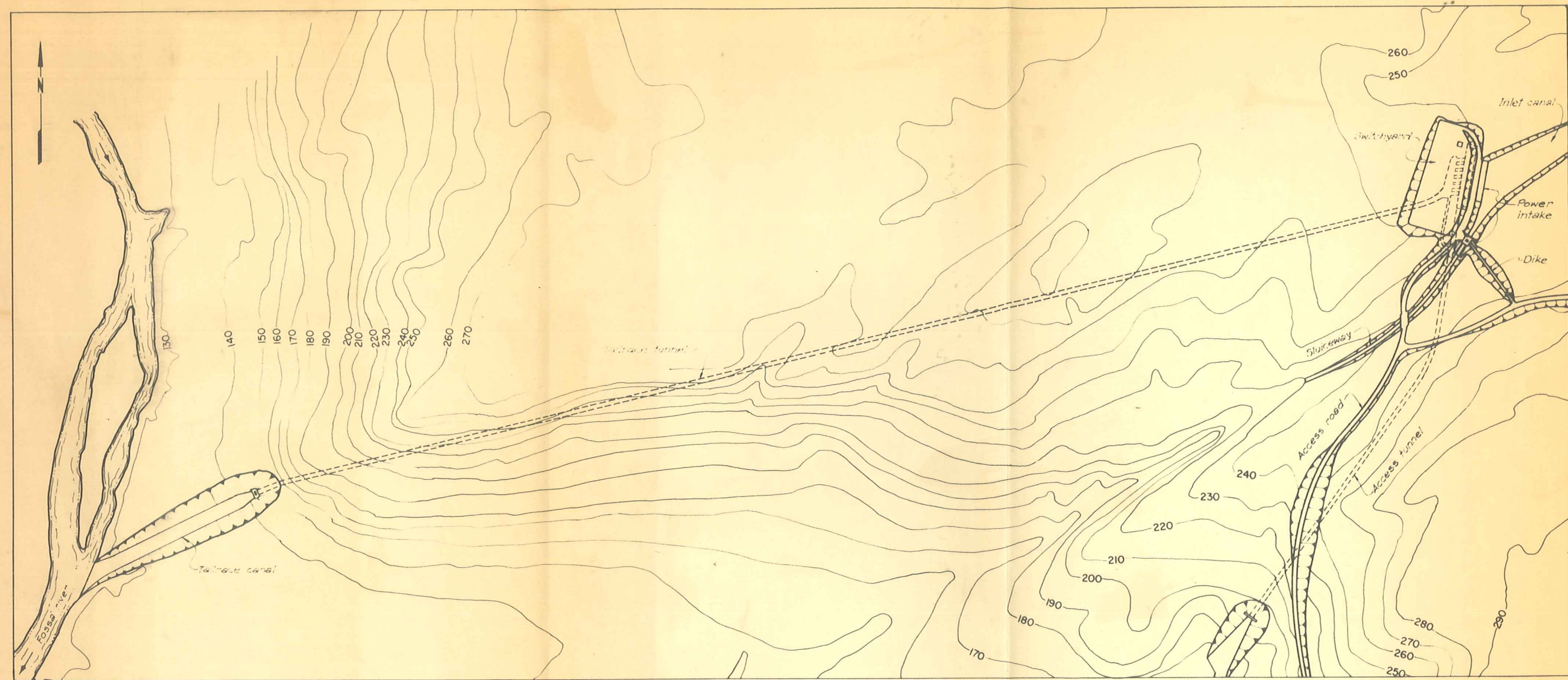
Scale 0 5Meters

NOTE:

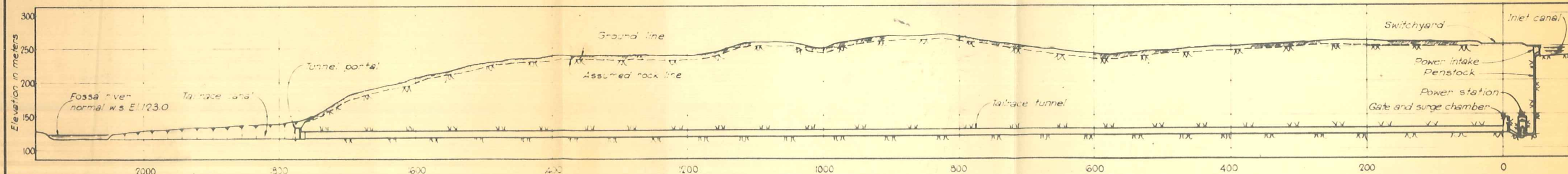
For location of Structures see drawing 247 P 21 and 247 P 23

THE STATE ELECTRICITY AUTHORITY ICELAND	
BURFELL PROJECT	UPPER ALTERNATIVE
POWER INTAKE AND BJARNALAEKUR OUTLET STRUCTURE	
HARZA ENGINEERING COMPANY	
APPROVED: <i>[Signature]</i>	
CHICAGO, ILLINOIS	DATE: March, 1962
DWG. NO.	247 P 24

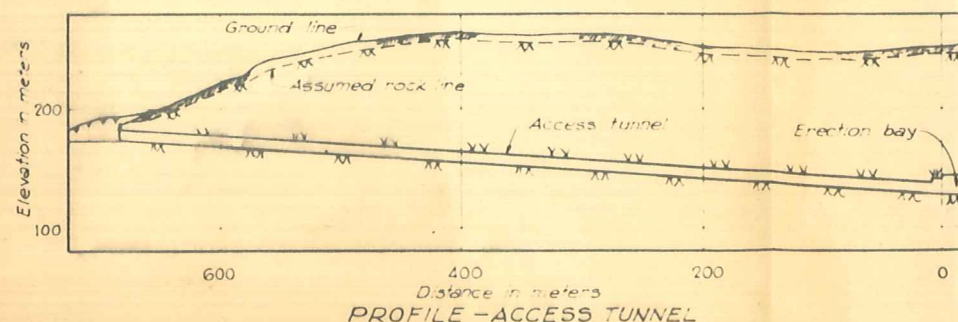
REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.



PLAN
Scale 0 50 100 Meters

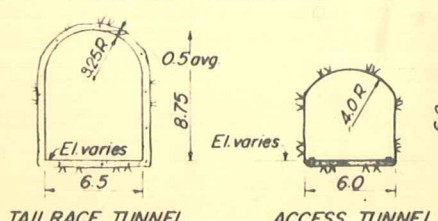


NOTE: For plan of entire project see drawing 247 P 20

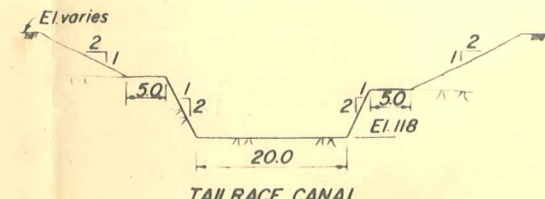


PROFILE - ACCESS TUNNEL

PROFILE - TAILRACE



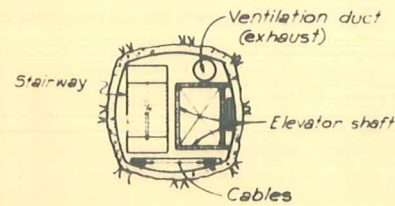
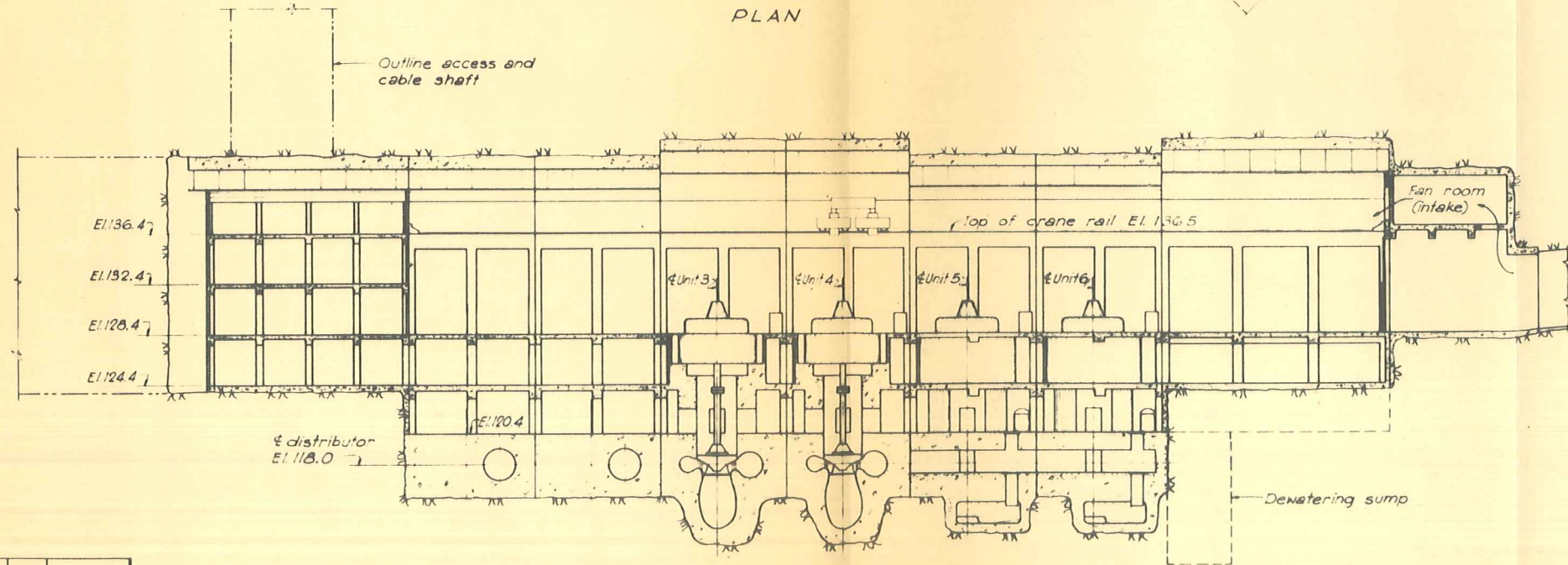
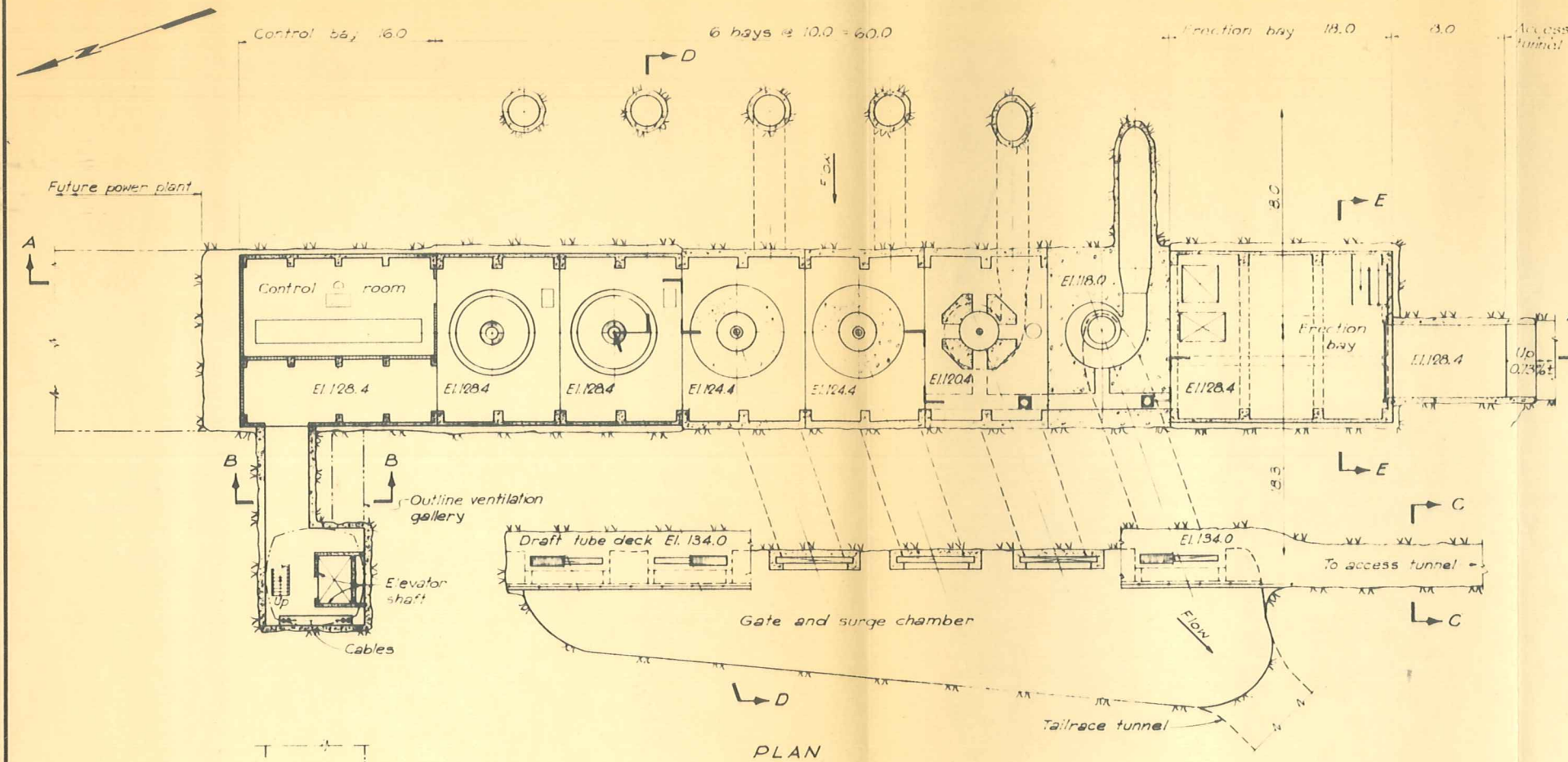
TAILRACE TUNNEL ACCESS TUNNEL
Scale 0 10 Meters



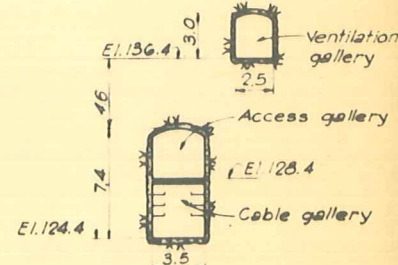
TAILRACE CANAL
Scale 0 20 Meters

PRINTS				
BY	DATE	CHKD.	DATE	
DSGN.				
DWN.	VEY.			
DEPT.	GROUP	SECT.	DEPT.	
	LEADER	HEAD	HEAD	
CIVIL				
MECH.				
ELECT.				
PLAN.		RFE		
STAFF				
				CHEVER

THE STATE ELECTRICITY AUTHORITY ICELAND	
BURFELL PROJECT	UPPER ALTERNATIVE
POWER STATION AND TAILRACE GENERAL LAYOUT	
HARZA ENGINEERING COMPANY	
APPROVED: <i>[Signature]</i>	
CHICAGO, ILLINOIS	DATE: March 1962
	DWG. NO. 247 P 23

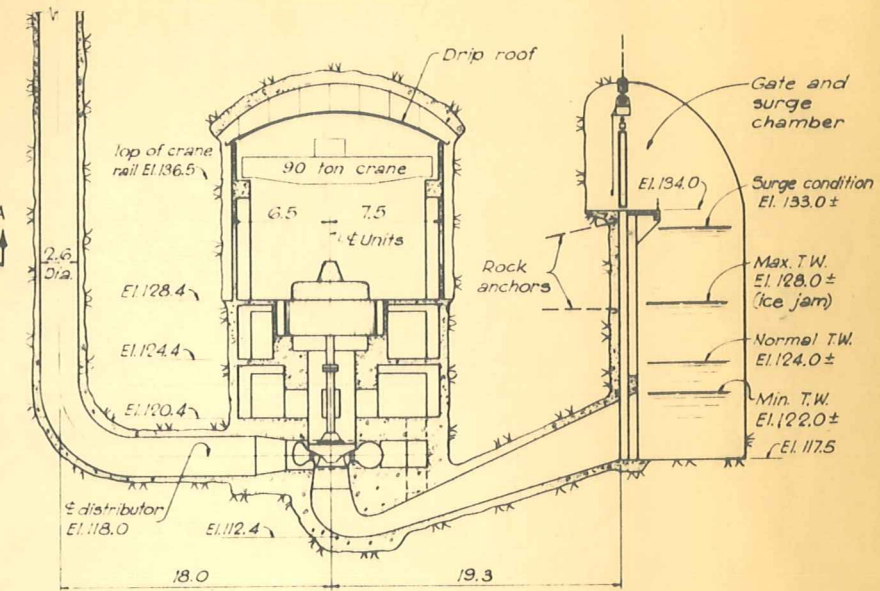


ACCESS AND CABLE SHAFT

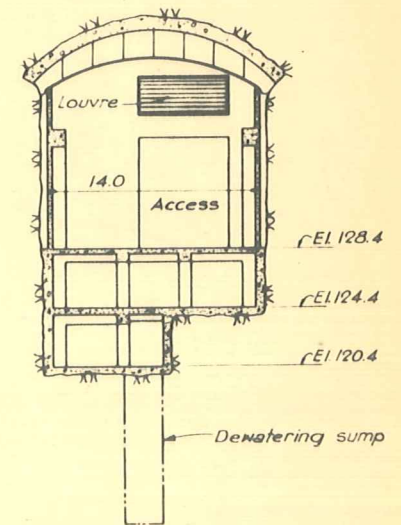


SECTION B-B

SECTION C-C



SECTION D-D



SECTION E-E

Scale 0 5 10 Meters

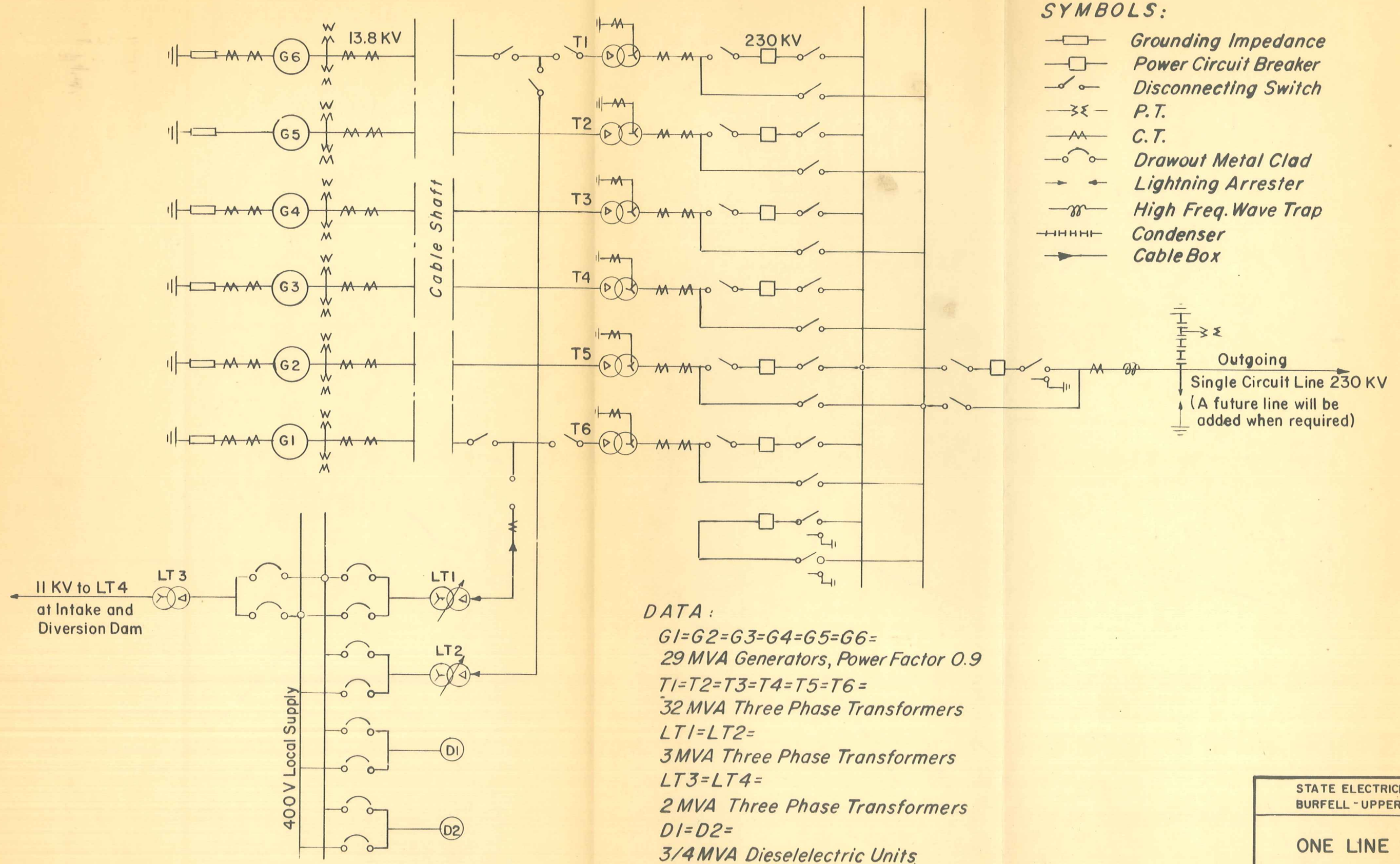
Turbines : Francis - 375 r.p.m.
42,500 Metric Hp @
116 meters net head.
Generators : Rated 29,000 kva -
0.9 power factor.

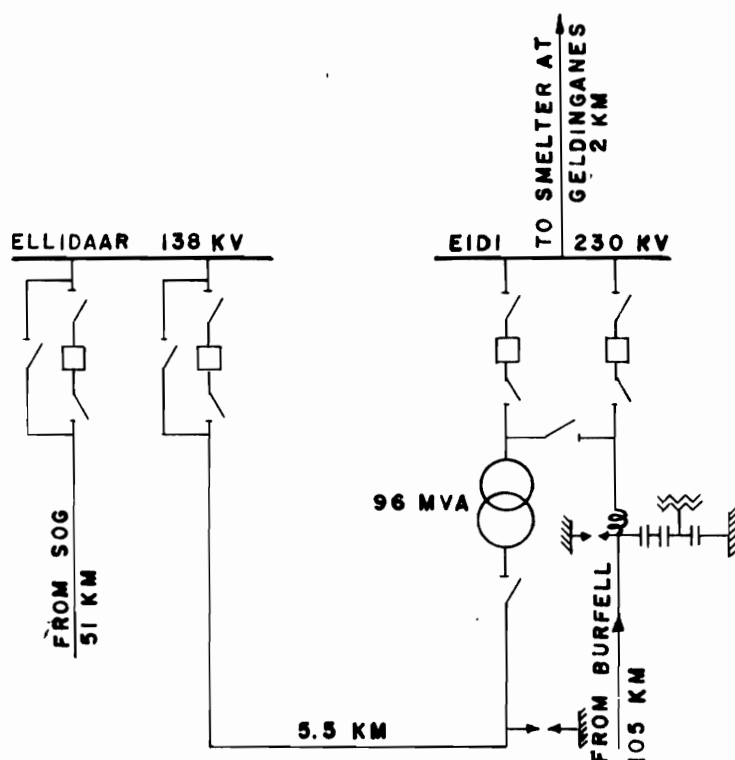
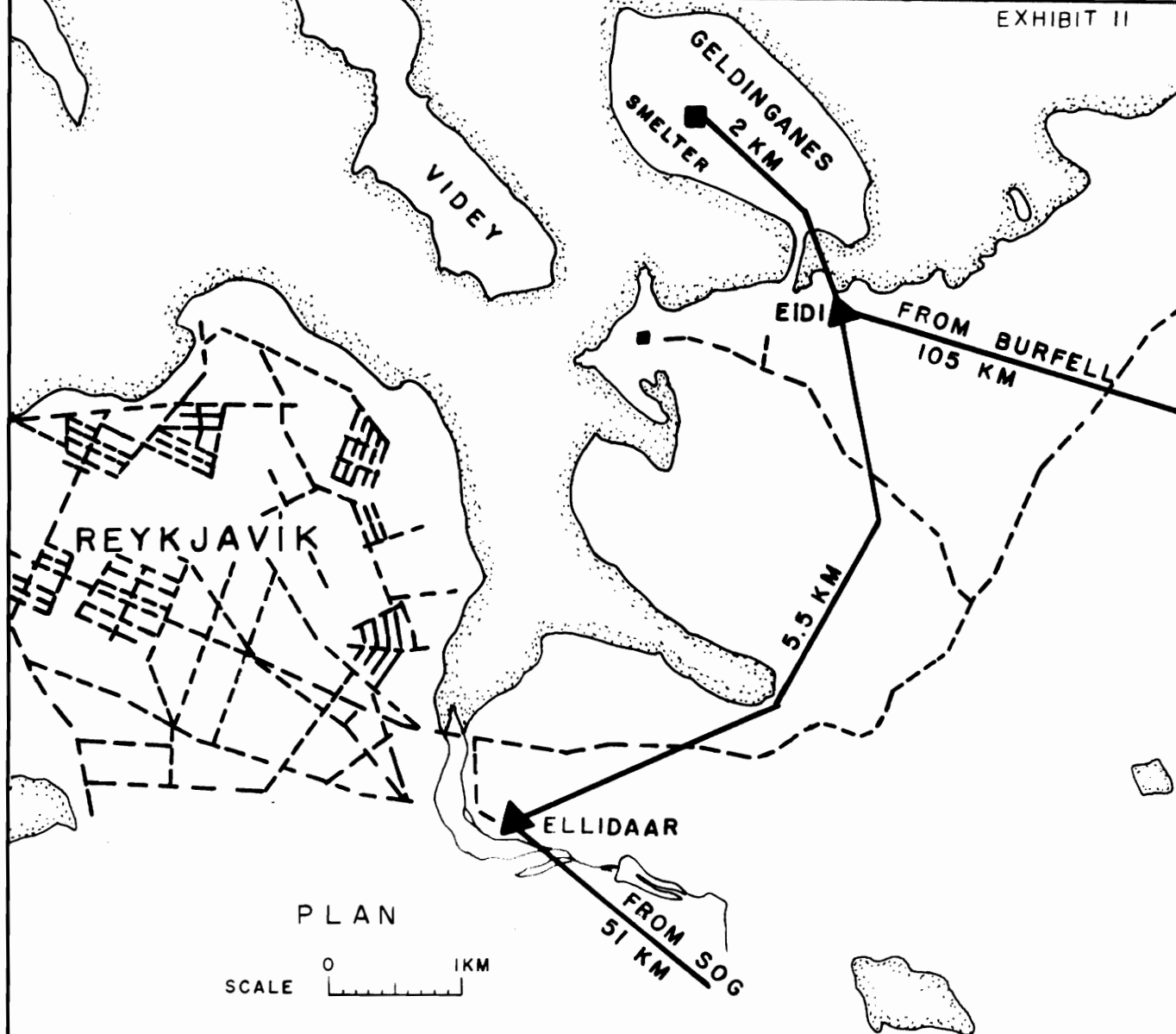
NOTE:
For location of power station
see drawing 247 P 23

DATE	NO	DISTRIBUTION			
PRINTS					
	BY	DATE	CHKD.	DATE	
DGNL					
DWN	G.K. 1/1/62				
DEPT.	GROUP	SECT.	DEPT.		
	LEADER	HEAD	HEAD		
CIVIL					
MECH.					
ELECT					
PLAN		ARE			
STAFF				CHIEF	

THE STATE ELECTRICITY AUTHORITY ICELAND	
BURFELL PROJECT	UPPER ALTERNATIVE
POWER STATION PLAN AND SECTIONS	
HARZA ENGINEERING COMPANY	
APPROVED - <i>[Signature]</i> -----	
CHICAGO, ILLINOIS	DATE March, 1962
	DWS. NO. 247 P 25

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.





ONE LINE DIAGRAM

THE STATE ELECTRIC AUTHORITY ICELAND			
BURFELL PROJECT			
TRANSMISSION TIES AT REYKJAVIK			
HARZA ENGINEERING COMPANY			
APPROVED			
CHICAGO, ILL.	DATE March 1963	DWG. NO.	247 P 35

COST ESTIMATE
SUMMARY .

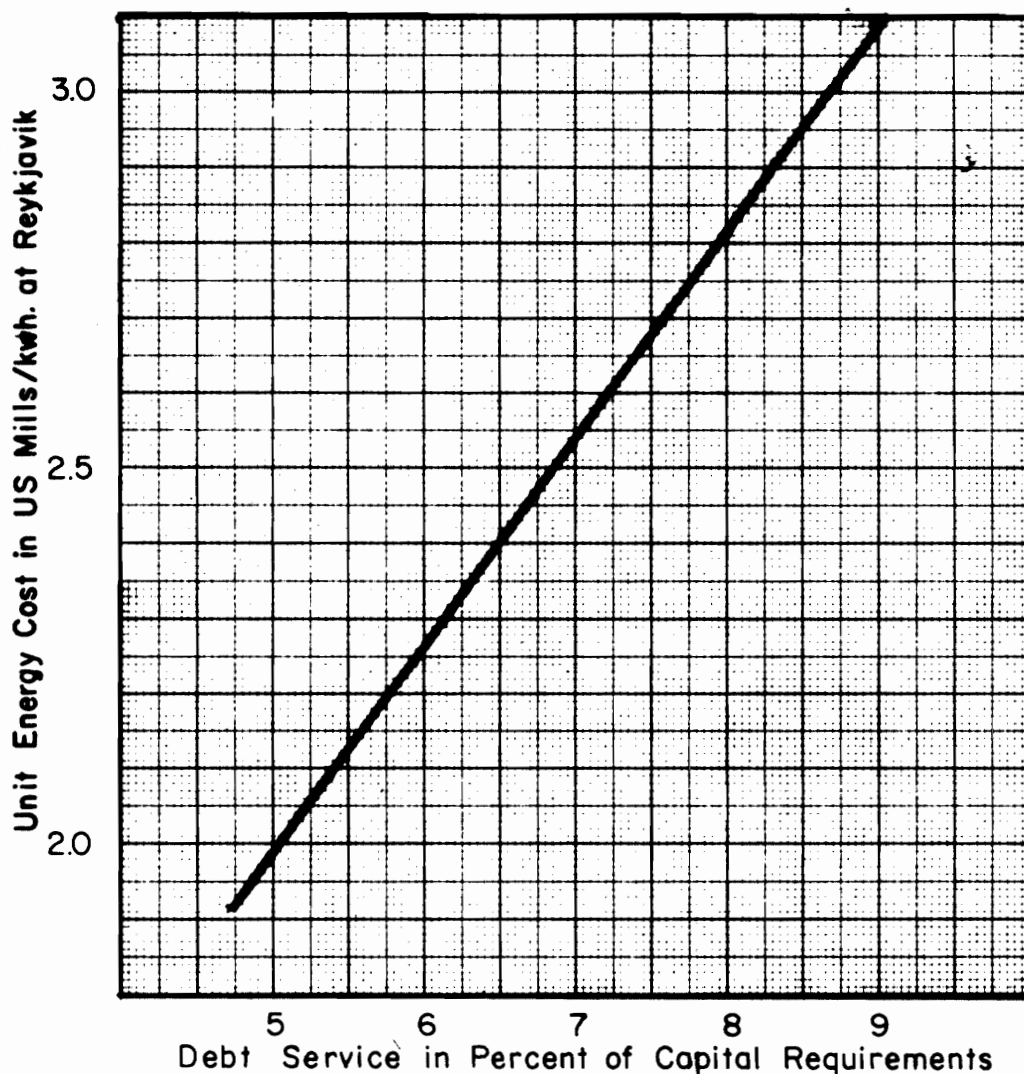
Burfell ProjectUpper Alternative - 6 UnitsProduction Plant

Power Plant Structures	\$	2.744.800
Reservoir, Dams and Waterways		7.207.355
Turbines and Generators		3.360.000
Accessory Electrical Equipment		1.065.000
Miscellaneous Power Plant Equipment		431.000
Roads and Bridges		600.000
Total Production Plant	\$	15.408.155

Transmission Plant

Burfell Substation	\$	1.620.000
Transmission Line (one)		1.602.000
Tie to Sog System in Reykjavik		500.000
Total Transmission Plant	\$	3.722.000

<u>Subtotal Direct Cost</u>	\$	19.130.155
Contingencies 20% <u>±</u>		3.829.845
	\$	22.960.000
Cost Escalation 5% <u>±</u>		1.140.000
<u>Total Direct Cost</u>	\$	24.100.000
Engineering and Supervision 8% <u>±</u>		1.930.000
Preliminary Investigations		500.000
<u>Total Construction Cost</u>	\$	26.530.000
Interest during Construction 10% <u>±</u>		2.650.000
	\$	29.180.000
Working Capital 2% <u>±</u>		580.000
	\$	29.760.000
One Year Interest Reserve		1.910.000
<u>TOTAL CAPITAL REQUIREMENTS</u>	\$	31.670.000



1. Total capital requirements \$31,670,000
2. Annual cost other than debt service \$775,000.
3. No allowance made for income from sales of secondary energy.
4. Import duties and taxes not included.

BURFELL-UPPER ALTERNATIVE

ESTIMATED COST OF
FIRM ENERGY

MARZA ENGINEERING CO. CHICAGO

APPROVED *[Signature]*

DATE March, 1962

DWS.NO. 247 P 26

COST ESTIMATE - SUMMARY
BURFELL PROJECT - UPPER ALTERNATIVE

6 - UNIT PLANT - ULTIMATE CAPACITY 156.000 kw.

Production Plant.

Power Plant Structures	\$ 2,744,800
Reservoir, Dams and Waterways	7,207,355
Turbines and Generators	3,360,000
Accessory Electrical Equipment	1,065,000
Miscellaneous Power Plant Equipment	431,000
Roads and Bridges	600,000
Total Production Plant	\$ 15,408,155

Transmission Plant

Burfell Substation	\$ 1,620,000
Transmission Line (one)	1,602,000
Tie to Sog System in Reykjavik	500,000
Total Transmission Pl.	\$ 3,722,000

<u>Subtotal Direct Cost</u>	\$ 19,130,155
Contingencies 20% <u>±</u>	3,829,845
Subtotal	\$ 22,960,000
Cost Escalation 5% <u>±</u>	1,140,000

<u>Total Direct Cost</u>	\$ 24,100,000
Engineering and Supervision 8% <u>±</u>	1,930,000
Preliminary Investigations	500,000

<u>Total Construction Cost</u>	\$ 26,530,000
Interest during construction 10% <u>±</u>	2,650,000

Subtotal	\$ 29,180,000
Working Capital 2% <u>±</u>	580,000
Subtotal	\$ 29,760,000
One Year Interest Reserve	1,910,000
<u>TOTAL CAPITAL REQUIREMENTS</u>	\$ 31,670,000

COST ESTIMATE - SUMMARY
BURFELL PROJECT - UPPER ALTERNATIVE

5 - UNIT PLANT - ULTIMATE CAPACITY 155,000 kw.

Production Plant

Power Plant Structures	\$	2,695.420
Reservoir, Dams and Water- ways		7,123.715
Turbines and Generators		3,330.000
Accessory Electrical Equip- ment		920.000
Miscellaneous Power Plant Equip- ment		421.000
Roads and Bridges		600.000

Total Production Plant \$ 15,090.135

Transmission Plant

Burfell Substation	\$	1,530.000
Transmission Line (one)		1,602.000
Tie to Sog System in Reykjavik		500.000

Total Transmission Plant \$ 3,632.000

Subtotal Direct Cost \$ 18,722.135

Contingencies 20% \pm 3,747.865

Subtotal \$ 22,470.000
Cost Escalation 5% \pm 1,130.000

Total Direct Cost \$ 23,600.000

Engineering and Supervision 8% \pm 1,900.000
Preliminary Investigations 500.000

Total Construction Cost \$ 26,000.000

Interest during construction 10% \pm 2,600.000

Subtotal \$ 28,600.000

Working Capital 2% \pm 570.000
Subtotal \$ 29,170.000

One Year Interest Reserve 1,880.000

TOTAL CAPITAL REQUIREMENTS \$ 31,050.000

COST ESTIMATE - SUMMARY
 BURFELL PROJECT - UPPER ALTERNATIVE
 INCREMENTAL COST - ONE UNIT

6 - UNIT PLANT - 156.000 kw.

Production Plant

Power Plant Structures	\$ 42.300
Intake	28.400
Penstocks	74.500
Turbines and Generators	560.000
Accessory Electrical Equipment	160.000
Miscellaneous Powerplant Equipment	<u>15.000</u>
Total Production Plant	\$ 880.200

Transmission Plant

Burfell Substation	\$ 230.000
Sog Tie at Reykjavík	<u>80.000</u>
Total Transmission Plant	\$ 310.000

<u>Subtotal Direct Cost</u>	\$ 1.190.200
Contingencies 20% <u>±</u>	<u>249.800</u>
	\$ 1.440.000
Cost Escalation 5% <u>±</u>	<u>70.000</u>
<u>Total Direct Cost</u>	\$ 1.510.000

Engineering and Supervision 8% <u>±</u>	<u>120.000</u>
<u>Total Construction Cost</u>	\$ 1.630.000
Interest during construction 10% <u>±</u>	<u>160.000</u>
Subtotal	\$ 1.790.000
Working Capital 2% <u>±</u>	<u>35.000</u>
Subtotal	\$ 1.825.000
One Year Interest Reserve	<u>115.000</u>
<u>TOTAL CAPITAL REQUIREMENTS</u>	\$ 1.940.000

COST ESTIMATE - SUMMARY
BURFELL PROJECT - UPPER ALTERNATIVE
INCREMENTAL COST - ONE UNIT

5 - UNIT PLANT - 155.000 kw

Production Plant

Power Plant Structures	\$	48.100
Intake		30.850
Penstock		86.500
Turbines and Generators		666.000
Accessory Electrical Equipment		170.000
Miscellaneous Power Plant Equipment		15.000
Total Production Plant	\$	1.016.450

Transmission Plant

Burfell Substation	\$	262.000
Sog Tie at Reykjavík		98.000
Total Transmission Plant	\$	360.000

Subtotal Direct Cost \$ 1.366.450

Contingencies 20% + 273.550

Subtotal \$ 1.640.000

Cost Escalation 5% + 80.000

Total Direct Cost \$ 1.720.000

Engineering and Supervision 8% + 140.000

Total Construction Cost \$ 1.860.000

Interest during construction 10% + 190.000

Subtotal \$ 2.050.000

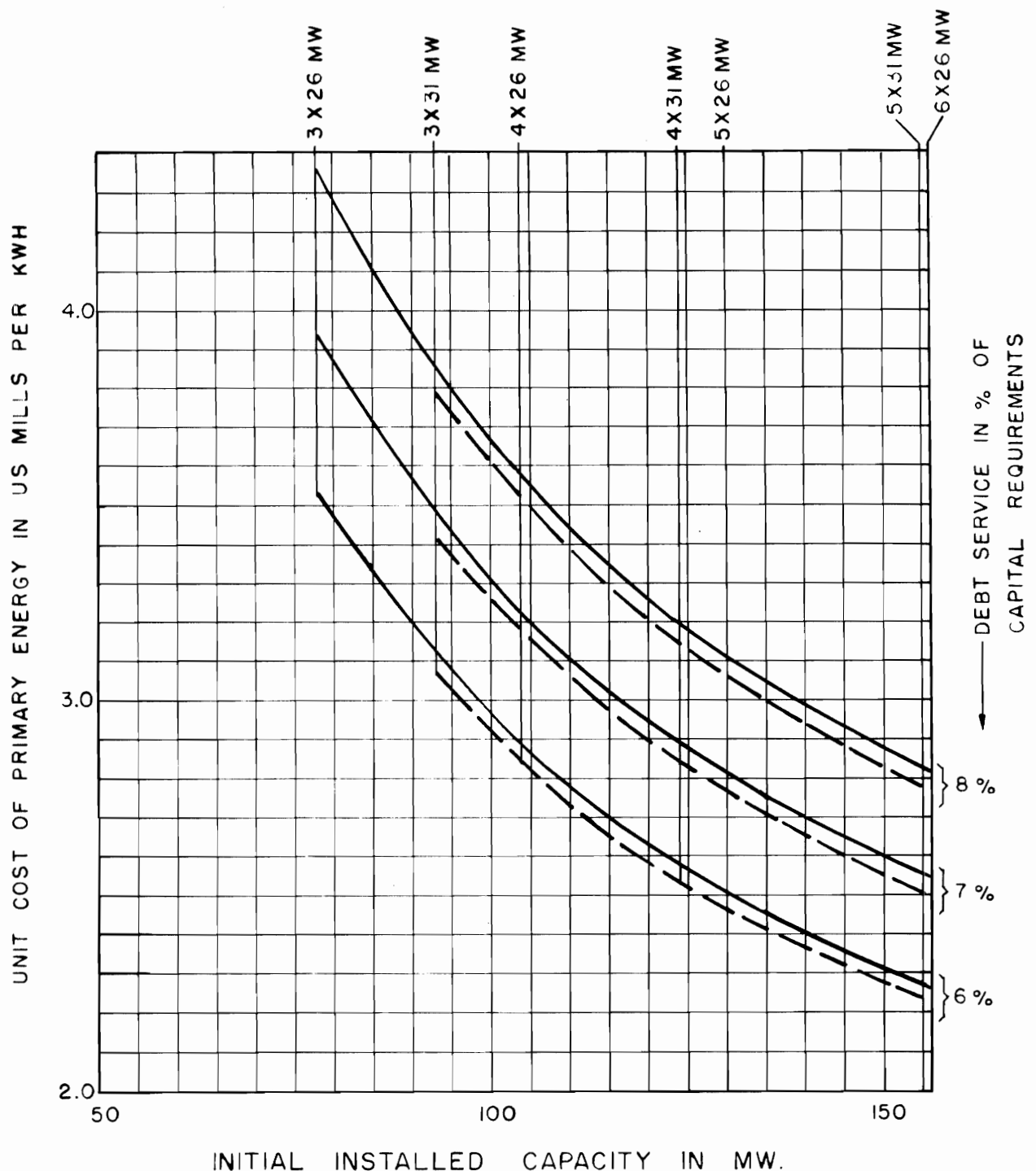
Working Capital 2% + 40.000

Subtotal \$ 2.090.000

One Year Interest Reserve 130.000

TOTAL CAPITAL REQUIREMENTS \$ 2.220.000

NO. & SIZE OF UNITS



LEGEND:

- 6-UNIT PLANT - 156 MW
- 5-UNIT PLANT - 155 MW

NOTES:

1. ENERGY DELIVERED H.T. REYKJAVIK.
2. FIXED CHARGES FOR O&M, WATER RIGHTS AND RESERVES ARE INCLUDED.
3. SECONDARY ENERGY NOT CONSIDERED
4. IMPORT DUTIES & TAXES NOT INCLUDED

THE STATE ELECTRICITY AUTHORITY
ICELAND

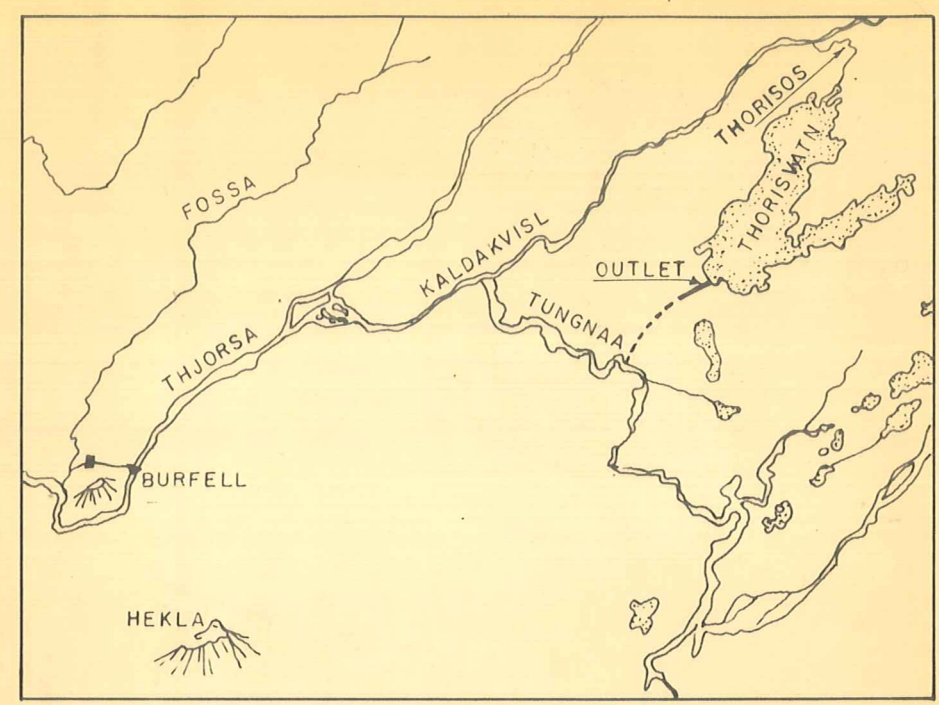
BURFELL PROJECT

COST OF ENERGY

HARZA ENGINEERING COMPANY

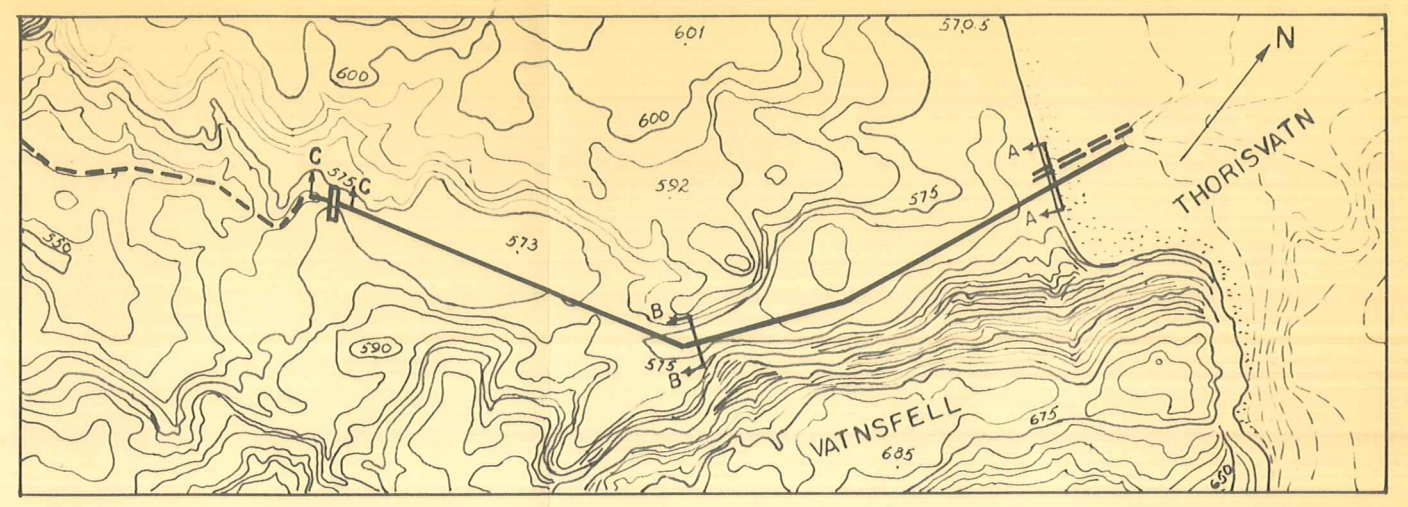
APPROVED *C.K. Williams*

CHICAGO, ILL. DATE March 1962 DWG. NO. 247 P 27



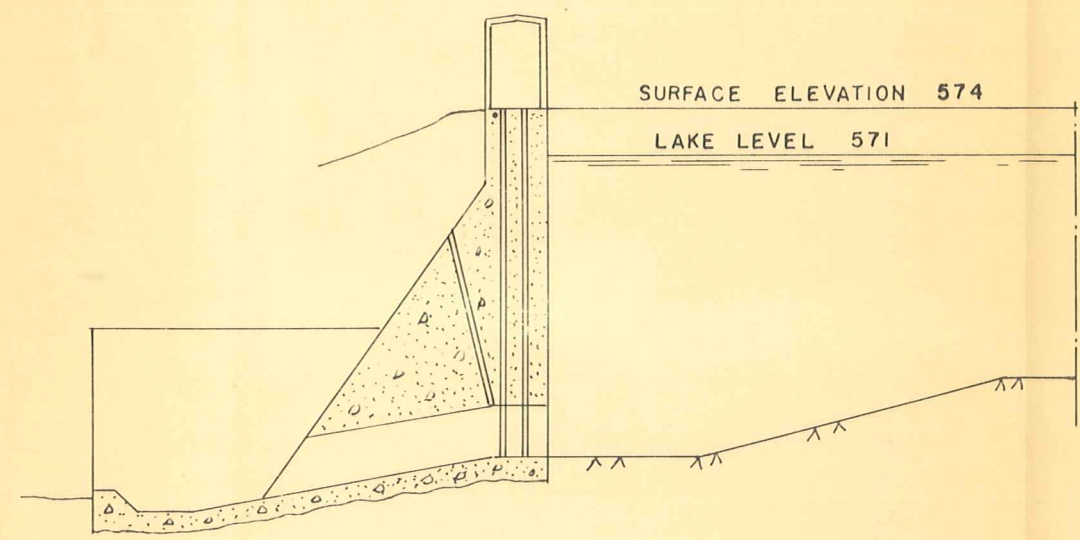
KEY PLAN

SCALE 0 5 KM

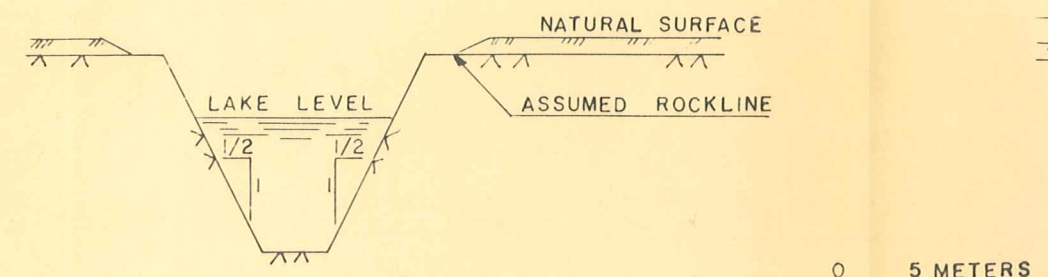


PLAN OF VATNSFELL OUTLET

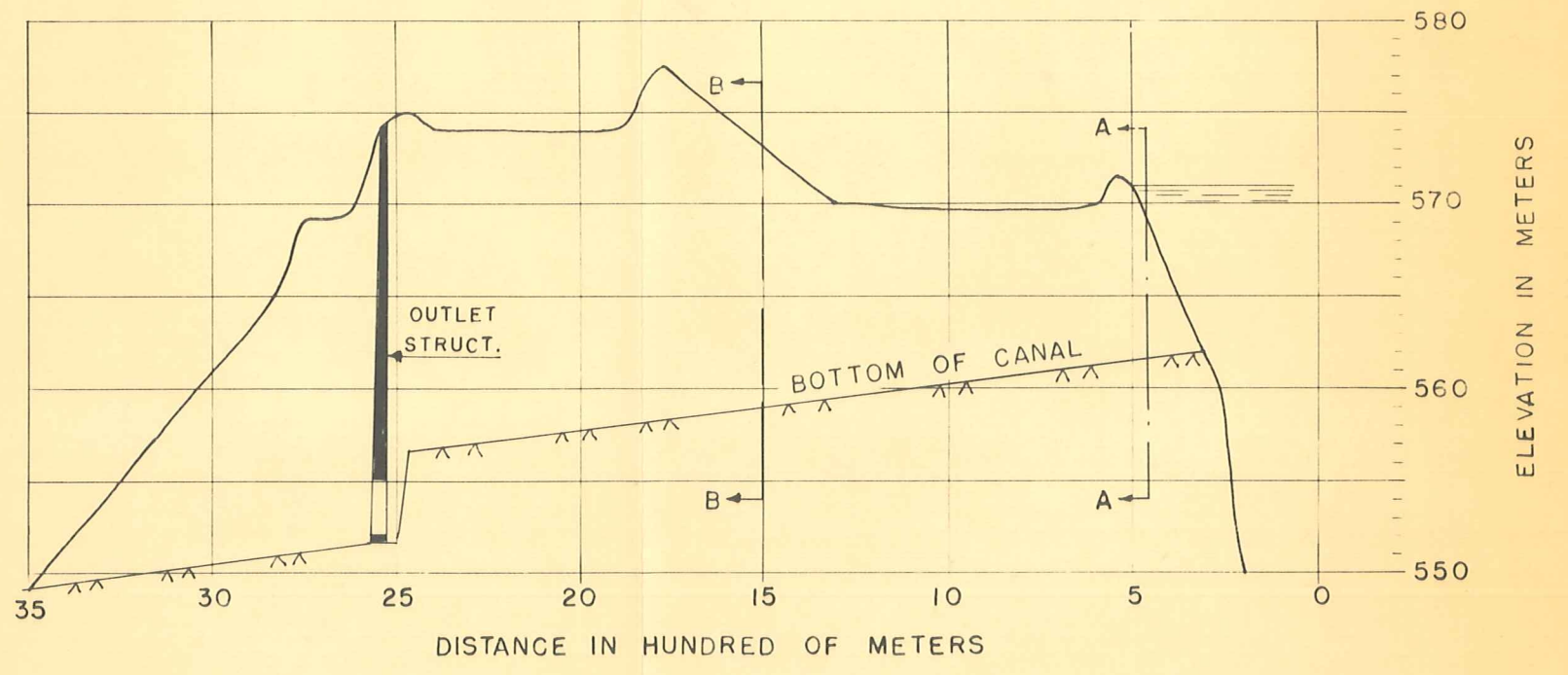
SCALE 0 500 M



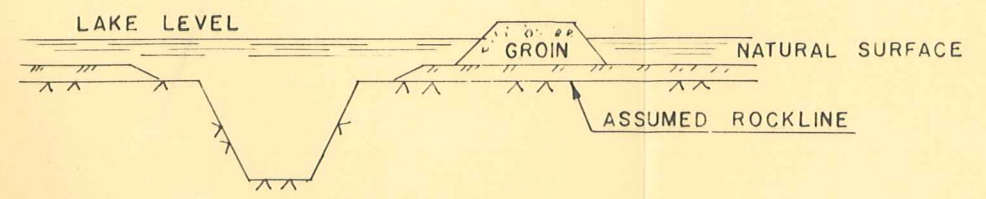
SECTION C-C



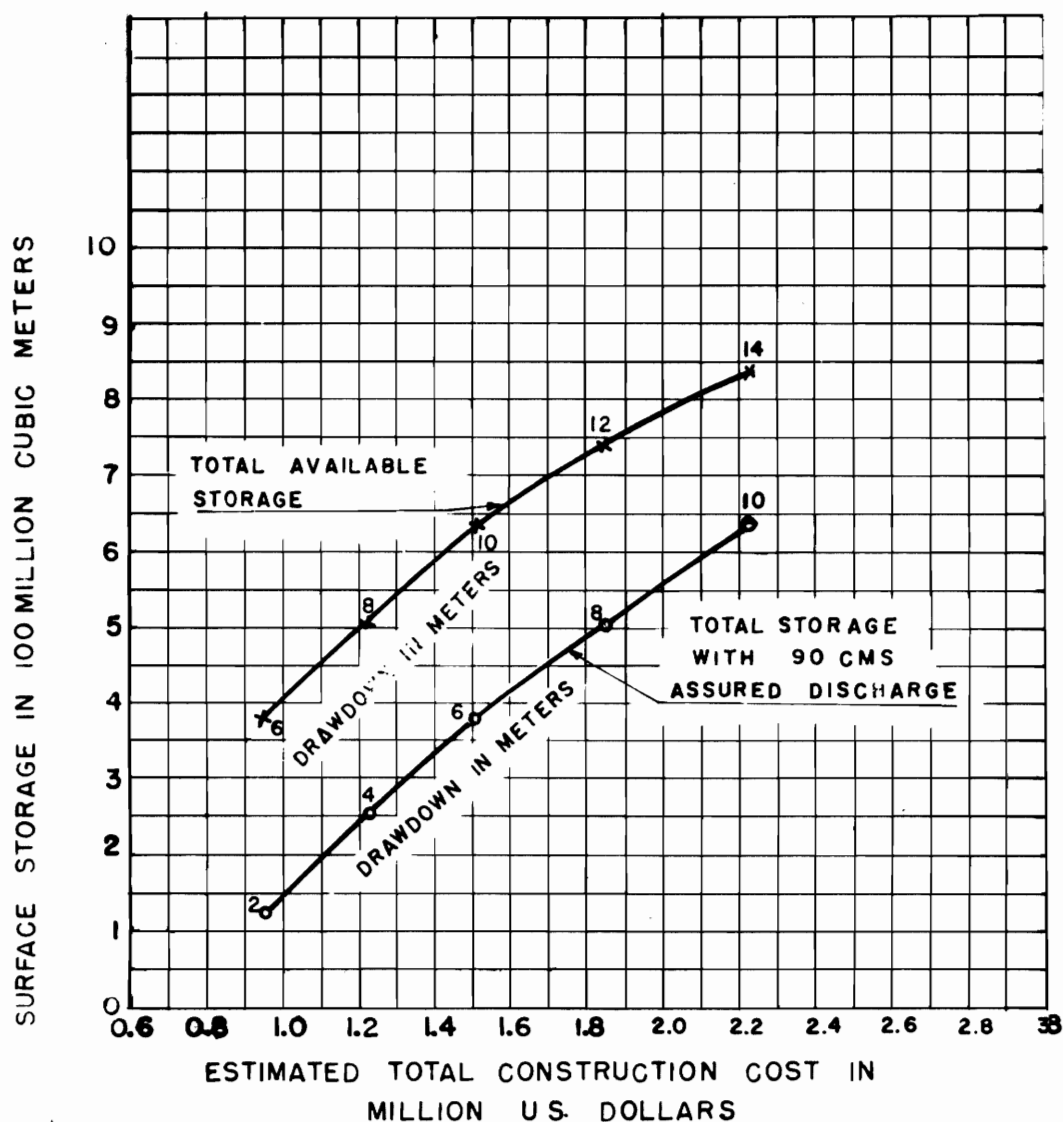
SECTION B-B



SECTION A-A



THE STATE ELECTRIC AUTHORITY ICELAND			
THORISVATN STORAGE			
OUTLET FACILITIES PLAN & SECTIONS			
HARZA ENGINEERING COMPANY APPROVED <i>C. A. Willey</i>			
CHICAGO, ILL	DATE March, 1962	DWG. NO.	247 P 37



1. OUTLET FACILITIES AT VATNSFELL ROUTE
2. INTEREST DURING CONSTRUCTION,
WORKING CAPITAL AND CAPITALIZED
RESERVES NOT INCLUDED
3. IMPORT DUTIES AND TAXES NOT
INCLUDED.

THE STATE ELECTRIC AUTHORITY ICELAND	
LAKE THORISVATN	
ESTIMATED COST OF STORAGE	
HARZA ENGINEERING COMPANY	
APPROVED <i>C. R. Whalley</i>	
CHICAGO, ILL.	DATE <i>March 1962</i> DWG. NO. <i>247 P 37</i>