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United Nations Industrial Development Organization (UNIDO)
Vienna, AUSTRIA

Contract No: 2003/183
Project No: XA/RAF/03/633

Site Selection and Installation of Small Hydropower Equipment in UGANDA & TANZANIA

(ORIGINAL)

FINAL REPORT

Submitted by:
International Network on Small Hydropower

I. Background

Reliable and affordable sources of energy are the pre-requisites for economic and social development. Currently, some 2 billion people, one third of the world's population have no access to electric power. In addition, the major sources of commercial energy in developing countries rely on imported fossil fuels giving rise to both high import bills and environmental problems. Small hydropower potential exists in most developing regions and if this renewable and clean energy resource can be harnessed it could provide economic and environment benefits to developing countries. In China it has been estimated that some 300 million people depend on small hydropower for electric power and that annually there is an increase of about 1,200 small hydro power stations with an installed capacity of around 2 million KW.

Throughout the world, opportunities are abundant for the development of SHP schemes. Thanks to the active role SHP technology has been playing in the supply of rural energy, environment protection and poverty alleviation, the international community is paying more attention to the potential of SHP in developing countries and countries with economies in transition. As a technology with excellent social, economic and environmental benefits, SHP systems have been widely used in rural areas in many countries. As an environmentally sound and affordable energy technology it has become an effective way of stimulating the economy of rural and remote areas.

In Tanzania and Uganda there is great potential for the utilization of small hydropower for decentralized electricity for productive use. The aim is to install one 75 kW unit in Tanzania and one 250 kW unit in Uganda to demonstrate the value of decentralized power generation for improving productivity and employment in rural areas.

The work which has been performed could be summarized as Site Selection, Field Consultation Mission, Designing and preparing the layout of civil works.

II. Site Selection

A. Nyahuka River site in Uganda

We have thoughtfully reviewed the data of the 2 possible sites available for demonstration that have been provided, including the hypsometric curves, the annual flow distribution, hydrology data, head considerations, power potential, the geology and vegetation, etc. Based on the analysis and comparison made by the project team, the site on the Nyahuka River has been selected as the demonstration project with an installed capacity of per unit 250 kW and the potential to be upgraded to 2 x 250 kW once the funding is sourced later.

Here is a brief account of the project parameters:

Design water head	= 238 m
Design discharge	= 0.15m3/s
Design output	= 250 kW

Technical characteristics

1) Intake Area

The proposed intake area is a narrow valley over a stretch of distance and is characterized by rock outcrops of the granite family. The proposed damming area is a narrow gorge with a rock rising vertically on the right side to a height of about 8 m. The rock on the left rises vertically for about 3 m before slanting at an angle of about 50^0 with a thin overburden covering it. The width of the gorge at the 3 metre height mark is about 4 m. A sketch of the cross sectional profile of the dam site is attached. Other possible damming sites can also be identified in the proximity of the described location.

2) Horizontal Canal

The horizontal canal proposed runs on the right side of the river for a distance close to 400 metres winding along the contours of the neighboring hill. The hill is so steep in some parts that it might necessitate the use of some low-pressure pipes. Similarly there is a likelihood of encountering rocky parts or parts with thin overburden where digging the canal might prove cumbersome and would require blasting, building or use of pipes.

3) Fore Bay Area

The area proposed for the fore bay is a relatively flat piece, which might require limited levelling to get an area of about 2,000 m^2 or more. For the length of the canal the altitude would fall by <4 metres.

4) Penstock

The length of the penstock from the fore bay to the powerhouse would be close to 1,000 metres. The penstock would fall sharply at an angle close to 45^0 at the beginning and become very gentle and almost horizontal towards the powerhouse. The river valley at the powerhouse location is wide and relatively flat. Since the fall at that point is gradual, the powerhouse could be shifted for some distance upstream or downstream without losing or gaining a lot of head respectively. The penstock would have to make a few gradual bends along its way.

5) Powerhouse

As described above the river valley downstream is very wide and relatively flat. There is a whole range of suitable locations for the powerhouse. The area proposed for the powerhouse was that one where we attained a head of 160 metres. It is a question of striking a balance between the machine efficiency and cost of penstock.

6) Catchment Area

No attempt has been made to determine the catchment area but this can be estimated from the topographic map attached.

7) Flow Rate

There is no gauging station on the river and therefore no existing measurements of flow and no flow duration figures/curves. By timing a floating object over a definite length of the river section and estimating the cross sectional area of the river we have estimated the flow about 2 m^3/sec. The natives also told us that the river has never run dry even during the dry seasons. The levels however go much higher and at times flood some parts of the valley during heavy rains. The river originates from a snow capped Mountain Rwenzori in the tropics.

8) The Road

The road is navigable up to about one km away from the proposed location of the powerhouse. Beyond that point there are narrow winding footpaths in the mountainsides all the way up to the intake becoming very steep in some parts. We reached the terminus of the navigable part of the road during our tour with the UNIDO mission.

9) Load Centers

The potential load centers are five settlements within the vicinity of the proposed project area in a radius of about 5 kilometers. The loads include domestic, commercial and institutional set-ups. The majority of loads are of single-phase nature. In circumstances where three phase loads will emerge, special consideration may be given. The nominal capacity of 250 kW can suffice for a start and may be up rated gradually with load growth. The proposed load centers include the following settlements of: Kabutabule, Butaama, Kakuka,.Busunga and Bunyangule.

Accordingly, the most cost-effective equipment for the site parameters identified above has been selected as follows:

Project Tech Parameters	Equipment	Specifications
Nyahuka H=238 m Q=0.15m3/s N=250 kW HZ=50 Voltage: 415v	Turbine	CJ22-w-55/1x 5.5 Impulse Turbine, Horizontal shaft; Nominal diameter of runner: 55cm; Number of nozzle: 1; Diameter of jet: 5.5 cm
	Generator	SFW250-6P/740 Output: 250 kW
	Excitation System	"Three in One" Control Panel plus Excitation System
	Governor	D.S.T-300 (manual\auto)
	Valve	Z941H-25DY ф 250 Valve diameter: 250mm

B. Muse River site in Tanzania

The 6 selected sites with potential for micro hydropower generation in Tanzania listed by UNIDO Representative in Tanzania have been carefully assessed and evaluated. According to the calculation of the technical parameters of each site, the Muse River project, with technical and financial advantages outweighing others, has been selected to be the most suitable for project demonstration.

Muse River has its origins on the plateau north-west of Sumbawanga and flows eastwards down the escarpment, where it drops several hundred meters. In the escarpment there are two steep falls, 200 and 80 meters respectively, which could be developed for hydro power. The River flows onto the plain at Muse Village.

Access to the River is possible from the Sumbawanga/Muse road. From this road it is possible to reach the river at a number of places.

The area near the river is populated down on the plain of Rukwa Valley, and irrigation is obviously of a great interest, in addition to common facilities such as grain grinding and lighting to homes.

Here is a brief account of the demonstration site details:
Design water head = 80 m
Design Discharge = 0.14m3/s
Output = 84 kW

Similarly, the most cost-effective equipment for the site parameters identified above has also been selected as follows:

Project Tech Parameters	Equipment	Specifications
Muse River H=80 m Q=0.14m3/s N=84 kW Hz=50 Voltage: 415V	Turbine	XJ_A-W-32/1x7 Turgo Turbine, Horizontal shaft Nominal diameter of runner: 32cm; Number of nozzle: 1; Diameter of jet: 7cm
	Generator	SFW75-6P/493 0.415kV Output: 75 kW
	Excitation System	"Three in One" Control Panel plus Excitation System
	Governor	D.S.T-300 (manual/auto)
	Valve	Z941T-10DY Φ 250 Valve diameter: 250mm

The preliminary selection of the site has been reassessed and confirmed during the field visit conducted consequently.

III. Consultation Mission

A. Mission Objectives

The objectives of this mission were to:

1. Conduct field visit to the preliminary selected sites, one (250 kW) on Nyahuka River in Bundibugyo District of Uganda and one (80 kW) on Muse River in northwest of Sumbawanga of Tanzania
2. Assert technical and financial viability of two proposed small/mini/micro hydro demonstration projects in Nyahuka and Muse River Basin
3. Collect first hand data and information on civil works designing
4. Provide on-site guidance and consultation on establishing a SHP unit
5. Hold discussions with relevant agencies on construction of civil works
6. Visit and discuss future collaborations with the local partners

B. Members of the Experts Mission

The first mission team from IN-SHP constituted of following officials:

1. Prof. Tong Jiandong, Director-General, International Network on Small Hydro Power (IN-SHP), Hangzhou, China
2. Prof. V. K. Damodaran, MD, IN-SHP, Hangzhou, China
3. Prof. Li Zhiming, Chief Engineer, IN-SHP, Hangzhou, China

C. Site Visits:

On 11th Dec 2003, the consultation team arrived Entebbe/Kampala, Uganda at 19:30 hrs. The team inspected 3 sites on the rivers in Bundibugyo District, Uganda.

Bundibugyo is located in the extreme west of the country towards the border with Zaire. It is 400 km from Kampala, the capital of Uganda taking the Kampala-Mubende-Fort Portal-Bundibugyo route.

The township and areas around lack electric power, which is a critical ingredient for socio-economic development. It has been widely acknowledged that the provision of a hydroelectric plant harnessing the available water resources would greatly enhance the development of the areas and meet the existing and potential demand.

The geology of this area is classified under the Buganda-Toro rock system. This is the most extensive of the cover formations and occupies much of the south-central and westerly parts of Uganda. The vegetation is typically equatorial grasslands, shrubs, mini forest, a variety of creeping plants and group crops cover most parts of the lands.

Bwamba country in Bundibugyo district has a population of 120,000 people. Taking into account all the areas around the proposed sites, a total of 400,000 people, is a good estimate. The people in Bundibugyo have been clustered together in protected villages. It is unlikely that they will move back to their villages, because they have been provided with services like water supply and sanitation. This has led to urbanization too and provides a strong case for electric power supply. The domestic demand is therefore high for this setting. Agriculture takes place nearby and associated activities like agro-processing and produce merchandising require power. There is also great potential demand in the health, administrative and educational sectors.

The site selection has been conducted based on the following criteria, mainly:

1) Suitable water head 50 m-100 m
2) Required diversion channel length
3) Required penstock length to be less than 40 m
4) The slope of the location of the powerhouse not to be more than 20 degree
5) The availability of the ram material locally
6) Promote local development
7) Simple technology and local maintenance
8) Joint UNIDO- Government budget

After the first site was decided to be changed by local government in view of future grid extension plans in the region, an alternative site was proposed and the second consultation mission was conducted from 17-23 September 2004 to evaluate the site. Three officials from ICSHP were assigned to undertake the mission, namely Mr. WANG Yansong, Mr. YUAN Peisheng and Mr. DENG Simao.

The proposed site for SHP pilot project is at the foot of Rwenzori Mountains. It takes 7 hours drive from Kampala to the town nearest to the village. The road that vehicle can access ends about 4 km before the weir site and about 1.5 km before the powerhouse site.

This SHP site is located at a heavily forested area. There are also some plantations and houses along the channel route. There is no road leading to the site and so, the transportation facility for project construction is very poor. Moreover, the mountain slope is very steep and the earth layer is loose, which will aggravate the difficulties in project construction. A gross head of 250 m is available.

There are about 17,300 people living in 5 villages around the project area, who can benefit by electricity from this project. The farthest one is about 12 km away from the powerhouse. There is no electricity supply in this area right now. However, government has a plan to have power grid extension to this project area also in future.

The catchment area for the weir site is about 32 km^2. The runoff in the river comes from two sources: the snow thawing and rainfall. The current flow in the river is about 0.7~0.8 m^3/s which will decrease to about one half during dry season.

The evaluation of the site

A previous mission prepared the rough layout of the project. The present mission followed the proposed canal route up to the weir site. The selection of the main structures is basically reasonable. However, we suggest that further investigation be done on the following three issues:

1) The weir site: The earlier suggested weir site will leave very limited space for accommodating the intake and sluice gate. The storage of the pond will also be very small. Moreover, the chance of bypass leakage of the weir abutment is quite big, since fractures are observed on the rock on both sides and there will be no easy remedies for stopping this leakage. To this end, we suggest that an alternative weir site should be investigated for

comparison. About 50 metres downstream from the current site, an alternate weir site is identified and informed to the MoME engineer who accompanied this mission.

2) The canal route: An aquaduct is suggested for very steep, rocky areas where excavation will be very difficult. Adopting an aqueduct will minimize the excavation.
3) The fore bay: The fore bay area seems to be a now settled, landslide area. The stability of the fore bay foundation needs to be further studied.

The installed capacity

This site is initially proposed for 250 kW, and later considered for a 500 kW SHP project. But the flow available in the river is enough for a larger capacity. Given the catchment area and the rainfall above the weir site, it is suggested that 1000 kW should be installed. Although the total investment for 500 kW scheme will be lower, the per kW investment will be much higher, since no matter how small the installed capacity is, the investment for civil construction & penstock will not come down in proportion with the capacity. A larger capacity will definitely have more commercial value.

The investment

It is noticed that the material and transportation costs in the project area are very high, which directly contribute to the high cost of this project. The total investment of the 1000 kW scheme will be US$ 2.77 million (including equipment cost of another 3 sets of 250 kW unit) and that for a 500 kW scheme will be US$ 2.48 million (including equipment cost of another 250 kW unit). Per kWh investment will be about US$ 0.554 for 1000 kW scheme and US$ 0.71for 500 kW scheme. The breakdown of the total investment for 500 kW scheme is attached herewith. In Uganda, the power generation and distribution has already been privatized with the power transmission of higher than 33 kV only being controlled by government. So, it is important to find a commercial partner to develop and run this project. According to MoME, the tariff for the electricity from this project can be as high as US$ 0.10/kWh (the subsidy from the government also considered). If this tariff can be guaranteed, then the commercial value of the 1000 kW scheme is very obvious.

IV. Homework of Designing and layout of Civil Works

The layout and design of the powerhouse have been finished and attached as Appendix A & B for the Tanzania and Uganda projects.

The detailed design drawing of the turbine, generator, and control panel have been attached as Appendix C and will facilitate the civil work and the installation in later stages as well.

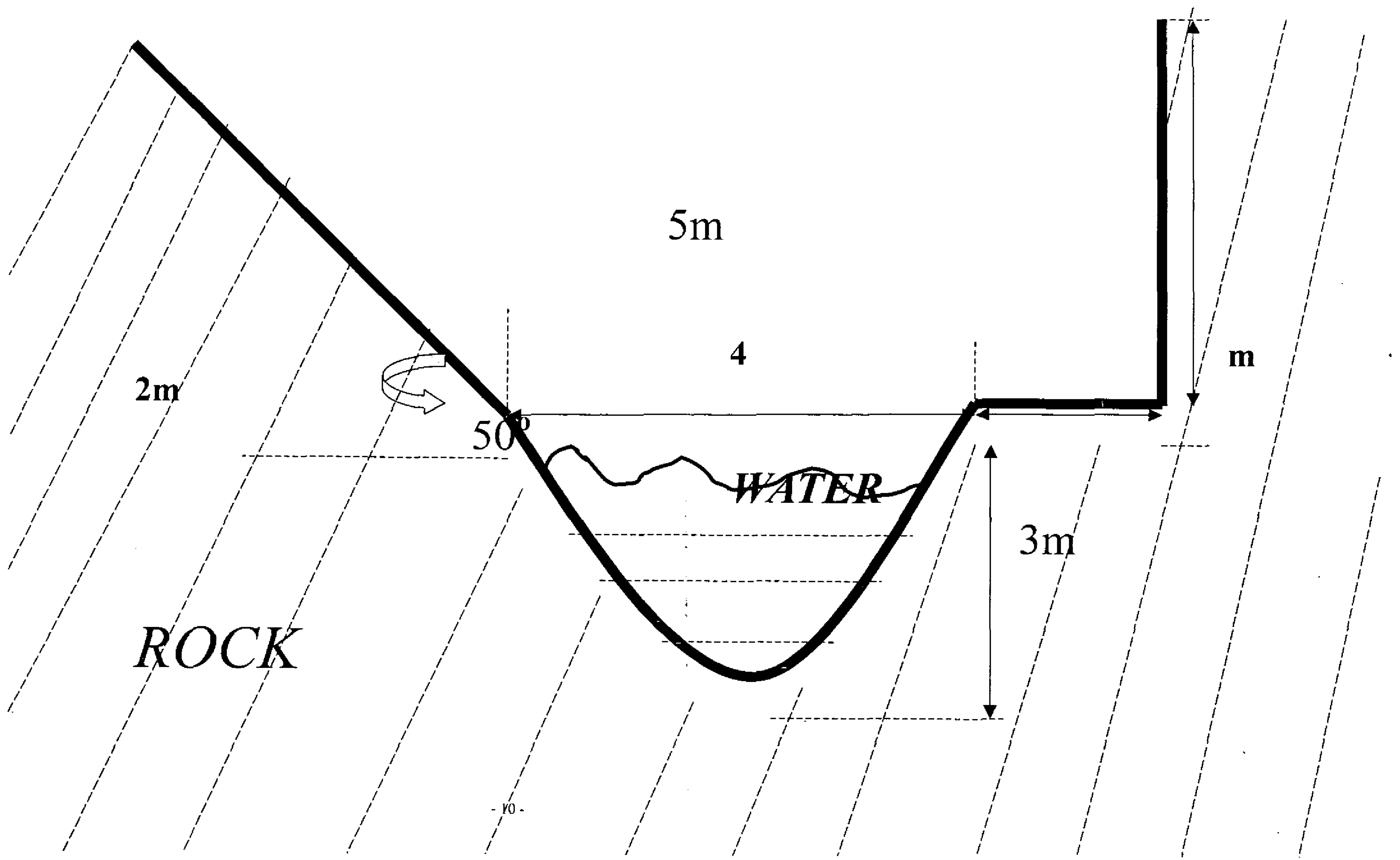
V. Equipment Supply

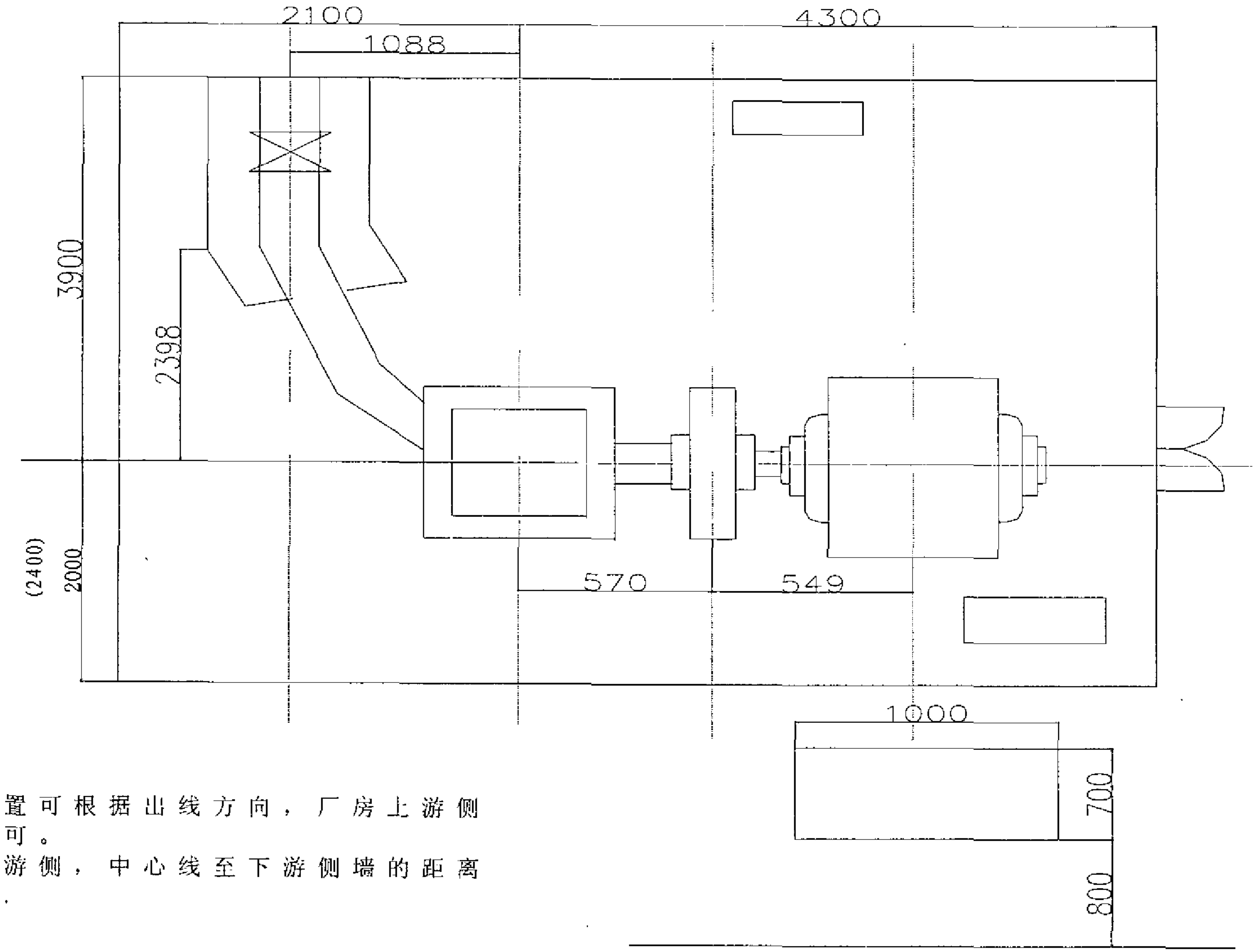
After the site visit in 2003, the equipment under UNIDO Purchase Order No: 15000505 B/15000508B for Project: XA/RAF03/633 was shipped from Shanghai Port, China on 9th December 2003 by vessel DELMAS CHARCOT V.406W. And it reached Dar es Salaam on January 2004 for further transportation to Kampala.

Appendix:

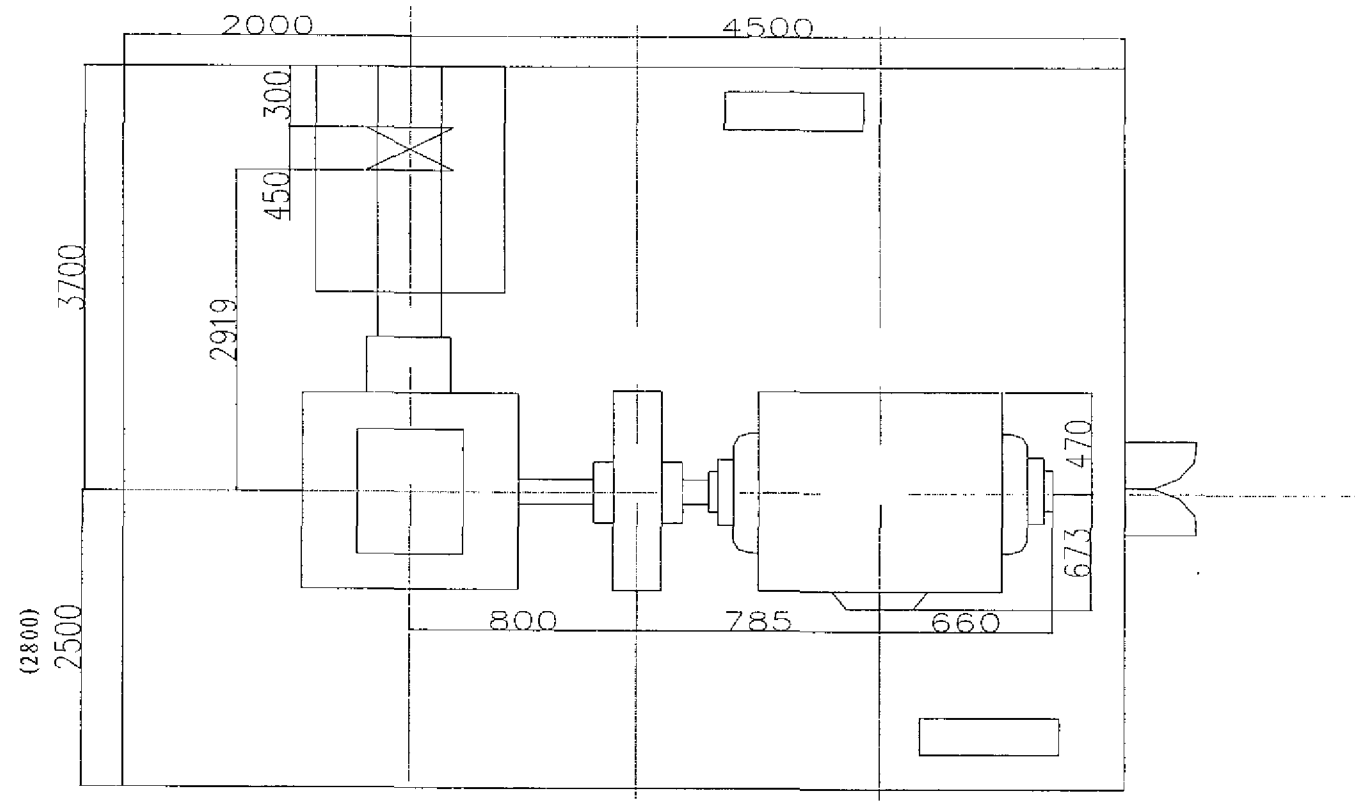
A. Profile of Dam site in Uganda
B. Powerhouse Design of Tanzania SHP Demo Project 1 x 75kw
C. Powerhouse Design of Uganda SHP Demo Project 1 x 250kw
D. Design Drawings for 500 kW Scheme-Uganda
E. Design Drawing for 1000 kW-Uganda

PROFILE OF DAM SITE in Uganda



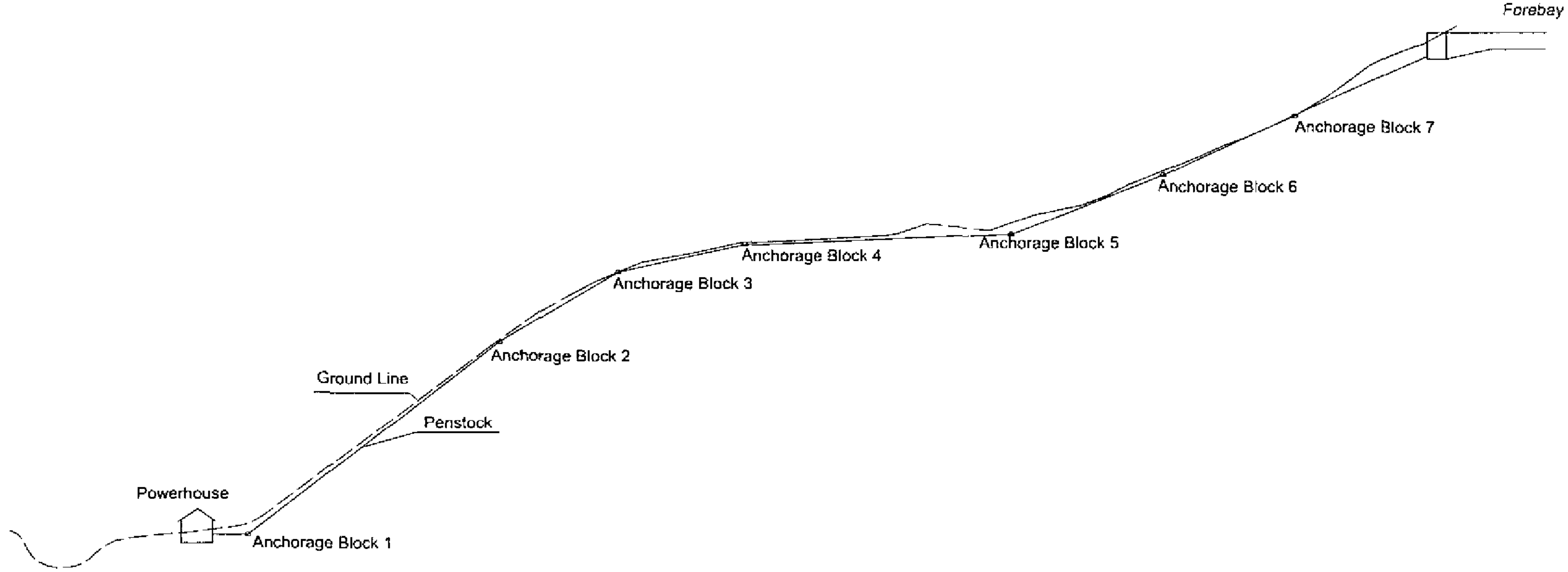


控制柜的布置可根据出线方向，厂房上游侧和下游侧均可。
若分布在下游侧，中心线至下游侧墙的距离应为2400mm.

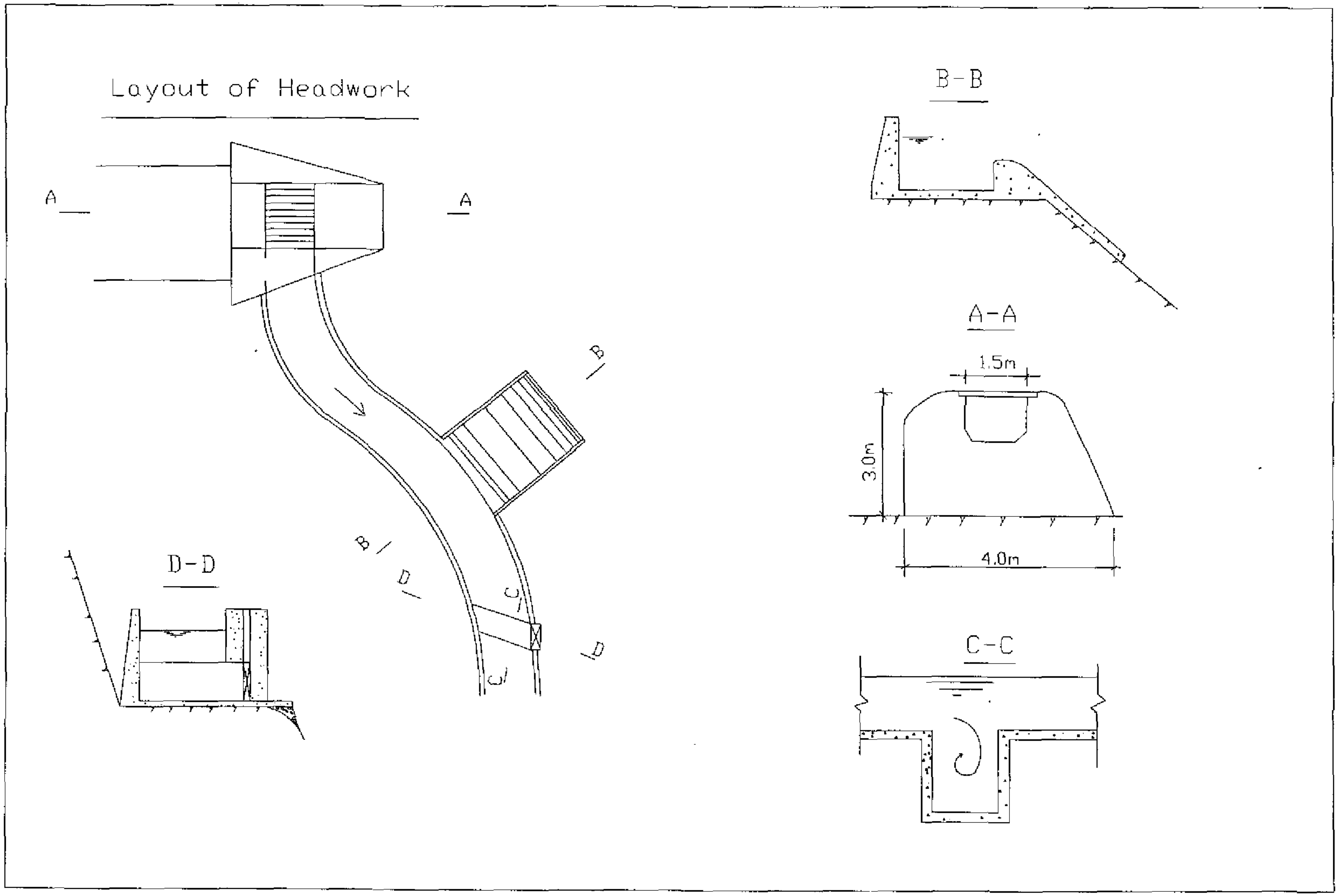


控制柜的布置根据出线方向，可布置在上游侧或下游侧。

若布置在下游侧，中心线至下游侧墙的距离应为2800mm.



The Longitudinal Section of The Penstock


Layout of Headwork
A
A
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1.5m
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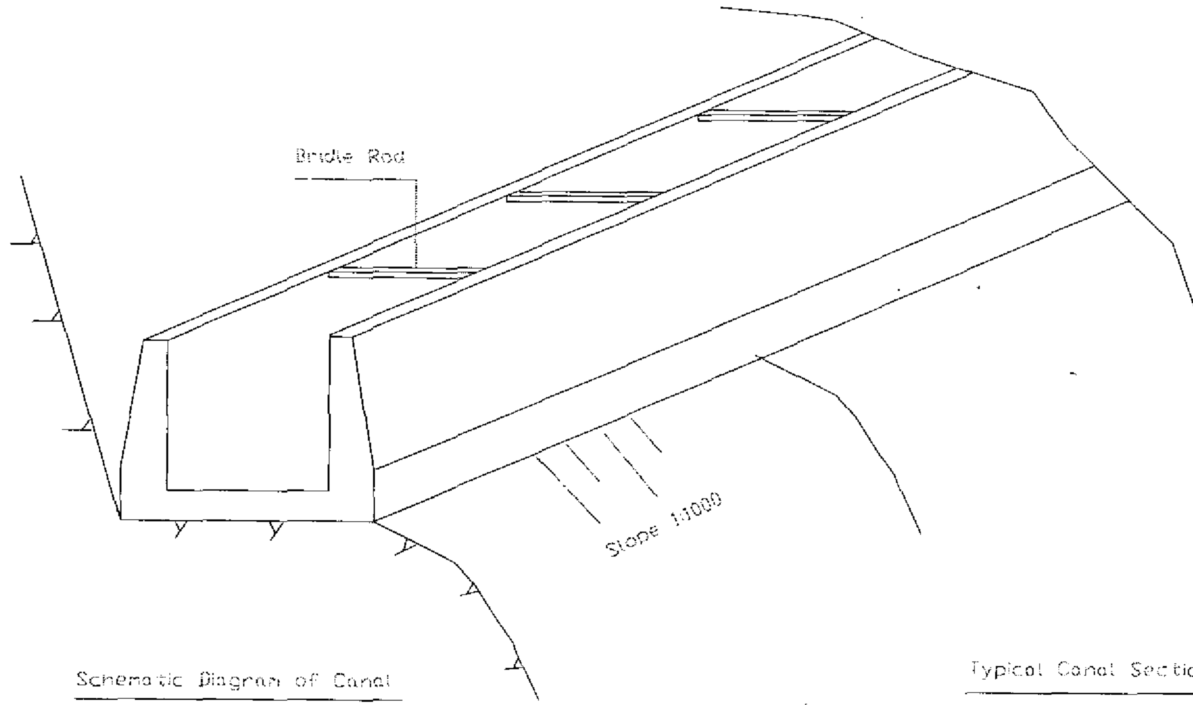
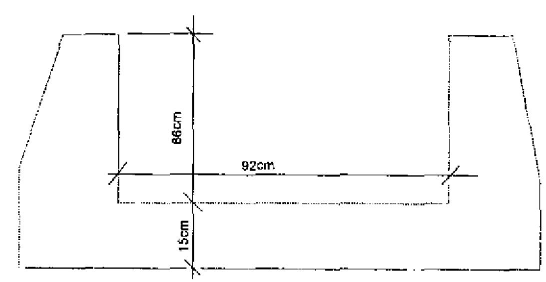
4.0m
C-C
D-D

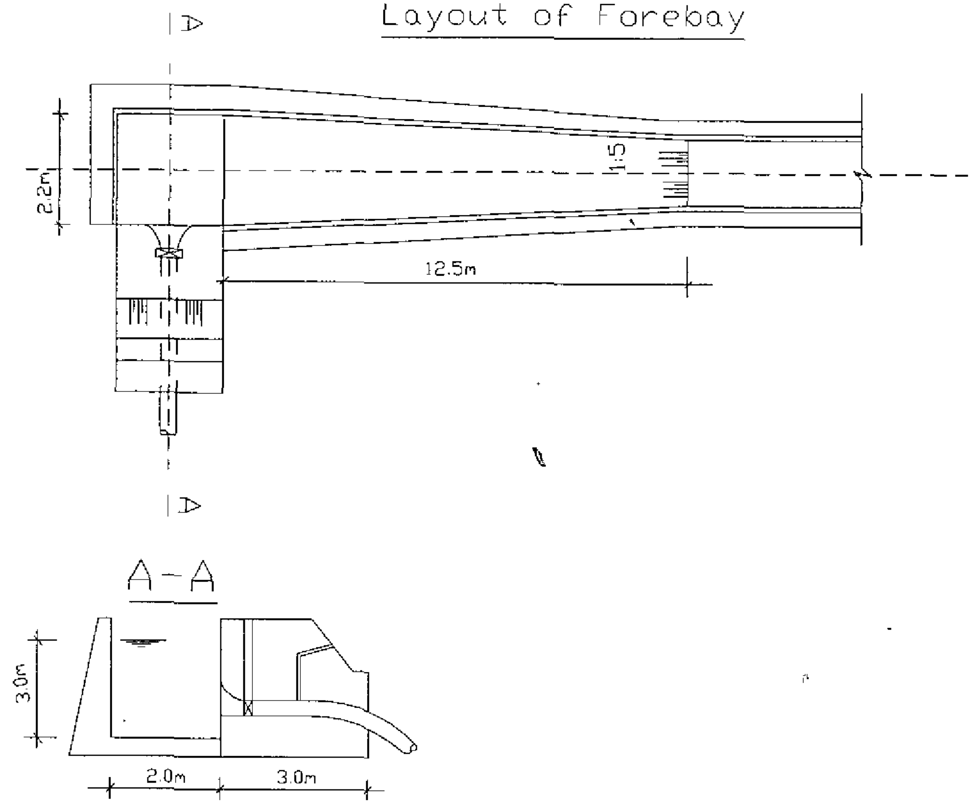


Schematic Diagram of Canal

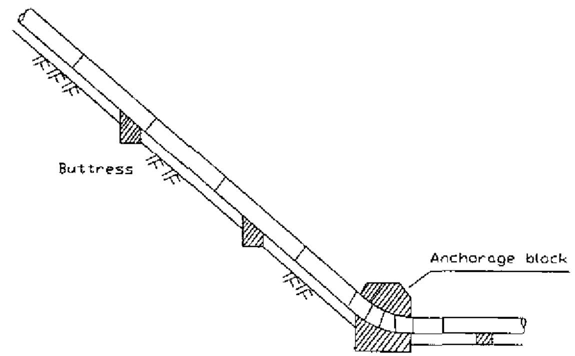


Typical Canal Section for 2x250 kW

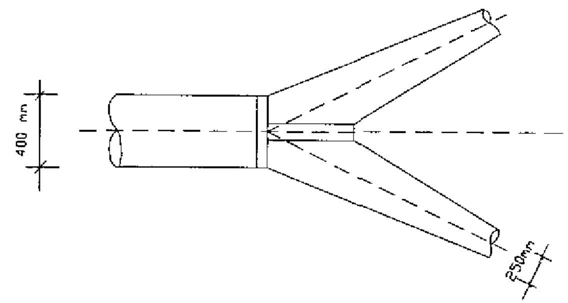
Layout of Forebay

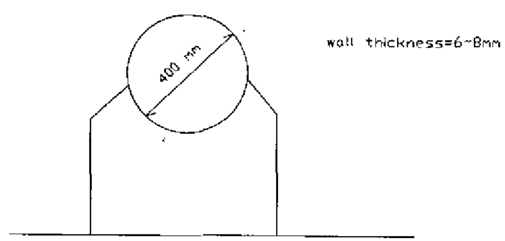


Layout of penstock

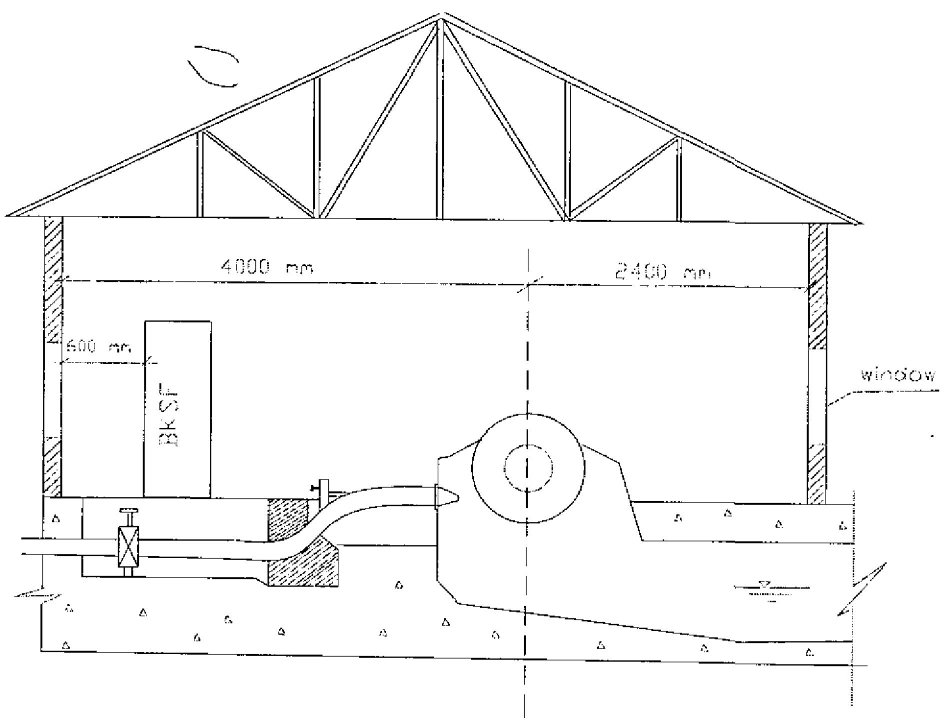


Bifurcated pipe for 2×250 kW

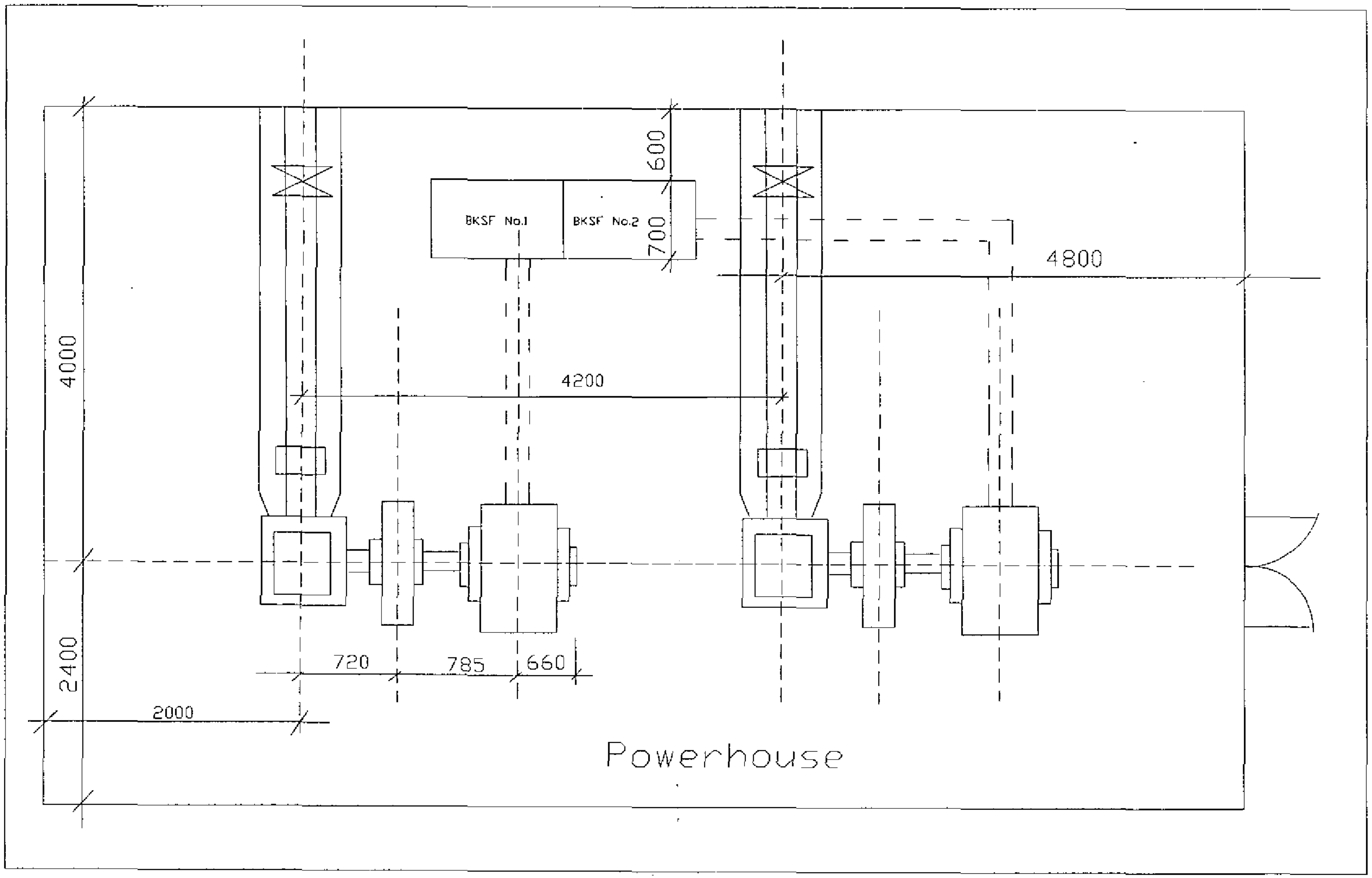




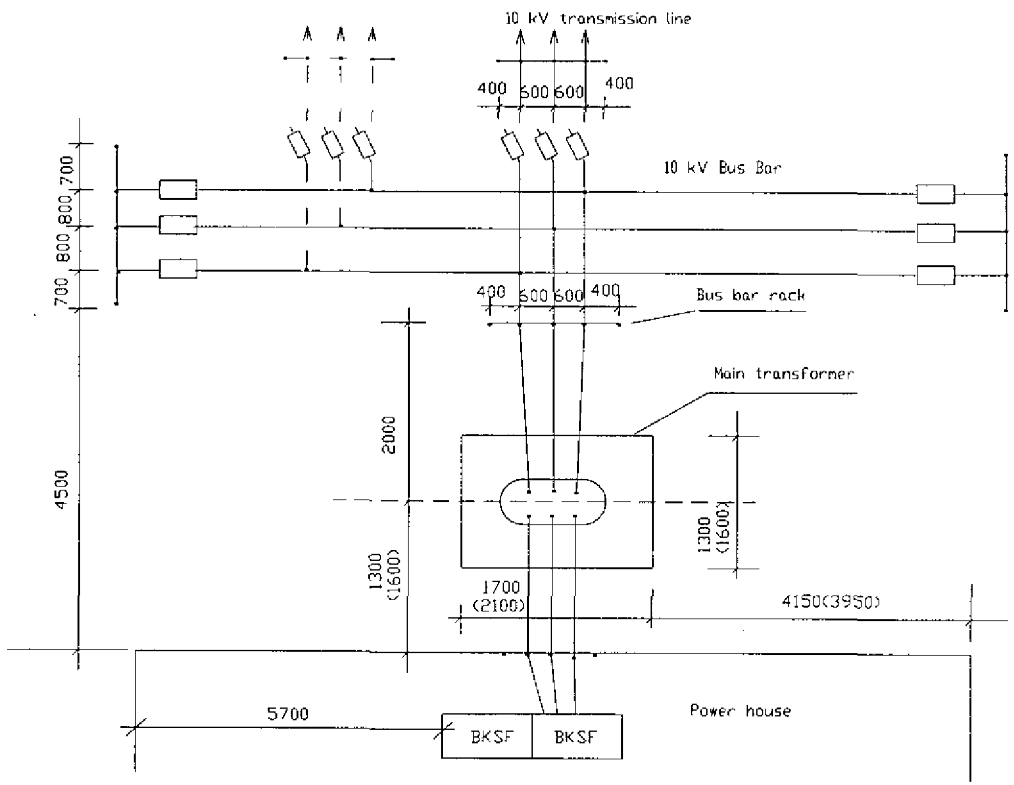
Cross section of penstock



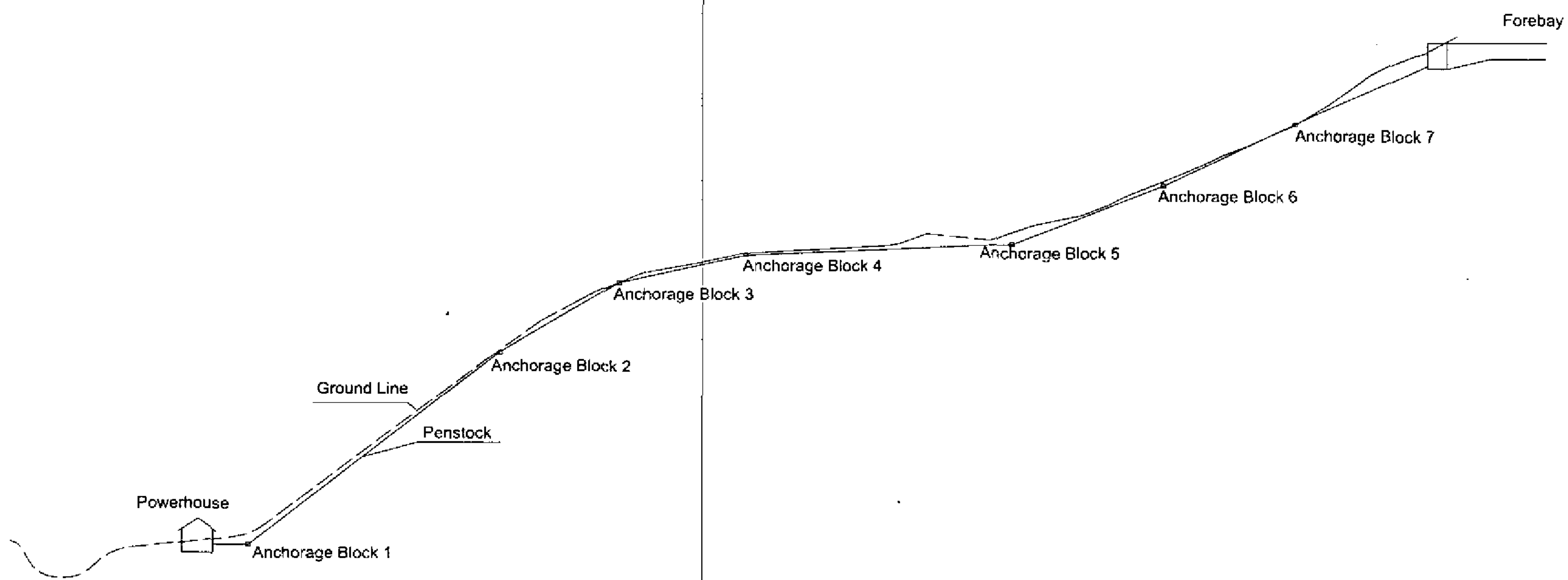
The highest tall water level should be at least 1.0 meter below the runner bottom



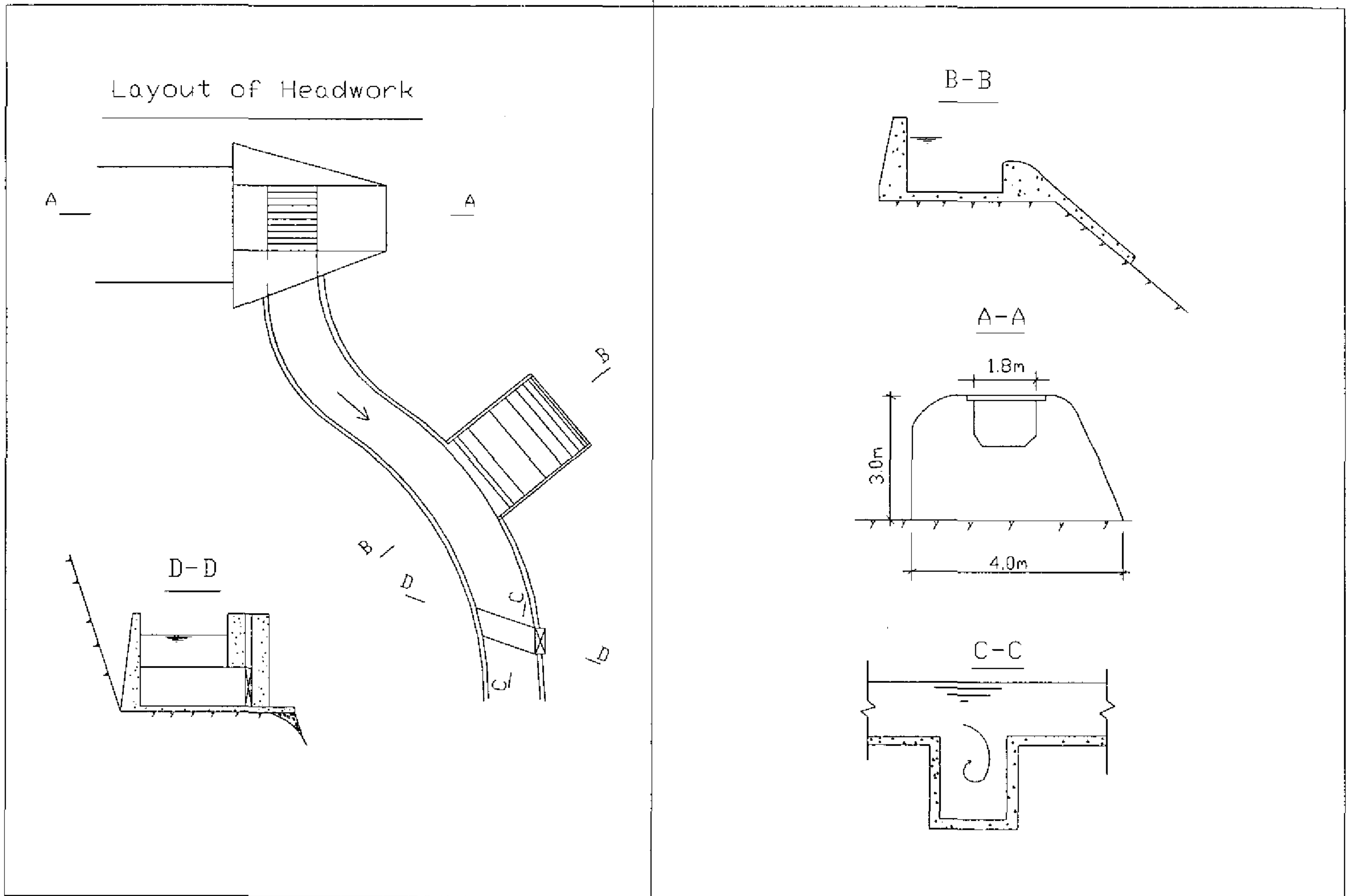
BKSF No.1
BKSF No.2
600
700
4800
4000
4200
2400
720
785
660
2000
Powerhouse



Note: 1) This layout is only on a schematic level.
2) The information of transmission line route, direction and load conditions are not available.
3) The length of the bus bar in the substation should be decided according to the interval of the power transmission lines.
4) The data in the parenthesis is for 630 kVA transformer.
5) The "Three-in-One" control panel BKSF-62(H) is recommended for this project, which intergrates the functions of excitation regulation, grid-connection, protection/distribution in one panel.
6) For the needs of construction power supply and power supply reliability in the future, a 55 kW diesel generator should be equipped at the station.
7) The 10 kV transmission lines should be equipped with fuse switches.



The Longitudinal Section of The Penstock


Layout of Headwork
A
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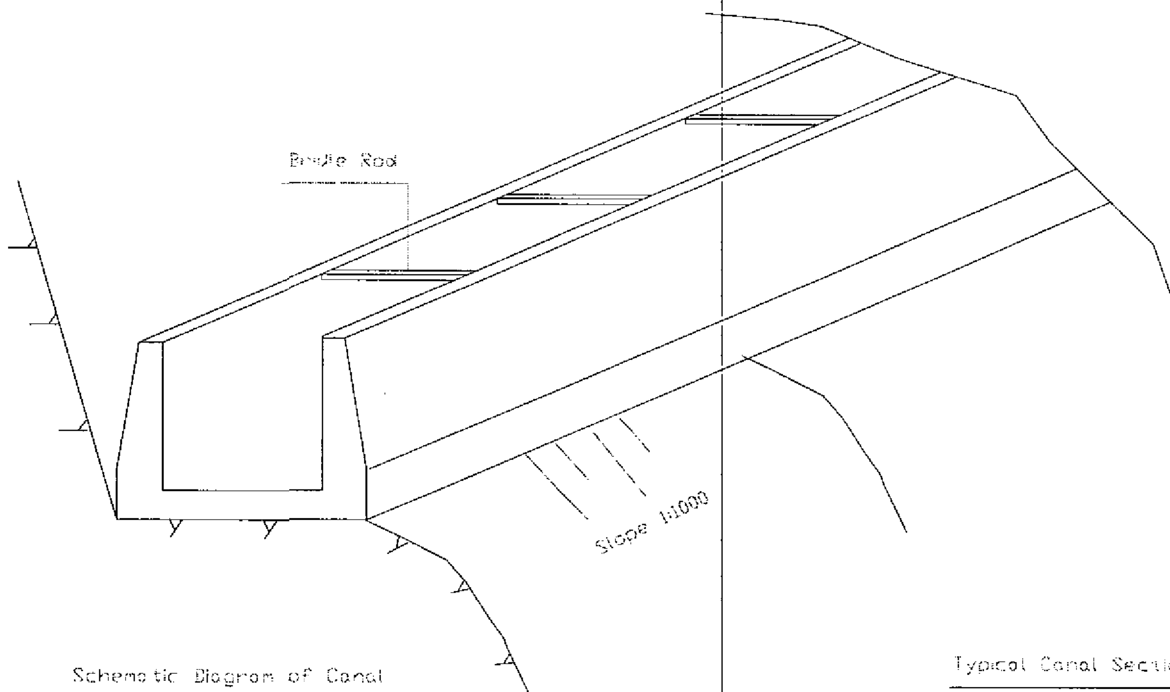
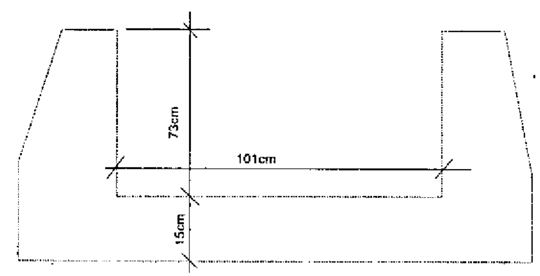
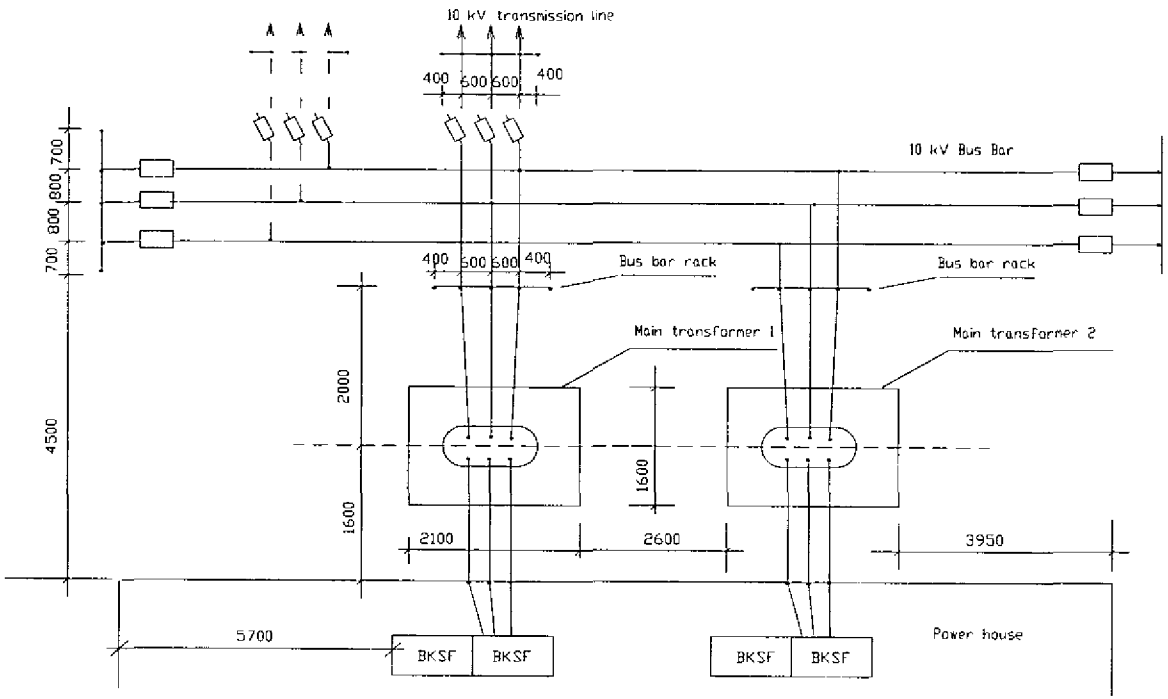
C-C



Schematic Diagram of Canal

Typical Canal Section For 4X250 kW





Note: 1) This layout is only on a schematic level.
2) The information of transmission line route, direction and load conditions are not available.
3) The length of the bus bar in the substation should be decided according to the interval of the power transmission lines.
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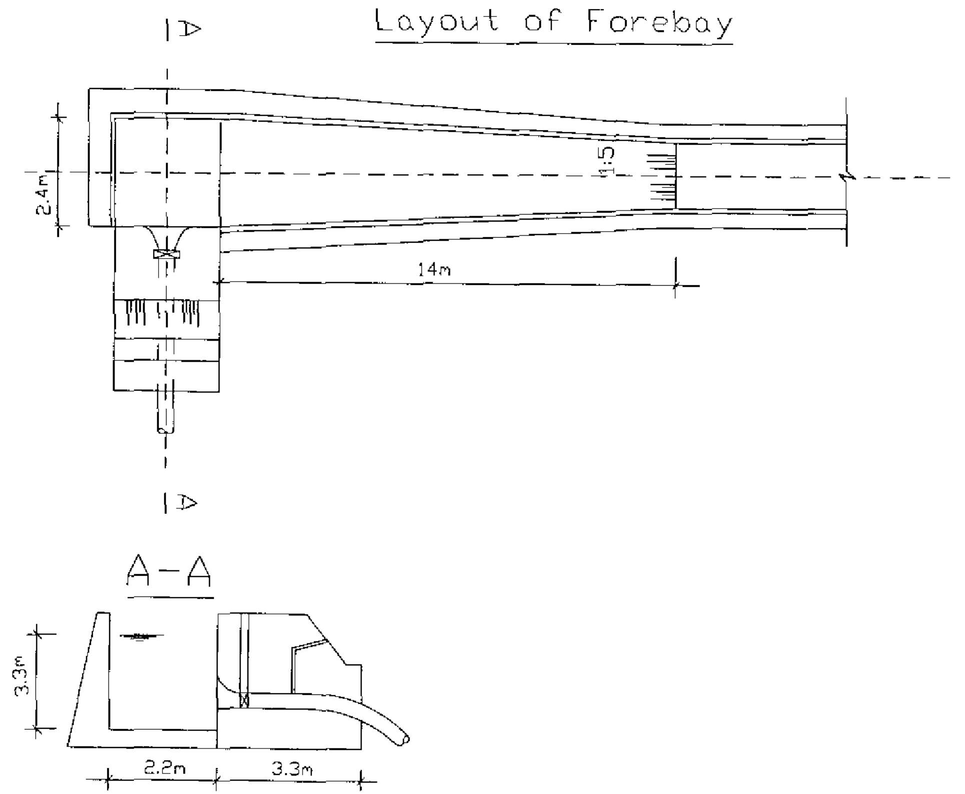
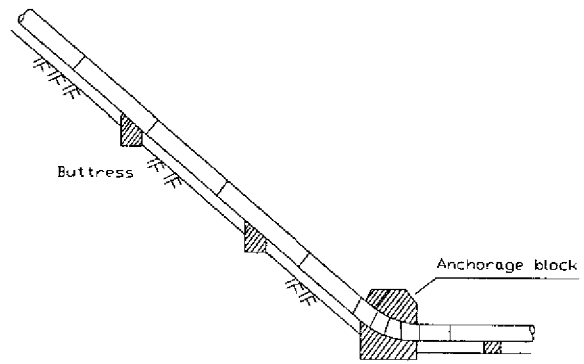
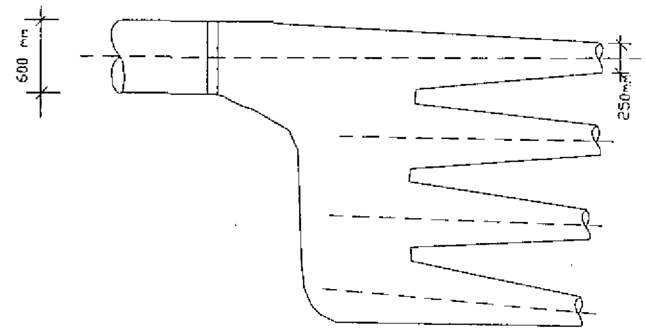
Layout of Forebay

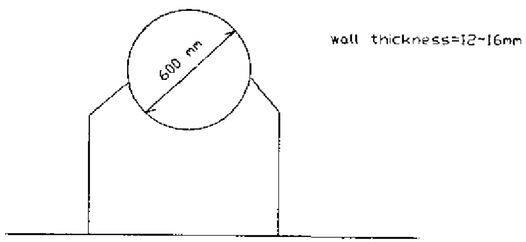


Layout of penstock

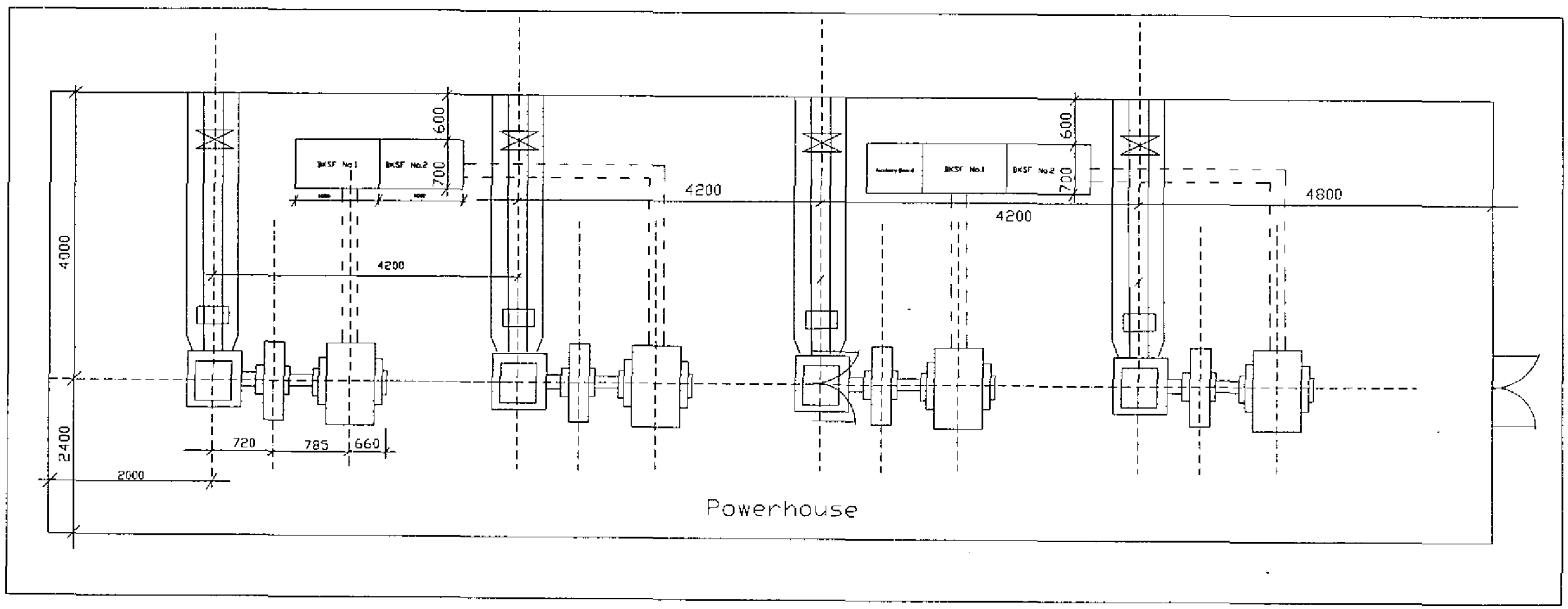


Bifurcated pipe for 4×250 kW

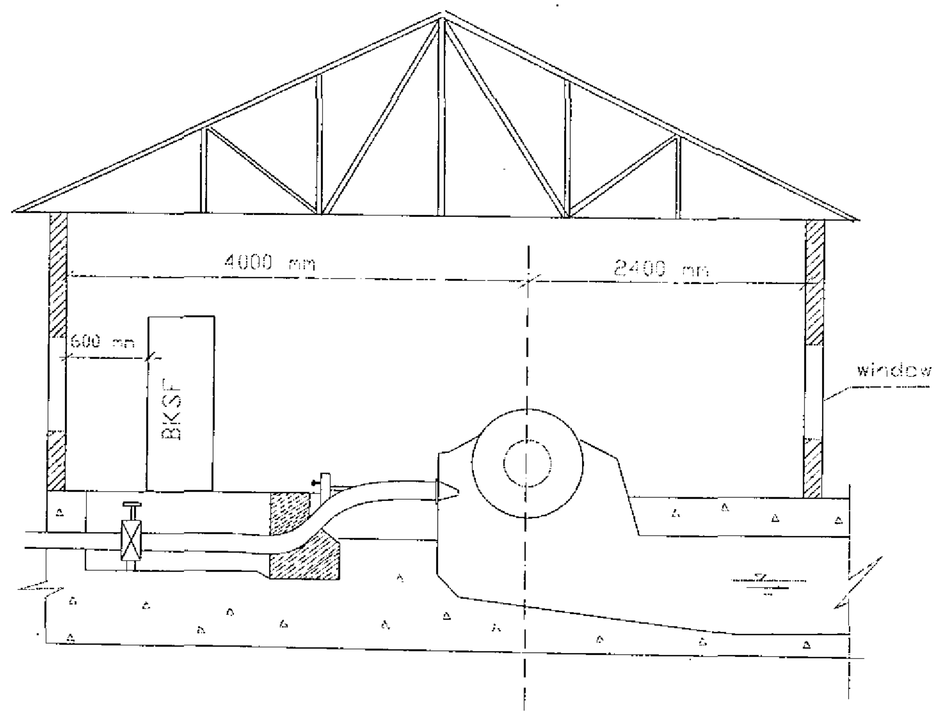




Cross section of penstock



Powerhouse
BKSF No.1
BKSF No.2
Auxiliary Board
4000
2400
2000
720
785
660
4200
600
700
4200
4200
4800



The highest tail water level should be at least 1.0 meter below the runner bottom