MONGA
HYDROPOWER PROJECT

A SMALL HYDRO ELECTRIC

POWER PLANT IN ZAIRE

A SMALL HYDRO POWER SCHEME IN ZAIRE

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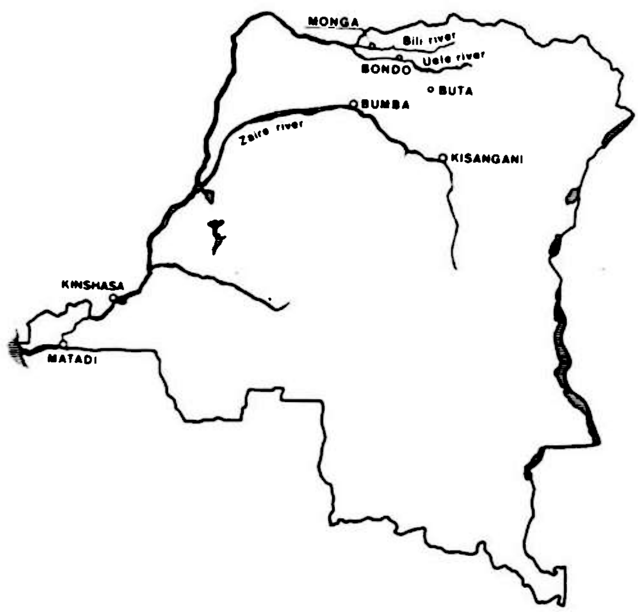
ABSTRACT

This paper describes the planning and construction of a SHP scheme in northwest Zaire using an old turbine. The scheme includes the following construction works: A 1 km long road, a 100 m long suspension bridge, a 40 m long channel, a 70 m long and 0,5-2,0 m high retaining wall, a 90 m long penstock, an intake construction and a powerhouse. The exploitable head is about 9 m, and the output will be approximately 150 kW at a maximum flow of 2,3 m^3/s. The total costs will be about 350.000 US$. (Dec. 85)

1 INTRODUCTION

1.1 General

The Norwegian Baptist Church has three missions in the Uele province in northwest Zaire. One of them is in the village Monga. Between forty and fifty thousand people belong to this administration center.



The Uele province belongs to the Equatorial region characterised by daily temperatures of 26°C, about 1700 mm rainfall per annum, no really dry month and dense tropical rain forests.

Life is based on subsistance farming, hunting and fishing. The main products are bananas, coffee, pineapples, mangoes, rice, peanuts and cotton. The district is poor in natural resources and there is no industry.

The health condition is generally bad. Most people have worms, and a combination of this and malaria, pneumonia and different forms of posioning, are the main reasons of the high infant mortality rate.

A 12 kW diesel unit has supplied the mission with the necessary electrical energy. However, this has been an expensive and unreliable source due to the cost of diesel, the long transportation lines and frequent breakdowns.

The activities of the mission are now going to be expanded by a new hospital, and different kinds of small workshops are expected to develop, thus increasing energy demand drastically. In addition a catholic mission near by and local traders have a requirement for electrical supply. This resulted in the idea of using rapids in the river near by for energy production.

1.2 Initial Plan

The Bili river is about 100-150 m wide where it flows close to the village. The Baptists looked into the possibility of utilising the water in a small sidebranch of the main river. The scheme consisted of an intake construction in the sidebranch of the river, a 350 m long penstock and a powerhouse. The total head was measured to be about 9 m. A team was organised in Norway collecting information about used turbines and necessary electrical equipment for the plant.

The choise fell on a Francis turbin built in 1940 which they obtained as a gift. It belonged to an old chemical plant in Norway, and was no longer in operation.

The turbine was disassembled and completely overhauled. A new drum and a new suction pipe was constructed. For this work the Baptists got assistance from Sørumsand A/S, a Norwegian turbine manufactorer.

An application for financial support was sent to Norwegian Ministry for Development Cooperation (NORAD). They got the financial support (approximately 75% of the total costs) on the condition that they engaged experts in hydropower to make a survey of the site and make a feasibility study.

From a company in Sweden the Baptists now bought a French built 4 pole generator of 400 kVA, 400 r/p.m. and a Finnish gearbox.

All the equipment was put into containers and sent by ship to Zaire.

The Norwegian Water Resources and Electricity Board was contacted and here a team of four senior engineers agreed to make a feasibility study on a private basis.

From the information given by the Baptists the team realised that following limitations had to be taken into account in the planning of the scheme.

1. The turbine, generator and much of the other equipment were already purchased and shipped from Norway.

2. The resources were limited and very little machinary could be obtained.

3. Dynamite was difficult to get hold of

4. The transportation lines were long.

5. There were no skilled workers among the villages.

6. The man who was going to be responsible for the construction works was a skilled worker, but had no formal education. He had never worked on a hydro power scheme before.

7. The site visit had to be carried out in 14 days.

1.3 Survey of the site

A site visit in January 1984 resulted in following comments to the initial plan:

a) The gross head, using a 350 m long penstock, was only 6.8 m. Extending the penstock by 100 m would increase the gross head to 8.2 m.

b) Construction of a channel to replace part of the pipeline to reduce frictionloss would involve much blasting and removal of large quantities of soil and rock. Parts of the channel would have to be secured by concrete works.

c) In the dry season the sidebranch of the river would not provide enough water. Major construction works would have to be carried out in the main river to increase the quantity.

d) An increase in output later on would involve further major construction works.

e) The villagers would loose two popular places for washing and collecting water.

The conclusion was that the scheme involved insurmountable constructional works with the available resources. Even if the scheme was implemented the energy output would be much lower than predicted.

A new solution had to be found, and this led to a project on the other side of the river.

2. THE HYDRO POWER SCHEME

2.1 A new site for the scheme

Further investigations showed that the rapids was situated at the head of a 180^{o} bend in the main river. The horizontal distanse between the upper and lower water level was only 100-150 m, and the ground sloped regularly downwards. At several places along the bank the river overflowed, specially in the rainy reason, and the ground was washed free from soil and vegetation. The site here was much more suitable for a powerscheme, even if the necessity of crossing the river for access would be a disadvantage during the construction period and in the running of the power station.

2.2 Monga powerplant - general layout

The exploitable head in Bili river at Monga was measured to approximately 9 m. The powerstation will utilize a small part of the average discharge in the river, much less than minimum waterflow in the dry season. There will be no weir or dam crossing the river. The intake is at 90° to the innerside of the riverstream. A feeder channel is blasted from the bank to the deeper part of the river to get enough water to the powerstation in the dry season. The intake is large enough for 2 turbines of 150 KW. A welded steel penstock takes the water from the intake to the turbine which is placed some 3 m above the normal water level in the tail water. The power house is made of concrete and ~~bricks~~ blocks and constructed for two turbines. To prevent damage of the penstock and powerhouse by riverbank flooding in the high flood period a retaining wall has been constructed on both sides of the intake. The maximum output will be about 150 kW at a net head of 8.5 m and flow through the turbine 2.3 m^3/s. The possible annual energy production is calculated to 1,230,000 kWh and the 1985/86 costestimate is NOK 2,8 mill (US$ 350.000).

2.3 Hydrology

There has not been any measuring of the flow in Bili river or in nearby rivers, and it has not been possible to find detailed maps that cover the catchment area. However, a survey covering the project area has been carried out in the river.

Bili river is a large river (mean width about 100 m) with a minimum flow higher than the flow through the turbine. The anticipated highest water level during high floods has been estimated by given reports from the local people and by looking at the vegetation.

The rain forest has a buffer effect on the water flow in Bili river, and it prevents a dramatic variation between the wet and dry season.

Due to the lack of hydrologic data no duration curve has been constructed. However, the turbine has a max flowrating of 2.3 m^3/s which is much less than the lowest waterflow in the river during the dry season. The turbine can therefore be runned at maximum output all the year round if this is required.

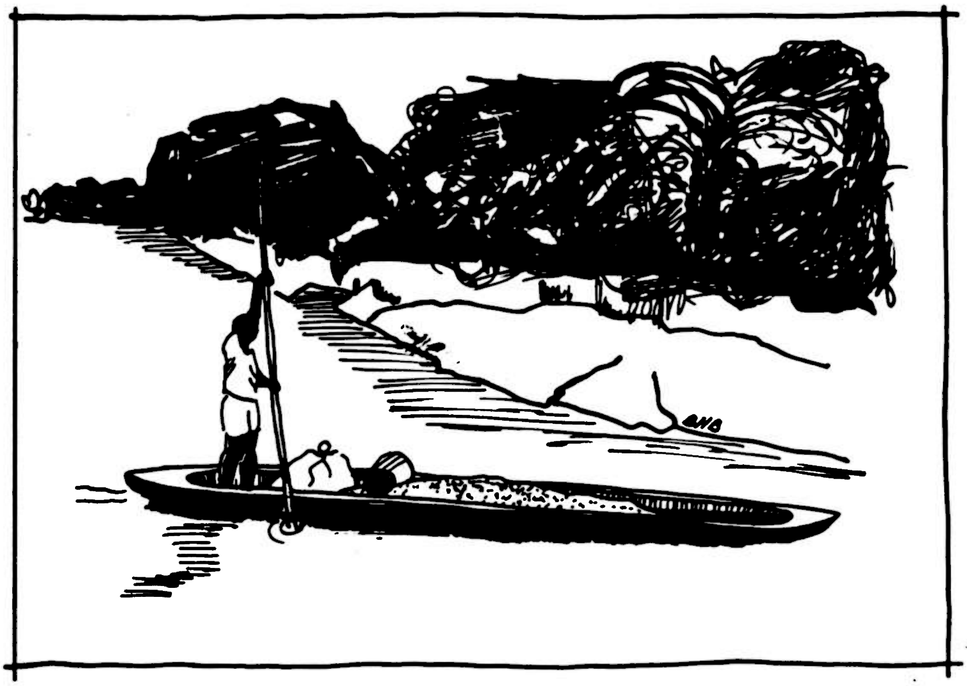
A daily monitored gauge has been put into operation from 1984, and a second turbine could be chosen in the future depending on the data optained from the gauge.

2.4 Siltation

There is no information about the sediment transport in Bili river, so the siltation problems are expected to be as average in this part of Africa. However, ~~the intake layout and~~ the fact that there is no dam or weir making a reservoir in the river means that the possibility of siltation problems is small. The water is quite clean in the dry season and siltation will be no problem. In the wet season when the flood is high, there are suspended materials in the water and some siltation problems can be expected in the feeder channel which has to be blasted in the riverbed to the deeper part of the river. This, however, can easily be cleaned in the low flood period. If the suspended material in the water is hard (quarts) it can have a scouring effect on the runner in the turbine, but this is not expected because the water velocity is low and the runner and guide vanes are of stainless steel.

2.5 Geology

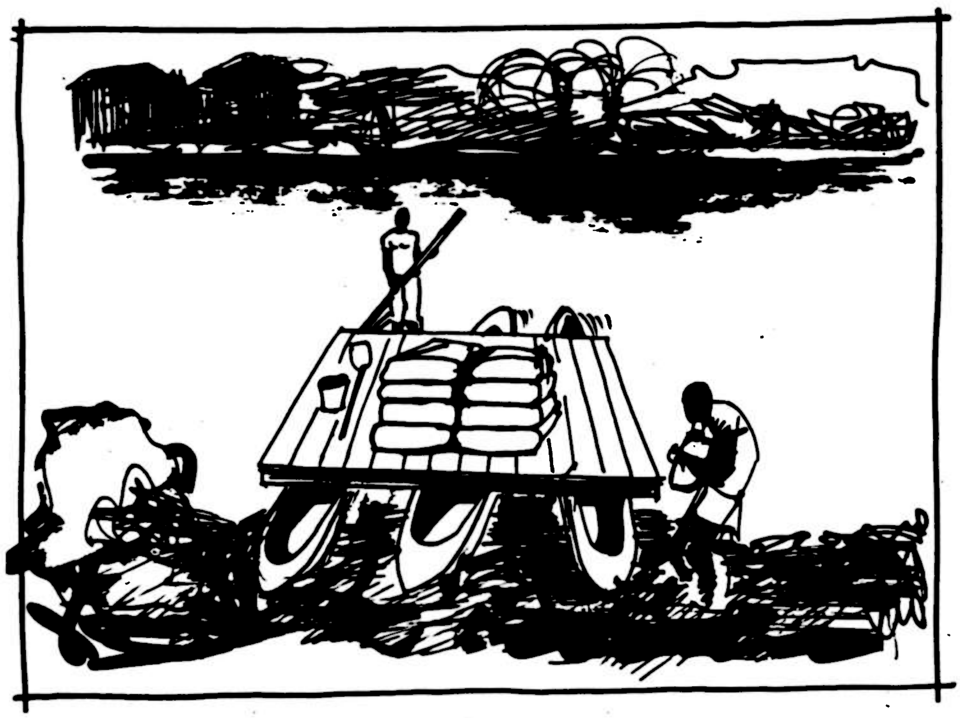
On the outside of the riverbend the ground is covered with soft red earth (laterite). Because of the frequent flooding in the project area the earth is eroded leaving exposed bedrock. This means that rock is exposed at the intake and powerhouse area, and boulders occur in the retaining wall, penstock and tailrace area. The foundation for the suspension bridge will be on exposed rock in the river. The rock is bedded and fissured but did not cause serious problems in drilling and blasting.



Deposits of sand and gravel are common allong the river and these were found both upstream and downstream of the project site. Transportation of sand and gravel from upstream was done by using canoes which the villages filled by using wash basins. They transported the gravel directly to the site where they were paid for each conoe load. Downstream they filled their canoes in the same way, brought the sand and gravel ashore and loaded it onto a lorry. Then the gravel sand was transported 4 km along the road and ferried across the river on a raft.

The necessary rockfill for the retaining wall and intake was obtained from blasting the feeder channel in the river and the riverbank for the intake.

2.6 Transportation



Most of the equipment (making at total weight of about 70 tons) was bought in Scandinavia and shipped from Norway to Matadi in containers. The containers were transported from Matadi to Monga by use of riverboat, railroad and lorries, a distance of about 2000 km. All the handling of the heavy containers caused much delay, and the transport took from 9 to 12 months.

Cement, reinforcement, dynamite and petrol were purchased in Kinshasa and transported to Monga in lorries owned by traders living in Bondo.

A small sawmill in Bondo produced all the necessary timber.

For transport within Monga an old lorry and a tractor were used. Materials and equipment were transported across the river on a raft or in canoes. The turbine unit was floated across the river in the rainy season using a ferry normally operating 2 km downstream but which brought the turbine unit up to the required position.

2.7 Access

The power scheme is on the opposite side of the river from the village and the misson. To get access a 1 km long road had to be clared through the forest. Everything had to be transported across the river on a raft or in canoes. For easy access in the running of the station a 100 m long suspension bridge had to be built.

3. CONSTRUCTION WORKS

3.1 General

The intake is constructed at 90^o to the direction of the flow in the river. The deepest part of the river is on the opposite side. When the survey took place the depth of the water just outside the intake was about 1 m. 10 m out into the river the depth was about 2.5 m. Further out the bottom of river sloped steeply downwards. There was no possibility of getting exact information about maximum and minimum waterlevel in the wet and the dry season, but a rough estimate was 1.5 m above and 0.7 m below the measured waterlevel respectively.

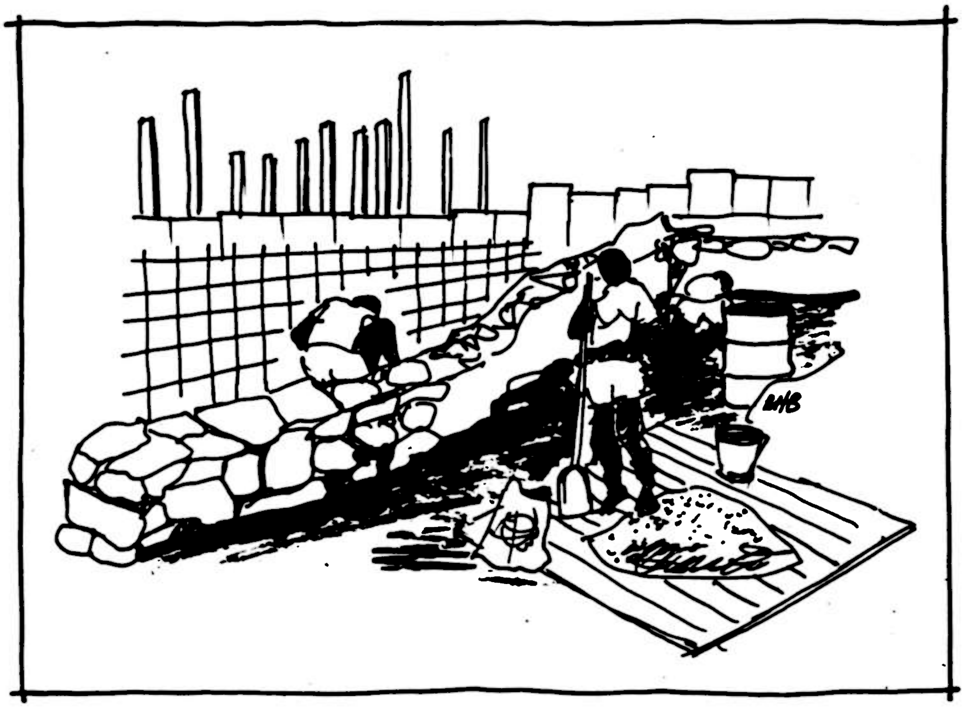
3.2 The feeder channel

To obtain enough water in the dry season a 4-5 m deep channel was blasted through the bank and into the river. The channel was made to take a second pipe so the output of the powerstation can be doubled in the future.

The channel has a total length of 40 m and a width of 5-6 m. About 500 m^3 of rock was excevated. The blasting of the channel was done in two sections. The onshore section was blasted first. The rubble was lifted out of the channel by hand and used in the retaining wall. A cofferdam was built with bags of clay 20 m out into the river forming a semi-circle in front of the intake. Then the second part of the channel was blasted through the bank and 15 m into the river.

The boreholes were made using a small drillingrig. 700 kg of dynamite was used. The dynamite was obtained through a contact in the Parliament in Zaire, and two soldiers kept an eye on the explosives all the time until it was used.

3.3 The retaining wall



In the wet season large quantities of water flow over the bank. To prevent this a flood prevention barrier had to be constructed on top of the bank on both sides of the intake construction.

The total length of the retaining wall is 70 m with a height varying from 0.5 m to 2.0 m. To reduce the necessary amount of concrete firstly a wall of mortar and rocks from the channel was made. The mortar was mixed by hand.

Then a 20 to 30 cm thick reinforced plate anchored to the ground was cast in front, using plywood and the mortar/rock wall as formwork. The concrete for the plate was made in a mixer.

3.4 The Intake (appendix 1)

A critical factor with Small Hydro Power Schemes is the intake, which often causes a problem for stabilized energyproduction. This powerstation is not a "run-of-the-river-station" as it only uses a small part of the available water in the river.

The intake is built to cater for two turbines each of 2.3 m^3/s and consists of two side by side trashracks, barrier of wood beams, slidegates and inlet cones for the pipes.

Arrangements have been made for a small platform to enable easy cleaning of the trashracks and operation of the barrier of beams. The latter will only be used when there is a need for cleaning the intake in front of the inlet. The spacing between the steelbars in the trashrack is less than the max. opening in the turbine guide vanes, so that anything which gets through the trashrack will also pass through the turbine.

The open area between the trashrack and the gates will be covered with a net or an additional trashrack will be installed in front of the gates to prevent any foreign bodies from getting into the pipe.

A drainpipe is incorporated to make it possible to empty the intake when the barrier of beams is used.

The side and back wall of the intake are made of mass concrete and rock-fill as the retaining wall. The concrete walls are anchored to the ground and the inlet cones are cast in the mass concrete. The base in the intake area is of mass concrete to prevent leakage.

3.5 The Penstock

The pipe was made in Monga from 5 mm steelplates 1.20 m x 3.60 m. The plates were shaped in a bending machine and welded together, forming a section 1.2 m in length and 1,14 m in diameter.

Three such sections were then welded together in the workshop before it was transported across the river on the raft. The 3.6 m sections were welded together on site, making a total length of 90 m.

The pipe is supported on reinforced concrete columns anchored to the ground. The distance between the columns is 6 m. The friction in the pipe gives a head loss of approximately 0.45 m at maximum output.

3.6 The Powerhouse

The powerhouse is built of local made blocks. The unit with turbine, gear and generator will be bolted to the machineroom floor of mass concrete which is anchored to the rock. The suction pipe is cast in the floor. There is room for switchgear and transformer. For safety reasons the transformer will be placed in a separate room. The powerhouse is built to take a second unit.

3.7 The Tailrace Channel

The channel takes the water from the powerstation out into the river. It is constructed deep enough to enable full use of the head and wide enough to provide capasity for the second turbine. The length of the channel is dependent on various factors such as the availability of sufficient explosives and the maximum turbine suction head. The final decision will be taken on site. A bulkhead or a simple gate is used when necessary to empty the tailrace for water.

3.8 The Suspension Bridge (appendix 2)

For the operators's safe and quick crossing of the river, it was found necessary to build a suspension bridge. Immediately upstream of the intake a convenient place was found. A crag in the 112 m wide river made it possible to reduce the length of the main span of the bridge to 85 m with a 27 m long side span at the "station side" of the river.

For free passage of floating trees and branches it was necessary to have minimum height of 2 m from flood water level to the lowest point of the bridge. The river banks are very low and this together with the 2 m free height made it necessary to build high towers to keep the stresses in the cables low.

The dimensioning was based on a useful load of 80 kp pr meter bridge which corresponds to 1 person pr meter when no other useful loads work. The dead weight of the bridge is 100 kp pr meter.

The construction work had to be adapted to the local materials, to difficult material transport and also to the unskilled workers. A simple construction was therefore required. Rebuilt truck frames were chosen for towers. It was also necessary to minimize the use of concrete (cement) which decided the height of the tower foundation. These criterias decided the height of the towers (with top 7.7 m above flood water level) and hence the tension of the cables.

Two single Ø 21 mm cables of type 37 x 3 mm with minimum breaking load of 145 kp/mm corresponding to 35 tons pr cable were used. The 1 m wide gang way is hanging in 10 mm reinforcing rods which has one end bent and hanged in chackles fastened to the cables by guy clamps - horisontal distance 2 m. L-formed steel profiles connect two and two reinforcing rods. The deck consisting of local wood materials is laid on the profiles. A 1 m high fence net is used as guard rail.

3.9 The Workers

On average 100 villagers have been working on the construction of the scheme, but in peak periods up to 140 workers have been engaged. The workers have their own trade union which is strong, and a man cannot be sacked unless a very good reason is given. Fortunately only minor personnel problems have arisen. Generally the workers and the village population have shown a great interest in the scheme and been very keen to give a hand.

The villagers have been working under supervision of their own foremen with the missionary as instructor and overseeing the whole work. The welding of the pipes has been done by a skilled worker from Norway. The workers have been paid 4 NOK a day which is about twice as much as the official rate.

4. ELECTRICAL AND MECHANICAL EQUIPMENT (appendix 1)

A single Francis unit with nominal discharge of 2.3 m^3/s giving approximately 150 kW nominal output at 8.5 m net head is to be installed.

The turbine is 45 years old and comes from a closed down chemical plant in Norway. The turbine, which was no longer in operation had been producing 100 kW at a head of 6 m. The hydraulic regulator is automatic of the Pendulum type. It can be disconnected for manual opening and closing of the guide vanes, thus giving the correct discharge according to the present powerload in the distribution network.

The turbine was given as a gift and disassambled and complitely overhauled. A new drum and a new suctionpipe were fitted. The runner is of stainless steel with good durability against abrasion. The turbine can be operated at very low discharge without damage, to supply the power demand in the hospitals and other buildings during the night. The suction head has a maximum of 5 m, and to avoid flood damage in the wet season, the turbine axle will be placed approximately 3 m above tailwater.

The turbine is coupled to the generator axle by a gear, bearings and a flywheel. It is served by a butterfly valve.

A standard frequency generator giving a nominal rating of 200 kVA at 1500 r/p.m. and the gear to raise the r/p.m. from the turbine was put on a frame together with the turbine. The frame will be bolted onto a concrete base in the powerstation.

The generator is aircooled and a ventilation system will be constructed to provide sufficient airchanges.

The generator output is 400 V and will be stepped up to 1000 V by a 200 kVA transformer.

The power will be transmitted to Monga via a 1 km long 1000 V transmission line.

5. POWER DEMAND AND PRODUCTION

Monga lies in a rural area and is not connected to the main grid. The power supply today is based on diesel units run by the Baptist Mission and the Catholic Mission. The peak demand is approximately 30 kW, but is expected to rise to 60-80 kW when cheap energy is available. Both the missions run small hospitals, which urgently need a more reliable power supply. New consumers will be schools, public buildings and communal lighting of public places. There is cotton cultivation in the area and the cheap electricity from the powerstation can make the construction and operation of a cotton mill possible. It is therefore expected that within a few years the peak demand may exceed the maximum output of the turbine. The intake and powerhouse are constructed to take a second turbine of maximum output 150 kW to meet the power demand in the future.

The annual energy requirement in the first 5 years after implementation of the scheme is expected to be 3-400,000 kWh. The load factor of the order of 0.4 implies that efforts should be made to develop more uniform consumption of electricity (water pumping for water supply, refrigeration to store food and meat, washing machines in the hospitals and airconditioning etc.)

Due to transport costs and the rural situation of Monga the energyproduction so far has been expensive and unreliable. Hence, the use of electrical equipment has been difficult or impossible at times. The hydro power scheme will give a reliable energyproduction with little operation and maintenance cost.

For emergency cases a stand by diesel generating unit of 25 kW will be installed in Monga to give sufficient energy to hospital equipment if there is a breakdown in the Hydro Power Plant.

Monga Hydro Power Plant can produce 1,230,000 kWh a year. Only 25-30% of this possible production is expected to be used the first years. However, it is anticipated that the availability of cheap energy will influence on the implementation of projects like the cotton mill.

6. PROJECT COSTS AND ECONOMIC EVALUATION

6.1 Project costs

The estimates of the project costs are based on the available equipment already owned by the baptists and the possibilities of buying different kinds of goods (cement, reinforcement, dynamite etc) in Zaire. All kinds of expenses concerning the project are included such as the cost of overhauling the turbine.

However, what is not included are items such as the hours spent by the energetic Baptists in getting help and equipment, their initial planning work and applications to NORAD and Zaire Authorities.

Costestimate 1985/86 (NOK), (100 NOK is about 12.5 US$, Nov. 85)

Access, transportation (roads 1 km, suspension bridge, transportation)	650,000
Reservoir (the river is 100 m wide and acts like a reservoir	-
Intake (retaining wall, intake, gates, trashrack)	300,000
Penstock (civil works, plates, bendingmachine, welding)	140,000
Powerstation (civil works)	160,000
Mechanical/Electrical equipment (turbine)	500,000
Transmission (incl. civil works in Monga and the village transformers)	500,000
Engineering/Administration	250,000
X Contingences	300,000
Total cost	2,800,000
	(about 350,000 US$)

Cost/kW: NOK 19,300 (150 kW)

The turbine is a gift and was cheaply overhauled. The generator is new, but cheap because it was obtained from a scheme which was never put into operation.

6.2 Economic evaluation

Annual consumption the first years is expected to be about 400,000 kWh which is approximately 30% of the possible energyproduction. According to this, a depreciation time of 10 years and an interest of 12%, the energy cost will be 1.3 NOK/kWh (~ 0.16 US$/kWh). If the whole energy potential could be used, the energy cost would be 0.42 NOK/kWh (~ 0.05 US$/kWh).

However, it is expected that the lifetime of the turbine, generator, penstock etc. is more than 20 years. After 10 years the energy price only needs to cover the maintenance and operation cost. (0.03-0.10 NOK/kWh depending on the energy demand).

The running cost of a diesel unit in this area varies between 2 and 4 NOK/kWh - if fuel is possible to get hold of at all. This shows that the hydro power scheme is more economical than a diesel unit even the first years, and the difference will only increase in time. Compared to a diesel unit the electricity from the hydro power will therefore give growth to other activities in the area which require energy.

7. CONCLUSION AND FINAL REMARKS

7.1 Conclusion

The different planning stages of the scheme have showed that it is important to consult experts before any decissions about layout, equipment, etc are made.

It also showes that missionaries are able to build a hydro power plant if layout, drawings and informations given is simple and adopted to the construction experience they have from other projects (building of hospitals, schools etc).

Major problems in implementation of a scheme in rural areas are often connected to transportation and how to get unskilled local people to carry out work of necesary quality. The missionaries know the people at the place, they usually have a very good net of contacts within the country and this enables them to solve different kind of problems as choosing the right foremen, transportation, getting hold of dynamite etc.

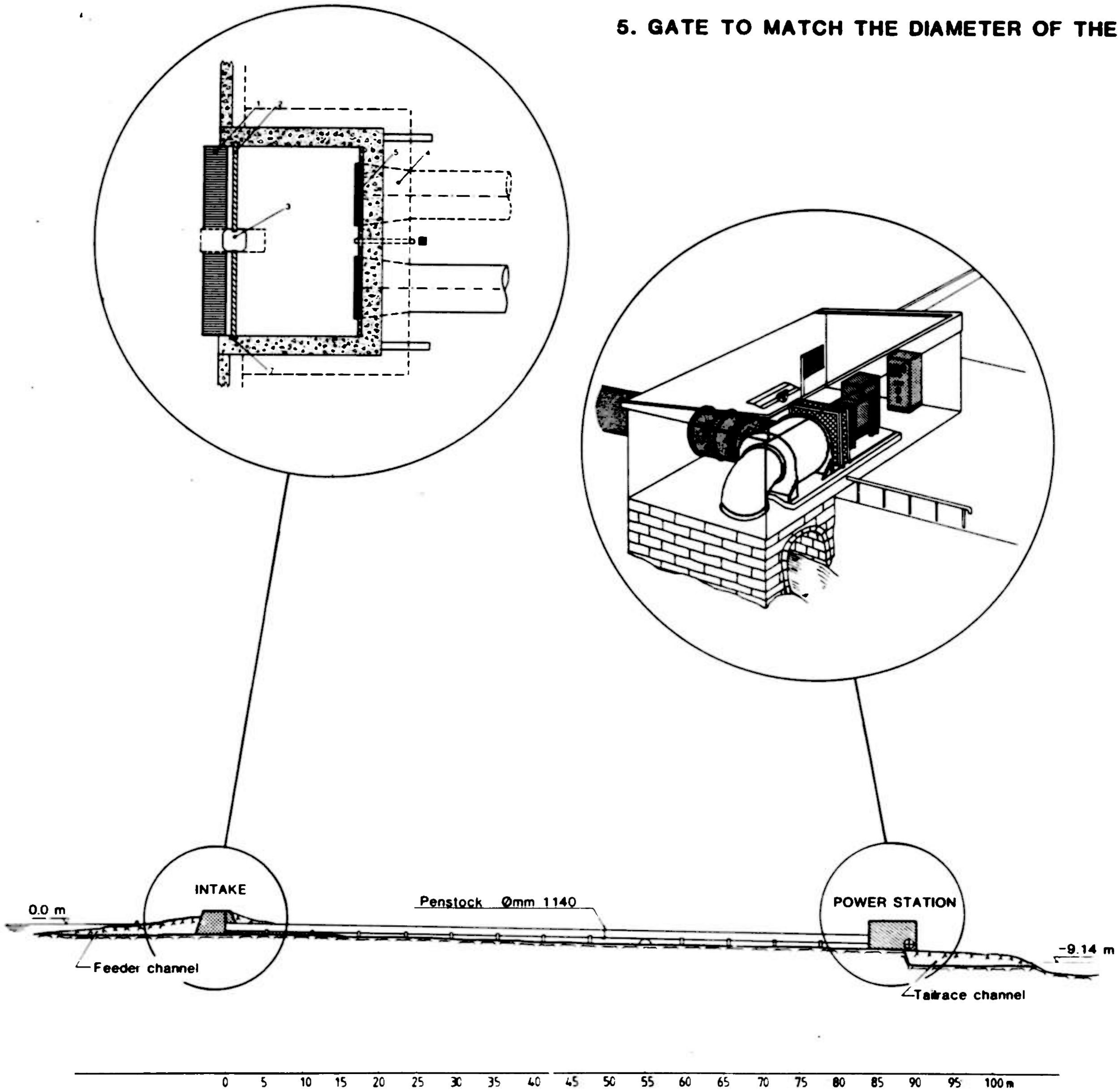
The combination of their interest in using secondhand equipment and their willingness to do a lot of work free of charge, usually results in projects much cheaper than ordinary implemented schemes.

7.2 Final remarks (appendix 3)

As the work schedule shows, the larger part of the construction works for the hydropower scheme is finished when this is written (Des. 1985), but there is still work left on the penstock, the installations in the power house, the transmission lines and the suspension bridge. However, the schedule has been kept up to now, and if nothing unexpected happens the powerstation should be put into operation in June 1986. A Mechanical Engineer with long experience on small hydro power plants will visit Monga and overlook the first operating hours to prevent any demage of the turbine. He will stay at the site a few weeks to give the Baptists knowledge of how to operate the powerplant. We hope that this project will be a step in the right direction to increase the quality of life for as many people as possible in this area.

MONGA HYDROPOWER SCHEME

1. TRASHRACK, 5 cm SPACING BETWEEN BARS, INCLINED AT 25°
2. BARRIER OF TIMBERPLANKS
3. COLUMN, DEVIDES THE LENGTH OF TRASHRACK, PLANKS AND PLATFORM
4. INLET CONE TO REDUCE HEAD LOSS
5. GATE TO MATCH THE DIAMETER OF THE INLET



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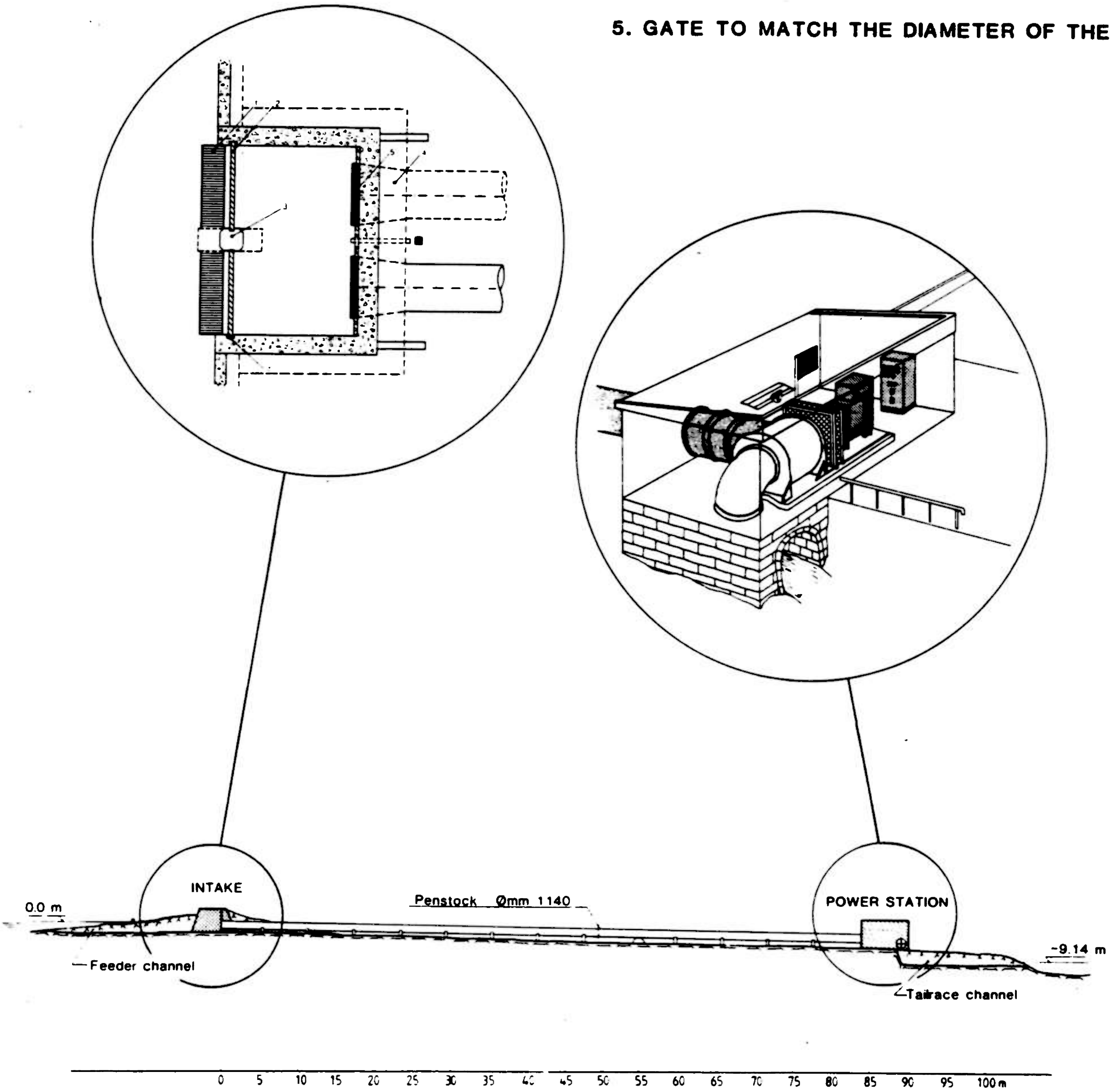
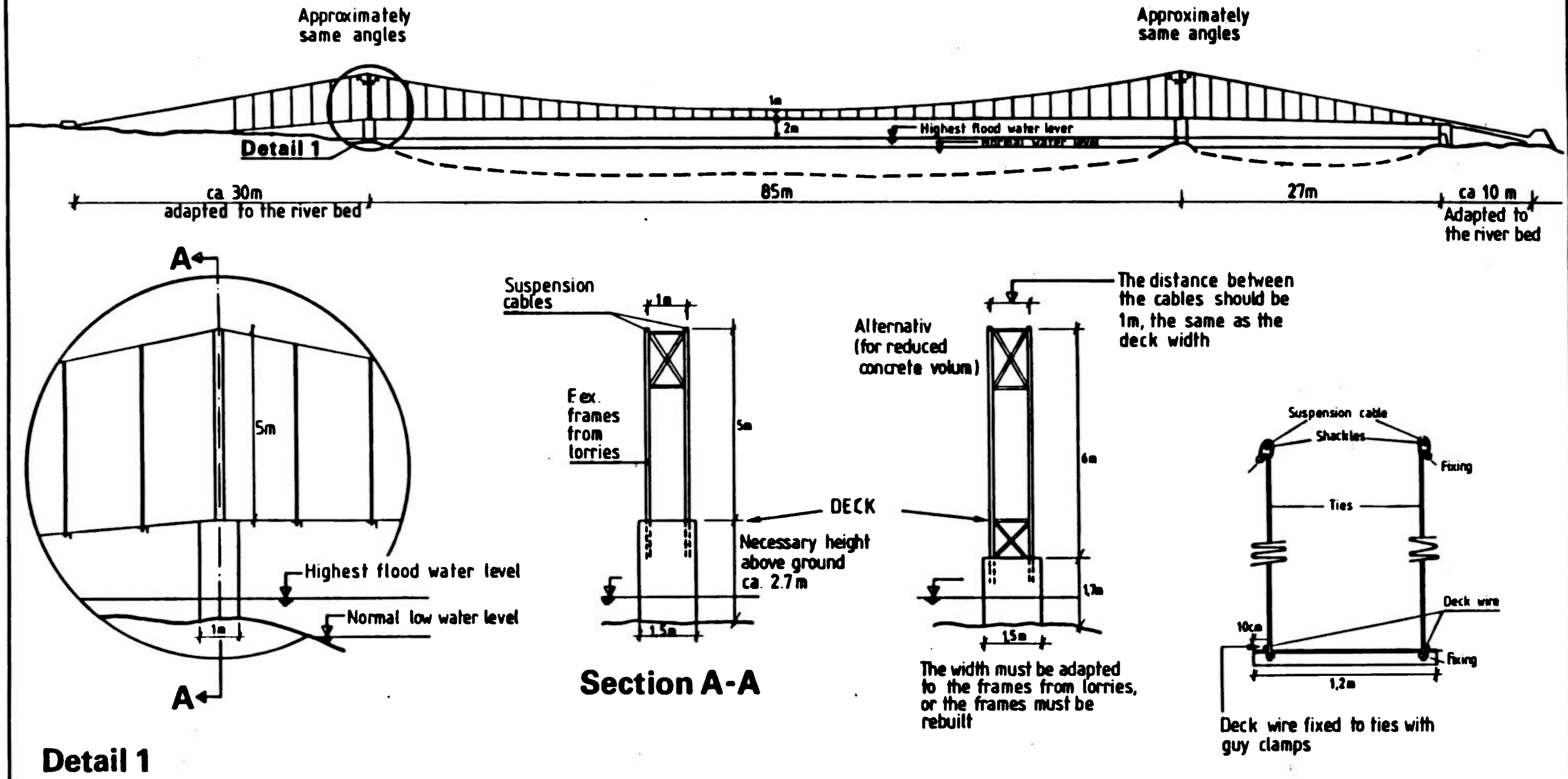
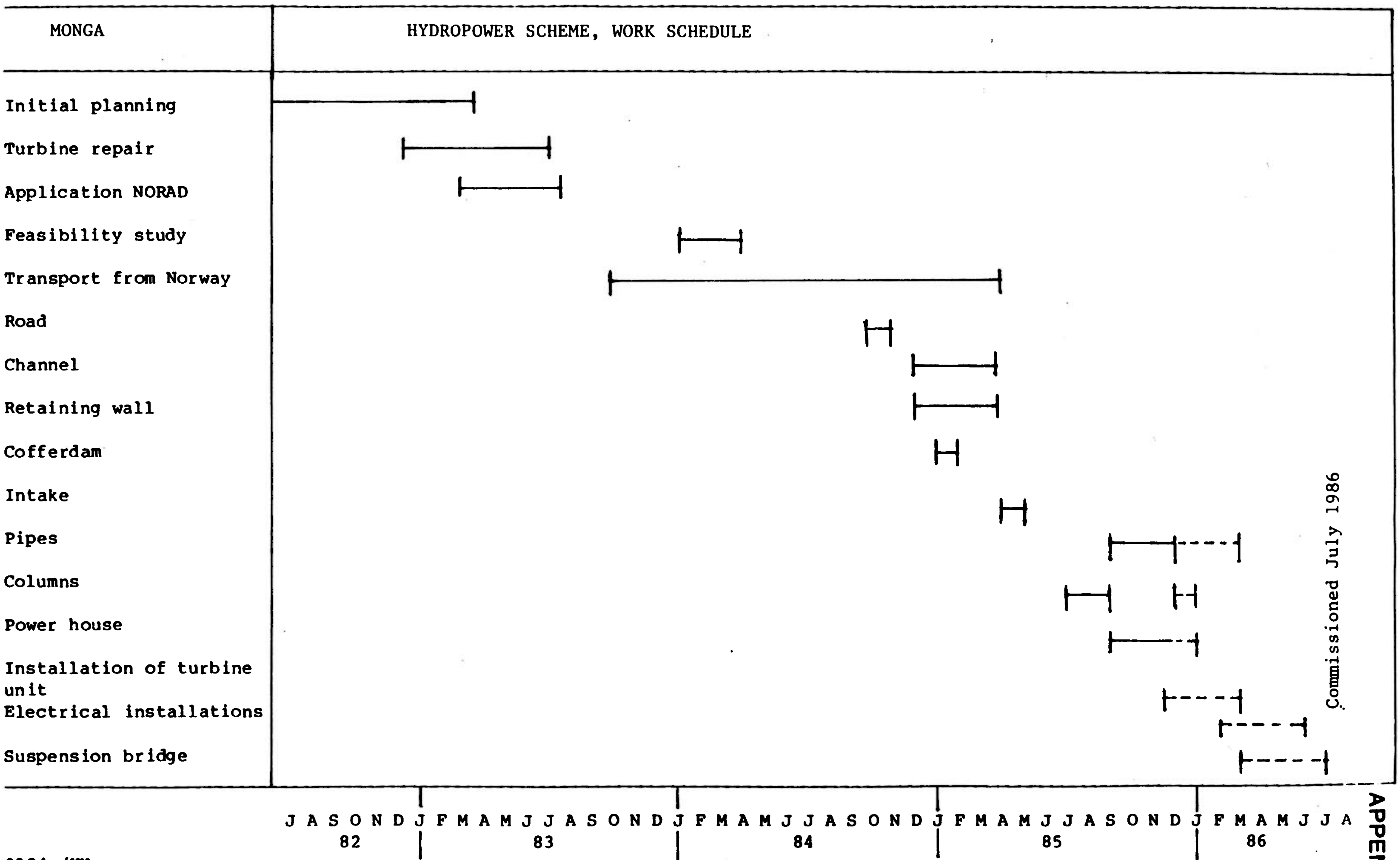




MONGA HYDRO POWER SCHEME	
Bridge across the river Bill	09.08 - 84

APPENDIX 2

APPENDIX 3



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