7.6 SELECTION OF DEVELOPMENT PLAN

In selection of the development plan, considerations must be given to the economic aspects and whether the reliability is satisfactory in that stable functioning can be maintained into the future.

As a result of comparison studies of the alternatives, the construction cost of 232 TD/kW of the "Upstream Plan, Available Drawdown 15 m, 350 MW Alternative" is the least expensive.

This alternative, although it takes into account dredging costs, the bed height of the outlet of 263 m is roughly the same height as the original river bed of the reservoir so that the effect of sedimentation will be a great concern, and it cannot necessarily be said to be a good plan.

The next best in terms of constructuion cost is the "Downstream Plan, Available Drawdown 15 m, 350 MW Alternative" at 265 TD/kW.

The alternative is free of any concern about sedimentation, but the construction cost will be increased because of increased length of the tailrace and increased outlet work, and compared with the first alternative, the construction cost increase will be 11,416.9 Dinars.

As described above, the "Upstream Plan, Available Drawdown 15 m, 350MW Alternative" and the "Downstream Plan, Available Drawdown 15 m, 350 MW Alternative" have their respective merits and demerits.

Which of the alternatives is to be adopted in the end must await the results of future field investigations on sedimentation made on the Tunisian side.

Accordingly, preliminary designs will be provided for bothe of the above alternatives in this Report.

Construction Cost of "Downstream Available Drawdown 20 m" is 1.634×10^3 Dinars higher than that of "Downstream Available Drawdown 15 m" and unit construction cost per kilowatt is respectively 270 DT/kW and 265 DT/kW.

CHAPTER 8. PRELIMINARY DESIGN AND WORK EXECUTION PLAN

CHAPTER 8 PRELIMINARY DESIGN AND WORK EXECUTION PLAN

8.1 CIVIL STRUCTURES

8.1.1 General

The type of the dam is to be rockfill judging from the topography and geology of the damsite and the availability of embankment materials, and the shape, because of the topography at the right bank and to reduce dam length, has been designed to be an arc of 800 m.

The intakes are to be of morning glory type for both alternatives and designed to be adapted to the characteristics of pumped-storage power generation. The spacing between the No. 1 and No. 2 intakes was taken to be 41.0 m. The No. 1 intake is for 75,000 kW × 2 units and the No. 2 intake for 100,000 kW × 2 units.

The penstocks are to be of horixontal type for both alternatives in view of the structures of the intake orifices, the geological conditions in the vicinities, and further, the design and connection with the underground powerhouse. The number of lines is to be two, No. 1 being for 75,000 kW × 2 units, and No. 2 for 100,000 kW × 2 units, and with bifurcation pipes provided approximately 100 m upstream of the powerhouse, each well become two lines to connest to the generators. Further, in consideration of the geological conditions, the steel pipe was designed for 50% of pressure to be carried by bedrock.

The underground powerhouse in the Upstream Alternative is to be situated in limestone within limits that tailrace lengths not requiring surge chambers can be adopted. The Downstream Alternative, because of the length of the tailraces will naturally require surge chambers so that the powerhouse location is to be provided in the best place in the limestone and also arranged in a manner that the penstocks can be shortened. The underground powerhouse is to have a transformer room, while the bus route is to be separate from the access road and lead to the outdoor switchyard povided above ground. Further, the equipment layout was arranged to be 75,000 kW × 2 units on the upstream side and 100,000 kW × 2 units on the downstream side in the Upstream Alternative, while in the Downstream Alternative, the layout was reversed. This is because the route of the access tunnel will differ depending on the location of the underground powerhouse and installation of the 75,000-kW machines which will be the preseding work was arranged to be at the far end so that Phase II work would not be hindered.

The tailraces in the Upstream Alternative are to be provided with gates at draft tube ends and at outlets, two each merged approximately 100 m downstream of the powerhouse to become two lines, No. 1 and No.2, for discharge downstream with no surge chambers provided. In the Downstream Alternative, gates are to be installed at outlets, merging done approximately 100 m from the powerhouse to become the No. 1 and No. 2 tailraces, with surge chambers provided part way down.

As shown in Fig.-8.1, the cross-sectional dimensions of waterways (penstock, surge-chamber, outlet tunnel, etc.) are so designed to have minimum additional value of annual construction cost and annual fuel charge for pumping up.

8.1.2 Dam and Reservoir

The dam and reservoir described here are concerned with the upper reservoir.

At the damsite, the topography of the left bank is that of a slope of approximately 30° where are alternations of outcropped hard limestone and marl. On the right-bank side, colluvial deposits are distributed indicating a gentle slope, but portions close to the river flow are eroded and steep.

Regarding the dam axis, it will be optimum at the vicinity of the upstream dam axis proposal which was recommended in the MECASOL report also.

The dam type is to be rockfill in view of the following:

(1) Spillway facilities will be unnecessary. This is because with 0.1% probability maximum flood discharge of 34 m^3/sec and discharge of 310 m^3/sec for power generation, outlet facilities for the dam can be limited to sand flushes.

(2) The topographical and geological conditions are suitable for rockfill. Topographically, the dam crest length is long compared with the dam height. Geologically, the bearing capacity and shear strength of the foundation ground are anticipated to be relatively weak.

(3) Embankment materials can be obtained from the vicinity.

(4) The meteorological conditions are that the number of days of rainfall is small.

Because of the above conditions, it was judged that a fill type would be optumum without any need for considering alternative proposals. However, soil tests of embankment materials and foundation ground have ont been sufficiently conducted.

Curtain grouting is to be done for foundation treatment. The reservoir will be subject to water level variation from high water level to low water level within a short period of time, once daily, a characteristic peculiar to pumped-storage power stations. Although there may be concern about resistance to surface sliding within the reservoir because of this and of leakage from sink holes in limestone, these will not be considered in the design since investigations for treatment are inadequate. These problems of the upper reservoir are matters of the greatest importance for this Project, and thorough prior investigations will be necessary in proceeding with working designs.

8.1.3 Intakes

The intakes are to be provided in the reservoir on the left-bank side of the dam approximately 200 m from the dam axis. In the Upstream Alternative they are to be parallel, while in the Downstream Alternative the No. 1 intake is to be set back approximately 20 m farther into the reservoir. The spacing between intakes is to be 41 m in both alternatives.

The geology of the intake vicinity is generally covered with cohesive overburden underlying which there is brown marl. In the mountainside in the direction of the tunnels there is a relative fractured line of weakness in the marl, while the contact plane with limestone is considerably fractured in addition to which swallow holes are alse conceivable, so that intake tower sections are to be set apart from the mountainside to avoid the influence of excavation.

The intakes are to have octagonal morning glory shapes. This was decided from the connections with the penstocks and to satisfy the conditions of the intakes at the time of power generation and the outlets at the time of pumping in view of the characteristics of pumpedstorage power genetation.

Cuts around the intakes, both slopes and beds are to be covered with concrete. The beds are to be lowered 1.50 m below the orifice heights.

It will be desirable for details of the structures to be determined upon carrying out model hydraulic tests at the time of preparing working designs.

8.1.4 Penstocks

The penstocks have been designed to be vertical shafts from the relation with the locations and structures of the intakes and the connections with them, and at the starting points on the dam side in order to safely pass the places thought to be fractured at the contact planes between the marl and limestone formations, and to pass through the hard limestone at a gradient of 2% to reach the underground powerhouse.

The penstocks are to be two lines in both alternatives, and under the conditions of bedrock carrying 50% of the pressure, they are to be of welded steel pipe embedded in concrete. Upon the entire lines being backfilled with concrete the surrounding original ground is to be reinforced through grouting.

The cross-sectional dimensions of the penstocks, as a result of economic comparisons Fig. 8-1, are to be inner diameter of 6.0 m for No. 1 and inner diameter of 6.7 m for No. 2. After branching each into two lines at a bifurcation pipe the sizes are to be gradually reduced, and after the lines have passed through valves, No. 1 will connect to 75,000 kW × 2 units and No. 2 to 100,000 kW × 2 units.

In design of the penstocks, internal pressure was considered as being static head plus head due to surging or water-hammer pressure, whichever is the higher.

Designing has been done under the condition that 50% of the pressure is to be carried by bedrock, but at the time of preparing working designs, it may be necessary to make partial changes according to the results of test adit investigations, boring investigations and bedrock water pressure tests which are to be carried out hereafter.

8.1.5 Underground Powerhouse

The locations of the underground powerhouse will be in hard limestone in both a alternatives, and are to be at sites reasonable from the standpoint of the overall project. In design of the underground powerhouse where 350,000 kW of equipment will be installed on excavating an underground cavern, careful geological investigations will be required, but in the present investigations it was unavoidable for judgments to be made based only on surface reconnaissance and a small amount of boring data.

The RQD*(%) measured by the core of Borehole SU-7 (not complete, but serving as a measure to an extent) was approximately 63%, and this value is one that would be of Class A for an underground powerhouse site in Japan, while in view of the excavation conditions at limestone in the vicinity of the existing Kasseb Dam, it was judged that construction of an underground powerhouse will be amply possible.

The underground powerhouses are as indicated in Fig. 8.7, 8.9, 8.13-15, and both are to be of reinforced concrete

structure capable of accomodating the main equipment of 75,000 kW × 2 units and 100,000 kW × 2 units, appurtenant equipment, and main transformers as well. The tunnel used for excavating the arch portion is to be diverted into a bus tunnel to lead to the outdoor switchyard provided at the surface.

The plan layouts of the underground powerhouses were determined by the ingress route of the access tunnel which will be the main route during construction and after completion. In effect, in both the Upstream and Downstream alternatives the 75,000-kW units are to be at the far end of the powerhouse with the transformer room correspondingly arranged. This layout was selected in order not to hinder Phase II work.

The draft tubes are to be L-type and connected to the steel liner pipes of the tailraces.

8.1.6 Tailraces and Outlets

Tailrace tunnels are to be connected with the draft tubes and two each are to merge about 100 m from the center of the powerhouse to become pressure tunnels of diameter of 7.50 m for discharge to the lower reservoir via outlets.

In the Upstream Alternative, various studies were made including the relation with turbines regarding provision of surge chambers in consideration of the tailrace length, and as a result it was judged surge chambers would be unnecessary.

$$* \quad \text{RQD} = \frac{\text{Sampled Core Length longer than 10 cm}}{\text{Length of Core Boring}} \times 100\ (\%)$$

Tailrace gates are to be draft tube gates provided at the ends of draft tubes, and gates to be provided at outlets.

From the draft tubes to the merging points will be reinforced with steel pipe linings, but downstream from these points will be reinforced concrete, while it will be necessary to consolidate the original ground by grouting.

The outlets are to be bell-mouth type concrete structures. They are outlets when generating power, but they will be intatkes when pumping up, so that there will be fear of air vortices being produced, and it will be necessary for detailed configurations to be determined upon model hydraulic tests at the time of preparing working designs.

The geology of the area passed through by the tailraces is described in the chapter on geology. As there will be pressurized water spring, it will be necessary to make a careful study of excavation method of these large-diameter pressure tunnels.

The elevation of the outlet portals is roughly the same as the present riverbed height and sedimentation over the years naturally must be considered, It will be necessary for sedimentation measurements to be made yearly and to take measures to remove sand without fail. Neglecting to do so will result in serious effects on both power generation and pump-up and thorough consideration must be given to this matter.

In the Downstream Alternative the tailraces will run through limestone which is geologically of high stability, and moreover, will take the shortest route to outlets provided at a point approximately 0.8 km upstream from Kasseb Dam, the location of the outlets having been selected to lessen the problem of sedimentation accompanying the Upstream Alternative as much as possible. As a result, the tailrace length will be extended approximately 1,400 m in addition to which because of hydraulic conditions surge chambers will be provided.

Tailrace gates will be draft tube gates and outlet gates for ease of inspection of the tailraces.

Steel liner pipes are to be provided for reinforcement from the draft tubes to merging points and further on to the surge chambers, downstream of which will be reinforced concrete structure, while it will be necessary to consolidate the original ground through grouting.

The outlets, as a result of various studies taking into consideration topography, water level and other factors, are to be of special structure using a pneumatic caisson method. Regarding the configuration and hydraulic characteristics of the outlets it will be necessary to decide details through model hydraulic tests at the time of preparing working designs similarly to the case of the Upstream Alternative.

8.1.7 Outdoor Switchyard

The outdoor switchyard would be provided more or less at the same location for both alternatives; while the length and gradient of the bus cable tunnel will differ depending on the alternative since in both cases the work adit for arch excavation will be utilized for the cable tunnel after completion of construction. There will be no obstacle to laying buses in either case.

The outdoor switchyard site will involve some cutting and banking because of the topography, but there will be no problem in earthwork. However, judging from the geology of this vicinity it will be necessary for thorough investigations to be made and to consider pile driving in foundation work equipment.

8.2 POWERHOUSE EQUIPMENT

8.2.1 Pump-Turbines

Kasseb Pumped-Storage Power Station is planned for a total output of 350 MW with two 75-MW units as Phase I, and two 100-MW units as Phase II. The particulars are the following:

	Up stream alternative	Down stream alternative
Normal Effective Head	137.4 m	134.5 m
Maximum Flow	304 m^3/sec	310 m^3/sec
Pumping Head	approx. 126 - 160 m	

The pump-turbine suitable for the above is a vertical-shaft, Francis type, reversible pump-turbine. Although it would also be possible to adopt an diagonal flow type reversible pump-turbine, the equipment cost would be high, while the structure and control would be complex, and since there is no engineering necessity because of which it would be unavoidable for the diagonal flow type to be used, the Francis type pump-turbine is to be adopted.

The turbine outputs are 76,600 kW for Phase I and 102,200 kW for Phase II under the normal effective head with maximum pump input estimated to be approximately 88,000 kW (89,000 kW) for Phase I, and approximately 117,000 kW (118,000 kW) for Phase II.

The rotating speed of a pump-turbine, from the critical specific speed of turbine of approximately 155 m-kW and critical specific speed of pump of 65 m-m^3/sec, can be considered to be at 214.3 rpm, 200 rpm or 188 rpm, but from the aspects of reduction in machinery dimensions and lowering of machinery cost, 214.3 rpm will be adopted for both phase I and Phase II.

Note: Figures in parenthesis show the down stream alternative characteristics.

The runner submergence (height of installation of pump-turbine) of the pump-turbine is to be -14 m for both Phase I and Phase II. This runner submergence of -14 m may be changed slightly depending on detailed design of the pump-turbines.

The inlet valves are to be butterfly valves.

The appurtenant apparatus required for pump-turbines are air compressors, water level regulators, speed governors, pressure oil supply apparatus, greasing and oiling apparatus, cooling-water supply apparatus, drainage apparatus, etc. Air compressors are to be provided to inject compressed air into the draft turbes in order to alleviate resisting torques of the pump-turbines at time of starting up of motors, and also for braking.

Inspection of a pump-turbine is done by draining the casing and draft tube, and making observations from the inspection manholes provided at the casing and upper draft tube. Dismantling of pump- turbines is done from within the generator-motor stator.

8.2.2 Generator-Motors

The method adopted for starting a synchronous motor of a pumped-storage power station is generally one of the following:

(1) Damper winding starting method

(2) Direct-coupled motor starting method

(3) Synchronous starting method

(4) Thyrister starting method

The direct-coupled motor starting method is to be adopted as the starting method for Kasseb Pumped-Storage Power Station because of the reasons given below. With the damper winding starting method, electrical shock due to rush current will be heavy at the time of starting. This electrical shock will be undesirable for the Kasseb Electric Power System. The synchronous starting method requires a starting generator and is generally advantageous when the number of units is large. Kasseb Pumped-Storage Power Station is to be a pure pumped-storage power station without a generator exclusively for power generation, while the number of units is relatively small at 4 units. The thyrister starting method is comparatively expensive in case the number of units is small, while there is no engineering necessity for this method to be adopted.

The coupled-motor starting method does not effect the power system very much at the time of starting, while control is relatively simple, and is a method suited to Kasseb Pumped-Storage Power Station.

The structure of the generator-motor is that of a vertical-shaft, semi-umbrella type, 3-phase synchronous generator-motor which is installed on barrel concrete.

The generator and motor capacities are 89,800 kVA (90,900 kVA) and 88,000 kW (89,000 kW) for Phase I, and 119,400 kVA (120,400 kVA) and 117,000 kW (118,000 kW) for Phase II. The frequency is 50 Hz, and the speed 214.3 rpm. The excitation system is to be a static excitation system using a thyrister.

The appurtenant apparatus of the generator-motors are wound-rotor induction motors for starting, liquid resistors for controlling motor speed, transformers for starting, cooling-water supply apparatus, excitation apparatus, neutral grounding apparatus, voltage regulation apparatus, etc.

Control of the generator-motors is to be by a one-man control system, carried out by remote control from a control room provided adjacent to the outdoor switchyard.

8.2.3 Main Transformers

The main transformers are to be of 3-phase, indoor-type, oil-immersed, water-cooled type, installed in the powerhouse along with the main units. Assembly is to be done in the assembly hall next to the main equipment hall. The low-voltage sides are to be connected to the generator-motors by isolated phase buses via disconnecting switches and circuit breaker, while the high-voltage sides are to be connected with outdoor switchyard equipment by OF cables laid in a cable tunnel. The main transformer capacities are to be 99,800 kVA (100,900 kVA) for Phase I and 129,400 kVA (130,400 kVA) for Phase II, to which capacities are to be added the inputs of wound-rotor induction motors required when starting the motors of pump mode and station service power.

8.2.4 Main Circuit Connections

The synchronizing and paralleling of the generator-motors with the electric power system is to be by a system on the low-voltage sides of main tranformers. Therefore, the transformers for starting motors (used also as station-service transformers) are to receive power from the low-voltage sides of main transformer. Phase reversal during motor operation are made between the branching points toward starting transformers and generator-motor terminals (see single-line diagram). The connections at the outdoor switchyard are to be ring-type connections which are standard for the S. T. E. G. power system. Kasseb Pumped-Storage Power Station is to be connected by 225 kV, single-circuit transmission lines to Tajerouine and M'Nihla substation.

Principal characteristics of electrical equipment and single line diagram show the Table 8-1 and the Fig. 8-19, 8-20, respectively.

8.3 TRANSMISSION LINES AND TELECOMMUNICATION FACILITIES

8.3.1 Preliminary Design of Transmission Lines

(1) Outline of Transmission Line Facilities

The transmission line facilities of this Project are to consist of the following:

Sections: From Kasseb PS to M'Nihla SS
(Phase I)
From Kasseb PS to Tajerouine SS
(Phase II)

Distance: Phase I 110 km
Phase II 120 km

The following are to be identical for both Phase I and Phase II.

Voltage: 225 kV
Electric System: 3 phase, 3 wire, 50 Hz
Number of Circuits: Single circuit
Conductor: ACSR 410 mm^2
Grounding Wire: Galvanized steel cable (GSC) 70 mm^2
Insulator: 254 mm dia., standard type, suspension insulator, 12 string
Support: Single-circuit type
Grounding System: Direct grounded

(2) Transmission Line Route

The route between Kasseb Power Station and M'Nihla Substation of Phase I is straight in a roughly east-west direction with the Kasseb Switchyard at the west end at a gentle mountain slope on the south side of Djebel El Famaha, the elevation of this site being roughly about 300 m. The M'Nihla Substation site located at the east end is at a plain at the northwest suburb of the capital city of Tunis and at present is at the stage of land acquisition having been completed. This M'Nihla Substation is to be an important substation serving as the key point for forming a 225 kV outer loop connecting with Naassen Substation at the sourthern part of Tunis.

This transmission line route for Phase I comprises a generally flat topography with the highest elevation not exceeding 600 m. There is no forest requiring felling of trees, the greater part consisting of wheat fields and olive orchards, with grape orchards becoming prominent at the M'Nihla side, so that it is thought special steel towers of large height will not be necessary except at river clossings.

The route between Kasseb Power Station and Tajerouine Substation of Phase II will run roughly north-south, and when constructed, this together with Phase I would mean that a part of the 225 kV system grid of Northern Tunisia, Kasseb-Tajerouine-Oueslatia-Naassen-M'Nihla- Kasseb will have been completed. The route of Phase II, when compared with that of Phase I will run deep through the Atlas Mountain Range so that the terrain is slightly rough, but not to the extent that it can be said to be especially rugged. This route runs south from Kasseb Power Station and crosses the T'eboursouk Mountain Range along the Tessa River. This part is of the highest elevation for both Phase I and Phase II, but the mountains are of gentle slope and it is thought there will be no necessity for special types of steel towers. On crossing the T'eboursouk Mountain Range, the line will run south along National Highway No. 5 and then along National Highway No. 17 to reach Tajerouine Substation. This route also will not pass through forests where felling of trees would be required as wheat fields and olive orchards are main.

Selection of the routes was made by desk studies using 1/200,000 and 1/50,000 topographical maps, field reconnaissances, and referring to advices from the STEG counterpart to arrive at approximate routes which would be technically feasible. At the stages of working design, it will be necessary for more detailed investigations of the routes to be made including convenience of construction and maintenance, and geological investigations.

(3) Meteorological Conditions

Although it was not possible to obtain past meteorological data, air temperatures are lowest at the Kasseb site and at the part crossing the T'eboursouk Mountain Range (approx. 900 m), and although extremely small, there is snowfall at the Kasseb site in the wintertime.

Further, it should be noted that the design conditions of STEG are for maximum air temperature of 50°C, minimum air temperature of -5°C, mean air temperature of 20°C, and design wind speed of a maximum of 30 m/sec (108 km/hr), and these are thought to be more or less reasonable valurs.

(4) Preliminary Design

(a) Insulation Design

Whith elevations of the routes below 1,000 m, IKL unknown, and maximum voltage of system Vm at 245.5 kV ($Vm = V_N \times \frac{12}{11}$ (kV)), insulation design was done considering switching surge voltage in a direct grounded system and commercial frequency abnormal voltage.

It was considered that the transmission line routes would not be subjected to soiling such as salt damage so that the appropriate number of insulators would be 12, and standard insulation gap and minimum insulation gap would be 1,600 mm and 1,250 mm, respectively. These are of basic insulation level (BIL) 170 or over.

(b) Conductor Design

According to the results of Power System analyses and power flow calculations in the previous report, the maximum power flow between Kasseb and M'Nihla at peak hours in 1988 will normally be 166.4 MVA (163.4 MW + j 31.7 Mvar), and between Kasseb and Tajerouine at peak hours 188.4 MVA (186.6 MW + j 26.2 Mvar), and with 188.4 MVA, the current will be 484 A when voltage is 225 kV. Assuming that the temperature of the conductor having this xurrent capacity will be 90°C, the size would be ACSR

200 mm^2, but considering loss by corona discharge, noise, and allowance for coping with demand increase as a part of the frid of STEG in the future, it has been decided to adopt ACSR 410 mm^2 which is of the same size as for the existing 225 kV transmission line. By doing so the 225 kV transmission lines of STEG will all be ACSR 410 mm^2 and it will be possible to use items of identical specifications such as in case of stringing hardware. The conductor surface potential gradient will be approximately 21 kV/cm and there will be no problems in the aspect of corona loss and noise.

There will be no concern about salt damage in view of the environment of the route and use of conductors of special specifications for corrosion-preventive structure are not necessary.

In stringing design it will be necessary to use every day stress. In this case, mechanical fatigue of conductors are to be considered and every day stress made 20%, with maximum working tension 4,130 kg.

The cramping point of conductors are to be provided with dampers from the standpoint of vibration-resistant design.

(c) Lightning Design

Although data on lightning observations required for lightning design of the facilities were not available, one overhead ground wire is to be strung in view of the fact that the existing 225 kV transmission lines of STEG are provided with overhead ground wires, and arcing horns are to be attached to insulator strings for protection of insulators.

(d) Supports

Single circuits are to be strung for both Phase I and Phase II sections. The necessity for double circuits cannot be recognized, at least not until 1990. With 225 kV class transmission lines steel towers would be of advantage without any question. Compared with other types, for example, concrete poles, they are economical and are mechanically of high reliability

Spacing of conductors is to be 8.6 m between horizontal lines and 4.5 m between vertical lines at standard-type steel towers. The standard spans are to be 350 m. Ordinary structural steel is to be used for steel tower members as there is no necessity for special weather-resistant steel to especially increase corrosion resistance.

A drawing of a standard steel tower is given in Fig. 8.21.

8.3.2 Preliminary Designs of Substations

The outlines of the take-out facilities of the 225-kV Substations for receiving power in this Project are as given below.

(1) M'Nihla Substation (Phase I)

- Circuit breaker, 3ø, 1 unit, 2,500 MVA, 800 A, with BCT
- Disconnecting switch, 3ø, 2 units, 800 A
- Potential device, 1ø, 3 units
- Lightning arrestor, 1ø, 3 units
- Blocking coil, 1ø, 3 units

(2) Tajerouine Substation (Phase II)

- Circuit breaker, 3ø, 1 unit, 2,500 MVA, 800 A, with BCT
- Disconnecting switch, 3ø, 2 units, 800 A
- Potential device, 1ø, 2 units
- Lightning arrestor, 1ø, 3 units
- Blocking coil, 1ø, 3 units

Regarding the locations of these two receiving substations they have already been decided on by STEG, and it is said there are no special problems about environment (salt damage, etc.). The substation bus systems are to be the ring bus system which is standard for STEG, and the necessary amounts of equipment have been calculated.

8.3.3 Preliminary Design of Telecommunication Facilities

The outline of telecommunication facilities for this Project are to be the following:

Description		Kasseb	M'Nihila	Tajerouine
Transmission téléphonique par ligne electrique	35 dBm 3 circuits	2	1	1
Système de blocage		2	1	1
Protection de la ligne	40 dBm	2	1	1
Localisateur de défaut	Type C	2		
Téléphone THF à la centre	10 W	1	1	1
Téléphone micro-onde portable	1 W	2	1	1

The blocking apparatus are required to be provided at M'Nihla substation and Tajerouine Substation to avoid frequency interference with existing power line carrier channels. The distances of the transmission lines in the Phase I and Phase II works are 110 km and 120 km, respectively, and there should be no special problems from such occurrences as carrier wave attenuation.

8.3.4 Circuit Structures

The telecommunication circuits required for load dispatching and maintenance of transmission lines are to be structures as follows:

(1) Load Dispatching Telephone Channels

Load dispatching commands to Kasseb Power Station, M'Nihla Substation and Tajerouine Substation are to be transmitted by the route of National Dispatching Center of Tunis → M'Nihla Substation → Kasseb Power Station → Tajerouine Substation, and load dispatching telephone channels are to be provided between the sections by power line carrier equipment.

The outlines of the power line carrier channels concerned with this Project are the following:

National Dispatching Center - M'Nihla Substation
3 ch, 35 dBm, 1 system
M'Nihla Substation - Kasseb Power System
2 ch, 35 dBm, 1 system
Kasseb Power Station - Tajerouine Substation
1 ch, 35 dBm, 1 system

(2) Transmission Protection Relay by Power Line Carrier

Power line carrier protection relays are to be provided between the sections of Kasseb Power Station to M'Nihla Substation and Kasseb Power Station to Tajerouine Substation, and signals for circuit breaker opening and reclosing are to be transmitted to the other end in case of transmission line faulting.

(3) VHF Channels for Line Maintenance

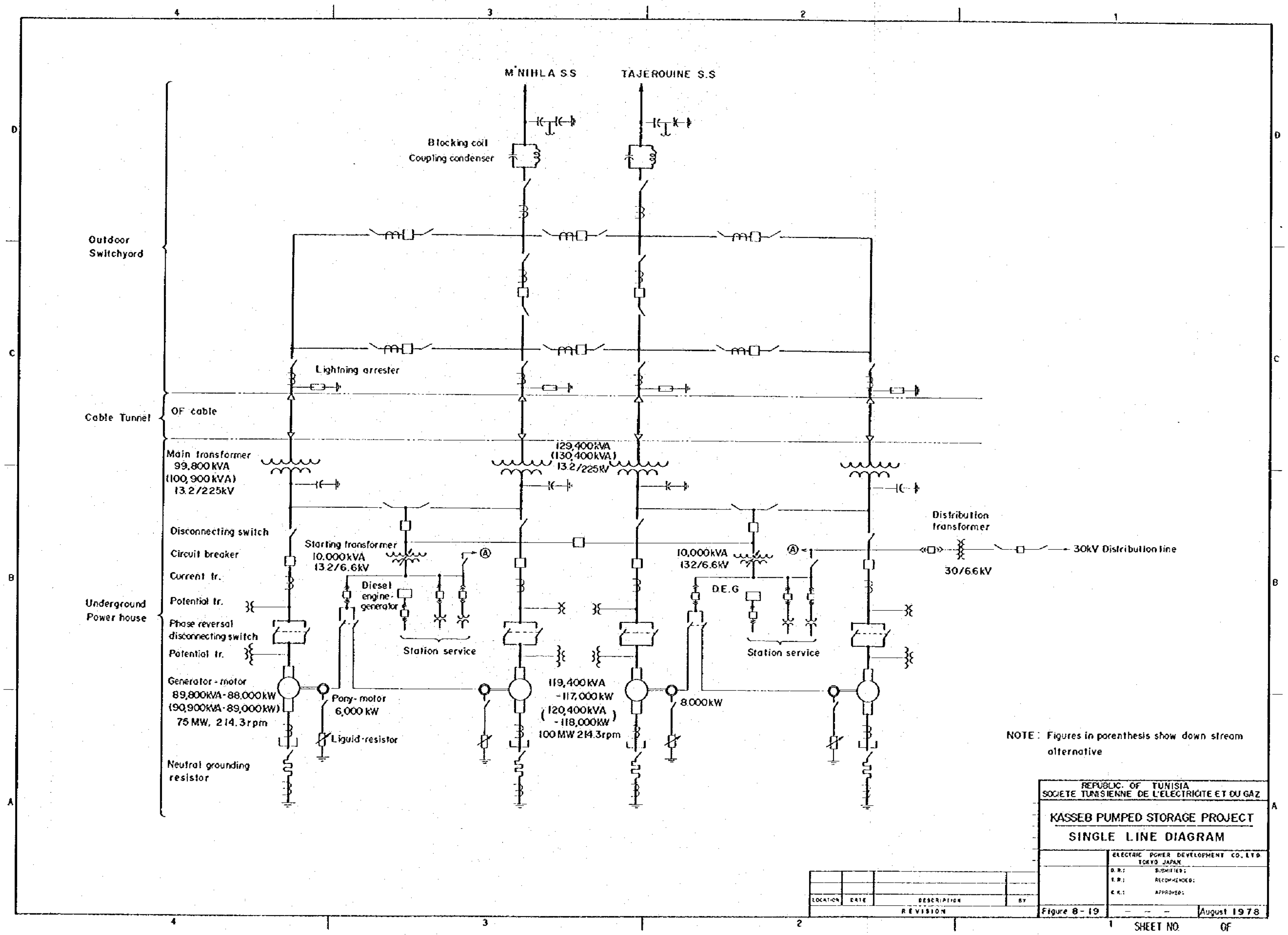
It will be tentatively considered here that the base for maintenance of the Phase I and Phase II transmission lines will be located at Kasseb Power Station, and a VHF base station will be installed, but with only this the radio waves will not reach far enough to cover the entire sections so that base stations will need to be provided at both the M'Nihla and Tajerouine substations also.

(4) Fault Locater

For rapid restoration from transmission line faulting, fault locater apparatus will be installed at Kasseb Power Station, which will be activated for locating faults in the transmission lines going out to M'Nihla and Tajerouine.

Tableau 8-1 CARACTERISTIQUES PRINCIPALES DE L'APPAREILLAGE ELECTRIQUE

Description	Groupe 75 MW (Phase I) Variante amont	Groupe 75 MW (Phase I) Variante aval	Groupe 100 MW (Phase II) Variante amont	Groupe 100 MW (Phase II) Variante aval
Pompe-turbine : Francis réversible à axe vertical				
Turbine				
Puissance	76.600 KW	76.600 KW	102.200 KW	102.200 KW
Chute nette utile	137,4 m	134,5 m	137,4 m	134,5 m
Débit maximum équipé	64,2 m^3/s	65,5 m^3/s	85,6 m^3/s	87,5 m^3/s
Vitesse de rotation	214,3 tr/mn	214,3 tr/mn	214,3 tr/mn	214,3 tr/mn
Pompe				
Puissance maximum fournie	88.000 KW	89.000 KW	117.000 KW	118.000 KW
Portée maximum de pompage	159 m	160 m	159 m	160 m
Débit maximum	65,6 m^3/s	66,0 m^3/s	87,5 m^3/s	87,9 m^3/s
Vitesse de rotation	214,3 tr/mn	214,3 tr/mn	214,3 tr/mn	214,3 tr/mn
Alternateur-moteur : Triphasé synchrone, du type semi-parapluie à axe vertical				
Alternateur				
Puissance	89.800 kVA	90.900 kVA	119.400 kVA	120.400 kVA
Tension	13,2 kV	13,2 kV	13,2 kV	13,2 kV
Fréquence	50 Hz	50 Hz	50 Hz	50 Hz
Facteur de puissance	0,84	0,83	0,84	0,83
Moteur				
Puissance	88.000 kW	89.000 kW	117.000 kW	118.000 kW
Tension	13,2 kV	13,2 kV	13,2 kV	13,2 kV
Fréquence	50 Hz	50 Hz	50 Hz	50 Hz
Facteur de puissance	0,98	0,98	0,98	0,98
Moteur "Poney" : Moteur à induction à rotor bobiné				
Puissance	6.000 kW	6.000 kW	8.000 kW	8.000 kW
Tension	6,6 kV	6,6 kV	6,6 kV	6,6 kV
Vitesse de rotation	250 tr/mn	250 tr/mn	250 tr/mn	250 tr/mn
Transformateur de puissance : Type triphasé, à refroidissement par circulation d'huile dans les hydro-réfrigérants				
Puissance	99.800 kVA	100.900 kVA	129.400 kVA	130.400 kVA
Tension	13,2/225kV	13,2/225kV	13,2/225kV	13,2/225 kV
Transformateur de démarrage : Type triphasé, à refroidissement par circulation d'huile dans les hydro-réfrigérants				
Puissance	10.000 kVA	10.000 kVA	10.000 kVA	10.000 kVA
Tension	13,2/6,6kV	13,2/6,6kV	13,2/6,6kV	13,2/6,6kV


M'NIHLA S.S
TAJEROUINE S.S
Blocking coil
Coupling condenser
Outdoor Switchyard
Lightning arrester
Cable Tunnel
OF cable
Main transformer 99,800 kVA (100,900 kVA) 13.2/225kV
129,400kVA (130,400kVA) 13.2/225kV
Disconnecting switch
Circuit breaker
Current tr.
Potential tr.
Phase reversal disconnecting switch
Potential tr.
Generator - motor 89,800kVA - 88,000kW (90,900kVA - 89,000kW) 75 MW, 214.3rpm
Neutral grounding resistor
Underground Power house
Starting transformer 10,000kVA 13.2/6.6kV
Diesel engine-generator
Station service
Pony-motor 6,000 kW
Liquid-resistor
119,400kVA -117,000kW (120,400kVA -118,000kW) 100MW 214.3rpm
10,000kVA 13.2/6.6kV
D.E.G
Station service
8,000kW
Distribution transformer
30/6.6kV
30kV Distribution line
NOTE : Figures in parenthesis show down stream alternative
REPUBLIC OF TUNISIA
SOCIETE TUNISIENNE DE L'ELECTRICITE ET DU GAZ
KASSEB PUMPED STORAGE PROJECT
SINGLE LINE DIAGRAM
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
LOCATION
DATE
DESCRIPTION
BY
REVISION
Figure 8 - 19
August 1978
SHEET NO.
OF

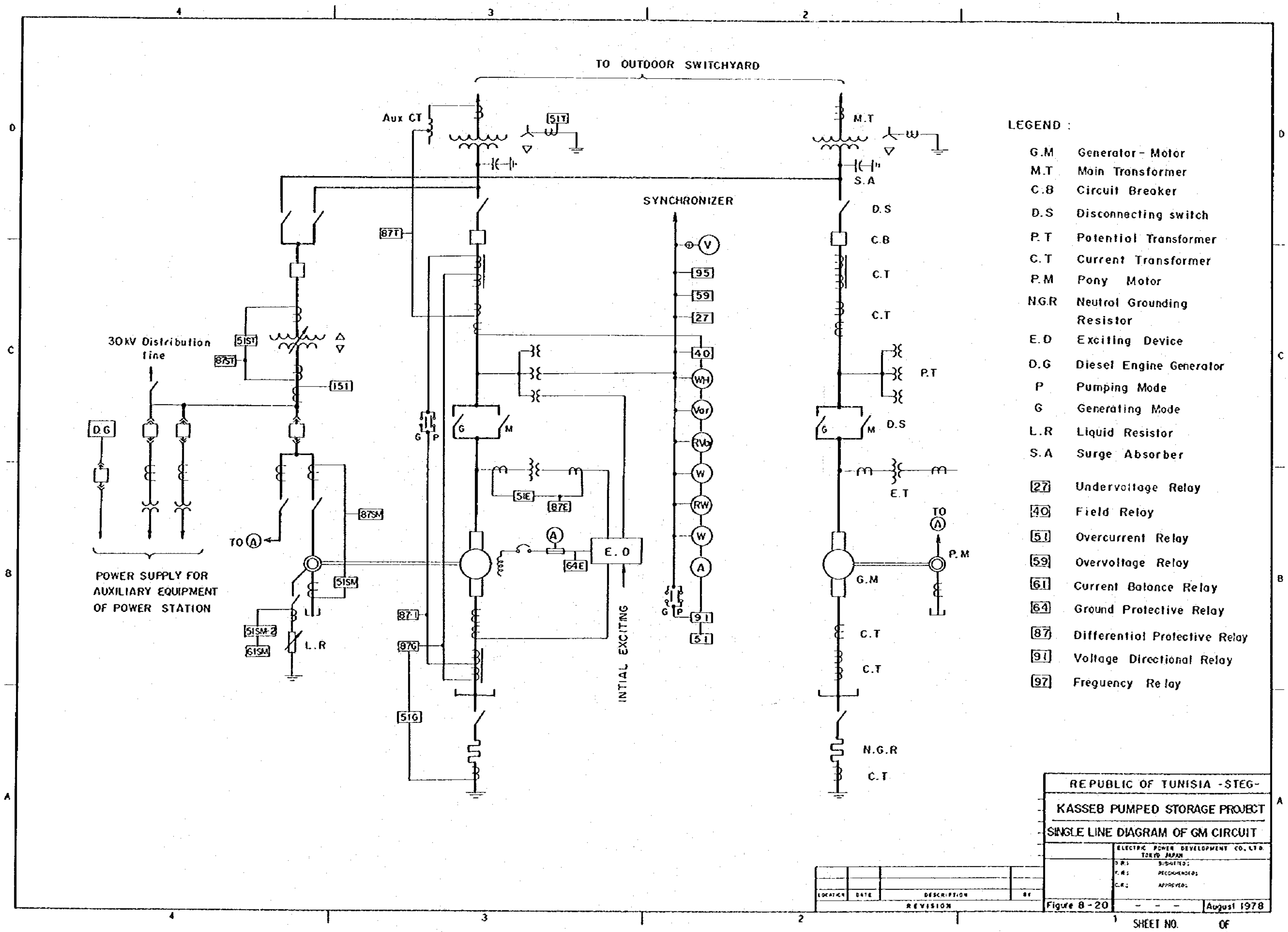

TO OUTDOOR SWITCHYARD
Aux CT
51T
M.T
S.A
D.S
C.B
C.T
SYNCHRONIZER
87T
95
59
27
40
WH
Var
RVa
W
RW
A
V
151
51ST
87ST
30kV Distribution line
D.G
87SM
TO A
51SM
51SM-2
61SM
L.R
POWER SUPPLY FOR AUXILIARY EQUIPMENT OF POWER STATION
G
M
P
51E
87E
E.D
64E
INTIAL EXCITING
87-1
87G
51G
91
51
P.T
E.T
P.M
G.M
N.G.R
LEGEND :
G.M Generator - Motor
M.T Main Transformer
C.B Circuit Breaker
D.S Disconnecting switch
P.T Potential Transformer
C.T Current Transformer
P.M Pony Motor
N.G.R Neutral Grounding Resistor
E.D Exciting Device
D.G Diesel Engine Generator
P Pumping Mode
G Generating Mode
L.R Liquid Resistor
S.A Surge Absorber
27 Undervoltage Relay
40 Field Relay
51 Overcurrent Relay
59 Overvoltage Relay
61 Current Balance Relay
64 Ground Protective Relay
87 Differential Protective Relay
91 Voltage Directional Relay
97 Frequency Relay
REPUBLIC OF TUNISIA -STEG-
KASSEB PUMPED STORAGE PROJECT
SINGLE LINE DIAGRAM OF GM CIRCUIT
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
REVISION
Figure 8-20
August 1978
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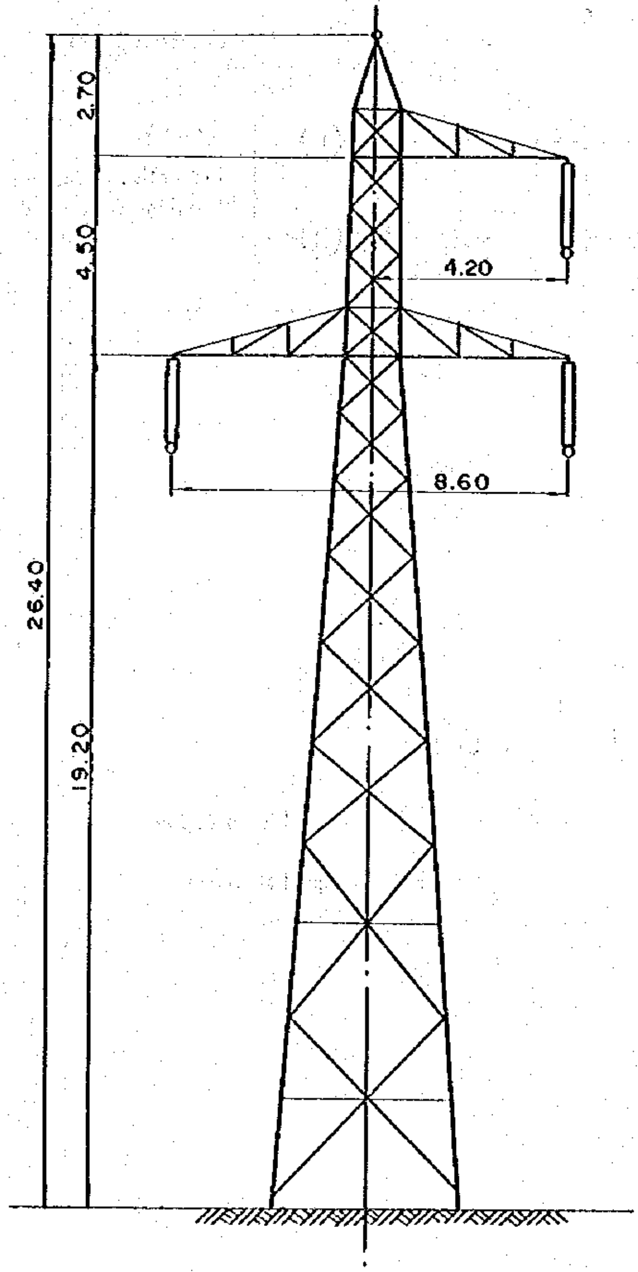
Figure 8-21 PYLONE A SUSPENSION STANDARD POUR LA LIGNE 225 KV



Nombre de terne : un terne

Portée normale : 350 mètres

Conducteur : Al-Ac 410 mm²

Fil mis à la terre : câble d'acier galvanisé 70 mm²

Unité : mètre

Echelle : 1/150

Figure 8-22 POWER LINE CARRIER PROTECTIVE RELAYING SYSTEM DIAGRAM

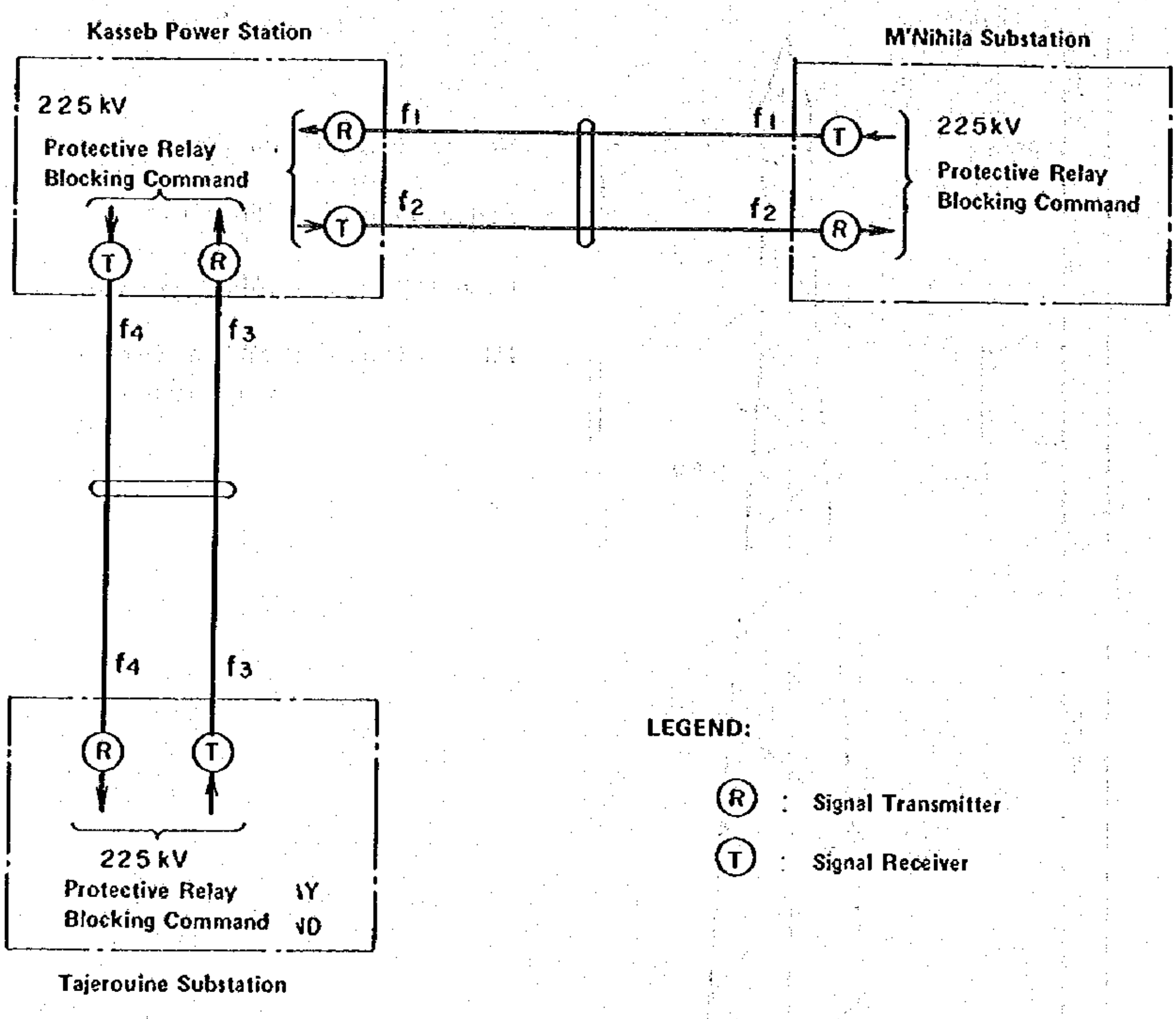
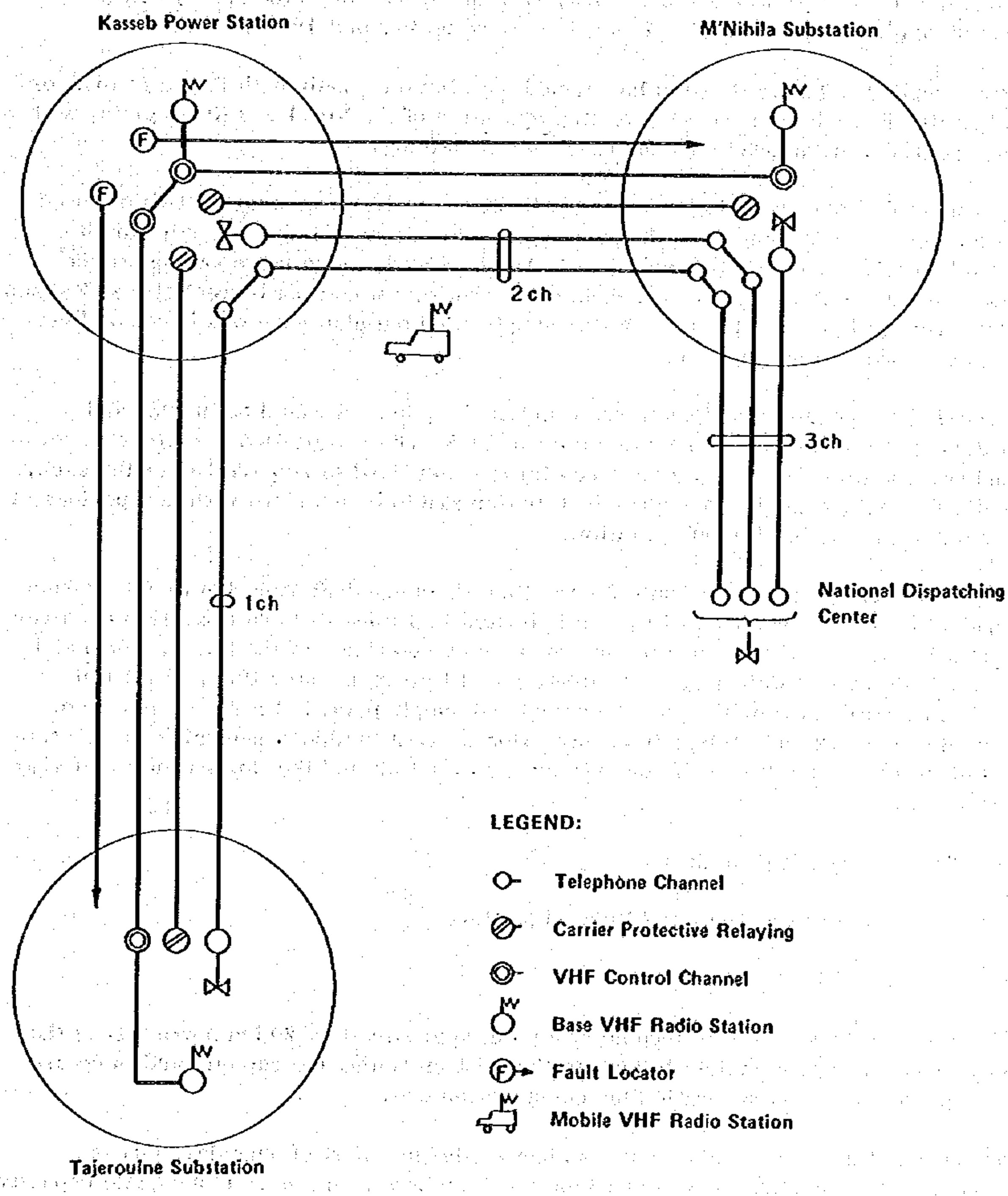


Figure 8-23 TELECOMMUNICATION CIRCUIT DIAGRAM



8.4 CONSTRUCTION SCHEDULE AND WORK EXECUTION PLAN

Civil works will begin with preparatory work (access road, temporary field facilities) in the latter half of 1980, and except for concrete work around the No. 3 and No. 4 turbine units and part of building work, all other work (more than 98%) will be completed by the time the No. 1 Unit is started up in April 1985.

Civil works for Phase II are to be carried out simultaneously with Phase I work, or otherwise it would be necessary to stop operation of the No. 1 and No. 2 units, with only partial work around turbines to be left remaining.

The most difficult work in the Project will be the underwater construction of outlets at a depth of more than 30 m. If it were possible to dry up Kasseb Reservoir this would allow the construction schedule to be shortened, make large savings in the construction cost and avoid hazardous work, but this would not be realistic as Kasseb Reservoir is being used for city water supply, and the plan here was based on lowering of the water level by 10 m.

Ordering of hydraulic equipment and electrical equipment would be in 1981 and ordering of transmission line materilals in 1982. The installation of turbine-generators and transmission line work (both circuits) is considered to require 18 months each, while the turbine-generators after installation are to be provided with test periods of 4 months each until start of operation.

The entire construction schedule for the Kasseb Pumped-Storage Power Generation Project based on the above will be as indicated in Tables 8.2 and 8.3. This construc tion schedule was established in view of the start-up times of the No. 2, No. 3 and No. 4 units (No. 2 Unit in January 1986, No. 3 Unit in January 1988, No. 4 Unit in January 1989) based on the power demand and supply plan, but for convenience of installation work and savings in construction cost, it is also conceivable for the No. 2 Unit to be started up a half year after the No. 1 Unit and the No. 4 Unit a half year after the No. 3 Unit.

8.4.2 Construction Method

(1) Regional Conditions and Related Matters

(a) Transport Road

The Kasseb Project site is located at a point approximately 20 km northwest of the city of Beja, approximately 100 km to the west of Tunis, the capital, and is favored with good conditions of location for construction work.

Tunis is not only the capital, but also has the largest port of Tunisia. Beja is connected to Tunis by a paved two-lane trunk highway, and there is adequate capacity for landing and transporting imported material, machinery and equipment for the Kasseb Project. The road from Beja to the construction site will be serviceable with only a few minor improvements made.

(b) Electric Power for Construction

For transmission of electric powere required for work in the Kasseb Project, utilization of the 33,000 kV transmission line of the existing Kasseb Power Station thought to have been used during construction of Kasseb Dam may be made.

Further, a power-receiving substation is to be provided near Kasseb Power Station, and electric power is to be supplied by 16.6-kV destribution lines to the dam, penstocks, powerhouse and tailrace. It is thought that the electric power required for this Project will be approximately 6,000 kW with the length of destribution lines being estimated to be approximately 6 km.

(c) Water Supply Facilities

Water springs at the upper reservoir may partially be used as construction water and drinking water, but the water of Kasseb Reservoir will be mainly used.

(2) Procurement of Construction Materials

The quantities of the principal materials to be used for construction are estimated to be 72,000 tons of cement, 9,200 tons of reinforcing steel, 8,600 tons of other steel, and approximately 1,500 kiloliters of oils such as kerosene,gasoline and heavy oil. Almost all of these materials would be imported.

Core and rock materials for the fill dam can be readily collected from the vicinity of the construction site. Since filter material cannot be found in the vicinity, an aggregate plant is to be provided to manufacture this material along with coarse and fine aggregates for concrete quarrying limestone from the neighborhood of the upper reservoir.

Further, utilization of soil excavated for the dam in embankment, and utilization of muck from excavation for underground structures in embankment and for aggregates are to be planned.

(3) Study of Kasseb Reservoir Water Level during Construction

Whether the outlet work of this Project can be done in the dry or will be underwater work is a matter that will greatly affect design, construction and construction costs.

For the purpose of this Report the study below was made and it was assumed that Kasseb Reservoir would be operated during construction at 10 m or more below high water level.

(a) Conditions of Study are as follows,

(i) Discharge from Kasseb Reservoir is to be a constant 1.40 m^3/sec throughout the year according to Item (4) of the basic consitions of the development plan.

(ii) The capacity of the outlet pipe of Kasseb Dam is to be a maximum 75 m^3/sec at high water level.

(iii) Runoff data and the period covered are to be for the 18-year period shown in Table 6.1, B-11.

(iv) The relation between water level and storage capacity is to be according to Fig. 7.9.

(b) Method

The restricted water level of the reservoir is to be determined where the discharge conditions would be satisfied, while moreover, lowering water level as much as possible.

(c) Results

As shown in Fig. 8.24, it was found that the water level reaches once at the bottom in the said eighteen years in case the Kasseb reservoir would be operated at 10 m below. It will be not unreasonable to assume, however, that real water shortage can be avoided by saving water consumption in Tunis or increasing water supply from Ben Metir reservoir. Thus the restricted water level during construction was finally set as 10 m lowered from the high water level.

(4) Construction of Principal Structures

(a) Care of River

The flood discharge at the upper reservoir is small with the estimated past maximum being 5.7 m^3/sec.

Care of river at the upper reservoir dam is to be done by burying a pipe from upstream to downstream on the foundation at the damsite. This facility is to be utilized in the future as a sand flush cum outlet pipe facility.

(b) Dam and Upper Reservoir

At the left bank there is outcropping in general so that excavation would be limited to the degree of removing surface layers of rock where weathering is severe, while at the right bank there are colluvial deposits and softening by weathering so that excavation is to be done to depths of 2 to 8 m.

It is expected that faults will exist along the river flow at the damsite and these will cross the dam axis more or less perpendicularly, and treatment will be considered according to the results of further investigations.

Grouting for foundation treatment will be carried out for prevention of leakage and improving bearing capacity of the foundation ground.

The volumes required for embankment of the dam are the following:

Fill dam	959,500 m^3
Impervious material	146,700 m^3
Filter material	92,200 m^3
Shell material	720,600 m^3

The main heavy equipment to be used for embankment will consist of wheel-loaders of capacity of 4-m^3 class, dump trucks of 20-ton capacity, two bulldozers of 20- to 30- ton class, and sheepsfoot rollers. The transport road from the construction material borrow area to the dam will be a road with width, grade and curvatures allowing trucks to be capable of passing at adequate speed.

The lift heights of embankment and the methods of compaction should be determined on execution of test embankments.

(c) Intake and Penstock

For the intake, care must be exercised not to cause unnecessary disturbance in excavation from the standpoint of protection from erosion.

Excavation for the penstocks will be done by first providing a work adit branching from the access tunnel immediately above the penstock bifurcation point 100 m upstream from the powerhouse with tunnel excavation done in the upatream and downstream directions from this point. Steel pipes are to be installed after completion of excavation and the gaps between the original ground and the steel pipes backfilled with concrete. The work adit is to be utilized for ventilation, mucking and hauling in of materials and equipment.

(d) Powerhouse and Switchyard

Construction of the powerhouse is to be done by first connecting to the arch portion of the powerhouse utilizing the cable tunnel as a work adit to perform excavation of the arch portion. The arch portion is to be lined with concrete to fix the ceiling. A work adit from the tailrace and the access tunnel are to be utilized for excavation of the powerhouse proper and the foundation part.

Depending on the strength of the ground, concrete placement is to be done in parallel with excavation for reinforcement purposes.

The crane and electrical equipment are to be erected and installed after placement of concrete.

Regarding the Switchyard, the cable tunnel is to be provided on a priority basis from the standpoint of powerhouse construction, and the necessary plot is to be made level through a combination of excavation and embankment.

(e) Surge Chamber and Tailrace

The surge chamber is to be excavated starting with the upper air vent and the lower work adit.

The tailrace is to be excavated in the upstream and downstream directions from the surge chamber, and also in the upstream and downstream directions from a work adit provided approximately 500 m upstream from the outlet. The portion upstream of the surge chamber is to have lining pipes installed after excavation with backfill concrete placed in the gaps between the pipes and rock.

The surge chamber and downstream portions are to be lined with concrete after excavation.

Advance boring is to be done in the vicinity of the connection with the outlet to confirm whether the original ground is weak or whether there is springing of water, and in such cases the original ground must be thoroughly reinforced by grouting or other means.

(f) Tailrace Outlet

Kasseb Reservoir is to be operated lowering the water level 10 m during construction.

The construction is to be done by a method utilizing a pneumatic caisson because of the topographical conditions and the work will be underwater.

The construction method would consist of dumping soil at the outlet site to make a mound on which to rest the pneumatic caisson. Follwing this, the caisson is to be lowered to the specified depth (by diggingunder) to install the caisson. After installation, the surrounding area of the vertical shaft at the lower part of the outlet is to be improved by grouting to make the bedrock watertight upon which excavation is to be done and connection made to the tailrace.

The mound is to be removed subsequently so that there will be no hindrance to power generation, and pump-up operations.

Installation of outlet gates and screens, and placing of concrete will be done.

In the case of Upstream Alternative, the original ground along with the existing Kasseb reservoir is used as watertight coffer block after grouted or sheet-piled, if necessary. The outlet will be constructed after excavation, and then the coffer block will be removed partly under the water.

Fig.-8.1 Study on Tunnel Diameter

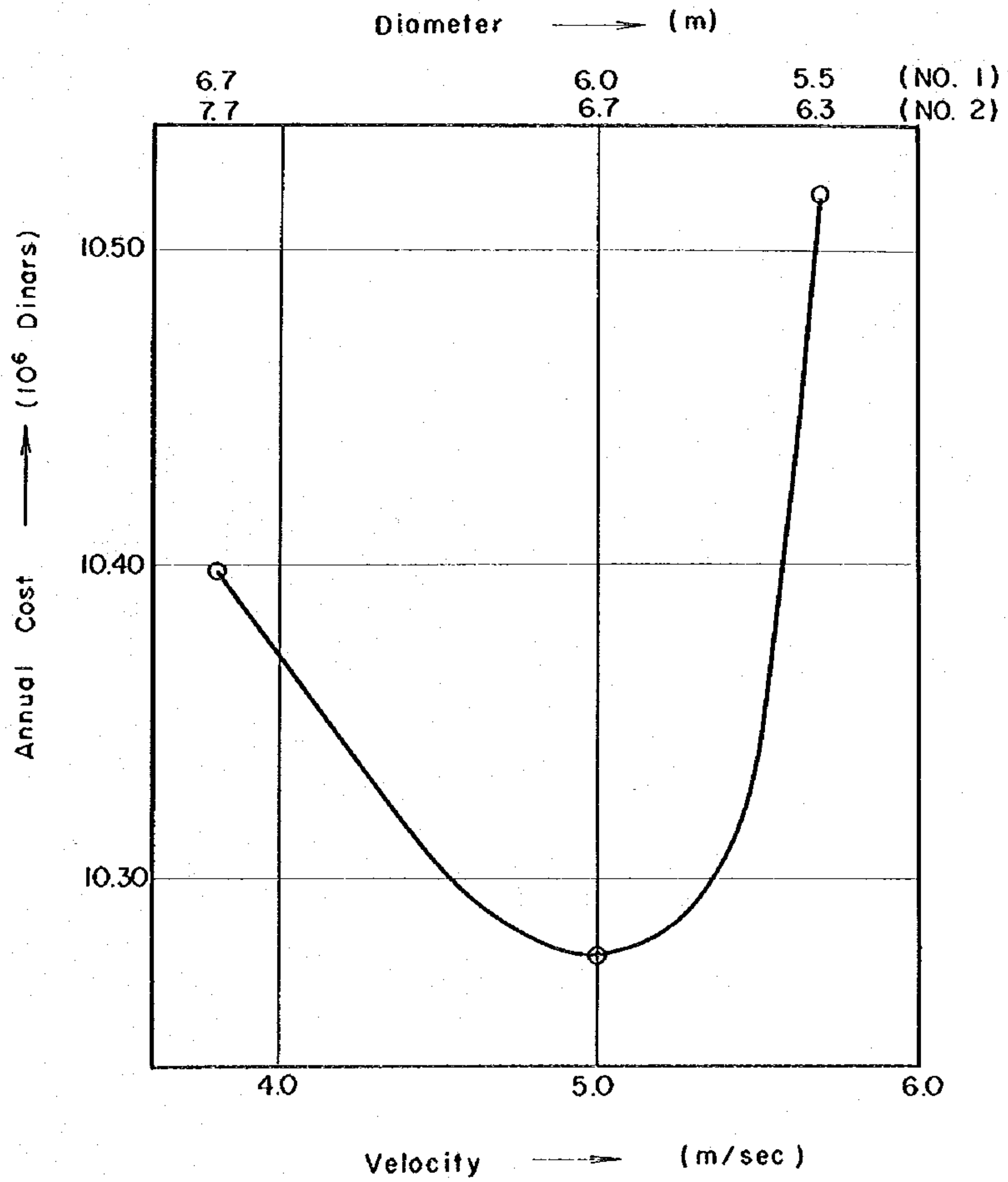
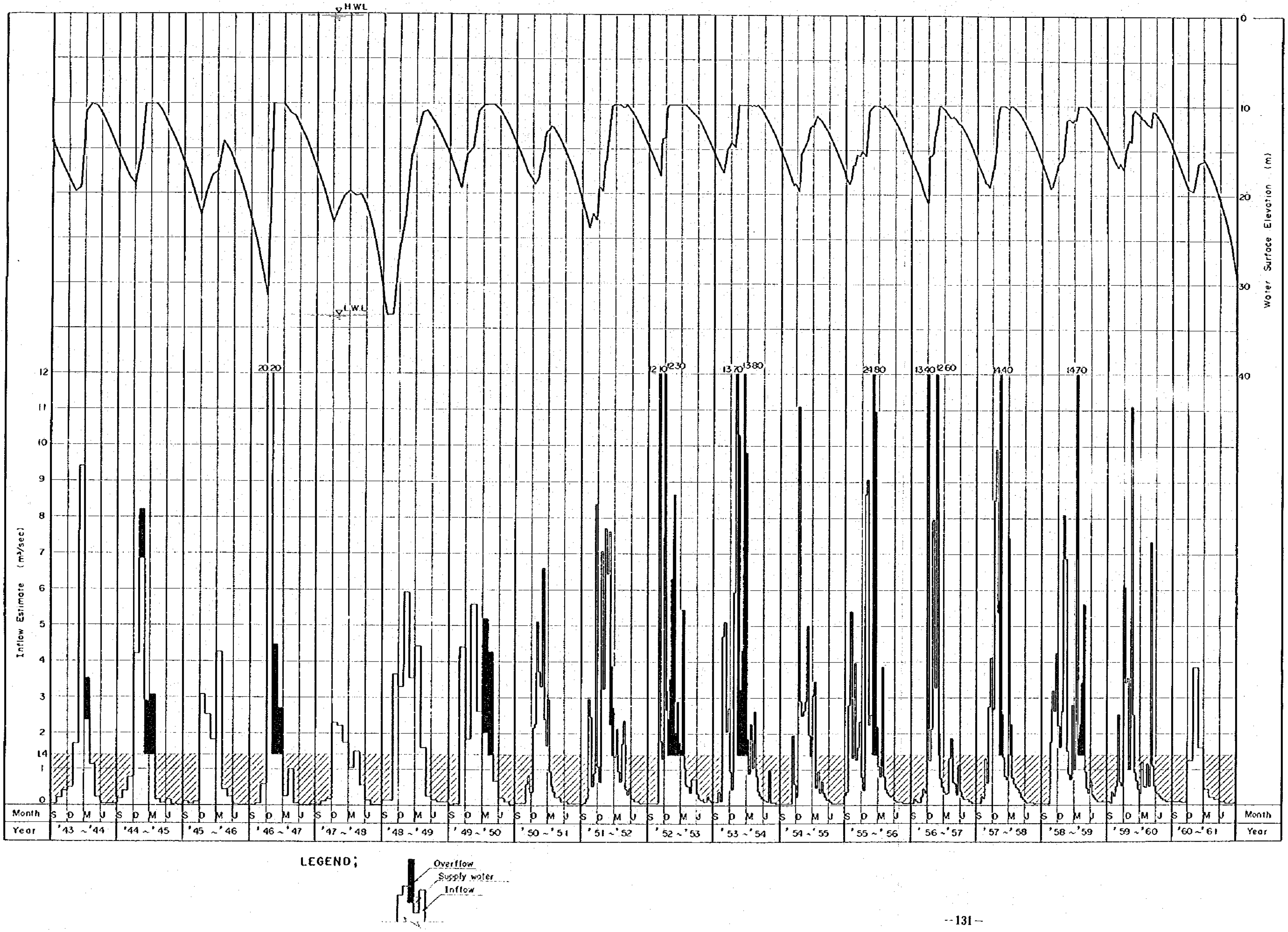


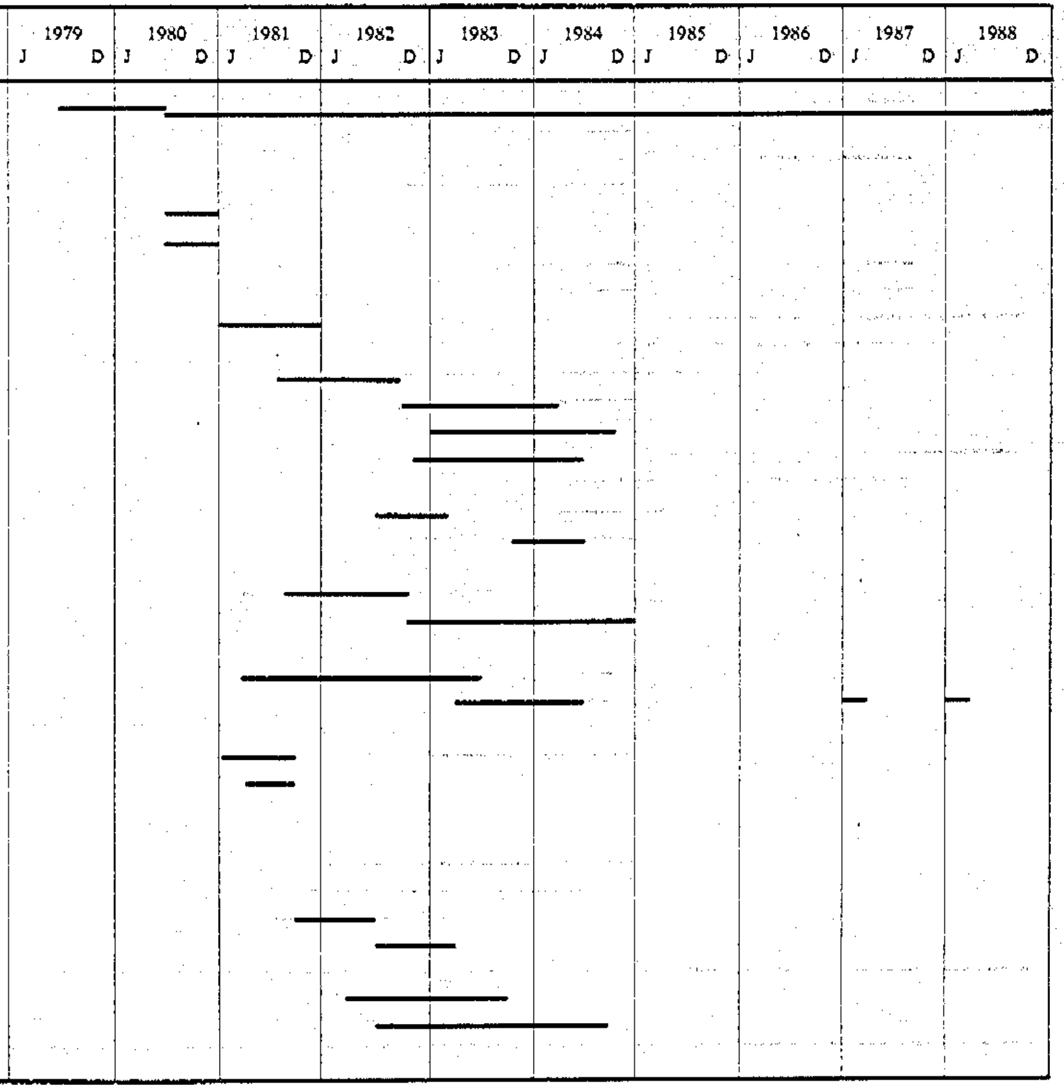
Figure 8-24 WATER LEVEL OF LOWER RESERVOIR DURING CONSTRUCTION

– Discharge : 1.40 m³/sec –



Graphique 8-1 PROGRAMME DES TRAVAUX
— Variante amont —

Description	Quantité des travaux
1. ETUDE DETAILLEE ET SURVEILLANCE DES TRAVAUX (Ingénierie)– ADMINISTRATION	
2. TRAVAUX PREPARATIFS	
2.1 CITE DU CHANTIER	
2.2 ROUTES D'ACCES	
3. TRAVAUX DE GENIE CIVIL	
3.1 DERIVATION PROVISOIRE	
3.2 BARRAGE SUPERIEUR:	
Excavation	165.100 m³
Bétonnage	440 m³
Remblais	959.500 m³
Injection	7.400 m³
3.3 PRISE D'EAU AMONT:	
Excavation	114.300 m³
Bétonnage	14.520 m³
3.4 GALERIE D'AMENEE: (Conduite forcée) Excavation	117.000 m³
Bétonnage	51.100 m³
3.5 CENTRALE:	
Excavation	125.800 m³
Bétonnage	42.750 m³
3.6 TUNNEL D'ACCES:	
Excavation	26.500 m³
Bétonnage	7.190 m³
3.7 CHAMBRE D'EQUILIBRE:	
Excavation	
Bétonnage	
3.8 GALERIE DE FUITE:	
Excavation	65.300 m³
Bétonnage	25.150 m³
3.9 PRISE D'EAU AVAL:	
Excavation	749.400 m³
Bétonnage	22.860 m³
Remblais	60.000 m³



Description	Quantité des travaux	1979 J D	1980 J D	1981 J D	1982 J D	1983 J D	1984 J D	1985 J D	1986 J D	1987 J D	1988 J D
3.10 POSTE DE SECTIONNEMENT:											
Excavation	225.300 m³										
Remblais	12.600 m³										
3.11 SALLE DE CONTROLE											
4. MATERIEL HYDRAULIQUE											
4.1 CONDUITE DE VIDANGE DE FOND											
4.2 CONDUITE FORCEE											
4.3 VANNE DE DIFFUSEUR											
4.4 BLINDAGES											
4.5 VANNE DE LA PRISE D'EAU AVAL											
5. MATERIEL ELECTRIQUE											
5.1 PONT ROULANT											
5.2 POMPE-TURBINE:											
1er Groupe											
2e Groupe											
3e Groupe											
4e Groupe											
ALTERNATEUR-MOTEUR:											
1er Groupe											
2e Groupe											
3e Groupe											
4e Groupe											
5.3 POSTE DE SECTIONNEMENT											
5.4 TELECOMMUNICATION											
6. LIGNE DE TRANSPORT ET LES POSTES											
6.1 LIGNE KASSEB – M'NIHILA	110 km										
6.2 LIGNE KASSEB – TAJEROUINE	120 km										
6.3 POSTE DE M'NIHILA											
6.4 POSTE DE TAJEROUINE											

Graphique 8-2 PROGRAMME DE TRAVAUX
— Variante aval —

Description	Quantité des travaux	1979 J D	1980 J D	1981 J D	1982 J D	1983 J D	1984 J D	1985 J D	1986 J D	1987 J D	1988 J D
1. ETUDE DETAILLEE ET SURVEILLANCE DES TRAVAUX (Ingénierie) – ADMINISTRATION											
2. TRAVAUX PREPARATIFS											
2.1 CITE DU CHANTIER											
2.2 ROUTES D'ACCES											
3. TRAVAUX DE GENIE CIVIL											
3.1 DERIVATION PROVISOIRE											
3.2 BARRAGE SUPERIEUR:											
Excavation	165.000 m³										
Bétonnage	440 m³										
Remblais	959.500 m³										
Injection	7.400 m³										
3.3 PRISE D'EAU AMONT:											
Excavation	100.200 m³										
Bétonnage	13.800 m³										
3.4 GALERIE D'AMENEE:											
(Conduite forcée) Excavation	93.300 m³										
Bétonnage	42.910 m³										
3.5 CENTRALE:											
Excavation	127.100 m³										
Bétonnage	43.280 m³										
3.6 TUNNEL D'ACCES:											
Excavation	24.000 m³										
Bétonnage	7.500 m³										
3.7 CHAMBRE D'EQUILIBRE:											
Excavation	40.400 m³										
Bétonnage	17.730 m³										
3.8 GALERIE DE FUITE:											
Excavation	207.400 m³										
Bétonnage	79.340 m³										
3.9 PRISE D'EAU AVAL:											
Excavation	214.900 m³										
Bétonnage	26.200 m³										
Remblais	290.000 m³										

Description	Quantité des travaux	1979 J D	1980 J D	1981 J D	1982 J D	1983 J D	1984 J D	1985 J D	1986 J D	1987 J D	1988 J D
3.10 POSTE DE SECTIONNEMENT:											
Excavation	225.300 m³										
Remblais	12.600 m³										
3.11 SALLE DE CONTROLE											
4. MATERIEL HYDRAULIQUE											
4.1 CONDUITE DE VIDANGE DE FOND											
4.2 CONDUITE FORCEE											
4.3 VANNE DE DIFFUSEUR											
4.4 BLINDAGES											
4.5 VANNE DE LA PRISE D'EAU AVAL											
5. MATERIEL ELECTRIQUE											
5.1 PONT ROULANT											
5.2 POMPE-TURBINE:											
1er Groupe											
2e Groupe											
3e Groupe											
4e Groupe											
ALTERNATEUR-MOTEUR:											
1er Groupe											
2e Groupe											
3e Groupe											
4e Groupe											
5.3 POSTE DE SECTIONNEMENT											
5.4 TELECOMMUNICATION											
6. LIGNE DE TRANSPORT ET LES POSTES											
6.1 LIGNE KASSEB – M'NIHILA	110 km										
6.2 LIGNE KASSEB – TAJEROUINE	120 km										
6.3 POSTE DE M'NIHILA											
6.4 POSTE DE TAJEROUINE											

CHAPTER 9. CONSTRUCTION COST

CHAPTER 9 CONSTRUCTION COST

9.1 CONDITIONS FOR ESTIMATION

The construction cost must be estimated taking into overall account natural conditions, regional conditions, project scale, and the level of construction technology of Tunisian contractors, and moreover, necessary allowances.

9.1.1 Civil Works Construction Cost

With regard to unit civil works construction costs in Tunisia, there are the unit construction costs given in the prefeasibility study report on the Kasseb Pumped-Storage Power Generation Project prepared by THCHSULT in 1975, and the unit construction cost as of March 1977 estimated by the Ministry of Construction based on the unit cost for the Sidi Salem Dam and Power Station Project put out to bid in 1976. Based on these unit costs, the unit construction cost as of March 1978 was set up for this Report in accordance with the procedure below.

(a) In connection with the Ministry of Construction unit cost, the 1978 unit cost is to be established assuming a rise of 17.5% in labor wages during the past year and 7% in materials costs.

(b) With regard to the unit cost in the THCHSULT report, the estimated unit price escalation rate of 21% (1.10 × 1.10 = 1.21) for the 2-year period of 1975 to 1977 is to be applied to check the Ministry of Construction unit cost as of 1977 indicated above.

(c) The unit cost for this Report is to be set upon comprehensive consideration of the 1978 unit cost according to (a), the revision according to (b), and the unit cost in Japan as of 1978.

9.1.2 Costs of Hydroelectric Equipment, Electrical Equipment, and Power Transmitting and Transforming Equipment

Equipment costs were estimated referring to the prices at present in Japan, Europe and America.

9.1.3 Contingency Expenses

Contingency expenses were estimated to amount to 10% for civil works and hydraulic equipment such as gates and penstocks, and 7.5% for power station electrical equipment, transmission lines, substation equipment, and telecommunication equipment.

9.1.4 Engineering Fee and Administrative Expenses

The engineering costs for preparing working designs and for construction supervision, and the administrative expenses of STEG during the construction period were each estimated to be 5% of the direct construction cost.

9.1.5 Domestic and Foreign Currency Portions

The construction cost would be separated into a domestic currency portion and a foreign currency portion, of which the former would include wages of indigenous laborers, personnel costs of STEG administrative staff, construction materials such as cement, reinforcing steel, lumber, fuel, fats and oils, etc. Other than these, hydraulic equipment, electrical equipment, power transmission and substation materials, construction machinery, temporary facilities, and expenses for foreign work supervisors, installation instructors and consultants would be calculated to be in the foreign currency portion.

For each of the above domestic and foreign currency portions, summations were made by cost item fot hydraulic equipment, electrical equipment, and transmission and substation materials, while for civil works a global rate reflecting EPDC experience was applied. The results are as indicated below.

	Domestic Currency Portion	Foreign Currency Portion
Civl work	40%	60%
Hydraulic equipment (incl. installation)	10%	90%
Electrical equipment (incl. installation)	9%	91%
Transmission & substation facilities (incl. installation)	22%	78%

9.2 TOTAL CONSTRUCTION COST

Total construction costs were estimated for the Upstream Alternative and the Downstream Alternatives both for available drawdown of 15 m. As a result, the Upstream Alternative is estimated to cost 81,327,900 Dinars and the Downstream Alternative 92,744,800 Dinars, and the latter alternative will result in an increase in construction cost of 11,416,900 Dinars.

The breakdowns of these total construction costs separated into domestic and foreign currency portions are as indicated in Table 9-1. According to this table the ratios of the domestic and foreign currency portions in the total construction costs are as given below.

	Upstream Alternative	Downstream Alternative
Domestic currency portion	20,670,900 DT (25%)	25,784,400 DT (28%)
Foreign currency portion	60,657,000 DT (75%)	66,960,400 DT (72%)
Total	81,327,900 DT (100%)	92,744,800 DT (100%)

Note: Total construction cost of Drawdown Alternative (Available Drawdown 20 m) is as a reference indicated in Table 9-2.

9.3 FUND REQUIREMENT BY YEAR

The following predications are to be applied to disbursement of construction cost by year:

	Work accomplished
Civil Work:	
Hydraulic Equipment:	
At contracting	10%
At loacing on ship	60%
At installation completion	20%
At water passage	10%
Electrical Equipment:	
At contracting	10%
At loading on ship	50%
At start-up	40%
Transmission Line Material:	
At contracting	20%
At loading on ship	60%
At construction completion	20%

On calculating the fund requirements by year based on the above predications and the construction schedules of the preceding section, the results will be as indicated in Tables 9.3 and 9.4.

Further, these annual fund requirement tables have been based on prices as of March 1978, and in formulating the actual funding plan the subsequent escalation in commodity priecces and interest during construction must be included.

Tableau 9-1 COUTS TOTAUX D'AMENAGEMENT
— Variante amont —

(Milliers de Dinars)

Description	Monnaie domestique	Devise étrangère	Total
COUTS DIRECTS			
I. Centrale pompage turbinage			
1. Travaux de génie civil	10.788,0	16.182,1	26.970,1
2. Matériel hydraulique	1.218,0	10.965,0	12.183,0
3. Appareillage électrique	1.992,4	19.710,0	21.707,4
Sous-total	14.003,4	6.857,1	60.860,5
II. Ligne de transport et les postes			
1. Ligne de transport	1.300,5	5.202,9	6.503,4
2. Postes	95,0	379,0	474,0
Sous-total	1.395,5	5.581,9	6.977,4
Total	15.398,9	52.439,0	67.837,9
COUTS INDIRECTS			
I. Contingeances			
1. Travaux de génie civil	1.080,0	1.620,0	2.700,0
2. Matériel hydraulique	122,0	1.098,0	1.220,0
3. Appareillage électrique	150,0	1.480,0	1.630,0
4. Ligne de transport et les postes	220,0	320,0	540,0
Sous-total	1.572,0	4.518,0	6.090,0
II. Ingénierie et l'administration			
1. Ingénierie	--	3.700,0	3.700,0
2. Administration	3.700,0	–	3.700,0
Sous-total	3.700,0	3.700,0	7.400,0
Total	5.272,0	8.218,0	13.490,0
Coûts totaux d'aménagement	20.670,9	60.657,0	81.327,9
Taux de répartition	25 %	75 %	100 %

Tableau 9-2 COUTS TOTAUX D'AMENAGEMENT
— Variante aval —

(Milliers de Dinars)

Description	Monnaie domestique	Devise étrangère	Total
COUTS DIRECTS			
I. Centrale pompage turbinage			
1. Travaux de génie civil	15.118,2	22.677,5	37.795,7
2. Matériel hydraulique	1.082,3	9.742,0	10.824,3
3. Appareillage électrique	1.997,4	19.710,0	21.707,4
Sous-total	18.197,9	52.129,5	70.327,4
II. Ligne de transport et les postes			
1. Ligne de transport	1.300,5	5.202,9	6.503,4
2. Postes	95,0	379,0	474,0
Sous-total	1.395,5	5.581,9	6.977,4
Total	15.398,9	52.439,0	67.837,9
COUTS INDIRECTS			
I. Contigeances			
1. Travaux de génie civil	1.512,0	2.268,0	3.780,0
2. Matériel hydraulique	109,0	981,0	1.090,0
3. Appareillage électrique	150,0	1.480,0	1.630,0
4. Ligne de transport et les postes	220,0	320,0	540,0
Sous-total	1.991,0	5.049,0	7.040,0
II. Ingénierie et l'administration			
1. Ingénierie	–	4.200,0	4.200,0
2. Administration	4.200,0	–	4.200,0
Sous-total	4.200,0	4.200,0	8.400,0
Total	6.191,0	9.249,0	15.440,0
Coûts totaux d'aménagement	25.784,4	66.960,4	92.744,8
Taux de répartition	28 %	72 %	100 %

Tableau 9-3 PROGRAMME DES INVESTISSEMENTS
—Variante amont—

(Milliers de Dinars)

Catégorie		Travaux	Total	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
TRAVAUX DE GENIE CIVIL	1.1	Routes d'accès	952,0		952,0								
	1.2	Dérivation provisoire	203,6			203,6							
	1.3	Barrage supérieur	2.691,5			33,0	436,1	1.481,4	741,0				
	1.4	Prise d'eau amont	1.027,5				167,2	258,0	602,3				
	1.5	Galerie d'amenée	5.660,6			509,0	2.034,3	1.559,0	1.558,3				
	1.6	Centrale	5.776,1			611,0	612,0	2.584,1	1.519,9			224,0	225,1
	1.7	Tunnel d'accès	891,7			891,7							
	1.8	Chambre d'équilibre											
	1.9	Galerie de fuite	3.423,8			450,0	2.396,8	577,0					
	1.10	Prise d'eau aval	4.416,3				1.600,0	2.085,9	730,4				
	1.11	Poste de sectionnement	927,0			172,0	430,0	238,3	86,7				
	1.12	Salle de contrôle	1.000,0				300,0	300,0	300,0	50,0		25,0	25,0
		Sous-total	26.970,1		952,0	2.870,3	7.976,4	9.083,7	5.538,6	50,0		249,0	250,1
	1.13	Contingeances	2.700,0		96,0	288,0	798,0	909,0	554,0	5,0		25,0	25,0
		Total	29.670,1		1.048,0	2.158,3	8.774,4	9.992,7	6.092,6	55,0		274,0	275,1
MATERIEL HYDRAULIQUE	2.1	Conduite de vidange de fond	96,5				96,5						
	2.2	Conduite forcée	9.895,3			990,0	5.937,0		1.978,3	990,0			
	2.3	Vanne de diffuseur	805,6					81,0	643,6	81,0			
	2.4	Blindages	910,0				91,0	546,0	182,0	91,0			
	2.5	Vanne de la prise d'eau aval	475,6					48,0	379,6	48,0			
		Sous-total	12.183,0			990,0	6.124,5	675,0	3.183,5	1.210,0			
	2.6	Contingeances	1.220,0			99,0	613,0	68,0	319,0	121,0			
		Total	13.403,0			1.089,0	6.737,5	743,0	3.502,5	1.331,0			
APPAREILLAGE ELECTRIQUE	3.1	Centrale et poste de sectionnement	21.332,4			457,0	457,0	4.572,0	1.220,0	6.704,0	3.048,0	2.437,2	2.437,2
	3.2	Télécommunication	375,0					18,0	162,0				
		Sous-total	21.707,4			457,0	457,0	4.590,0	1.382,0	6.704,0	3.048,0	2.437,2	2.437,2
	3.4	Contingeances	1.630,0			34,0	34,0	344,0	104,0	503,0	237,0	189,0	185,0
		Total	23.337,4			491,0	491,0	4.934,0	1.486,0	7.207,0	3.400,0	2.706,2	2.622,2
LIGNE DE TRANSPORT ET LES POSTES	4.1	Ligne de transport	6.503,4				650,0	1.950,0		3.253,4		650,0	
	4.2	Postes	474,0					47,0	143,0	47,0	190,0	47,0	
		Sous-total	6.977,4				650,0	1.997,0	143,0	3.300,4	190,0	697,0	
	4.3	Contigeances	540,0				50,0	155,0	11,0	256,0	15,0	53,0	
		Total	7.517,4				700,0	2.152,0	154,0	3.556,4	205,0	750,0	
		COUTS DIRECTS D'AMENAGEMENTS	73.927,9		1.048,0	4.738,3	16.702,9	17.821,7	11.235,1	12.149,4	3.605,0	3.730,2	2.897,3
COUTS INDIRECTS	5.1	Ingénierie	3.700,0	370,0	778,0	166,0	585,0	624,0	394,0	426,0	126,0	140,0	91,0
	5.2	Administration	3.700,0		52,0	221,0	836,0	892,0	562,0	608,0	180,0	200,0	149,0
		Total	7.400,0	370,0	830,0	387,0	1.421,0	1.516,0	956,0	1.034,0	306,0	340,0	240,0
		COUTS TOTAUX D'AMENAGEMENTS	81.327,9	370,0	1.878,0	5.125,3	18.123,9	19.337,7	12.191,1	13.183,4	3.911,0	4.070,2	3.137,3
REPARTITION DES COUTS		Monnaire domestique	20.670,9		471,2	1.638,4	5.214,9	5.879,9	3.519,2	2.190,3	537,1	719,7	500,2
		Devises étrangères	60.657,0	370,0	1.406,8	3.486,9	12.909,0	13.457,8	8.671,9	10.993,1	3.373,9	3.350,5	2.637,1

Tableau 9-4 PROGRAMME DES INVESTISSEMENTS
— Variante aval —

(Milliers de Dinars)

Catégorie	Travaux	Total	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
TRAVAUX DE GENIE CIVIL	1.1 Routes d'accès	1.020,0		1.020,0								
	1.2 Dérivation provisoire	203,6			203,6							
	1.3 Barrage supérieur	2.691,5		33,0	436,1	1.481,4	741,0					
	1.4 Prise d'eau amont	978,5				148,5	249,0	581,0				
	1.5 Galerie d'amenée	4.673,3			409,0	1.635,1	1.315,0	1.314,2				
	1.6 Centrale	5.861,3			606,0	643,0	2.625,2	1.538,0			224,0	225,1
	1.7 Tunnel d'accès	900,1			900,1							
	1.8 Chambre d'équilibre	2.379,4			85,6	2.293,8						
	1.9 Galerie de fuite	11.244,1			892,0	3.567,7	3.876,0	2.908,4				
	1.10 Prise d'eau aval	5.916,9				1.762,0	2.719,6	1.435,3				
	1.11 Poste de sectionnement	927,0			172,0	430,0	238,3	86,7				
	1.12 Salle de contrôle	1.000,0				300,0	300,0	300,0	50,0		25,0	25,0
	Sous-total	37.795,7		1.053,0	3.704,4	12.261,5	12.064,1	8.163,6	50,0		249,0	250,1
	1.13 Contigeances	3.780,0		105,0	371,0	1.226,0	1.207,0	816,0	5,0		25,0	25,0
	Total	41.575,7		1.158,0	4.075,4	13.487,5	13.271,1	8.979,6	55,0		274,0	275,1
MATERIEL HYDRAU-LIQUE	2.1 Contuide de vidange de fond	96,5				96,5						
	2.2 Conduite forcée	7.749,0			775,0	4.649,0		1.550,0	775,0			
	2.3 Vanne de fiffuseur	699,6					70,0	559,6	70,0			
	2.4 Blindages	990,0				99,0	594,0	198,0	99,0			
	2.5 Vanne de la prise d'eau aval	1.289,2					129,0	1.031,2	129,0			
	Sous-total	10.824,3			775,0	4.844,5	793,0	3.338,8	1.073,0			
	2.6 Contigeances	1.090,0			80,0	486,0	81,0	335,0	108,0			
	Total	11.914,3			855,0	5.330,5	874,0	3.673,8	1.181,0			
APPAREIL-LAGE ELEC-TRIQUE	3.1 Centrale et poste de sectionnement	21.332,4			457,0	457,0	4.572,0	1.220,0	6.704,3	3.048,0	2.437,2	2.437,2
	3.2 Télécommunication	375,0					18,0	162,0		115,0	80,0	
	Sous-total	21.707,4			457,0	457,0	4.590,0	1.382,0	6.704,3			
	3.3 Contingeances	1.630,0			34,0	34,0	344,0	104,0	503,0	237,0	189,0	185,0
	Total	23.337,4			491,0	491,0	4.934,0	1.486,0	7.207,0	3.400,0	2.706,2	2.622,2
LIGNE DE TRANSPORT ET LES POSTES	4.1 Ligne de transport	6.503,4				650,0	1.950,0		3.253,4		650,0	
	4.2 Postes	474,0					47,0	143,0	47,0	190,0	47,0	
	Sous-total	6.977,4				650,0	1.997,0	143,0	3.300,4	190,0	697,0	
	4.3 Contigeances	540,0				50,0	155,0	11,0	256,0	15,0	53,0	
	Total	7.517,4				700,0	2.152,0	154,0	3.556,4	205,0	750,0	
	COUTS DIRECTS DES AMENAGEMENTS	84.344,8		1.158,0	5.421,4	20.009,0	21.231,1	14.293,4	11.999,4	3.605,0	3.730,2	2.897,3
COUTS IN-DIRECTS	5.1 Ingénierie	4.200,0	420,0	880,0	190,0	697,0	740,0	498,0	418,0	126,0	140,0	91,0
	5.2 Administration	4.200,0		58,0	270,0	996,0	1.038,0	712,0	597,0	180,0	200,0	149,0
	Total	8.400,0	420,0	938,0	460,0	1.693,0	1.778,0	1.210,0	1.015,0	306,0	340,0	240,0
	COUTS TOTAUX DES AMENAGEMENTS	92.744,8	420,0	2.096,0	5.881,4	21.702,0	23.009,1	15.503,4	13.014,4	3.911,0	4.070,2	3.137,3
REPARTITION DES COUTS	Monnaie Tunisienne	25.784,4		521,2	2.030,8	7.119,5	7.350,3	4.841,4	2.164,2	537,1	719,7	500,2
	Devises étrangères	66.960,4	420,0	1.574,8	3.850,6	14.582,5	15.658,8	10.662,0	10.850,2	3.373,9	3.350,5	2.637,1

CHAPTER 10. ECONOMIC ANALYSIS

CHAPTER 10 ECONOMIC ANALYSIS

10.1 METHOD OF ANALYSIS

10.1.1 Comparison with Alternative Project

In general, the economic analysis of a power development project can be made in the form of comparison of its total cost converted to present worth with that of an alternative project which provides "equal service" to the project under consideration. The "equal service" in this case means generating power in response to fluctuation in daily and seasonal loads, and the optimum alternative project to Kasseb is one of gas turbine power stations from the standpoint of their quick motive power to be able to meet such load fluctuation. Consequently, the economic analysis in this study is made in the form of comparison of total costs converted to present worth between the Kasseb project and the gas turbine power stations having equal supply capacity with Kasseb. In this case, with regard to the Kasseb project, the economic analysis adopts the "upstream plan" and the "downstream plan".

10.1.2 Analysis by "Internal Rate of Return"

(1) Method of Computation

The economic analysis is basically made by converting total costs - including construction costs, operation and maintenance costs, fuel costs and equipment replacement costs - of the Kasseb project and the alternative one respectively to present worth by means of several discount rates, for example, 8%, 10% and 12% annually, and by indicating the internal rate of return to be decided at the intersecting point of the two total cost curves. Then this internal rate of return is compared with the social discount rates usually applied to projects in the public sectors in Tunisia and thereby the economical efficiency of the Kasseb project is judged.

(2) Application of Rising Rate of Prices

Although the problem of inflation today is not new, the drastic increase in demand for limited resources such as petroleum, coal and natural gas has recently caused the problem to become increasingly aggravated. The observation of the world trend of construction prices reveals that even toward 1950 to 1958 when the economic conditions were relatively quiet, the United States saw annual rises in prices no less than 5% and that during the period of 1970 to 1977 in which the oil crisis was inserted, average annual price hikes of 7% to 10% went down to almost all the countries of the world.

The actualization of the economic comparison between the two separate projects with different durable years of equipment, therefore, reasonably requires allowances made for the future rises in prices. Virtually, it is in no way realistic to take for granted operation and maintenance costs and equipment replacement costs in the future at the same level with the present prices. Generally speaking, it is thought that the economic comparison between the two separate projects permits the effects of inflation to be ignored because of its consequences upon both benefits and costs.

This, however, may be said only when the given consequences on both the projects are quite at the same level. In case of the pumped storage power station and the gas turbine power station having a big difference between their durable years, it is reasonable to take into consideration the effects of inflation.

The report of the World Bank made in March 1975 a forecast of the rising rate of prices from 1979 to 1987, suggesting the application of annual rate of 7% to 8% to machinery, 10% to 12% to civil works and 10% to engineering. Allowances made for the recent world trend of prices, however, make this forecast to appear somewhat high as indicated as follows:

a) Wholesale Price Index of Manufactured Goods (1970=100)

	Index in 1977	Annual Rising Rate
Japan	159.5	6.9%
U.S.A.	178.0	8.6%
West Germany	142.2	5.2%
France	168.7	7.7%
	Average	7.1%

b) Price Index of Electrical Machinery

The observation of the price hike in electrical machinery during the same period reveals that the prices of a power generator, a transformer and a breaker respectively annually rose by approximately 7%, 5.5% and 6%. The almost dominant weight of the price of a power generator in the entire electrical machinery leads to the presumption that the rising rate of the price of the overall machinery was approximately 7%.

In this report, the economic evaluation of the Kasseb project will be done, taking into account a correlation between the internal rate of return and the inflation rate.

10.2 TOTAL COST CONVERTED TO PRESENT WORTH

The total costs of the Kasseb Project and the alternative projects of gas turbines respectively consist of construction costs, operation and maintenance costs, fuel costs and equipment replacement costs. In consideration that it will be reasonable for preparations for working designs of the Kasseb Project to be started during 1979, all these costs should be converted to present worth at the beginning of the same year for the purpose of economic comparison.

10.2.1 Construction Costs

(1) Kasseb Project

The construction costs of "the upstream plan" and the downstream plan" of the Kasseb Project - including engineering fee and administration cost - were respectively given in Chapter 9. Although the transmission lines leading from Kasseb to M'Nihla Substation and Tajerouine Substation are necessary for the Kasseb Project, they are very much contributable to the strengthened stability of the nationwide transmission system and the elevated reliability of electric supply. In the economic analysis of the Kasseb Project, therefore, it is roughly estimated that half the construction costs of these transmission and substation facilities should be allocated to the Kasseb Project.

Thus, the construction costs of the Kasseb Project applicable to the economic analysis are as follows:

(1,000 Dinars)

Item	Upstream Plan			Downstream Plan "A"		
	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total
Pumped Storage P.S.	51,055.1	15,355.4	66,410.5	56,858.5	19,968.9	76,827.4
Transmission & Substation Facilities	2,950.9	807.8	3,758.7	2,950.9	807.8	3,758.7
Engineering, Fee and Administration Cost	3,700.0	3,700.0	7,400.0	4,200.0	4,200.0	8,400.0
Total	57,706.0	19,863.2	77,569.2	64,009.4	24,976.7	88,986.1

The rate of disbursement and the amount converted to present worth by fiscal year of the costs mentioned above are given in Table 10-1.

(2) Alternative Gas Turbine Project

(a) Gas Turbine Power Station

As stated in Chapter 3 it may be expected that gas turbines of unit capacity of 76-MW class will come into common use around 1985 - 1989. For this reason, a gas turbine project of 76 MW x 6 units, a total of 456 MW, was considered as the alternative for the Kasseb Project.

Regarding the outage rate of gas turbine due to faults or inspections, it was 13.7% according to the records of Tunis Sud (TG-1, TG-2) and Ghannouch II (TG-1, TG-2, TG-3) in 1976 - 1977. Constrasted to this, the rate normally seen in Japan for pumped storage power stations is about 2%. Therefore, the required capacity for gas turbine power stations to correspond to the installed capacity of 350 MW of Kasseb would be 397 MW as indicated below.

$$(350 \text{ MW} \times 0.98)/(1 - 0.137) = 397 \text{ MW}$$

Consequently, from the standpoint of an economic comparison, in order to estimate the construction cost of the alternative gas turbine project, it will suffice to multiply 397 MW by the unit construction cost per kW of a gas turbine of unit capacity of 76 MW.

In July 1978 a gas turbine power station of 76 MW x 2 units started operation in Japan and the total construction cost including substation facilities was 8,342 million yen. Therefore, the cost was 54,920 yen per kW. Accordingly, when converted at the exchange rate of 180 = US$1.00 = 0.406 Dinars, the cost per kW was 124 Dinars. Approximately 20% of this cost consisted of the cost of substation facilities.

Consequently, the construction cost of the alternative gas turbine project estimated according to the construction schedule of the project described in Chapter 3 will be as indicated below.

(1,000 Dinars)

Year	Capacity	Total	Breakdown	
			TG	Substation Facilities
1985	76 MW x 1 x 124	9,424	7,544	1,880
1986	76 MW x 1 x 124	9,424	7,544	1,880
1988	76 MW x 2 x 124	18,848	15,088	3,760
1989	76 MW x 2 x 124	18,848	15,088	3,760
Subtotal	456 MW	56,544	45,264	11,280
	59 MW x 124	-7,316	-5,856	-1,460
Total	397 MW	49,228	39,408	9,820

Judging from data obtained in Tunisia, 90% of the above cost will comprise a foreign currency portion and 10% a domestic currency portion. Therefore, the breakdown of domestic and foreign currencies in the above cost will be the following:

(1,000 Dinars)

Item	Foreign Currency	Domestic Currency	Total
Gas Turbine Power Station	35,468	3,940	39,408
Substation Facilities	8,840	980	9,820
Total	44,308	4,920	49,228

Furthermore, the rate of disbursement and the amount converted to present worth by fiscal year of this construction cost are given in Table 10-2.

10.2.2 Operation and Maintenance Costs

(1) Kasseb Project

The operation and maintenance costs can roughly divided into the personnel expenses and the maintenance and repair costs.

(a) Personnel Expenses

According to the result of deliberations between us and the Power Production Department of STEG on the would-be operation and maintenance personnel of Kasseb Power Station following the completion, STEG is considering the following organization:

Chief of P.S.	1	
Vice-chief	1	
Chief of quarter	4	
Shift personnel	4	
Electrician	1	
Mechanic	2	
Welder	1	
Driver	1	
Handyman	1	
Total	16	persons

Furthermore, STEG estimates the unit price of personnel expenses in fiscal 1978 at an extra 12% over the estimation in our previous report (1,650 Dinars/capita), that is, as much as 1,850 Dinars/capita.

Next, since international statistics estimate the personnel expenses of power transmitting and transforming facilities to amount to approximately 0.5% of the direct construction costs, this percentage should be applied.

Consequently, the annual total amount of the personnel expenses after the completion of the project is estimated as follows:

Dam & Power Station	1,850 Dinars x 17	= 31,450 Dinars
Transmission & Substation Facilities	3,758,700 Dinars x 0.005	= 18,790 "
	Total	50,240 Dinars

(b) Maintenance and Repair Costs

Likewise, in view of the results of international statistical investigations, maintenance and repair costs amount to approximately 1% and 2% of the direct construction costs in case of a dam-power station and transmitting and transforming facilities respectively. To these percentages should be applied. Furthermore, of these maintenance and repair costs, approximately 80% is assumed to be attributable to imported maintenance materials.

Consequently, the annually estimated amount of the maintenance and repair costs are given in the following:

Dam-Power Station

66,410,500 Dinars x 0.01 = 664,105 Dinars (Upstream Plan)
76,827,400 Dinars x 0.01 = 768,274 Dinars (Downstream Plan)

Transmission and Substation Facilities

3,758,700 Dinars x 0.02 = 75,174 Dinars

Total 739,379 Dinars (Upstream Plan)

Total 843,448 Dinars (Downstream Plan)

Thus, the annual total operation and maintenance costs after the completion of the Kasseb Project is estimated as follows:

(1,000 Dinars)

Item	Upstream Plan			Downstream Plan		
	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total
Personnel Expenses	-	50.2	50.2	-	50.2	50.2
Maintenance and Repair Costs	591.5	147.9	739.4	674.7	168.7	843.4
Total	591.5	198.1	789.6	674.7	218.9	893.6

Furthermore, the rate of disbursement and the amount converted to present worth by fiscal year (note) of these operation and maintenance costs are given in Table 10-3.

(Note) Operation and maintenance costs are reasonably converted to present worth from the middle of the year. When the constant disbursement of annual expenses is taken as A and the discount rate as i, the present worth of A in the n year is as follows:

$$A/[(1 + 1/2)(1 + i)^{n-1}]$$

If the annual rate of inflation is taken as e, the present worth mentioned above is indicated in the following:

$$A(1 + e/2)(1 + e)^{n-1} / [(1 + i/2)(1 + i)^{n-1}]$$

Consequently, when allowance are made for this rate of inflation, So, namely the total amount converted to present worth of annual disbursement as during n years, is formulated as follows:

$$Se = A(1 + e/2)/(1 + i/2) + A[(1 + e/2)(1 + e)/(1 + k/2)(1 + i)]$$
$$+ A[(1 + e/2)(1 + e)^2/(1 + i/2)(1 + i)^2] + \ldots\ldots$$
$$+ A[(1 + e/2)(1 + e)^{n-1}]/[(1 + i/2)(1 + i)^{n-1}]$$
$$= \frac{A(1 + e/2)}{(1 + i/2)} \times \frac{(1 + i)\,[(1 + i)^n - (1 + e)^n]}{(1 + i)^n\,(i - e)}$$

Thus, this formula is applied to the Kasseb Project and the alternative gas turbine project respectively to compute the present worth tempered with inflation.

(2) Alternative Gas Turbine Project

In case of a gas turbine project also, operation and maintenance costs are roughly divided into personnel expenses and maintenance and repair costs.

(a) Personnel Costs

According to investigations made by the Survey Team in 1977 the operation and maintenance personnel of Ghannouch II Gas Turbine Power Station for base-load operation consisted of 26 men. The gas turbine power plants as the alternative for Kasseb will generate power only to meet peak demand. This point was taken into consideration in this Report and 10 men each were estimated for the alternative gas turbine power stations planned at the 3 locations of Goulette, Sfax and Metlaoui. Consequently, there will be a total of 30 men for the 3 locations.

The personnel costs will therefore be the following:

1,850 DT x 30 = 55,500 DT

(b) Maintenance and Repair Costs

Likewise, according to the result of the statistical investigations, maintenance and repair costs of a gas turbine power station as well as a substation amount to approximately 2% of the respective direct construction costs. Of the former costs, approximately 80% is assumed to be attributable to imported maintenance materials. Consequently, the annually estimated amount of the maintenance and repair costs are given in the following:

49,228,000 DT x 0.02 = 984,560 DT

As for the breakdown according to domestic and foreign currencies it will be the following:

(1,000 Dinars)

Item	Foreign Currency	Domestic Currency	Total
Personnel Costs	-	55	55
Operation & Maintenance Costs	788	197	985
Total	788	252	1,040

Furthermore, the rate of disbursement and the amount converted to present worth by fiscal year of these operation and maintenance costs are given in Table 10-4.

10.2.3 Fuel Cost

(1) Fuel Used

It is expected that at the initial stage of start-up of the No. 1 unit of Kasseb Power Station the electric power necessary for pump-up will be supplied from Sousse Steam Power Station (150 MW x 2) or Ghannouch Steam Power Station (unit capacity 30 MW), but then as additional new generators of large unit capacities are successively installed, the entire electric power required for pump-up will be supplied by a 150-MW generator of Sousse Steam Power Station.

Meanwhile, as described in Chapter 4, the 3 hypotheses below were made with regard to the fuel used.

- The first hypothesis (Case "X") is that sufficient natural gas to satisfy all of the demand will be available in Tunisia. In this case the price of gas will be the supply cost of 25 DT/TEP.
- The second hypothesis (Case "Z") considers the case of the natural gas of Tunisia being capable of satisfying only a part of domestic demand. In this case base-load thermals will use heavy oil costing 35 DT/TEP and gas turbines gas-oil of 50 DT/TEP.
- The third hypothesis (Case "Y") is based on the thinking that from the standpoint of marginal cost theory the gas costs for peak hours and for midnight offpeak hours should naturally differ, the explanation of this being as given below.

(2) Moderation of Gas Cost

(a) With regard to the prime supply cost of natural gas, the gas pipeline will be designed and constructed to cope with the scale of demand at peak hours of gas consumption, and so the more the gas demand at peak hours will increase over the capacity of the pipeline, the higher the prime supply cost will be pushed up by the additional equipment investment required. On the other hand, the more the increase in gas consumption during midnight off-peak hours, the higher the utilization factor of the facilities as a whole and the lower the prime supply cost. Thus, in case of gas consumption as well as electric power consumption, the customer responsibility during peak hours naturally differs from that during midnight off-peak hours. Therefore, a price equivalent to the prime supply cost properly adjusted should be applied to natural gas used for pump-up at Kasseb Power Station.

(b) As in the case of electric power, the greater part of supply cost of natural gas is taken up by capital cost (amortization cost) and its load curves also practically indicate the same shape with those of electric power. (The electric enterprise is the biggest consumer of natural gas.) To make a very bold approximation only in view of cost accounting, the ratio of the supply cost during peak hours to that during off-peak hours will be proportional to their respective demand scales (and consequently, to installed supply capacities) to a certain extent. In this economic analysis, therefore, the ratio between the scales of demands during peak and off-peak hours, that is, 2:1, is taken into consideration, and so a reduction rate, 0.5, is assumed for the gas supply cost during midnight peak-off hours.

Thus, in this economic analysis, fuel cost is computed on the basis of the following three types of fuel prices:

Item	Power for Pumping		Alternative Gas Turbine	
	Fuel Used	Price	Fuel Used	Price
Case "X"	Natural Gas	25 DT/TEP	Natural Gas	25 DT/TEP
Case "Y"	"	12.5 DT/TEP	"	25 DT/TEP
Case "Z"	Fuel	35 DT/TEP	gas-oil	50 DT/TEP

(3) Fuel Consumption Rate

(a) Fuel Consumption Rate of Base Steam Power Station for Pump-up

As described in 10.2.3(1), electric power for pump-up of water at Kasseb Power Station will be supplied from Sousse Steam Power Station with the unit capacity of 150 MW.

The fuel consumption rate vaires according to the load factor of a generator, but the rate for unit capacity of 150 MW, in case of a load factor of 60%, is 2,486 Kcal/kWh (thermal efficiency: 34.6%) and in case of a load factor of 100%, 2,453 Kcal/kWh (thermal efficiency: 35.1%). When it is assumed that the load factor of the generator has to be raised from 60% to 100% in order to supply electric power for pump-up, the fuel consumption rate of a base steam power station in pumping up water is as follows:

$$\frac{(2,543 \times 100) - (2,486 \times 60)}{40} = 2,404 \text{ Kcal/kWh}$$

(b) Alternative Gas Turbine Project

According to the specifications of gas turbines of unit capacity of 76-MW class presently being used the fuel consumption rate per kWh is 2,986 Kcal/kWh at the generating end and 3,282 Kcal/kWh at the transmission end.

In case of a gas turbine of unit capacity of 76 MW class the time required from starting to parallel running is approximately 10 minutes and the fuel consumption rate during this time is approximately 35% of the rate at 100% load factor. Consequently, the fuel consumption rate of a peak-load gas turbine operated for 3.3 hours daily, with starting loss taken into consideration, is as shown below.

(3.282 Kcal/kWh x 10/60 x 0.35 + 3.282 Kcal x 3.3)/3.3 = 3,340 Kcal/kWh

(4) Overall Efficiency of Pumped Storage Power Station

The efficiency of apparatuses is assumed to be 0.995 for a transformer, 0.975 for a motor and 0.89 for a pump during pump-up and 0.89 for a turbine, 0.975 for a generator and 0.995 for a transformer during power production. Furthermore, since the efficiency of the water channel is estimated at 0.888 and the transmission loss at approximately 3%, the overall efficiency of Kasseb Pumped-Storage Power Station is assumed to be 64.3%.

(5) Fuel Cost per kWh

On the basis of the fuel price and the fuel consumption rate mentioned above, the fuel costs per kWh of the base thermal power station to supply electric power for pump-up and the alternative gas turbine power station respectively are computed as follows:

(1 TEP = 10,500 Kcal/kg)

	Electricity for Pump-up	Gas Turbine
Case "X"	5.7 millimes/kWh	8.0 millimes/kWh
Case "Y"	2.85 millimes/kWh	8.0 millimes/kWh
Case "Z"	5.7 millimes/kWh	15.9 millimes/kWh

The disbursement of fuel cost and its present worth by fiscal year computed on the basis of the unit fuel cost per kWh and the overall efficiency of the pumped storage power station mentioned above are given in Table 10-5.

10.2.4 Equipment Replacement Costs

(1) Kasseb Project

Taking into consideration the international standard and the standard in Tunisia, the durable years of the equipment are estimated as follows:

Civil work structures	50 years
Pylons and transmission line	50 years
Electric equipment	30 years

Consequently, in the Kasseb Project, the following equipment will be replaced after 30 years from the operation start.

Equipment of power station and switching station	-----		23,337,400 Dinars
Service equipment of substation	-----	474,000 x 1.075/2 =	254,800 Dinars
Total	-----		23,592,000 Dinars

(2) Alternative Gas Turbine Project

Various groups of gas turbine manufacturers have their own method of calculating the useful life of a gas turbine. In this study, however, the following formula is applied.

$$Ze = \underbrace{bB \cdot ZB + bp \cdot Zp + bR \cdot ZR}_{\text{Life depending on hours of operation}} + \underbrace{an \cdot Nn + af \cdot Nf}_{\text{Life depending on number of starting}}$$

Where: Ze = 80,000 hr.

- ZB ... Base load operation hours (no overload operation)
- ZP ... Peak load operation hours (approx. 8.5% overload operation)
- ZR ... Emergency operation hours (approx. 13% overload operation)
- Nn ... Number of starting in normal operation
- Nf ... Number of starting in rapid operation
- bB ... Constant
- bP ... Constant
- bR ... Constant
- an ... 5 hr.
- af ... 20 hr.

Regarding operation hours, it is assumed that the daily average for the alternative gas turbine power stations is 3.3 hours and that they will be operated 6 days every week with the exception of Sunday.

After a gas turbine is put into parallel running to the system, the time required for the turbine to reach full load is 10 minutes in case of normal starting and 3 minutes in case of rapid starting. The alternative gas turbine power stations will be comprised of 6 gas turbines of unit capacity of 76-MW class, and in order to follow load completely in the same way as Kasseb, at least half the entire gas turbines are conceivable required to be subject to rapid starting.

Thus, the average durable years of the alternative gas turbine power stations are estimated as follows:

$$80{,}000h \,/\, (1 \times 3.3h \times 365 \times 6/7 + 5h \times 365 \times 3/7 + 20h \times 365 \times 3/7)/\text{year}$$
$$= 16.2 \text{ years}$$

However, the durable years estimated based on the computation formula mentioned above is applicable only when running inspections (weekly), service inspections (inspections of combustion apparatus at given intervals of time), inspections of turbines and complete overhauls are all ideally performed, and the actual durable years are generally shorter than those estimated based on the computation formula. In this study, the useful life of the alternative gas turbine power stations is assumed to be 15 years.

Consequently, in case of the gas turbine project, the following equipment replacement costs will be disbursed every 15 years after the operation start regarding the gas turbines and every 30 years after the start regarding the appurtenant substations.

(1,000 Dinars)

	Gas Turbine	Substation
Substitute of Kasseb No. 1	7,544	1,880
Substitute of Kasseb No. 2	7,544	1,880
Substitute of Kasseb No. 3	15,088	3,760
Substitute of Kasseb No. 4	9,232	2,300
Total	39,408	9,820

(3) Formula of Converting Equipment Replacement Costs of Present Worth with Inflation Taken into Account

The alternative gas turbines, the substation facilities and the electric equipment of Kasseb Power Station itself, which will be replaced during 50 years, the useful life of the station, will be affected by inflation so that the equipment costs will rise every time of replacement. When the annual rising rate of prices attributable to inflation is taken as e and the discount rate as i, R, that is, the equipment replacement costs of the gas turbines having the amount of initial investment P and the useful life of 15 years is indicated as follows:

First time (15 years later) ... $R_1 = P(1 + e)^{15}/(1 + i)^{15}$

2nd time (30 years later) ... $R_2 = P(1 + e)^{30}/(1 + i)^{30}$

3rd time (45 years later) ... The following formula is obtained by applying the sinking fund method.

$$R_3 = P(1 + e)^{45} \times \frac{i(1 + i)^{15}}{(1 + i)^{15} - 1} \times [\frac{(1 + i)^{50} - 1}{i(1 + i)^{50}} - \frac{(1 + i)^{45} - 1}{i(1 + i)^{45}}]$$

Likewise, R', that is, the equipment replacement costs of the electric equipment of the substation and Kasseb Power Station with the amount of initial investment P' and the useful life of 30 years is obtained by means of the following formula:

$$R' = P'(1 + e)^{30} \times \frac{i(1 + i)^{30}}{(1 + i)^{30} - 1} \times [\frac{(1 + i)^{50} - 1}{i(1 + i)^{50}} - \frac{(1 + i)^{30} - 1}{i(1 + i)^{30}}]$$

The equipment replacement costs of the Kasseb project and the alternative gas turbine project respectively calculated by means of the formulas mentioned above are given in Table 10-6 and 10-7.

10.3 INTERNAL RATE OF RETURN

The various costs described in the preceding Paragraph 10.2 converted to present worths for the entire serviceable life (assumed to be 50 years) of Kasseb Pumped-Storage Power Station are as indicated in Tables 10-1 through 10-7, and the summarization of these tables is given in Table 10-8.

Based on Table 10-8, with discount rates on the abscissa and present worths of total costs on the ordinate, and on plotting the total cost curves of the Kasseb Project and the alternative gas turbine project, the intersecting point of these two curves shows the profit and loss equilibrium point of the Kasseb Project when compared with the alternative gas turbine project; that is, the economic internal rate of return is indicated. To summarize the above, it will be as follows:

Item		Internal Rate of Return		
		Constant Price	Price Escalation at 5%	Price Escalation at 7%
Case "X"	Upstream Alternative	2.8%	8.4%	10.6%
	Downstream Alternative	2.0%	7.2%	9.3%
Case "Y"	Upstream Alternative	5.4%	11.1%	13.2%
	Downstream Alternative	4.5%	9.8%	11.9%
Case "Z"	Upstream Alternative	2.6%	8.2%	10.4%
	Downstream Alternative	1.8%	7.0%	9.1%

10.4 CONCLUSIONS

The Tunisia, there is no officially set rate of discount (so-called social rate of discount) for economic assessments of projects. However, economic assessments are normally made using a discount rate of 10% per annum. Meanwhile, the long-term interest rates of international financing institutions such as the World Bank are around 8%. Based on the above, it should be permissible to set the criterion for internal rate of return expected of a public project at 8 to 10% per annum. The correlation between internal rate of return and commodity price escalation rate using the above table will be as indicated in Fig. 10.1. On the basis of this correlation graph, the following conclusions may be drawn on the economical nature of the Kasseb Project:

(1) Case of Assumption of Same Fuel (Natural Gas) Used and Same Fuel Price (Case "X")

So long as the commodity price escalation rate continues at 4.7% in case of the Upstream Alternative and at 5.8% in case of the Downstream Alternative of the Kasseb Project, the respective internal rates of return will be 8% or higher and the Kasseb Project will be more economical than the gas turbine project.

(2) Case of Same Fuel (Natural Gas) Used, but Fuel Price for Midnight Pumping Assumed to be 1/2 that at Peaking Time (Case "Y")

So long as the commodity price escalation rate continues at 2.3% in case of the Upstream Alternative and at 3.4% in case of the Downstream Alternative, the respective internal rates of return will be 8% or higher and the Kasseb Project will be more economical than the gas turbine project.

(3) Case of Assumption of Heavy Oil Used for Pumping Power and Gas-Oil Used for Alternative Gas Turbine (Case "Z")

So long as the commodity price escalation rate continues at 4.9% in case of the Upstream Alternative and at 6.0% in case of the Downstream Alternative, the respective internal rates of return will be 8% or higher and the Kasseb Project will be more economical than the gas turbine project.

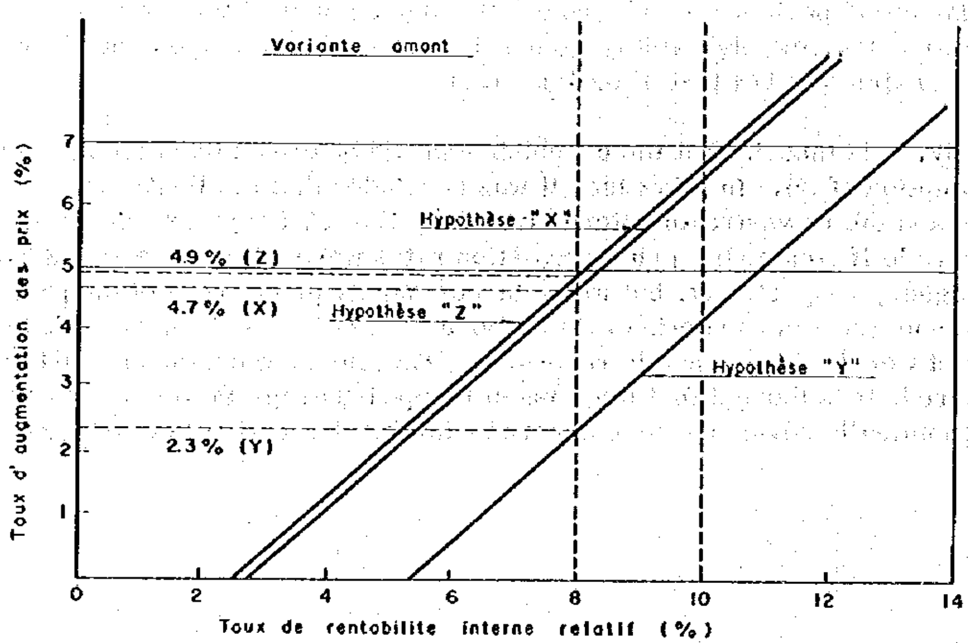
(4) Case of Calculation Ignoring Price Escalation

The internal rate of return for the Upstream Alternative of the Kasseb Project will be 2.8%, 5.4%, and 2.6% for the above cases (1), (2) and (3), respectively, while for the Downstream Alternative, they will be 2.0%, 4.5% and 1.8%, respectively. Consequently, implementation of the Kasseb Project will not be economically reasonable.

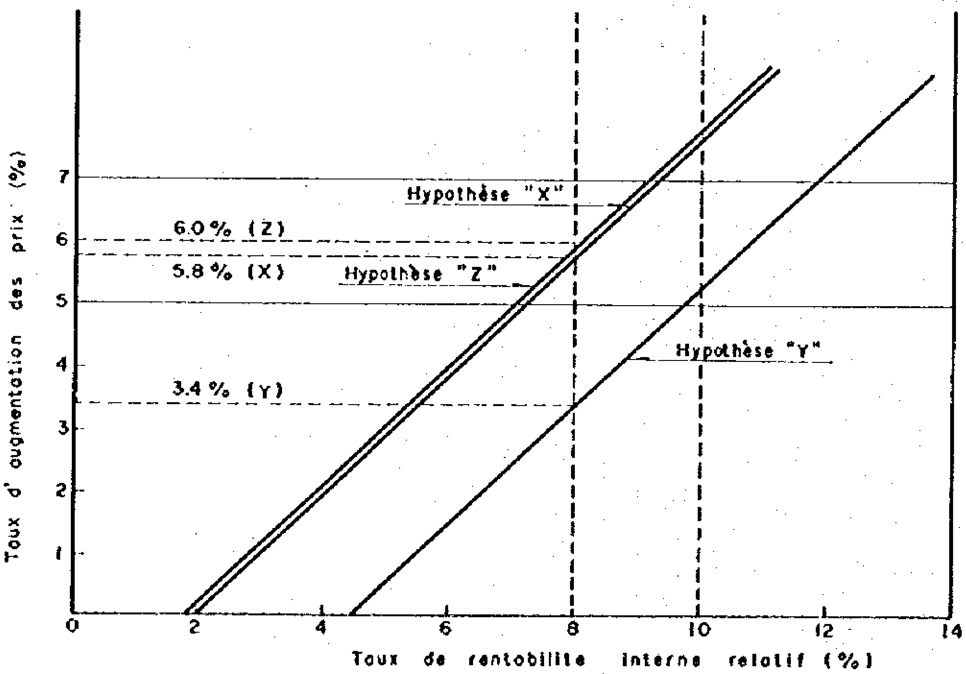
With regard to the 4 different conclusions given above, when the future gas situation of Tunisia is considered, it is inconceivable that alternative gas turbine power stations will use imported gas-oil as fuel in connection with the assumption of (3) above. As for the assumption of (4), it is not realistic to assume that present worth will not change from the period of construction of Kasseb Power Station through the entire serviceable life after start-up. Further, with regard to the assumption of (1), it is unsuitable from the standpoint of marginal cost theory for the fuel cost during midnight off-peak hours to be considered the same as for peak hours. (In case of power rates, the high-voltage general rate of STEG for midnight off-peak hours is approximately 1/4 that of peak hours.)

Consequently, it is thought that the conclusion should be drawn from the standpoint of the assumption of (2). In this case, it was concluded that the Upstream Alternative and the Downstream Alternative of the Kasseb Project would be econimically reasonable if commodity price escalation rates were to continue at 2.3% or 3.4% and higher, respectively, but when the commodity price trend of the past 30 years is considered, an escalation rate of more or less 5% has been recorded even in the face of world-wide economic recession. Therefore, when these situations are considered, it is thought that the Kasseb Pumped-Storage Power Station Project will be economically advantageous compared with the alternative gas turbine project.

Graphique 10-1 CORRELATION ENTRE LE TAUX DE RENTABILITE INTERNE RELATIF ET LE TAUX D'AUGMENTATION DES PRIX



Variante aval



Prix de combustible	Energie pour Pompage	Variante turbines à gaz
Hypothese "X"	25 DT/TEP	25 DT/TEP
Hypothèse "Y"	1/2 x 25 DT/TEP	25 DT/TEP
Hypothèse "Z"	35 DT/TEP	50 DT/TEP

Tableau 10-1 COUTS ACTUALISES D'AMENAGEMENT
(Projet de Kasseb)

(1.000 Dinars)

Description		Total	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
I. VARIANTE AMONT												
1. Coûts estimés aux prix 1978												
Coûts totaux d'aménagement		81.327,9	370,0	1.878,0	5.125,3	18.123,9	19.337,7	12.191,1	13.184,3	3.911,0	4.090,2	3.137,3
(moins) ½x ligne de transport		−3.758,7				−350,0	−1.076,0	−77,0	−1.778,2	−102,5	−375,0	
Total	(A)	77.569,2	370,0	1.878,0	5.125,3	17.773,9	18.261,7	12.114,1	11.405,2	3.808,5	3.695,2	3.137,3
2. Coûts augmentés:												
Au taux de 5% par an	(B)	102.052,8	388,5	2.070,5	5.933,0	21.604,1	23.305,5	16.234,1	16.048,2	5.626,6	5.732,3	5.110,0
Au taux de 7% par an	(C)	113.724,8	395,9	2.150,1	6.278,4	23.296,2	25.612,0	18.171,1	18.313,3	6.543,3	6.793,2	6.171,3
3. Coûts actualisés:												
Au taux de 8% — Coûts constants	(A)	51.156,8	342,5	1.610,0	4.068,4	13.063,8	12.427,0	7.633,0	6.653,7	2.057,3	1.848,3	1.452,8
Au taux de 8% — Coûts augmentés	(B)	66.447,2	359,7	1.775,0	4.709,6	15.879,0	15.859,3	10.229,1	9.362,5	3.039,4	2.867,2	2.366,4
Au taux de 8% — Coûts augmentés	(C)	73.667,7	366,5	1.843,2	4.983,7	17.122,7	17.428,9	11.449,6	10.683,9	3.533,4	3.397,9	2.857,9
Au taux de 10% — Coûts constants	(A)	46.457,6	336,3	1.551,9	3.850,6	12.129,5	11.338,6	6.837,1	5.852,0	1.776,6	1.565,6	1.209,4
Au taux de 10% — Coûts augmentés	(B)	60.169,9	353,1	1.711,0	4.457,4	14.755,6	14.470,3	9.162,5	8.234,3	2.624,8	2.431,0	1.070,0
Au taux de 10% — Coûts augmentés	(C)	66.623,6	359,8	1.776,8	4.716,9	15.911,3	15.894,9	10.255,7	9.396,5	3.052,4	2.880,3	2.379,0
Au taux de 12% — Coûts constants	(A)	42.270,3	330,3	1.496,9	3.647,6	11.295,3	10.361,6	6.137,0	5.158,5	1.537,8	1.331,5	1.009,8
Au taux de 12% — Coûts augmentés	(B)	54.639,1	346,8	1.650,3	4.222,5	13.729,4	13.223,5	8.224,1	7.258,6	2.272,0	2.067,0	1.644,9
Au taux de 12% — Coûts augmentés	(C)	60.072,2	353,4	1.713,8	4.468,3	14.804,7	14.532,2	9.205,4	8.283,1	2.642,1	2.082,7	1.986,5
II. VARIANTE AVAL												
1. Coûts estimés aux prix 1978												
Coûts totaux d'aménagement		92.744,8	402,0	2.096,0	5.881,4	21.702,0	23.009,1	15.503,4	13.014,4	1.911,0	4.070,2	3.137,3
(moins) ½ x ligne de transport		−3.758,7				−350,0	−1.076,0	−77,0	−1.778,2	−102,5	−375,0	
Total	(A')	88.986,1	402,0	2.096,0	5.881,4	21.352,0	21.933,1	15.426,4	11.236,2	3.808,5	3.695,2	3.137,3
2. Coûts augmentés:												
Au taux de 5% par an	(B')	116.455,0	441,0	2.310,8	6.808,3	25.953,3	27.991,0	20.671,3	15.810,4	5.626,6	5.732,3	5.110,0
Au taux de 7% par an	(C')	127.500,9	449,4	2.399,7	7.204,7	27.986,0	30.761,0	23.150,3	18.041,9	6.543,3	6.793,2	6.171,3
3. Coûts actualisés:												
Au taux de 8% — Coûts constants	(A')	59.105,7	388,8	1.796,9	4.668,6	15.693,7	14.925,4	9.720,1	6.555,2	2.056,6	1.847,6	1.452,8
Au taux de 8% — Coûts augmentés	(B')	76.437,9	408,3	1.981,0	5.404,4	19.075,6	19.047,8	13.024,9	9.223,8	3.039,4	2.866,3	2.366,4
Au taux de 8% — Coûts augmentés	(C')	84.598,6	416,1	2.057,2	5.719,1	20.569,7	20.932,9	14.587,4	10.527,4	3.534,7	3.396,6	2.857,9
Au taux de 10% — Coûts constants	(A')	53.759,4	381,8	1.732,1	4.418,7	14.583,4	13.618,3	8.706,6	5.765,3	1.776,7	1.567,1	1.209,4
Au taux de 10% — Coûts augmentés	(B')	69.359,1	460,9	1.909,6	5.115,1	17.726,1	17.379,6	11.666,9	8.117,1	2.624,8	2.431,1	1.969,9
Au taux de 10% — Coûts augmentés	(C')	76.654,2	408,5	1.983,1	5.412,9	19.114,4	19.099,6	13.066,0	9.257,3	3.052,4	2.881,0	2.379,0
Au taux de 12% — Coûts constants	(A')	49.022,5	374,9	1.670,7	4.185,7	13.569,1	12.444,8	7.815,0	5.082,1	1.537,8	1.332,5	1.009,9
Au taux de 12% — Coûts augmentés	(B')	63.063,6	393,7	1.841,9	4.845,5	16.493,3	15.822,1	10.472,1	7.151,0	2.272,0	2.067,1	1.644,9
Au taux de 12% — Coûts augmentés	(C')	69.641,7	401,2	1.912,8	5.127,6	17.785,1	17.453,8	11.727,9	8.160,4	2.642,2	2.449,6	1.986,5

Tableau 10-2 COUTS ACTUALISES DE CONSTRUCTION
(Turbines à gaz)

(1.000 Dinars)

Description		Total	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1. Coûts estimés aux prix 1978												
76 MW x 1 x 124 =		9.424					942	6.598	1.884			
76 MW x 1 x 124 =		9.424					942		8.482			
76 MW x 2 x 124 =		18.848								1.884	16.964	
(76 MW x 2 – 59 MW) x 124 =		11.532									1.154	10.378
Total	(A)	49.228					1.884	6.598	10.366	1.884	18.118	10.378
2. Coûts augmentés:												
Au taux de 5% par an	(B)	73.617,0					2.403,9	8.840,0	14.585,0	2.783,4	28.101,0	16.903,7
Au taux de 7% par an	(C)	86.143,6					2.642,3	9.897,0	16.644,7	3.236,9	33.308,1	20.414,6
3. Coûts actualisés:												
Au taux de 8% — Coûts constants	(A)	26.367,6					1.281,1	4.156,7	6.047,5	1.017,3	9.059,0	4.806,0
Au taux de 8% — Coûts augmentés	(B)	39.095,2					1.635,8	5.569,2	8.510,3	1.503,0	14.050,5	7.826,4
Au taux de 8% — Coûts augmentés	(C)	45.601,3					1.798,0	6.235,1	9.712,2	1.747,9	16.654,1	9.454,0
Au taux de 10% — Coûts constants	(A)	22.774,1					1.168,0	3.723,9	5.318,8	878,9	7.683,8	4.000,7
Au taux de 10% — Coûts augmentés	(B)	33.695,7					1.490,4	4.989,3	7.483,6	1.298,5	11.917,6	6.516,3
Au taux de 10% — Coûts augmentés	(C)	39.270,2					1.638,2	5.586,9	8.540,4	1.510,0	14.125,9	7.869,8
Au taux de 12% — Coûts constants	(A)	19.720,3					1.069,0	3.342,5	4.685,4	759,2	6.522,5	3.341,7
Au taux de 12% — Coûts augmentés	(B)	29.122,3					1.363,9	4.478,3	6.596,8	1.123,9	10.116,4	5.443,0
Au taux de 12% — Coûts augmentés	(C)	33.876,9					1.499,2	5.013,8	7.528,4	1.307,0	11.991,0	6.573,5

Tableau 10-3 FRAIS ACTUALISES D'ENTRETIEN ET D'EXPLOITATION (Projet de Kasseb)

(1.000 Dinars)

Description		Total	1985	1986	1987	1988	1989	(1989–2035) Accumulés au début 1989	début 1979
I. VARIANTE AMONT									
1. Frais estimés aux prix 1978									
Frais de personnel			50,2	50,2	50,2	50,2	50,2		
Frais d'entretien et de réparation			386,6	636,9	636,9	710,3	739,4		
Total	(A)		436,8	687,1	687,1	760,5	789,6		
2. Frais augmentés:									
Au taux de 5% par an	(B)		614,6	1.015,1	1.065,9	1.238,8	1.350,4		
Au taux de 7% par an	(C)		701,4	1.180,5	1.263,1	1.495,9	1.661,9		
3. Frais actualisés:									
Au taux de 8% – Frais constants	(A)	5.598,7	254,8	371,1	343,7	352,2		9.974,2	4.276,9
Au taux de 8% – Frais augmentés	(B)	17.092,6	358,5	548,3	533,2	573,6		35.165,7	15.079,0
Au taux de 8% – Frais augmentés	(C)	29.499,5	409,2	637,7	631,8	692,7		63.265,2	27.128,1
Au taux de 10% – Frais constants	(A)	3.994,6	224,1	320,5	291,4	293,1		8.117,9	2.865,5
Au taux de 10% – Frais augmentés	(B)	10.739,2	315,4	473,5	452,0	477,6		25.744,0	9.020,7
Au taux de 10% – Frais augmentés	(C)	17.331,0	359,9	550,7	534,9	576,7		43.689,7	15.308,8
Au taux de 12% – Frais constants	(A)	2.956,1	197,6	277,5	747,8	244,8		6.918,5	1.988,4
Au taux de 12% – Frais augmentés	(B)	7.186,2	278,0	409,9	384,4	398,7		19.886,0	5.715,2
Au taux de 12% – Frais augmentés	(C)	10.956,2	317,2	476,7	455,4	481,5		32.099,6	9.225,4
II. VARIANTE AVAL									
1. Frais estimés aux prix 1978									
Frais de personnel			50,2	50,2	50,2	50,2	50,2		
Frais d'entretien et de réparation			465,8	741,1	741,1	814,4	843,4		
Total	(A')		516,0	791,3	791,3	864,6	893,6		
2. Frais augmentés:									
Au taux de 5% par an	(B')		828,5	1.359,6	1.454,8	1.694,5	1.880,8		
3. Frais actualisés:									
Au taux de 8% – Frais constants	(A')	6.391,9	327,2	427,4	395,8	400,4		11.287,9	4.840,3
Au taux de 8% – Frais augmentés	(B')	19.386,6	423,5	631,5	614,0	652,1		39.798,4	17.064,5
Au taux de 8% – Frais augmentés	(C')	33.433,7	483,3	634,4	727,7	787,0		71.598,3	30.701,3
Au taux de 10% – Frais constants	(A')	4.545,5	264,7	369,1	335,5	333,3		9.255,0	3.242,9
Au taux de 10% – Frais augmentés	(B')	12.190,1	372,5	545,3	520,5	542,8		29.135,5	10.209,0
Au taux de 10% – Frais augmentés	(C')	19.656,6	425,1	634,2	616,9	655,1		49.444,4	17.325,3
Au taux de 12% – Frais constants	(A')	3.366,6	233,4	319,5	285,3	178,1		7.829,7	2.250,3
Au taux de 12% – Frais augmentés	(B')	8.229,7	393,7	462,0	442,6	453,3		22.505,7	6.468,1
Au taux de 12% – Frais augmentés	(C')	12.435,8	374,7	549,0	524,6	547,0		36.327,6	10.440,5

Tableau 10-4 FRAIS ACTUALISES D'ENTRETIEN ET D'EXPLOITATION
(Turbines à gaz)

(1.000 Dinars)

Description		Total	1985	1986	1987	1988	1989	(1989–2035) Accumulés au début 1989	(1989–2035) Accumulés au début 1979
1. Frais estimés aux prix 1978									
1ère phase : Frais de personnel			9,0	9,0	9,0	9,0	9,0		
Frais d'entretien et de répara.			164,0	164,0	164,0	164,0	164,0		
2e phase : Frais de personnel				9,0	9,0	9,0	9,0		
Frais d'entretien et de répara.				164,0	164,0	164,0	164,0		
3e phase : Frais de personnel						19,0	19,0		
Frais d'entretien et de répara.						329,0	329,0		
4e phase : Frais de personnel							18,0		
Frais d'entretien et de répara.							328,0		
Total	(A)		173,0	346,0	346,0	694,0	1.040,0		
2. Frais augmentés:									
Au taux de 5% par an	(B)		243,4	511,2	536,6	1.130,5	1.778,7		
Au taux de 7% par an	(C)		277,8	594,4	636,0	1.365,1	2.189,0		
3. Frais actualisés:									
Au taux de 8% — Frais constants	(A)	6.415,7	100,9	186,8	173,0	321,3		13.137,3	5.633,7
Au taux de 8% — Frais augmentés	(B)	21.075,9	141,9	276,0	268,3	523,4		46.319,1	19.866,3
Au taux de 8% — Frais augmentés	(C)	37.173,7	162,1	321,0	318,0	632,0		83.330,9	35.740,6
Au taux de 10% — Frais constants	(A)	4.433,8	88,7	161,2	146,7	267,2		10.771,3	3.770,0
Au taux de 10% — Frais augmentés	(B)	12.894,1	125,0	238,2	227,5	435,2		33.909,1	11.868,2
Au taux de 10% — Frais augmentés	(C)	21.356,7	142,5	277,0	269,7	526,2		57.546,6	20.141,3
Au taux de 12% — Frais constants	(A)	3.184,8	78,2	139,4	124,6	222,8		9.112,5	2.619,8
Au taux de 12% — Frais augmentés	(B)	8.404,0	110,0	206,4	193,2	363,9		26.193,1	7.530,5
Au taux de 12% — Frais augmentés	(C)	13.189,7	125,6	240,1	229,0	439,4		42.280,5	12.155,6

Tableau 10-5 FRAIS ACTUALISES DE COMBUSTIBLE

(1.000 Dinars)

	Description	Total	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	(1994-2035) Accumulés au début 1994	(1994-2035) Accumulés au début 1979
HYPOTHESE "X"	A. Energie pour le pompage (GWh)		-	-	-	49	60	-	86	264	109	567		
	B. Frais de combustible au prix unitaire de 5,7 millimes/kWh													
	– Au prix constant de 1978		-	-	-	279,3	342,0	-	490,2	1.504,8	621,3	3.231,9		
	– Au prix augmenté de 5 % par an		-	-	-	454,7	584,8	-	924,3	2.979,4	1.291,6	7.054,6		
	– Au prix augmenté de 7 % par an		-	-	-	549,4	719,8	-	1.181,3	3.880,1	1.714,2	9.540,9		
	C. Frais actualisés au début 1979													
	(a) Au taux d'actualisation de 8 %													
	– Au prix constant de 1978	12.957,4	-	-	-	129,3	146,6	-	180,2	511,6	195,7	-	40.418,1	11.794,0
	– Au prix augmenté de 5 % par an	52.893,8	-	-	-	210,5	250,8	-	339,8	1.013,0	406,9	-	173.656,0	50.672,8
	– Au prix augmenté de 7 % par an	99.637,8	-	-	-	254,4	308,7	-	434,2	1.319,2	539,9	-	331.670,3	96.781,4
	(b) Au taux d'augmentation de 10 %													
	– Au prix constant de 1978	8.158,9	-	-	-	107,7	119,7	-	142,0	395,8	148,7	-	33.295,0	7.245,0
	– Au prix augmenté de 5 % par an	30.036,1	-	-	-	175,3	204,7	-	267,6	783,3	309,1	-	130.037,4	28.296,1
	– Au prix augmenté de 7 % par an	53.783,0	-	-	-	211,8	251,9	-	342,1	1.021,6	410,2	-	236.881,5	51.545,4
	(c) Au taux d'actualisation de 12 %													
	– Au prix constant de 1978	5.325,9	-	-	-	89,9	98,3	-	112,3	307,0	113,1	-	28.237,1	4.605,5
	– Au prix augmenté de 5 % par an	17.986,6	-	-	-	146,0	167,8	-	211,7	607,8	235,1	-	101.889,6	16.618,2
	– Au prix augmenté de 7 % par an	30.794,2	-	-	-	176,4	206,6	-	270,5	791,5	312,0	-	178.032,2	29.037,2
HYPOTHESE "YZ"	A. Energie pour le pompage (GWh)		65	157	207	383	420	124	369	567	410	567		
	B. Frais de combustible au prix unitaire de 5,7 millimes/kWh													
	– Au prix constant de 1978		370,5	894,9	1.179,9	2.183,1	2.394,0	706,8	2.103,3	3.231,9	2.337,0	3.231,9		
	– Au prix augmenté de 5 % par an		521,3	1.321,7	1.830,4	3.555,8	4.093,7	1.269,3	3.966,0	6.398,8	4.858,4	7.054,6		
	– Au prix augmenté de 7 % par an		594,9	1.537,6	2.169,1	4.294,4	5.038,9	1.591,8	5.068,5	8.333,5	6.447,8	9.540,9		
	C. Frais actualisés au début 1979													
	(a) Au taux d'actualisation de 8 %													
	– Au prix constant de 1978	17.971,0	216,0	483,2	590,0	1.010,8	1.026,5	280,6	771,9	1.061,9	736,1	-	40.418,1	11.794,0
	– Au prix augmenté de 5 % par an	61.672,7	303,9	713,7	915,2	1.646,3	1.755,4	503,9	1.455,5	2.175,6	1.530,4	-	173.656,0	50.672,8
	– Au prix augmenté de 7 % par an	110.544,5	346,8	830,3	1.084,6	1.988,3	2.156,6	631,9	1.860,1	2.833,4	2.031,1	-	331.670,3	96.781,4
	(b) Au taux d'actualisation de 10 %													
	– Au prix constant de 1978	12.242,9	190,1	417,0	500,3	840,5	837,9	224,7	607,9	821,0	558,5	-	33.295,0	7.245,0
	– Au prix augmenté de 5 % par an	37.151,1	267,4	615,9	776,1	1.369,0	1.432,8	403,6	1.146,2	1.682,9	1.161,1	-	130.037,4	28.296,1
	– Au prix augmenté de 7 % par an	62.609,6	305,2	716,5	919,7	1.655,5	1.763,6	506,2	1.464,8	2.191,7	1.541,0	-	236.881,5	51.545,4
	(c) Au taux d'actualisation de 12 %													
	– Au prix constant de 1978	8.692,9	167,5	360,6	424,8	700,2	687,1	180,9	481,7	659,3	425,3	-	28.237,1	4.605,5
	– Au prix augmenté de 5 % par an	23.784,3	235,6	523,6	658,9	1.141,4	1.174,9	324,9	908,2	1.305,4	884,2	-	101.889,6	16.618,2
	– Au prix augmenté de 7 % par an	37.973,2	268,9	619,7	780,9	1.378,5	1.446,2	407,5	1.160,7	1.700,1	1.173,5	-	178.033,2	29.037,2

Tableau 10-6 COUTS ACTUALISES DE RENOUVELLEMENT
(Projet de Kasseb)

(1.000 Dinars)

Description	Mise en service	Couts initiaux	1er Renouvellement Actualisation : 8% (A)	Actualisation : 8% (B)	Actualisation : 10% (A)	Actualisation : 10% (B)	Actualisation : 12% (A)	Actualisation : 12% (B)	Remarque
I. Au prix constant de 1978									
(1) Centrale de Kasseb									(B) – Coûts actualisés au début de l'année de mise en service.
1er groupe	1985	5.000,8	252,8	433,4	132,8	258,8	69,0	154,7	
2e groupe	1986	5.000,8	234,1	433,4	120,7	258,8	62,5	154,7	
3e groupe	1988	6.667,9	267,6	577,9	133,0	345,1	66,4	206,3	(A) – Coûts actualisés au début 1979.
4e groupe	1989	6.667,9	247,8	577,9	120,8	345,1	59,3	206,3	
Sous-total		23.337,4	1.002,3		507,3		257,2		
(2) Postes									
Poste M'Nihila	1985	127,4	6,4	11,0	3,4	6,6	1,8	3,9	
Poste Tajerouine	1988	127,4	5,1	11,0	2,5	6,6	1,3	3,9	
Sous-total		254,8	11,5		5,9		3,1		
Total		23.592,2	1.013,8		513,2		260,3		
II. Au prix augmenté de 5%/an									
(1) Centrale de Kasseb									
1er groupe	1985	7.036,6	1.537,3	2.635,2	807,6	1.574,1	425,5	940,7	
2e groupe	1986	7.386,1	1.494,5	2.766,1	776,7	1.652,2	398,7	987,5	
3e groupe	1988	10.860,7	1.883,5	4.067,3	936,6	2.429,5	467,4	1.452,0	
4e groupe	1989	11.404,1	1.831,3	4.270,8	893,9	2.551,1	438,1	1.524,7	
Sous-total		36.687,5	6.746,6		3.408,8		1.729,7		
(2) Postes									
Poste M'Nihila	1985	179,2	39,1	67,1	20,5	40,0	10,9	24,0	
Poste Tajerouine	1988	207,5	36,0	77,9	17,9	46,4	8,9	27,7	
Sous-total		386,7	75,1		38,4		19,8		
Total		37.074,2	6.821,7		3.447,2		1.749,5		
III. Au prix augmenté de 7%/an									
(1) Centrale de Kasseb									
1er groupe	1985	8.029,7	3.090,3	5.297,1	1.623,3	3.163,7	855,3	1.891,0	
2e groupe	1986	8.591,8	3.061,8	5.668,0	1.579,1	3.385,1	817,0	2.023,4	
3e groupe	1988	13.116,4	4.007,2	8.652,9	1.992,1	5.167,8	994,3	3.088,9	
4e groupe	1989	14.034,5	3.970,1	9.258,6	1.937,6	5.529,6	949,9	3.305,1	
Sous-total		43.772,4	14.129,4		7.132,1		3.616,5		
(2) Postes									
Poste M'Nihila	1985	204,6	78,7	134,9	41,4	80,6	21,8	48,2	
Poste Tajerouine	1988	250,6	76,6	165,3	38,1	98,7	19,0	59,0	
Sous-total		455,2	155,3		79,5		40,8		
Total		44.227,6	14.284,7		7.210,7		3.657,3		

Tableau 10-7 COUTS ACTUALISES DE RENOUVELLEMENT
(Turbines à gaz)

(1.000 Dinars)

	Description	Mise en service	Coûts initiaux	1er Renouvellement Taux d'actualisation 8 %	1er Renouvellement Taux d'actualisation 10 %	1er Renouvellement Taux d'actualisation 12 %	2e Renouvellement Taux d'actualisation 8 %	2e Renouvellement Taux d'actualisation 10 %	2e Renouvellement Taux d'actualisation 12 %	3e Renouvellement Taux d'actualisation 8 %	3e Renouvellement Taux d'actualisation 10 %	3e Renouvellement Taux d'actualisation 12 %
TURBINES A GAZ	1. Au prix 1978											
	lère phase	1985	7.539	1.429,6	926,0	622,9	437,2	221,7	113,8	64,2	26,5	10,5
	2e phase	1986	7.539	1.284,4	841,8	556,2	404,8	201,6	101,7	59,5	24,1	9,4
	3e phase	1988	15.078	2.202,1	1.391,4	886,7	694,1	333,0	162,1	102,0	39,7	15,0
	4e phase	1989	9.252	1.251,2	776,4	486,2	394,6	185,8	34,3	58,0	22,2	8,2
	Total		39.408	6.167,3	3.935,6	2.552,0	1.930,7	942,1	411,9	283,7	112,5	43,1
	2. Prix aug. 5%											
	lère phase	1985	10.607	4.055,7	2.708,4	1.892,9	2.657,9	1.348,2	692,3	811,3	334,3	132,9
	2e phase	1986	11.138	3.943,5	2.585,2	1.913,1	2.584,2	1.286,9	649,1	788,9	319,1	124,6
	3e phase	1988	24.560	7.454,9	4.698,6	3.002,4	4.885,6	2.345,0	1.140,8	1.491,2	581,5	218,9
	4e phase	1989	15.821	4.445,8	2.760,4	1.728,7	2.916,5	1.374,5	656,8	890,2	340,8	126,1
	Total		62.126	19.899,9	12.752,6	8.537,1	13.044,2	6.354,6	3.139,0	3.981,6	1.575,7	602,5
	3. Prix aug. 7%											
	lère phase	1985	12.106	6.144,1	4.102,1	2.759,7	5.342,8	2.709,4	1.391,0	2.165,5	891,8	354,2
	2e phase	1986	12.953	6.084,2	3.989,9	2.636,9	5.293,6	2.635,4	1.328,8	2.145,6	867,4	338,5
	3e phase	1988	29.661	11.950,2	7.550,3	4.812,6	10.392,2	4.987,1	2.425,9	4.212,4	1.641,4	617,7
	4e phase	1989	19.474	7.264,9	4.509,8	2.823,8	6.321,7	2.978,0	1.423,4	2.562,3	876,5	362,4
	Total		74.194	31.543,4	20.152,1	13.033,0	27.353,0	13.309,9	6.569,1	11.085,8	4.277,1	1.310,4
POSTES	1. Au prix 1978											
	lère phase	1985	1.885	95,3	50,1	31,6						
	2e phase	1986	1.885	88,2	45,5	23,6						
	3e phase	1988	3.770	227,9	113,4	56,7						
	4e phase	1989	2.280	85,0	41,5	20,4						
	Total		9.820	496,4	250,5	132,3						
	2. Prix aug. 5%											
	lère phase	1985	2.652	579,4	304,6	160,4						
	2e phase	1986	2.785	563,4	290,6	150,3						
	3e phase	1988	6.141	1.065,1	798,4	398,3						
	43 phase	1989	3.899	626,1	306,6	150,3						
	Total		15.477	2.834,0	1.700,2	859,3						
	3. Prix aug. 7%											
	lère phase	1985	3.027	1.165,0	612,1	322,4						
	2e phase	1986	3.239	1.153,9	595,4	308,0						
	3e phase	1988	7.415	2.265,3	1.698,8	847,7						
	4e phase	1989	4.799	1.357,5	664,7	325,9						
	Total		18.480	5.941,7	3.571,0	1.804,0						

Coûts totaux actualisés au début 1979	Au taux d'actualisation de: 8 %	10 %	12 %
1. Au prix de 1978			
Turbines à gaz	8.381,7	4.990,2	3.007,0
Postes	496,4	250,5	132,3
Total	8.838,1	5.240,7	3.139,3
2. Au prix augmentés de 5 %			
Turbines à gaz	36.925,7	20.682,9	12.278,6
Postes	2.834,0	1.700,2	859,3
Total	39.759,7	22.383,1	13.137,9
3. Au prix augmentés de 7 %			
Turbines à gaz	69.982,2	37.739,1	20.912,5
Postes	5.941,7	3.571,0	1.804,0
Total	75.923,9	41.310,1	22.716,5

Tableau 10-8 COMPARISON DES COUTS TOTAUX ACTUALISES AU DEBUT 1979

(1.000 Dinars)

Description	Taux d'actualisation : 8%			Taux d'actualisation : 10%			Taux d'actualisation : 12%		
	Projet de Kasseb		Turbines	Projet de Kasseb		Turbines	Projet de Kasseb		Turbines
	V. amount	V. aval	à gaz	V. amont	V. aval	à gas	V. amont	V. aval	à gaz
A. Prix constants de 1978									
Coûts d'aménagement	51.156,8	59.105,7	26.367,6	46.457,6	53.759,4	22.774,1	42.270,3	49.022,5	19.720,3
Entretien et exploitation	5.598,7	6.391,1	6.415,7	3.994,6	4.545,5	4.433,8	2.956,1	3.366,6	3.184,8
Prix de renouvellement	1.013,8	1.013,8	8.838,1	513,2	513,2	5.240,7	260,3	260,3	3.139,3
Sous-total	57.769,3	66.510,6	41.621,4	50.965,4	58.818,1	32.448,6	45.486,7	52.749,4	26.044,4
Combustible : Hypothèse "X"	12.957,4	12.957,4	11.687,6	8.158,9	8.158,9	7.359,3	5.325,9	5.325,9	4.804,0
Hypothèse "Y"	8.985,5	8.985,5	16.209,8	6.121,5	6.121,5	11.043,1	4.346,5	4.346,5	7.841,0
Hypothèse "Z"	25.159,4	25.159,4	23.110,7	17.140,0	17.140,0	15.744,4	12.170,0	12.170,0	11.179,1
Coûts totaux actualisés:									
Hypothèse "X"	70.726,7	79.468,0	53.309,0	59.124,3	66.977,0	39.807,9	50.812,6	57.975,3	30.848,4
Hypothèse "Y"	66.754,8	75.496,1	57.831,2	57.086,9	64.939,6	43.491,7	49.833,2	56.995,9	33.885,4
Hypothèse "Z"	82.928,7	91.670,0	64.732,1	68.105,4	75.958,1	48.193,0	57.656,7	64.819,4	37.223,5
B. Prix augmentés au taux annuel de 5%									
Coûts d'aménagement	66.447,2	76.437,9	39.095,2	60.169,9	69.359,1	33.695,7	54.639,1	63.063,6	29.122,3
Entretien et exploitation	17.092,6	19.386,6	21.075,9	10.739,2	12.190,1	12.894,1	7.186,2	8.229,7	8.404,0
Prix de renouvellement	6.821,7	6.821,7	39.759,7	3.447,2	3.447,2	22.383,1	1.749,5	1.749,5	13.137,9
Sous-total	90.361,5	102.646,2	99.930,8	74.356,3	84.996,4	68.972,9	63.574,8	73.042,8	50.664,2
Combustible: Hypothèse "X"	52.893,8	52.893,8	47.710,2	30.036,1	30.036,1	27.092,6	17.986,6	17.986,6	16.223,9
Hypothèse "Y"	30.836,4	30.836,4	55.628,8	18.575,6	18.575,6	33.510,3	11.892,1	11.892,1	21.453,4
Hypothèse "Z"	86.341,8	86.341,8	79.311,1	52.011,5	52.011,5	47.776,3	33.298,0	33.298,0	30.586,6
Coûts totaux actualisés:									
Hypothèse "X"	143.255,3	155.540,0	147.641,0	104.392,4	115.032,5	96.065,5	81.561,4	91.029,4	66.888,1
Hypothèse "Y"	121.197,9	133.482,6	155.559,6	92.931,9	103.572,0	102.483,2	75.466,9	84.934,9	72.117,6
Hypothèse "Z"	176.703,3	188.988,0	179.241,9	126.367,8	137.007,9	116.749,2	96.872,8	106.340,8	81.250,8
C. Prix augmentés au taux annuel de 7%									
Coûts d'aménagement	73.667,7	84.598,6	45.601,3	66.623,6	76.654,2	39.270,2	60.072,2	69.647,1	33.876,9
Entretien et exploitation	29.499,5	33.433,7	37.173,7	17.331,0	19.656,6	21.356,7	10.956,2	12.435,8	13.189,7
Prix de renouvellement	14.284,7	14.284,7	75.923,9	7.210,7	7.210,7	41.310,1	3.657,3	3.657,3	22.716,5
Sous-total	117.451,9	132.317,0	158.698,9	91.165,3	103.521,5	101.937,0	74.685,7	85.740,2	69.783,1
Combustible: Hypothèse "X"	99.637,8	99.637,8	89.873,3	53.783,0	53.783,0	48.512,2	30.794,2	30.794,2	27.776,4
Hypothèse "Y"	55.272,2	55.272,2	99.711,1	31.304,8	31.304,8	56.473,9	18.986,6	18.986,6	34.251,8
Hypothèse "Z"	154.762,3	154.762,3	142.160,2	87.653,4	80.653,4	80.515,9	53.162,5	53.162,5	48.833,5
Coûts totaux actualisés:									
Hypothèse "X"	217.089,7	231.954,8	248.572,2	144.948,3	157.304,5	150.449,2	105.479,9	116.534,4	97.559,5
Hypothèse "Y"	172.724,1	187.589,2	258.410,0	122.470,1	134.826,3	158.410,9	93.672,3	104.726,8	104.034,9
Hypothèse "Z"	272.214,2	287.079,3	300.859,1	178.818,7	191.174,9	182.452,9	127.848,2	138.902,7	118.616,6