4.1 Irrigation System

4.1.1 General

The central feature of The Aveyime Sugar Proejction Project is to produce 45,000 tons of sugar by processing about 450,000 tons of cane cultivated in 7,500 ha. For the successful fulfilment of this final goal, a well-established irrigation system is sine qua non. The irrigation system thus required includes eight pumping stations, one regulating pond, 85 farm ponds, 264-km long irrigation canals including main, secondary and distribution canals, and a number of the canal-related structures such as cross regulators, syphons, bridges, turnouts, drops, spillways, water measuring devices, etc.

The basis for determining the facility requirements for each function is that enough irrigation facilities be provided in the most effective and economical manner so that each function can be combined with and fully compatible with the other farming operations required at each stage of development.

Taking into consideration the above requirements, the following design criteria, preliminary study and design of the irrigation facilities are prepared.

4.1.2 Irrigation water requirement

(1) General

The crops considered for estimation of irrigation water requirements consists of sugar cane, maize, groundnuts and vegetables in accordance with the proposed cropping patterns to be applied to the estate and settlement farms.

Since the irrigation water requirement is the sum of the net irrigation requirement and losses due to application and conveyance, the irrigation water requirements for the project have been estimated through the following procedure.

(a) Calculation of the consumptive use of water by crops.

(b) Calculation of the net irrigation requirement; deducting of effective rainfall for crops from the amounts obtained in the above item (a).

(c) Estimate of irrigation water requirement dividing the net irrigation requirement by the overall irrigation efficiency (hereinafter referred to as the project efficiency) which is estimated on the basis of the assumed losses due to application and conveyance.

(2) Consumptive use of water

The consumptive use of water varies depending on (1) the climatic conditions and (2) the crops to be grown and their stages of growth at different times of the year.

It is recognized that the consumptive use (or evapo transpiration) has a high correlation with the evaporation which seems to represent (1) of the above. Then the consumptive use of water by crops can be estimated by the surface evaporation from the standard pan and crop coefficients, which take specific value for each crop varying with the growing stage of the crop.

The relations among the factors can be described by the following formula.

$$C = Kc \times Ep$$

where: C = Consumptive use of water (mm)

Kc = Crop consumptive use coefficient

Ep = Pan evaporation (mm)

This formula is applied to the estimation of the consumptive use of water.

(a) Pan evaporation

As mentioned in Annex I, the mean values of the evaporation data observed at the Ada and Akuse stations for 10 years are used as the basis of the calculation of the consumptive water requirements. Data used for the calculation are tabulated below.

Month	Pan Evaporation	
	Monthly (mm/month)	Daily (mm/day)
Jan.	144	4.6
Feb.	165	5.9
Mar.	198	6.4
Apr.	184	6.1
May	172	5.5
June	131	4.4
July	134	4.3
Aug.	139	4.9
Sept.	149	5.0
Oct.	171	5.5
Nov.	161	5.4
Dec.	137	4.4
Total (average)	1,885	(5.2)

(b) Crop coefficient

Major crops proposed in the report for the agricultural development are sugar cane, maize, groundnuts and vegetables. Crop coefficient of sugar cane are estimated using the experimental data in Taiwan, which are shown in Fig. IV-1, since no records are available in this country. Reliability of the data is confirmed by another information derived from Hawaii which is superimposed in the diagram. It is noted that there is small difference between the two. As for crop coefficient of other crops, data given by Hargreaves as shown in Fig. IV-2 are employed.

Crops	Source and procedure
Sugar cane	"Experimental data obtained by the use of lysimeter" in Taiwan conducted by Hao Chang and J. S. Wang. Reference: "Proceedings of the International Society of Sugar Cane Technologists", 13th Congress, March 1968, Taiwan. "Field experimental data in Taiwan" conducted by Hao Chang, Senior Agronomist, Taiwan Sugar Experiment Station. The average value of the coefficients from the above two sources was obtained and referred to the result in Hawaii (Reference: "The Gorwing of Sugar Cane" by R. P. Humbert). It is judged as referred to Fig. IV-1 that the assumed value of coefficient derived from the data in Taiwan fairly agrees with that in Hawaii, and has been decided to use as the basis for calculation.
Dry crops	"Crop Consumptive Use Coefficients" obtained by G. H. Hargreaves, Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, March, 1968.

Tables IV-1 and 2 show the calculation of crop coefficient for each crop assuming the proposed crop calander.

(c) Calculation of the consumptive use of water

The calculating procedure is shown in Tables IV-3 to 5, which indicates that the maximum values for each crop take place as shown in the following table.

Crops	Peak Amount (mm/month)	Peak Amount (mm/day)	Month
1. Sugar cane			
(1) Plant cane	180	6.0	April
(2) Ratoon	198	6.4	March
(3) Nursery	198	6.4	March
2. Maize	114	3.4	May
3. Groundnuts	80	2.7	September
4. Vegetables	87	2.8	October

(3) Effective rainfall

Effective rainfall supplies a part of the consumptive use by crops. It may be a nearly insignificant in the dry seasons, but it must be a major portion in rainy season. Since there is no records of effective rainfall available, it is necessary to utilize the rainfall records for the estimate of the effective rainfall.

In conformity with this, a trial calculation on water balance in the effective root zone is carried out to find out the effective rainfall using the daily rainfall records at Aveyime. The results show that the efficiency increases as the consumptive use increases, and it varies from 50% to 80% averaging about 65% of total rainfall.

On the other hand, the relationship between average monthly effective rainfall, mean monthly rainfall and average monthly consumptive use has been developed through the country-wide investigation in the United States as tabulated in Table IV-6 (Refer to Technical Release No.21, USDA.) As the abovementioned estimates fairly agree with this table, which seems more universally vallid, the relation given in this table is used for the estimate of effective rainfall in the project area.

(4) Net irrigation requirement

The net irrigation requirement is obtained by deducting the effective rainfall for crops from the consumptive use of water. The calculations of the net irrigation requirement for each crop are shown in Tables IV-3 to 5. The estimated irrigation requirement is incorporated in the design of the project in two ways; one is for the determination of discharge capacities of pumps and other facilities and the other is for the estimate of cost for pumping. For the former purpose, the maximum value of water requirement is necessary, while, for the latter purpose, the average value of water requirement is used. Therefore in Tables IV-3 to 5, both the maximum and average of net irrigation requirement are estimated. Herein called maximum net irrigation requirement takes the same value as the consumptive use as it it estimated assuming no rainfall.

The calculation results are integrated in Tables IV-7 to 10, which are the estimate of net irrigation requirement for the whole cropping calender proposed for the estate and settlement farms.

(5) Irrigation efficiency

Irrigation efficiency is the percentage of irrigation water that is stored in the soil and available for consumptive use by the crop to applied irrigation water. When the water is measured at the farm head gate, it is called application efficiency, and when measured at the point of diversion, it may be called project efficiency.

The following efficiencies in the application and conveyance of irrigation water have been adopted.

(a) Application efficiency (Ea)

Application losses for the fields include deep percolation and surface runoff. The extent of such losses will depend on a number of different factors. Among them, a most important factor influencing field application efficiency is the skillfulness of irrigators and their incentives in using the skill to practice good water management.

Other than the above, the application efficiency is affected mainly by the method of irrigation and site conditions, i.e., soil and topography. Table IV-11, which is extensively used in the United States as an approximate standard, is employed for the estimation of the efficiency, since there are no reliable data in the Project area.

In order to evaluate the soil and topographical conditions in terms of irrigation efficiencies, the following table is prepared for the upland and lowland area, respectively.

Soil condition	Lowland area	Upland area
Sandy soils	250 ha (8.7%)	5,040 ha (76.9%)
Medium textures, deep	2,230 ha (77.4%)	220 ha (3.4%)
Heavy soils	400 ha (13.9%)	1,290 ha (19.7%)
Total	2,880 ha (100%)	6,550 ha (100%)

Land slope	Lowland area	Upland area
0 % - 1 %	2,840 ha (99.6%)	3,620 ha (55.3%)
1 % - 2 %	20 ha (0.2%)	2,730 ha (41.7%)
2 % - 3 %	20 ha (0.2%)	200 ha (3.0%)
Total	2,880 ha (100%)	6,550 ha (100%)

This table indicates that there is a considerable difference in soil condition of the Project area between the lowland and upland areas. Referring to Table IV-11, much higher efficiency in lowland area can be expected than in upland area regardless of irrigation method. It is also seen that the lowland area is much favorable than the upland area in view of land slope.

Another important soil property relating to the application efficiency is the basic intake rate. The basic intake rates in the Project area were found to be 12mm/hr. to 45mm/hr. for lowland area and 25mm/hr. to 56mm/hr. for upland area according to the previous soil survey. The theoretical efficiency, which is calculated based on these figures in combination with the land slopes show that it can be as high as 75% in lowland area, whereas it is around 60% in upland area on average, providing that mostly furrow method for sugar cane are applied.

Taking into account the above relatively favourable soil textural and topographical conditions in the lowland area, and relatively inferior conditions in the upland area, irrigation efficiencies is estimated to be 65% for the lowland area, whereas 50% in the upland area.

(b) Distribution efficiency (Ed)

The distribution efficiency provides for water losses in the earthen unlined distribution canals measured between offtakes from the main or secondary canals and the field inlets. The distribution efficiency was taken at 90%.

(c) Main canal efficiency (Ec)

Allowance should be made for losses between the pumps and the turnouts from the main and secondary canals. The type and length of the main and secondary canals are very different between the lowland area (Block 1-4) and the upland area (Block 5-7) as shown below.

	Main and secondary canals	
Area	Canal type	Canal length for each block
Lowland area	earth canal	6.4 km - 8.8 km
Upland area	concrete block lined canal	18.7 km - 24.0 km

Losses through conveyance is the main and secondary canals will be inevitable but they are not so large for the earth canal in the lowland area owing to the relatively low permeability of the soil. In addition, losses will be reduced remarkably with the advance of siltation. Canals in the upland area are planned to be a concrete block lined canal because they are relatively long and are laid on relatively previous soils.

Taking these into account, losses through conveyance are taken at 10%; the main canal efficiency of 90%.

(d) Project efficiency (Ei)

The project efficiency is calculated as the product of the three efficiencies mentioned above.

$$Ei\ (\%) = Ea \times Ed \times Ec$$

The results of the calculation are;

Area	Project efficiency
Lowland area	52.7 %
Upland area	40.5 %

(5) Irrigation water requirement

The irrigation water requirement is the sum of the net irrigation requirement and the losses mentioned above. It is calculated as;

$$\text{Irrigation water requirement} = \frac{\text{Net Irrigation Requirement (mm)}}{\text{Project Efficiency}}$$

The results of the estimation are;

		Lowland area, Estate (ℓ/sec/ha)	Upland area Estate (ℓ/sec/ha)	Upland area Settlement (ℓ/sec/ha)
(a)	Maximum Peak Water Requirement	0.86	1.11	1.17
(b)	Average Water Requirement	0.39	0.51	0.52

The maximum peak values (a) are applied to the design of irrigation facilities and the average values (b) to the estimation of annual operating hours of pumping plants as stated in item (1). The monthly water requirement estimated are summarized in Table IV-12.

4.1.3 Pumping station

(1) General

Irrigation water for the whole project area is proposed to be supplied from the Volta by pumping.

As shown on Drawing No. 000-01, eight pumping stations are required for lifting irrigation water to the desired elevations. Of these, four pumping stations will be constructed on the Volta river, two pumping station, to lift water from the lagoons to be used as a regulating pond,

and remaining two pumping stations, to boost water, which is once pumped up from either the river or from the lagoon, to higher elevations.

It is a common practice to design the pumping facilities for continuous 24-hour operation with farm pond in order not only to save the construction cost of the pumping stations but also to make the operation of pump and irrigation facilities easy and efficient.

All pumping stations are proposed to be operated electrically, because hydroelectric power is expected to be available at relatively low cost from the Akosombo Power Station and electrification of the pumping stations has an advantage of less problems in their operation and maintenance compared to engine drivings. It is advised that the Electricity Cooperation of Ghana extend a transmission line of about 30 km from the Akuse Substation to the project area and provide distribution network connecting all these pumping stations.

The design of each pumping station are shown on Drawing No.200-01 to 200-03. Mixed flow type and volute type of pumps are recommended in accordance with the specific discharge and the total lift. The direction of shaft is subject to the variation of water level of the suction pondage.

Motors in the pumping stations will be installed above the expected maximum water stage of the Volta river and the lagoons in order to prevent the damage due to floods.

(2) Design conditions

The design conditions of the pumping installations for each pumping station are shown in Table IV-13.

(3) Type of pumps

In order to use pumps most profitably to obtain irrigation water, it is essential to select pumps well adapted to the particular conditions of operation and to obtain a relatively high efficiency. Pump characteristics suggest that the mixed flow type is most profitable for relatively low heads as the case of this project, except for No.2 pumping station of which total head is 21.5 meters. Since the type of pump applicable for No.2 pumping station is considered either mixed flow pump or volute pump, a selection is made based on the economical comparative studies which is shown in Table IV-14. This table shows that there is no significant difference between the two cases in terms of construction cost. However in view of operation and maintenance of pumping station, the volute pump is recommendable.

The choice between the horizontal and vertical-shafts depends on the suction head. The horizontal-shaft pumps, which have advantages of being efficient, simply constructed, relatively free of trouble, low cost and easy to install, are proposed for the cases where the water level of suction pondage is small and stable. All pumping stations located around the Bla lagoon as well as all booster pumping stations are grouped into this case. Whereas all the pumps which are situated along the Volta river

are to be of vertical-shaft type, since the maximum fluctuation of water level varies from 4.2 to 4.8 meters according to the location along the river.

(4) Capacity and numbers

Fig. IV-3 shows the monthly variation of average water requirement for No.2 pumping station. It is seen from the figure that the monthly average requirements are largely grouped into three, less than 2.7m3/sec from October to May, about 3.7 m3/sec in June and September, about 5.0 m3/sec in August.

Note that the design discharge is 5.963 m3/sec which is the peak water requirement.

To meet the above-mentioned variable discharge requirement, it is conceivable mathematically to select an assortment of different capacities of pumps. However, this selection causes difficult problems on operation and repairing. In this selection, therefore, several units the same capacity is recommendable.

The right graph in Fig. IV-3 shows the pump discharge when arbitrary number of units are fully operated for different number of installations. The dashed lines horizontally drawn indicates that five regular pump installation is the most fitted to the variation of water requirement. Another aspect to be taken into account in selection of number of pumps is economy. The comparison of the capital and operation costs in Table IV-15 also supports the installation of 5 regular pumps, although the cost differences are insignificant.

As for No.1 pumping station, the maximum water requirement for No.4 and factory pumps together corresponds to about 1/5 of the maximum discharge of No.2 pumping station. Therefore, with operational consideration the number of the regular pumps in No.1 pumping station is determined to be 6. By this arrangement No.1 pumping station can meet any combination of pumps which take water from the Bla lagoon. The Bla lagoon has so large storage capacity that any of fine adjustement between the supply and requirement is possible.

An economic comparison may be applied to the number of pumps in other pumping stations, but a large number of installation in a small pumping station usually show a high cost. In this regard, the number of pumps for these pumping stations are fixed to be two regular pump plus one stand-by.

The principal feature of all pumping stations are summarized in Table IV-16.

4.1.4 Farm pond

(1) Necessity and location of farm pond

For the planning of pump irrigation projects, it is important to study the operative combination of pumping station with other irrigation facilities. The plan established based on an unsuitable operative combination of these facilities would increase the capital costs, particularly those of pumps, and causes interference on economical and efficient irrigation practices, resulting in high operation and maintenance costs.

In this respect, the most possible 3 cases for water supply operation methods; (1) 24-hour pump operation and 24-hour field irrigation throughout the year, (2) concurrent pump operation with field irrigation, and (3) 24-hour pump operation and 18-hours field irrigation in peak time with a help of farm ponds, were compared for thier merits and demerits as mentioned below.

Case (1); For the peak water requirement, all the pump units are to be fully operated throughout the day. For less discharges, the number of the pump units, in operation is to be adjusted to meet the water requirement in 24 hours. For certain discharge, however, the pump units are obliged to be operated under the lower efficiency, causing more electric power consumption.

This case naturally necessitates 24-hour field irrigation works resulting in highest service cost for water control, and it also demand the end-water users to attend their field even at the mid-night where the shift is so allocation. for the farmer can be planned correctly. This case does not require any regulating pond, resulting in the least capital cost for the construction of facilities.

Case (2) In the peak watering season, full capacity operation of pump units for 24 hours is required the same as the above Case (1). For less discharges, the pump operation hours will be shortened to meet the water requirement and the time required for irrigation.

This case does not also require any regulating pond, so that the total capital investment for all the irrigation facilities is the same as the above Case (1).
It seems that this in the less water requirement season, makes a lower service cost for water control than Case (1), because the irrigation time can be shortened to some extents. However, the irrigation time allocation to the farmer is most difficult especially in the upland area because the time lag between the starting of pump operation and the time of water reaching to a certain unit farm is different from place to place depending on the canal distances and the different water supply discharges.

So that the allocation of irrigation time to farmers can hardly be programmed correctly. Many farmers would waste the time, because they must wait for water coming to their farmlands, or, sometimes, quite adversely, their attendance to their farmlands would not be too late resulting waste of water. Consequently, even if the service cost is lower than in case (1) waste or loss of time and/or water would occur very often, resulting in improper and uneven irrigation. In some cases, it may cause a deep discontent of water users, especially between the downstream users and upstream users because in general, the downstream users are more suffered from such uncertain time lags.

If such uneven irrigation on the fields is to be corrected by additional water supply or prolonged water supply, it makes much higher pump operation cost. Not only the cost resulting from the waste of water but also water-logging might be caused by such additional water supply. If, on the contrary, no such additional water is supplied to correct the uneven water content in soils, no monetary loss of cost side happens but lower benefits may occur due to lower crop yield.

Case (3) In order to avoid the above problems, a plan to provide regulating ponds or farm ponds can be conceived. It is, therefore, worthy to compare such regulating pond system with the above two cases.

This case requires farm ponds to store water during 6 hours of off-irrigation time in the peak requirement period. It has another advantage of saving the pump operation cost to the minimum because pump units can be operated under the highest efficiency by adjusting the pump operation time even throughout the off-peak season by utilizing the regulating function of the pond. In addition, this regulating pond system makes the time lag between the pond and unit farms the minimum, resulting in establishment of the most proper water management program, either for annual, seasonal or monthly, to fix the correct irrigation time allocation for the farmers. It assures the end users the most optimum use of water potential for plant growth without working during 6 hours at night.

As is clear from the above discussions, Case (3) would be the best solution from technical and economical viewpoints, and this solution was finally taken up for the design of the project.

To attain an efficient and economical irrigation practice under Case (3), another important consideration is to select the suitable location of the farm ponds fully taking into account the proposed

irrigation canal layout. In the lowland area, as mentioned in sub-paragraph 4.2.5-(1), all the main canals; B1, B2-1, B2-2, B3, B4-1 and B4-2 main canals, are fairly short and the lag between the starting time of canal water at the head of the canal and the arriving time at the end of the canal is 2 hours at most that does not give any trouble in the irrigation practice to the end water users. Then, the regulating pond cum farm pond is proposed to be provided at the head of every main canal, namely, at the delivery end of every pumping station.

As for the upland area, No. 2 pumping station is connected with a large canal system involving B5-1, B5-2, B6 and B7 main canals. The distance between the delivery end of the pumping station and the furthest end of B7 main canal is about 30 km. This means that a time lag of about 13 hours would occur between the said two points. By this reason, a regulating pond just enough for the pump operation is constructed at the delivery end of No. 2 pumping station to adjust the pumped water so as to meet the irrigation requirement, and a farm pond for the 6-hour storage is provided at the head of every distribution canal.

(2) Storage capacity

The pump supplies the daily volume of water in 24 hours, while the pond releases the same volume in 18 hours for the watering. The water pumped during the off-watering time of 6 hours is reserved in the pond and it is used to supplement the difference in discharges between the release and supply during the watering time. Consequently, the storage capacity required equals to the supply in 6 hours. The storage capacity of farm pond is determined assuming the operation in the peak irrigation period.

Irrigation Area	Peak Irrigation Requirement (ℓ/sec/ha)	Storage Capacity (m^3/ha)
Lowland, estate	0.86	19
Upland, estate	1.11	24
Upland, settlement	1.17	25

As for the regulating pond at the delivery end of No. 2 pumping station, it does not work as a farm pond but for the adjustment of pump discharge to meet the diversion requirement. The discharge is approximately adjusted by the number of pumps in operation, and the fine adjustment is, in principle, made by the operation of one of pumps in a limited time. Allowing an hour between the start and stop of a pump, the storage capacity is determined to be 4,320 m^3/sec.

(3) Drawdown

A small drawdown requires a large surface area, while a large drawdown means a loss in water head in the design of farm pond. Optimum drawdown of each farm pond should be dtaermined by a comparative study. In this report the drawdown is fixed to be 1 m for all the farm pond and a dead water depth of 0.5 m is assumed as a standard based on the experiences in similar projects.

(4) Structure

A farm pond or regulating pond is a reservoir surrounded by an earth dike which has a crest width of 2 m and side slope of 1:2 on both side. The crest elevation of the dike is 0.5 m higher than the proposed high water level.

At the upstream side, the dike is penetrated by a pipe which is a continuation of the delivery pipe of pump in case of Nos. 2 to 7 pumps. As for the Blocks 5 to 7, the farm pond is connected with the short connecting canal which branches off from the main or secondary canal at a turnout. A stoplog is provided between the connecting canal and farm pond. In some cases a distribution canal branches off from the connecting canal for the watering on higher elevation than the low water surface of the pond.

The downstream side of farm pond is open to a canal through a stoplog.

4.1.5 Irrigation canals

(1) Canal route and length

The irrigation canal system includes main canals, secondary canals, distribution canals and field ditches as shown on Drawings No. 000-05 to 11. The followings are brief descriptions about the proposed canal routes and their length.

B1 main canal will be constructed to cover the irrigation area of 400 ha. This canal starts from the farm pond annexed to No. 3 pumping station and flows eastward along the northern boundary of the block. The total length of this canal is about 4.0 km. The water thus delivered by the main canal will directly flow into 14 distribution canals. The total length of the distribution canals is estimated to be 13.6 km.

Two main canals, i.e., B2-1 and B2-2 main irrigation canals, are required for the irrigation of Block 2 area. B2-1 main canal with a total length of 5.6 km will be constructed in the northeast direction between the No. 4 and No. 5 pumping station. Its commanding area is about 335 ha. This canal requires the construction of a secondary canal with a length 11 distribution canals with a total length of 9.2 km.

On the other hand, B2-2 main canal starts from farm pond connected with No. 5 pumping station which will be constructed at the end of B2-1 main canal, and runs for about 1.8 km southeastward. This canal is intended to irrigate the further elevated lands of 315 ha the Block 2. No secondary canal is required in this canal system. Accordingly, 6 distribution canal with a total length of 5.0 km directly branches off from the main canal.

In Block 3, a main irrigation canal, B3 is provided to cover the area of 650 ha. The canal takes its general course to the west for about 3.6 km. This canal calls for the construction of two secondary canals with a total length of 2.2 km to irrigate the area extending over the eastern parts of the block. The distribution canals are 13 in number with a total length of 19.3 km.

Two main canals, i.e., B4-1 and B4-2 main canals are provided in Block 4 because of topographic conditions. B4-1 main canal with a total length of about 2.4 km will be constructed between No. 7 and No. 8 pumping station to irrigate the low-lying area of 192 ha in the northern parts of this block and to convey water to No. 8 pumping station. The water boosted by No. 8 pumping station enters in a farm pond and then released to B4-2 main canal which is about 3.5 km in length and runs. The commanding area of B4-2 main canal is 408 ha. The distribution canals branching off from these two canals are 15 in number and 21.3 km in total length.

For the irrigation of Block 5 area, two main canals are proposed, i.e., B5-1 and B5-2 main canals. B5-1 main canal is to be constructed to cover 1,470 ha in the western part of the block. This canal starts from the regulating pond of No. 2 pumping station. After taking a course of about 6.5 km south-westward, the canal changes its general direction to the north-west and runs for about 10.1 km crossing the Lota river and other small streams. This canal requires a 1.8-km long secondary canal branching off at its mid-course. In addition, 22 distribution canals with a total length of 30.6 km are required in this area. Another main canal, B5-2, is required for the irrigation of the eastern part of the Block 5, around 530 ha and conveyance of water to Blocks 6 and 7. This canal also starts from the regulating pond of No. 2 pumping station and runs southward for about 2 km. Then, it takes a northeast course of about 2 km. From the end of this canal, a 3.4-km long secondary canal is distributed to irrigate an easternmost area of about 235 ha. The distribution canals are 8 in number with a total length of 15.6 km.

B6 main canal will be constructed for Block 6 of 1,500 ha. This canal is the extention of B5-2 main canal mentioned above. Taking a meandering course of about 9.8 km, this canal crosses the Ayisa river and several natural streams on its way and finally connects with B7 main canal near the Taliba river. Two secondary canals, one locating in the upper reach and the other branching at the mid-course of the main canal, total 8.9 km in length. In addition, 23 distribution canals with a total length of 27.2 km are proposed.

B7 main canal is provided for Block 7 of 1700 ha. This is connected with B6 main canal at the western brink of the Taliba river. This canal takes a general direction to the east crossing the Taliba river at the head and the Wuonyi river in the midway. The length of B7 main canal is 16.0 km. Three secondary canals are proposed, i.e., one on the ridge between the Taliba and Wuonyi rivers, the second on the ridge to the east of the Wuonyi river and the third at the tail of main canal. Their total length is 5.5 km. The distribution canals are 29 in number and 31.6 in total length.

(2) Canal lining

The leakage from the canal involves two problems. One is the conveyance loss requiring more water at the canal head than the requirement on farm. The other is the water-lodging which demands the drainage. The seriousness of both the problems depends on the soil condition and the length of canal.

It is judged that the low permeable soils and relatively short canals allow unlined canals in the lowland area (Blocks 1 to 4), but all the main and secondary canals in Blocks 5 to 7 should be lined to avoid the operational difficulties and for the saving of pumping cost, in view of the long conveyance distance through sandy soils.

Among various designs, the proposed lining for the main and secondary canals in Blocks 5 to 7 is a 10 cm thick concrete blocks and 10 cm thick concrete bottom slab taking into account the availability of material, economy, construction equipment required, dirability and maintenance requirement.

(3) Canal section

(a) Design discharge

Based on the irrigation water requirements estimated in Annex 4.1.2, the design discharges for the canals are calculated and the results are illustrated in Fig. IV-4. Introduced assumptions pertaining the operation hours are as follows:

i) All the canals in the lowland area are operated for 18 hours a day in the peak irrigation period because a farm pond is provided at the head of each main canal (for the details about the farm pond, see the paragraph 4.1.2)

ii) All the main and secondary canals in the upland area are operated for 24 hours a day and the distribution canals and farm ditches are operated for 18 hours a day in the peak irrigation period because a farm pond is provided at the head of every distribution canal.

(b) Side slope of canal section

Soil mechanical test has not been carried out on the soils in the project area. The following table shows side slopes generally recommended for the irrigation canal.

Rock	Nearly vertical
Muck and peat soils	1 : 0.25
Stiff clay or earth with concrete lining	1:0.5 to 1
Earth with block lining, or earth for large canals	1:1 to 1.5
Firm clay or earth for small ditches	1 : 1.5
Loose sandy earth	1 : 2
Sandry loam or porous clay	1 : 3

Taking into account these figures, the side slope of the canal section is determined to be 1 : 1.5 for the earth canals and 1 : 1.25 for the concrete block-lined canals.

(c) Canal bottom width (B)/Water depth (H) ratio

A hydraulically ideal cross section is not necessarily adopted in the canal design. The prevention of growth of aquatic plants and moss, prevention of weed and grass growth in earth canals, safe velocity against erosion, prevention of silt deposits in canals and functional design for operation may give more decisive bearing on the canal design. Based on past experiences in many projects, the ratio between the bottom width and water depth in the proposed canals is determined as follows:

Canals	B/H ratio
Head race	2.0
Main and secondary canals	1.3 to 2.0
Distribution canals and field ditches	1.0 to 1.5

(d) Flow velocity and hydraulic gradient

In the lined canals, there is no limitation in the flow velocity which would cause the erosion, if sediment is small. It should, however, be noted that a high velocity exerts uplift on the lining. The following equation is well-known in estimate of allowable maximum velocity of water against uplift problem:

$$v = 2gwt$$

where, v; the allowable maximum flow velocity (m/sec)
g; acceleration of gravity (9.8 m/sec^2)
w; submerged unit weight of lining material
t; thickness of lining (m)

For the proposed lining, the above equation gives the allowable maximum velocity of 1.6 m/sec, if it is assumed that the value of w is 1.3 t/m^3 and value of t is 0.1 m, respectively. The allowable minimum velocity is determined against the silting and the growth of aquatic plant and moss. This velocity is very uncertain. Generally speaking, a mean velocity of 0.45 m/sec to 0.9 m/sec is safely used and if the percentage of silt in water is small, a mean velocity not less than 0.60 m/sec will prevent growth of vegetation, which would seriously decrease the carrying capacity of the canal.

As for the unlined canal, weed and grass growth in the canal is very significant problem. Although intermittent flow conditions inhibit aquatic growth, they favor weed and grass growth in earth canals between irrigation periods. A flow velocity of 0.6 to 0.8 m/sec in the canal will effectively prevent the growth. However, this velocity will cause soil erosion along the perimeter of canals built in erosive soils. The velocity should, therefore, be kept within a narrow range. The following velocity is generally recognized as the maximum-safe-nonerosive velocity.

Soil textures	Maximum-safe-nonerosive velocity (m/sec)
Fine sand under quick sand condition	0.20 to 0.30
Sandy soil	0.30 to 0.75
Sandy loam	0.75 to 0.90
Loam to clay loam	0.85 to 1.10
Stiff clay	1.10 to 1.50

The hydraulic gradient of the canal is determined mainly based on the topographic conditions along the route and the permissible velocity of flow mentioned above. Due attention is also paid to the balance of the earth volumes for excavation and embankment. The hydraulic gradient thus selected are as follows:

Canals	Hydraulic gradient
Main canals	1:3,000 to 1:3,500
Secondary canals	1:1,000 to 1:3,000
Distribution canal downwards	1: 500 to 1:1,000

(e) Freeboard

There is no universally accepted rule for the determination of freeboard, because wave action or water surface fluctuation in a canal may be created by many uncontrollable causes. For the canal design of this project, therefore, the following empirical equations, which are generally used in Japan, are adopted:

For concrete block-lined canal

$$Fd = 0.05\ h + hv + 0.15$$

For earth canal

$$Fd = 0.05\ h + hv + 0.35$$

where, Fd; freeboard (m)

h; maximum water depth (m)

hv; velocity head (m)

In actual design, however, some allowance, 0.15 to 0.2 meter at least, is given on the top of the height obtained by the above equation.

(f) Coefficient of roughness

In hydraulic calculation, related to the canal design, the following coefficient of roughness in Manning's formula (n) is adopted:

n = 0.017 for concrete block-lined canal,

n = 0.030 for earth canal.

4.1.6 Related structures

A number of structures such as cross regulators, culverts, syphons, bridges, turnouts, drops, spillways and measuring devices are required in conjunction with the irrigation canals. The location of these structures are shown on Drawing No. 000-05 to 11. The number of the structures required is given in Table IV-17.

(1) Cross regulator

In order to maintain a certain water elevation at the points of diversion or off-taking irrespective of the discharge, cross regulators are provided where a number of turnouts are densely provided or where a fairly large discharge is diverted. Over the canals in the project area, following two types of cross regulators are provided, depending on the discharge through the structures.

Type - A; Cross regulator provided with a steel slide gate, for the design discharge of more than 0.1 m^3/sec.

Type - B; Cross regulator provided with wooden stoplogs, for the design discharge of less than 0.1 m^3/sec.

All the cross regulators of Type - A have a culvert bridge with a length of either 4 meters (where a farm road crosses over the structure), or 2 meters (where only a foot path crosses over the structure). Whereas, any crossing is not provided on the cross regulators of Type-B.

(2) Culvert

A concrete pipe culvert is required where the main or secondary canal cross the farm road. The size of culvert is determined to pass the maximum discharge as a free-flow with an ample clearance. The flow velocity through the culvert is 1.3 times the velocity in the adjacent canal so that the culvert is free from silting.

(3) Syphon

Five inverted syphons will be constructed in the main and secondary canals. The syphon is a structure to convey the canal water by gravity across a stream. It consists of concrete inlet and outlet basins connected with concrete pipe barrel carried across the stream bottom. The flow in the barrel is a pressure flow because the barrel is usually located below the canal water surface. The flow velocity in the barrel is determined to be 1.5 times the velocity in the upstream canal to avoid silting.

(4) Bridge

A number of concrete bridges are constructed where main and secondary farm roads cross over the streams. These bridges are broadly divided into three types as follows, depending on the number of spans or span length.

Type - A; Two-span bridge, each span being 1.5 m.

Type - B; Single span bridge of 20 m.

Type - C; Single span bridge of 15 m.

The effective width of bridge is either 8 m for the main road or 6 m for the secondary road. The load condition is based on the pass of a 20-ton trailer truck. The minimum clearance between the water surface and the girder bottom is 1 m.

(5) Turnout

The turnout is a structure to distribute water from a canal to a lower grade canal.

In the design, the turnouts are classified into following three types;

Type - A; Turnout with a slide gate and a concrete pipe culvert, which is provided to divert water from a main canal to a secondary or distribution canal, or from a main or secondary canal to a distribution canal.

Type - B; Turnout with wooden stoplogs, which is provided to divert water from a distribution canal to a field ditch mainly in the lowland area.

Type - C; Turnout with wooden stoplogs and combined with a vertical drop, which is provided to divert water from a distribution canal to a field ditch mainly in the upland area.

(6) Drop

Vertical drops are required where the topography along the canal has a steeper slope than that of proposed hydraulic gradient in the canal. Wooden stoplogs are provided on the structure to keep the upstream flow velocity low and the upstream water surface high enough to permit the distribution through the upstream turnouts. A rectangular stilling pool is required at the downstream end of the structure as the energy dissipator.

(7) Spillway

Two types of spillway are provided in the canal system. One is a spillway with stoplogs (wasteway). This type of spillway is required to empty the canal, in case of emergency or cleaning and repairing canal. This structure is provided at the end of main or secondary canal. The other is an overflow type spillway. This type of spillway is provided to spill out an excess water which would otherwise cause unfavorably high water surface in the canal The spillways discharge are released to a stream or drainage canal.

(8) Water measuring device

The day-to-day measurement of water is required to know a daily water use and to compare it with inflow, reserves and demands. This can only be accomplished by knowing, with reasonable accuracy, the amount of water being diverted, withdrawn from storage, and delivered. Accurate and reliable measurement is essential for the beneficial use of water. Good water management creates confidence in the project operation and it can, in a long way, minimize the waste of water and inadequate irrigation practices. Water measurement is also needed to establish the charges to water users. In this context, a Parshall flumes is provided at the head of every distribution canal.

4.2 Drainage System

4.2.1 Present drainage system

The Volta river, flowing in the north of the project area, may inundate some part of the project area and it, therefore, demand the protection of land against the floods on it.

There are small tributaries generally flowing from the south to the north on gently sloping ground. They are the Lota, Ayisa, Taliba, Wuonyi and other rivers each having a catchment area of 15-68 km^2 as shown in Fig. IV-5 Certain structures are needed, where canals, roads or other facilities pass these tributaries.

The above-mentioned tributaries do not drain to the Volta river directly but once enter in lagoons which are back swamps behind the natural levees of the Volta river. Among the lagoons, it is proposed to utilize the Bla lagoon as the suction pond of No.2 and No.4 pumping stations and factory pumping station. The water stage in the depression of Ke and Keli lagoon determines the boundary of irrigable area around it.

The area and storage curves of the Bla, Aklamadow and Keli lagoons were prepared based on the topographic survey carried out in 1966. However the area and storage curves of the Ke lagoon were calculated based on 1/5,000 contour map. They are presented in Figs. IV-6 to 9.

The streams connecting lagoons or draining lagoons to the Volta river are generally small. The Bla lagoon is connected with the Aklagadow lagoon by a channel passing the proposed site of No.1 gate. The Keli and Ke lagoons are inter connected by an undefinable channel called the Mlagwe lagoon. A channel connected with the Keli Lagoon meet with the eastern end of the Aklamadow lagoon a little north of the proposed site of No.2 gate. In this vicinity the channel distribute to three streams which join with the Volta river. The Ke lagoon drains to the Angaw creek through the existing culverts across the Accra - Tefle highway. The Angaw creek is about 25 km in length and its downstream end joins with the Volta river at about 7 km upstream from Ada.

4.2.2 Design flood

The design flood in the Volta river for determining the boundary of the irrigable area and designing the pumping stations along the Volta river is herein set at 5,660 m^3/sec. The corresponding water surface elevation in the Volta river is estimated based on Fig. I-6 as follows;

	Unit: El. m
No.1 Pumping Station	5.1
No.3 Pumping Station	4.8
No.2 Gate	3.4
No.6 Pumping Station	3.4
No.7 Pumping Station	3.2

The design flood to determine the discharge capacity of facilities is calculated by the rational formula assuming 10-year-probable storm based on Fig. I-5.

The formula and the calculation results are presented hereunder:

$$Q = \frac{1}{3.6} \cdot f \cdot r \cdot A$$

where,
- Q : Peak discharge (m^3/sec)
- f : Coefficient of run-off (0.6)
- r : rainfall intensity in time T (mm/hr)
- T : Time of concentration, $T = L/w$ (hr)
- L : Length of river (km)
- w : Velocity of the run-off
  $$w = 72\ (H/L)^{0.6} \quad \text{(km/hr)}$$
- H : Head of water (km)
- A : Catchment area (km^2)

River	Lata	Ayisa	Taliba	Wuonyi
f	0.6	0.6	0.6	0.6
L (km)	15.0	12.5	12.5	19.0
H (km)	0.02	0.015	0.021	0.03
w (km/hr)	1.36	1.27	1.56	1.50
T (hr)	11.0	9.8	8.0	12.6
r (mm/hr)	13.0	15.0	18.0	11.0
A (km^2)	24.0	15.0	14.2	28.0
Q (m^3/sec)	52.0	37.5	42.6	51.3

Note that the catchment area A in the above table is measured at the site of the most upstream structure.

There may be a case that a storm would occur in the project area concurrently with a large flood in the Volta river. Such case is not assumed in determining the discharge capacity of a structure. For the safety of the pumping stations in the Bla lagoon, No.1 gate and the farms near the depression of the Ke and Keli lagoons, however, a 10-year-probable storm concurrently occuring with the Volta flood of 5,660 m^3/sec is assumed.

4.2.3 Gate structures

(1) No.1 gate

This gate is not a drainage facilities but an irrigation facilities. Its main function is to maintain the water surface of the Bla lagoon

between Els.3.5 and 4 m. However its structural feature is dominated by movable gates which are designed based on floods.

The dimensions of gate was determined assuming that the water surface in the Bla lagoon is at 4 m and that in the Volta river is at 0.8 m. For this condition, the gate can pass the peak flood discharge of once in 10 years.

The peak flood discharge was calculated to be 72 m^3/sec by the rational formula with the following values;

f = 0.6, A = 65 km^2, r = 6.6 mm/hr,
L = 27 km, H = 0.03 km

The safety against the Volta flood was checked up assuming 72 m^3/sec of discharge when the Volta water surface was at El.3.4 m. The calculation showed that the water surface in the Bla lagoon would rise up to El.4.72 m. All the structures such as No.2 and No.3 pumping stations, factory pump and No.1 gate are designed to be safe against this condition.

No.1 gate is located in the channel between the Bla and Aklamadow lagoons. The abutment on each bank is a concrete training walls backfilled with earth material. The discharge channel over the weir is bottomed at El.2 m and it is partitioned into four 5-m-wide channels by three piers. It is supported by concrete pile foundation. Four roller gates operated by ellectrically driven hoist of 5 m in width and 2 m in height are installed on a concrete ogee crest at El.2.3 m between the training walls and piers. In front of each gate, stoplog shot are provided for the inspection and repair. An 8-m-wide and 24.8 m - long concrete T-beam bridge is constructed over the discharge channel. Its central portion is divided into two 12.4 m-span bridge being simply supported by the abutment wall and a downstream extension of the center pier.

The approach channel on each side is a 23.4-m-wide and 10-m-long rectangular channel. It consists of a concrete apron continued by a rubble stone mattress and concrete walls. The channel between the Bla and the Aklamadow lagoons is rehabilitated as an approximately 40-m-wide trapezoidal channel. The design of No.1 gate is shown in Drawing No.500-01.

(2) No.2 gate

No.2 gate is proposed to prevent the Volta flood from entering into the depression of the Ke and Keli lagoons. This gate is proposed on the channel between the proposed No.2 and No.3 blocks. According to a study made by NEDECO /1, the water level in the Angaw Creek is usually lower than that in the adjacent channel of the Volta river. The penetration of the Volta flood to the depression through this creek is, therefore, not assumed. As the purpose directs, the crest elevation of No.2 gate is determined by the flood water surface El.3.4 m

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/1 NEDECO DE BILT, Angaw Basic Project, 1959.

which corresponds to the Volta flood of 5,660 m^3/sec.

Looking into the rainfall intensity curve in Fig.I-5. One day rainfall is about 160 mm at a return period of 10 years. Assume that this rain would occur, when No.2 gate is closed. Storage of water in the above-mentioned depression is calculated, assuming the catchment area of the depression to be 144 km^2 and the coefficient of runoff to be 0.6, as follows.

$$0.6 \times 160 \text{ mm} \times 144 \text{ km}^2 = 13.8 \times 10^6 \text{m}^3$$

This volume of water can be retained in the depression below El.3 m, as could be understood from Figs.IV-8 and IV-9.

There are three 2 m x 2.85 m culverts below the Accra-Tefle highway. The water in the depression may drain to the Angaw creek through these culverts. If the discharge therein is assumed to be 5 m^3/sec on an average, the depression will be drained in a month.

The above assumed case in regarded as extreme. Normally the water level in the Volta river is low. The depression will be drained in a short period, if No.2 gate is open. The proposed gate has a discharge capacity of 24.0 m3/sec when the water surface in the depression is at El.3 m and the water level in the opposit side is below El. 1.2 m. Assuming the relationship between the depression water surface elevation and discharge through the No.2 gate as shown in Fig.IV-10, a routing calculation resulted that the water once stored upto El. 3 m in the depression can be drained about in a week.

The structure of No.2 gate is briefly explained hereunder. The abutment on each bank is a concrete training wall and wing walls backfilled with earth material. The discharge channel over the weir is bottomed at El.1.2 m and partitioned into two 3-m-wide channels by the pier. It is supported by a concrete pile foundation. Two sluice gates operated by man-power of 3 m in width and 2.5 m in height are installed between the training walls and the pier. In front of the gates stoplogs slots are provided for the inspection and repair.
A 8-m-wide and 16.8-m-long concrete T-beam bridge consisting of two 8.4-m-span girder is provided over the discharge channel for the access between Nos.2 and 3 blocks. It is a simple beam bridge, being supported by the abutment walls and the center pier.
The approach channels on each side is a 9-m-wide and 6-m-long rectangular channel, consisting of a concrete apron continued by a rubble stone mattress and concrete wall. The channel on both side of this gate structure are rehabilitated to carry an appropriate discharge.

The design of No.2 gate is shown in Drawing No.500-02.

4.2.4 Surface drainage system

(1) General

The drainage system for fields and farms has been divided into

three types of drains, field drains, collector drains, and main drains. Field drains are the terminal drains at the farm. Collector drains are larger drains that collect the water from a number of field drains. Main drains, which are either natural channels or man-made channels, are provided to collect the water from the collector drains. The features of these drains are discussed in detail in the subsequent paragraphs.

(2) Design condition

It is usually desirable to remove excess water in a short period, for instance 12 hours, since the most crops especially at their early stage are not able to withstand long inundation. However, it entails very large capacities of drainage facilities resulting in enormous construction cost. Hence, it is a common practice to allow water-logging depending on growing stage, except for early stage and maturing period. According to the proposed cropping pattern, the planting and ratooning period of sugar cane is from August till April. The biggest flood occurs in June when the sugar cane has been grown as long as 2 months even the latest planted ones. Taking these conditions into account, it is proposed to take one-day waterlogging period as a design basis of this project.

The rate of removal of water by surface drainage is influenced by rainfall, size of the drainage area, runoff characteristics including slope, soil and vegetation, crops, degree of protection warranted, etc. Data on rainfall intensity and duration at Akuse and Ada, which are shown in Annex I, are employed to analyze the requirement of surface drainage. Based on these figures, a 10-year recurrence interval storm is estimated to be 160 mm/day on an average of the two stations. On the other hand, coefficient of run-off is assumed to be 0.7 as an average value in the project area. Therefore the rate of surface runoff which is to be wasted directly through the drainage canals is calculated to be 112 mm/day or 13 ℓ/sec/ha.

(3) Main and collector drains

In the project area, there exist numerous flood channels and tributaries. Although most of these flow only during the rainy seasons, the lands around these channels are subjected to annual inundations by heavy rainfalls because of the poor drainage conditions. Therefore, they should be improved to have an adequate capacity for the design runoff calculated above, through clearing, strengthing and enlarging.

Most of the existing channels have been taken as the proposed routes for main and collector drain canals, however, in places where no existing channel is available, new drain canals have been proposed to be located along the suitable routes.

The design of the drainage canal has been made using the Manning's Formula. The flow section is trapezoidal with the side slopes of 1:1.5. The hydraulic gradients vary with the topographic conditions of the area.

The alignment of the main and collecter drains are shown on Drawing No.000-01 and summarized as shown below.

Block	Total Length (km)	
	Main Drain	Collector Drain
No.1	5.8	21.0
No.2	3.7	23.5
No.3	6.2	9.6
No.4	7.0	16.0
No.5	18.8	34.7
No.6	15.0	16.6
No.7	12.6	23.7
Total	69.1	143.3

(4) Field drains

The excess water in the fields is collected by the field drains to be constructed in parallel with contours in the intervals of about 100 to 200 m, and then carried to the main or collector drains.

The hydraulic gradient of the drains varies with the topographic conditions of the land. But a canal with bottom width of 30 cm, water depth of 30 to 40 cm and side slopes of 1:1.5 has been taken up as representative for the estimates of the construction cost.

4.3 Road System

4.3.1 General

The project area is blessed with two existing roads. One is a laterite-paved road (approximately 5 km are paved with asphalt), which passes through the western part of the Project area connecting Aveyime with Sege to the south and with Mepe to the north. The other is an asphalt paved road, which runs eastmost Project area linking it with Accra and Tefle. The former is expected to be used mainly for the transportation of sugar produced in the factory as well as farm inputs and outputs from the factory, which is provided with warehouses in the yard, to Sege and vice versa after the completion of the project. Whereas the latter is planned to be used mainly for the transportation of construction materials and machinery during construction.

The new road system of which function is mainly to transport sugar cane to the factory is framed up based on these two trunk lines, and on the locations of the proposed farmlands, sugar factory, canals, pumps, etc. The system is proposed to cover the whole Project area for smooth transportation of goods and supplies to and out of the Project area, for communication between farmers' settlements, for operation and maintenance of project facilities and for farm operation.

Three types of roads are proposed; i.e., the main roads, the secondary roads and tertiary roads, their typical design being as shown in Fig. IV-11.

The main roads make a skeleton net over the whole Project area. These have been so located as to connect each block with the Accra-Tefle highway and Sege-Mepe road at possible minimum distance in accordance with the topographical conditions.

Branching from the main roads, the secondary roads are proposed mainly for transportation and communication within each block. Alignment of these roads depends mainly on the irrigation system to be taken up.

Tertiary roads are proposed for the same purpose as the secondary road but for the route of less traffic. The secondary and tertiary roads together forms a network of approximately 800 m squares.

4.3.2 Road system

(1) Main road

The function of main roads is to transport harvested sugar cane from each secondary road to the sugar factory. As shown in Drawing No. 000-01, this type of road has been so located as to run in parallel with the main irrigation canals in order to connect each irrigation block efficiently. Namely, one is proposed to run lengthwise the lowland area, and the other along the upland area. Both of them connect the two existing roads.

The effective width of the main road has been determined at 8 m taking into account the function, traffic intensity and design speed as the most fundamental parameters of road design, that is, the 6-ton trucks, which carry sugar cane, can pass without decreasing speed each other. Shoulders or verges with 1.5-m wide are provided at both sides of the carriageway for vehicles to stop free of traffic lane in case of emergency or vehicle trouble and for case of safety and also to provide stability to the carriageway.

The width of the main road corresponds to the secondary road of the design standards by the Department of Social Welfare and Communication. The surface of the roads are proposed to be paved with crushed stones.

(2) Secondary and tertiary roads

The secondary and tertiary roads are important for transportation and communication in the project area. They are the access between the fields and main road, being connected each other.

The effective width is determined at 6 m for the secondary road and 4 m for the tertiary road, respectively, with shoulders of 1.0 m, since these roads carry shorter distance local traffic which would tolerate lower speeds. The surface is proposed to be paved with laterite in order to be good for all weather condition.

(3) Horizontal and vertical alignments

The parameters in horizontal alignment, such as minimum radius of curves, etc. are planned as shown in Fig. IV-11 based on the inter-relationships of the driver, vehicle and road characteristics determined by safety requirements. Parameters in vertical alignment such as maximum gradient are determined, as shown also in Fig. IV-11 by the inter-relationships of the vehicle and road characteristics, whereas the length of vertical curve are determined by safety requirements.

4.4 Land Preparation

4.4.1 General

Land preparation is of prime importance in the new agricultural development, especially in the project involving a factory like our project. In this report, the land preparation up to the initial plowing is included in the construction work. The land preparation include land reclamation inclusive of necessary land levelling and the laying-out of the field including the construction of farm roads, supply head ditches, collector drains, etc.

4.4.2 Land reclamation

In the project area, the following operations are required for land reclamation.

(1) Grass cutting

The project area is generally grassland with scattered trees. The grass is not so high and does not exceed 0.6 to 0.9 m. However, in some areas around water courses and lagoons, a fairly dense-growing of grass with a height of over 1.5 m is found. The grass is cut down using a rotary grass cutter pulled by a tractor and then burnt after drying on the field. According to the experiences in the pilot farm, the capacity of the rotary grass cutter pulled by a 50 ps tractor will be about 1.5 ha per day under the normal working condition.

(2) Tree felling and its removing

Following the clearing of grass, tree felling is carried out. In the project area with scattered trees and bushes, felling of trees and bushes is best achieved by pushing over or digging out with the rakedozer of about 21 ton-class. Root cutting will be necessary before pushing over some large trees. By using this machine, small trees and bushes are uprooted, but bush cutter may be more useful for smaller bushes. Uprooting in this way creates ditches and mounds which have to be levelled. The felled trees will be burnt on the spot.

(3) Root cutting and raking

After the tree felling, the roots remaining in the ground will be carried out by scarifying the ground surface with the rakedozer. The rooting is finished up by removal by hand of small pieces of root still remain in the ground.

(4) Land grading and removing of the ant-hills

For the furrow irrigation system as proposed will not require land grading, but minor levelling will be required for grading exceptional uneveness of land surface.

In the land reclamation of the project area, there is a problem of ant-hills peculiar to this region. According to the experiences in the pilot farm, the removal of these ant-hills is difficult and expensive, and the sites from which the ant-hills have been cleared show poor yield in crop cultivation. In this sense, it would be probably best to leave at least the larger ant-hills.

4.4.3 On-farm facilities

(1) Construction of farm roads

Farm roads are so constructed as to encircle the standard farms at the grids of about 400 m x 100 m, according to the proposed field layout of the standard farm. The typical alignment of these farm roads are shown on the attached Drawing No. 400-08.

To reduce the initial cost, farm roads are not paved with any material. The surface of the proposed routes of the roads are stripped off and then tamped by a bulldozer of about 21 tons type. Side gutters are also proposed to be dug mechanically by small size of bulldozer with a back hoe. The soils excavated in the gutters will be used for embankment of roadbed.

(2) Construction of irrigation and drainage facilities

The construction of irrigation and drainage facilities is included in the works of land preparation. These are field ditches and field drains.

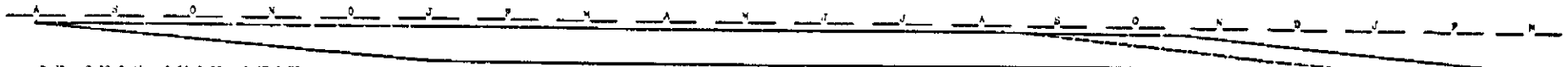
The capacities and sizes of the irrigation facilities vary with the size of the farms. However, the bottom width of the supply canals will not be smaller than 0.3 m from the technical viewpoint of mechanized construction. Small embankments constituting a side of canal will have a height of about 0.5 m a crest width of about 0.3 m and side slopes of 1:1.5.

(3) Initial ploughing

At the final stage of land preparation, the field will be ploughed up to the depth of about 0.5 m. This work is carried out using rakedozers. However, as this work is initial ploughing, further ploughing and harrowing will be finally required for planting crops.

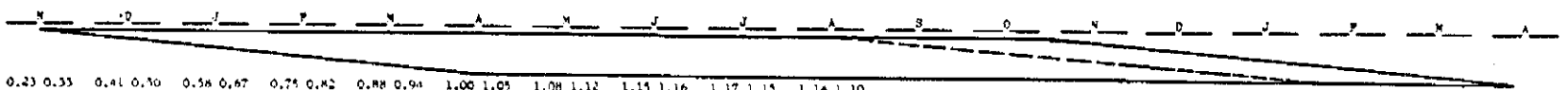
Table IV-1 Crop Coefficient of Sugar Cane

Plant Cane



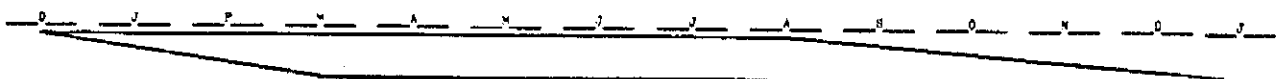
(k) for 1/5 area	0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16 1.17	1.15 1.14	1.10 1.06	1.02 0.97	0.91 0.84							
(k) for 2/5 area		0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16 1.17	1.15 1.14	1.10 1.06	1.02 0.97	0.91 0.84						
(k) for 3/5 area			0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16 1.17	1.15 1.14	1.10 1.06	1.02 0.97	0.91 0.84						
(k) for 4/5 area				0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16 1.17	1.15 1.14	1.10 1.06	1.02 0.97	0.91 0.84					
(k) for 5/5 area					0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16 1.17	1.15 1.14	1.10 1.06	1.02 0.99	0.91 0.84				
Average	0.23	0.32	0.41	0.50	0.57	0.65	0.75	0.86	0.98	1.06	1.09	1.10	1.07	1.05	1.02	0.99	0.94	0.88			

Ratoon



(k) for 1/5 area	0.23 0.33	0.41 0.50	0.58 0.67	0.75 0.82	0.88 0.94	1.00 1.05	1.08 1.12	1.15 1.16	1.17 1.15	1.14 1.10										
(k) for 2/5 area		0.23 0.33	0.41 0.50	0.58 0.67	0.75 0.82	0.88 0.94	1.00 1.05	1.08 1.12	1.15 1.16	1.17 1.15	1.14 1.10									
(k) for 3/5 area			0.23 0.33	0.41 0.50	0.58 0.67	0.75 0.82	0.88 0.94	1.00 1.05	1.08 1.12	1.15 1.16	1.17 1.15	1.14 1.10								
(k) for 4/5 area				0.23 0.33	0.41 0.50	0.58 0.67	0.75 0.82	0.88 0.94	1.00 1.05	1.08 1.12	1.15 1.16	1.17 1.15	1.14 1.10							
(k) for 5/5 area					0.23 0.33	0.41 0.50	0.58 0.67	0.75 0.82	0.88 0.94	1.00 1.05	1.08 1.12	1.15 1.16	1.17 1.15	1.14 1.10						
Average	0.28	0.37	0.46	0.54	0.61	0.68	0.82	0.93	1.02	1.08	1.11	1.13	1.15	1.14	1.12					

Nursery



(k) for 1/5 area	0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16					
(k) for 2/5 area		0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16				
(k) for 3/5 area			0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16			
(k) for 4/5 area				0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16		
(k) for 5/5 area					0.23	0.33 0.41	0.50 0.58	0.67 0.75	0.82 0.88	0.94 1.00	1.05 1.08	1.12 1.15	1.16	
Average	0.23	0.32	0.41	0.50	0.57	0.65	0.75	0.88	1.00	1.02	1.07	1.11	1.14	1.16

Table IV-2 Crop Coefficient of Dry Crops

Groundnuts

	A	M	J	J	A	S	O
(k)	0.21	0.34 0.46 0.21	0.57 0.64 0.34 0.46 0.21	0.65 0.59 0.57 0.64 0.34 0.46	0.39 0.65 0.59 0.57 0.64	0.39 0.65 0.59	0.39
Average	0.21	0.34	0.44	0.54	0.57	0.54	0.39

Vegetables, deep rooted

	J	J	A	S	O	N
(k)	0.20 0.24	0.37 0.56 0.20 0.24	0.70 0.62 0.37 0.56 0.20 0.24	0.43 0.27 0.70 0.62 0.37 0.56	0.43 0.27 0.70 0.62	0.43 0.27
Average	0.22	0.34	0.45	0.49	0.51	0.35

Maize

	M	A	M	J	J	A
(k)	0.26 0.42	0.67 0.85 0.26 0.42	0.90 0.86 0.67 0.85 0.26 0.42	0.73 0.56 0.90 0.86 0.67 0.85	0.73 0.56 0.90 0.86	0.73 0.56
Average	0.34	0.55	0.66	0.76	0.76	0.65

Table IV-3 Calculation of Net Irrigation Requirement (I)

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Plant cane																		
(1) Crop Coefficient	0.23	0.32	0.41	0.50	0.57	0.65	0.75	0.88	0.98	1.06	1.09	1.10	1.07	1.05	1.02	0.99	0.94	0.88
(2) Monthly Pan-Evaporation(mm)	139	149	171	161	137	144	165	198	184	172	131	134	139	149	171	161	137	144
(3) Consumptive Use(mm)	32	48	70	81	78	94	124	174	180	182	143	147	149	156	174	159	129	127
(4) Effective Rainfall(mm)	12	37	60	46	14	10	26	65	82	105	131	42	20	58	91	54	16	11
(5) Cropping Intensity	0.03	0.20	0.40	0.60	0.80	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10
(6) Net Irrigation Requirement(mm)	1	3	4	21	52	83	98	109	98	77	12	105	129	89	58	53	34	12

Ratoon																	
(1) Crop Coefficient	0.28	0.37	0.45	0.54	0.61	0.68	0.82	0.93	1.02	1.08	1.11	1.13	1.15	1.14	1.12		
(2) Monthly Pan-Evaporation(mm)	161	137	144	165	198	184	172	131	134	139	149	171	161	137	144		
(3) Consumptive Use(mm)	45	51	65	89	121	125	141	122	137	150	165	193	185	156	161		
(4) Effective Rainfall(mm)	39	13	9	24	59	74	97	122	41	20	60	96	57	17	11		
(5) Cropping Intensity	0.10	0.30	0.50	0.70	0.90	1.00	1.00	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10		
(6) Net Irrigation Requirement(mm)	1	12	28	46	58	51	44	0	96	130	95	68	64	42	15		

Note: Calculation Procedure (3) = (1) x (2), (6) = ((3) - (4)) x (5)

Table IV-4 Calculation of Net Irrigation Requirement (II)

	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Nursery														
(1) Crop Coefficient	0.23	0.32	0.41	0.50	0.57	0.65	0.75	0.88	0.98	1.06	1.09	1.10	1.07	1.05
(2) Monthly Pan-Evaporation(mm)	137	144	165	198	184	172	131	134	139	149	171	161	137	144
(3) Consumptive Use(mm)	32	46	68	99	105	112	98	118	136	158	186	177	147	151
(4) Effective Rainfall(mm)	13	9	23	56	70	91	98	40	19	59	93	56	17	11
(5) Cropping Intensity	0.03	0.20	0.40	0.60	0.80	0.98	1.00	1.00	0.98	0.80	0.60	0.40	0.20	0.03
(6) Net Irrigation Requirement (mm)	1	8	18	26	28	20	0	79	114	79	56	48	26	4

Note: Calculation Procedure

(3) = (1) x (2)

(6) = ((3) - (4)) x (5)

Table IV-5 Calculation of Net Irrigation Requirement (III)

Maize	Mar.	Apr.	May	June	July	Aug.
(1) Crop Coefficient	0.34	0.55	0.66	0.76	0.76	0.65
(2) Monthly Pan-Evaporation (mm)	198	184	172	131	134	139
(3) Consumptive Use (mm)	67	101	114	100	102	90
(4) Effective Rainfall (mm)	51	69	92	100	39	18
(5) Cropping Intensity	0.30	0.90	1.00	1.00	0.70	0.10
(6) Net Irrigation Requirement (mm)	5	28	22	0	43	7

Groundnuts	Apr.	May	June	July	Aug.	Sept.	Oct.
(1) Crop Coefficient	0.21	0.34	0.44	0.54	0.57	0.54	0.39
(2) Monthly Pan-Evaporation (mm)	184	172	131	134	139	149	171
(3) Consumptive Use (mm)	39	58	58	72	79	80	67
(4) Effective Rainfall (mm)	39	78	58	36	17	50	66
(5) Cropping Intensity	0.30	0.50	0.97	1.00	0.97	0.50	0.30
(6) Net Irrigation Requirement (mm)	0	0	0	36	60	15	1

Vegetables	June	July	Aug.	Sept.	Oct.	Nov.
(1) Crop Coefficient	0.22	0.34	0.45	0.49	0.51	0.35
(2) Monthly Pan-Evaporation (mm)	131	134	139	149	171	161
(3) Consumptive Use (mm)	29	46	63	73	87	56
(4) Effective Rainfall (mm)	29	33	17	49	75	43
(5) Cropping Intensity	0.10	0.70	1.00	1.00	0.90	0.30
(6) Net Irrigation Requirement (mm)	0	9	47	24	10	4

Note: Calculation procedure

(3) = (1) x (2),

(6) = ((3) - (4)) x (5)

Table IV-6 Average Monthly Effective Rainfall

Monthly Mean Rainfall in millimeters	Average Monthly Consumptive Use, in millimeters									
	25	50	75	100	125	150	175	200	225	250
	Average Monthly Effective Rainfall /1, in millimeters									
10	5	6	7	7	8	8	8	9	9	10
25	15	16	17	18	19	20	21	22	24	25
50	25	32	34	36	37	39	42	44	47	50
75	25	46	49	52	55	57	60	64	67	74
100	25	50	64	67	71	74	78	82	87	95
125	25	50	75	81	88	90	95	101	108	115
150	25	50	75	95	102	107	112	120	127	136
175	25	50	75	100	117	122	130	138	146	156
200	25	50	75	100	125	133	141	149	159	169

Note: /1: On the assumption that depth of application is 75 mm.

Source: United States Department of Agriculture, Irrigation Water Requirements, Technical Release No. 21, April 1967.

Table IV-7 Calculation of Consumptive Water Requirement for Estate Farm

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Cropping Pattern	2nd Ratoon				Nursery (1/10 area)							Plant cane
2nd Ratoon (mm)	16											
Nursery (mm)	1	3	6	9	11	10	12	14	13	12	8	3
Plant cane (mm)								1	11	28	49	62
Sub-total (mm)	17	3	6	9	11	10	12	15	24	40	57	65
Cropping Pattern	Nursery				Plant cane						1st Ratoon	
Nursery (mm)	1											
Plant cane (mm)	92	124	174	180	182	143	147	149	140	122	80	39
1st Ratoon (mm)											5	15
Sub-total (mm)	93	124	174	180	182	143	147	149	140	122	85	54
Cropping Pattern	Plant cane				1st Ratoon						2nd Ratoon	
Plant cane (mm)	13											
1st Ratoon (mm)	33	62	109	125	141	122	137	150	149	135	93	47
2nd Ratoon (mm)											5	15
Sub-total (mm)	46	62	109	125	141	122	137	150	149	135	98	62
Cropping Pattern	1st Ratoon				2nd Ratoon							Nursery
1st Ratoon (mm)	16											
2nd Ratoon (mm)	33	62	109	125	141	122	137	150	149	135	93	47
Nursery (mm)												1
Sub-total (mm)	49	62	109	125	141	122	137	150	149	135	93	48
Consumptive Water Requirement												
Average (mm/month)	51	63	100	110	119	99	108	116	116	108	83	57
Average (mm/day)	1.6	2.3	3.2	3.7	3.8	3.3	3.5	3.7	3.9	3.5	2.8	1.8

Table IV-8 Calculation of Consumptive Water Requirement for Settlement Farm

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Cropping Pattern	2nd Ratoon		Maize								Plant cane	
						Groundnuts						
								Vegetables				
2nd Ratoon (mm)	16											
Maize (mm)			7	31	38	34	24	3				
Groundnuts (mm)				1	10	19	24	26	14	1		
Vegetables (mm)						1	11	21	25	26	6	
Plantcane (mm)								1	11	28	49	62
Sub-total (mm)	16		7	32	48	54	59	51	50	55	55	62
Cropping Pattern	Plant cane									1st Ratoon		
Plantcane (mm)	92	124	174	180	182	143	147	149	140	122	80	39
1st Ratoon (mm)											5	15
Sub-total (mm)	92	124	174	180	182	143	147	149	140	122	85	54
Cropping Pattern	Plant cane			1st Ratoon						2nd Ratoon		
Plantcane (mm)	13											
1st Ratoon (mm)	33	62	109	125	141	122	137	150	149	135	93	47
2nd Ratoon (mm)											5	15
Sub-total (mm)	46	62	109	125	141	122	137	150	149	135	98	62
Cropping Pattern	1st Ratoon					2nd Ratoon						
1st Ratoon (mm)	16											
2nd Ratoon (mm)	33	62	109	125	141	122	137	150	149	135	93	47
Sub-total (mm)	49	62	109	125	141	122	137	150	149	135	93	47

Consumptive Water Requirement

Average (mm/month)	51	62	100	116	128	110	120	125	122	112	83	56
Average (mm/day)	1.6	2.2	3.2	3.9	4.1	3.7	3.9	4.0	4.1	3.6	2.8	1.8

Table IV-9 Calculation of Average Net Irrigation Water Requirement for Estate Farm

	Jan.	Peb.	Mar.	Apr.	May	June	July	Aug.	Spe.	Oct.	Nov.	Dec.
Cropping Pattern	2nd Ratoon / Nursery (1/10 area) / Plant cane											
2nd Ratoon	15											
Nursery	1	2	3	3	2	0	8	12	8	6	5	3
Plant cane								1	3	4	21	52
Sub-total	16	2	3	3	2	0	8	13	11	10	26	55
Cropping Pattern	Nursery / Plant cane / 1st Ratoon											
Nursery	1											
Plant cane	83	98	109	98	77	12	105	129	89	58	53	34
1st Ratoon											1	12
Sub-total	84	98	109	98	77	12	105	129	89	58	54	46
Cropping Pattern	Plant cane / 1st Ratoon / 2nd Ratoon											
Plant cane	12											
1st Ratoon	28	46	56	51	44	0	96	130	95	68	64	42
2nd Ratoon											1	12
Sub-total	40	46	56	51	44	0	96	130	95	68	65	54
Cropping Pattern	1st Ratoon / 2nd Ratoon / Nursery											
1st Ratoon	15											
2nd Ratoon	28	46	56	51	44	0	96	130	95	68	64	42
Nursery												1
Sub-total	43	46	56	51	44	0	96	130	95	68	64	43
Net Irrigation Water Requirement												
Average (mm/month)	46	48	56	51	42	3	76	101	72	51	52	50
Average (mm/day)	1.5	1.7	1.8	1.7	1.4	0.1	2.5	3.3	2.4	1.6	1.7	1.6

Table IV-10 Calculation of Average Net Irrigation Water Requirement for Settlement Farm

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Cropping Pattern	2nd Ratoon		Maize / Groundnuts / Vegitables									Plant cane
2nd Ratoon (mm)	15											
Maize (mm)			2	10	8	0	15	3				
Groundnuts (mm)				0	0	0	12	20	5	1		
Vegetables (mm)						0	3	16	8	4	2	
Plant cane (mm)								1	3	4	21	52
Sub-total (mm)	15		2	10	8	0	30	40	16	9	23	52
Cropping Pattern	Plant cane										1st Ratoon	
Plant cane (mm)	83	98	109	98	77	12	105	129	89	58	53	34
1st Ratoon (mm)											1	12
Sub-total (mm)	83	98	109	98	77	12	105	129	89	58	54	46
Cropping Pattern	Plant cane		1st Ratoon								2nd Ratoon	
Plant cane (mm)	12											
1st Ratoon (mm)	28	46	56	51	44	0	96	130	95	68	64	42
2nd Ratoon (mm)											1	11
Sub-total (mm)	40	46	56	51	44	0	96	130	95	68	65	53
Cropping Pattern	1st Ratoon		2nd Ratoon									
1st Ratoon (mm)	15											
2nd Ratoon (mm)	28	46	56	51	44	0	96	130	95	68	64	42
Sub-total (mm)	43	46	56	51	44	0	96	130	95	68	64	42
Net Irrigation Water Requirement												
Average (mm/month)	45	48	56	53	43	3	82	107	74	51	52	49
Average (mm/day)	1.5	1.7	1.8	1.8	1.4	0.1	2.6	3.5	2.5	1.6	1.7	1.6

Table IV-11 Average water application efficiencies for surface irrigation methods

Site Condition	Borders	Furrows or corrugations	Flooding with control grade ditches
1. Sandy soils			
(a) Well graded to optimum grade	60%	40-50%	45%
(b) Insufficient grade	40-50%	35%	30%
(c) Rolling or steep	--	20-30%	20%
2. Medium textures deep			
(a) Well graded to optimum grade	70-75%	65%	55%
(b) Insufficient grade	50-60%	55%	45%
(c) Rolling or steep	--	35%	35%
3. Medium textures shallow			
(a) Well graded to optimum grade	65%	50%	45%
(b) Insufficient grade	40-50%	35%	35%
(c) Rolling or steep	--	30%	30%
4. Heavy soils			
(a) Well graded to optimum grade	60%	65%	50%
(b) Insufficient grade	40-50%	55%	45%
(c) Rolling or steep	--	35-45%	30%

Source: "Irrigation Handbook" prepared by the Sprinkler Irrigation Association in the U.S.A.

Table IV-12 Summary of Irrigation Water Requirement

Unit: ℓ/sec./ha

Month	Lowland Area		Upland Area			
	Estate Farm		Estate Farm		Settlement Farm	
	Average	Maximum	Average	Maximum	Average	Maximum
Jan.	0.33		0.43		0.41	
Feb.	0.38		0.49		0.49	
Mar.	0.40		0.52		0.52	
Apr.	0.37		0.48		0.51	
May	0.30		0.39		0.40	
June	0.02		0.03		0.03	
July	0.54		0.70		0.76	
Aug.	0.72		0.94		0.99	
Sept.	0.53	0.86	0.69	1.11	0.71	1.17
Oct.	0.36		0.47		0.47	
Nov.	0.38		0.49		0.50	
Dec.	0.35		0.46		0.45	
Average	0.39		0.51		0.52	

Note: 1. Project efficiency: Lowland area = 52.7%
Upland area = 40.5%

2. Underlined values are for the design of the irrigation facilities.

Table IV-13 Design Condition of Pumping Stations

Pumping Station	Peak Diversion Requirement m^3/s (m^3/min)	Suction Water Level F.W.L. (m)	Suction Water Level N.W.L. (m)	Suction Water Level L.W.L. (m)	Delivery Water Level (H.W.L.) (m)	Actual Head (m)	Losses (m)	Total Head (m)
No. 1	7.217 (433.0)	5.10	0.80	0.30	4.70	4.70	0.40	5.10
No. 2	5.963 (357.8)	4.72	3.50 3.00	3.00	21.00	18.00	3.50	21.50
No. 3	0.344 (20.6)	4.80	0.80	0.30	8.93	8.33	0.97	9.30
No. 4	0.559 (33.6)	4.72	4.00 3.50	3.50	10.14	6.64	2.06	8.70
No. 5	0.274 (16.4)	H.W.L. 6.28	6.28 6.00	6.00	8.77	2.77	1.03	3.80
No. 6	0.560 (33.6)	3.40	0.50	0.00	7.41	7.41	1.09	8.50
No. 7	0.516 (31.0)	3.20	0.50	0.00	6.95	6.95	1.05	8.00
No. 8	0.352 (21.2)	H.W.L. 6.12	6.12 5.00	5.00	7.56	2.56	0.74	3.30
No. 9	0.694 (41.6)	4.72	4.00 3.50	3.50	8.60	5.10	0.90	6.00

Table IV-14 Comparison of Construction Cost of No.2 Pumping Station

Design Requirement: 1. Pump capacity required; 71.6 m3/min.
2. Total water head; 21.5 m
3. Numbers of pumps; 6
(including one stand-by pump)

Description	Case A	Case B
Type of pump	Double suction volute pump	Vertical shaft mixed flow pump
Suction Bore (mm)	ϕ800	ϕ800
Direct Construction Cost/1	(US$1,000)	(US$1,000)
Mechanical and electrical works		
Pump and Motor	600	660
Control panel and others	290	290
Crane	27	27
Instatllation	285	304
Sub Total	1,202	1,281
Civil works	154	126
Buildings	130	103
Miscellaneous (5%)	74	75
Grand Total	1,560	1,585

Note : /1 excluding the cost of the penstock and outlet structure.

Table IV-15 Numbers of Pumps and Cost Comparison

Design Requirements:
1. Total capacity of pumps; 357.8 m^3/min
2. Total water head; 21.5 m
3. Type of pump; Double suction volute pump
4. Number of stand-by pump; 1

Description	Case A	Case B	Case C	Case D	Case E
Numbers of Regular Pump	3	4	5	6	7
Pump Capacity (m^3/min)	119.3	89.5	71.6	59.6	51.1
Suction Bore (mm)	ϕ1000	ϕ900	ϕ800	ϕ700	ϕ600
Motor Output (kW)	600	450	355	315	255
	(US$1,000)	(US$1,000)	(US$1,000)	(US$1,000)	(US$1,000)
Direct Construction Cost					
Equipment	940	942	917	901	890
Installation	290	290	285	283	280
Civil works	140	147	154	165	170
Buildings	117	122	130	144	147
Miscellaneous (5%)	74	75	74	75	74
Total	1,561	1,576	1,560	1,568	1,561
O & M Cost (Annual)					
Electricity Charge/1	137	139	135	141	139
Maintenance Cost	38	39	37	36	35
Replacement Cost/2	19	19	18	18	18
Total	194	197	190	195	192

Note: /1 Estimated value in conformity with the Power tariffs regulations in 1975 published by the Ghana Electricity Corporation. Annual water requirement was assumed 70×10^6 m^3 in total at the No. 2 pumping station.

/2 Capitalized value assuming the interest rate of 9 % and a life of 20 years.

Table IV-16 Principal Features of Pumping Stations

Pumping Station	Location	Command Area	Diversion/1 Requirement (m^3/min)	Numbers of/2 Pump	Pump Capacity (m^3/min)	Total Head (m)	Motor Output (kW)	Suction Bore (mm)	Pump Type
No. 1	Volta River	Block-2,5,6, 7 & Sugar Factory	433.0	7	72.2	5.1	90	ϕ800	Vertical shaft mixed flow pump.
No. 2	Bla Lagoon	Block-5,6,7	357.8	6	71.6	21.5	355	ϕ800	Double suction volute pump.
No. 3	Volta River	Block-1	20.6	3	10.3	9.3	30	ϕ300	Vertical shaft mixed flow pump.
No. 4	Bla Lagoon	Block-2	33.6	3	16.8	8.7	37	ϕ350	Horizontal shaft mixed flow pump.
No. 5	Block-2	Block-2 (Booster)	16.4	3	8.2	3.8	7.5	ϕ300	- do -
No. 6	Volta River	Block-3	33.6	3	16.8	8.5	55	ϕ350	Vertical shaft mixed flow pump.
No. 7	Volta River	Block-4	31.0	3	15.5	8.0	45	ϕ350	- do -
No. 8	Block-4	Block-4 (Booster)	21.2	3	10.6	3.3	11	ϕ300	Horizontal shaft mixed flow pump.
No. 9	Bla Lagoon	Sugar Factory	41.6	4	13.9	6.0	22	ϕ350	- do -

Note: /1 All pumping stations will be 24-hour operation at the peak diversion requirement.
/2 Including one unit of stand-by pump for emergency and repairing.

Table IV-17 Principal Features of Irrigation Canals

Description	Unit	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Total
A. Net Irrigation Area	ha	400	650	650	600	2,000	1,500	1,700	7,500
B. Maximum irrigation water requirement	ℓ/sec/ha	0.86	0.86	0.86	0.86	1.11	1.17	1.17	-
C. Length of irrigation canals									
1. Main	km	4.0	7.4	3.6	6.0	20.4	10.5	16.0	67.9
2. Secondary	km	0.6	1.4	2.2	-	5.2	8.4	4.6	22.4
3. Distribution	km	13.6	14.2	19.3	21.3	46.2	27.2	31.6	173.4
Total	km	18.2	23.0	25.1	27.3	71.8	46.1	52.2	263.7
D. Numbers of related structures									
1. Farm pond	nos.	1	2	1	2	30/1	22	28	86
2. Turnout (Main & Secondary)	nos.	15	18	15	15	34	25	32	154
3. Turnout (Distribution)	nos.	137	131	148	200	526	294	415	1,851
4. Cross regulator	nos.	3	4	3	3	10	8	9	40
5. Culvert	nos.	2	1	-	1	1	3	3	11
6. Drop	nos.	1	1	-	-	7	4	3	16
7. Spillway	nos.	-	2	2	1	4	3	3	15
8. Wasteway	nos.	2	2	3	1	3	3	4	18
9. Syphon	nos.	-	-	1	-	2	2	2	7

Note: /1 including a regulating pond for No.2 pumping station

Fig IV - 1 CROP COEFFICIENT OF SUGAR CANE

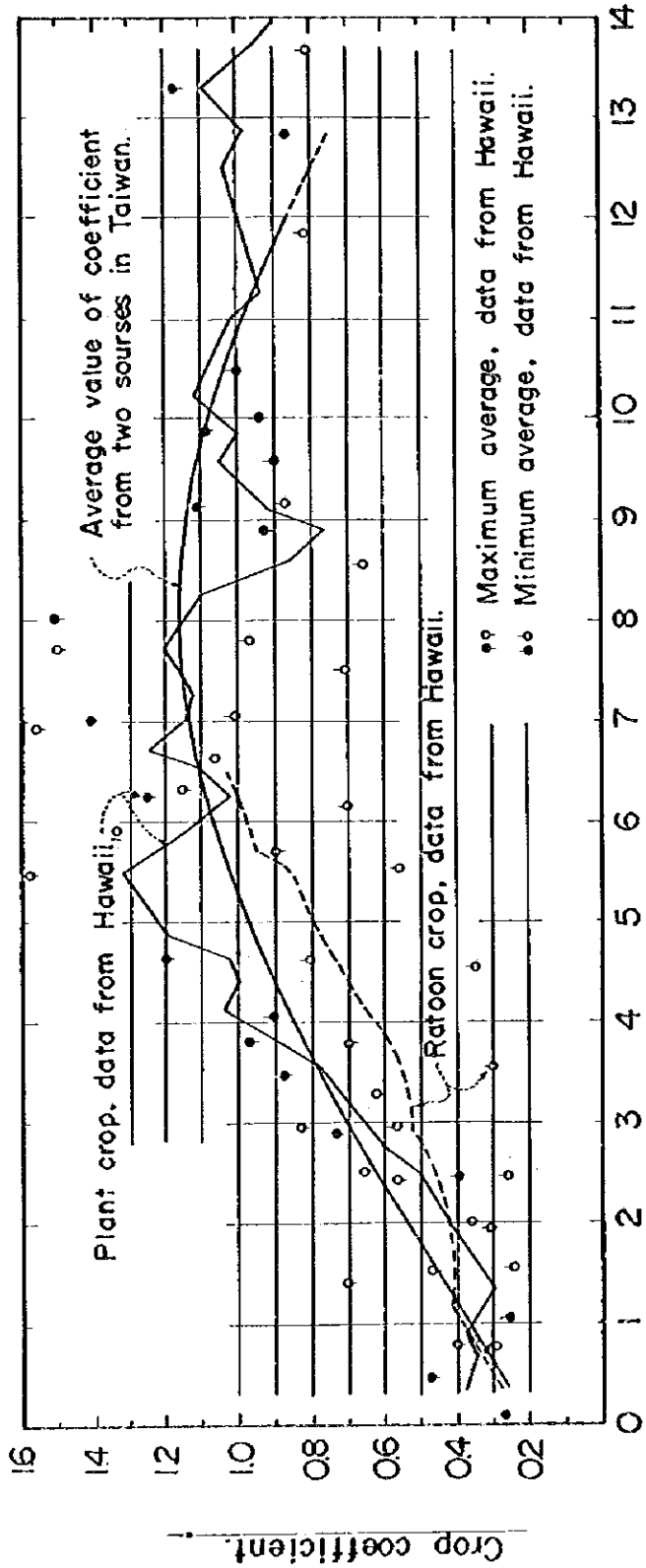


Fig. IV - 2 CROP COEFFICIENT OF DRY CROPS

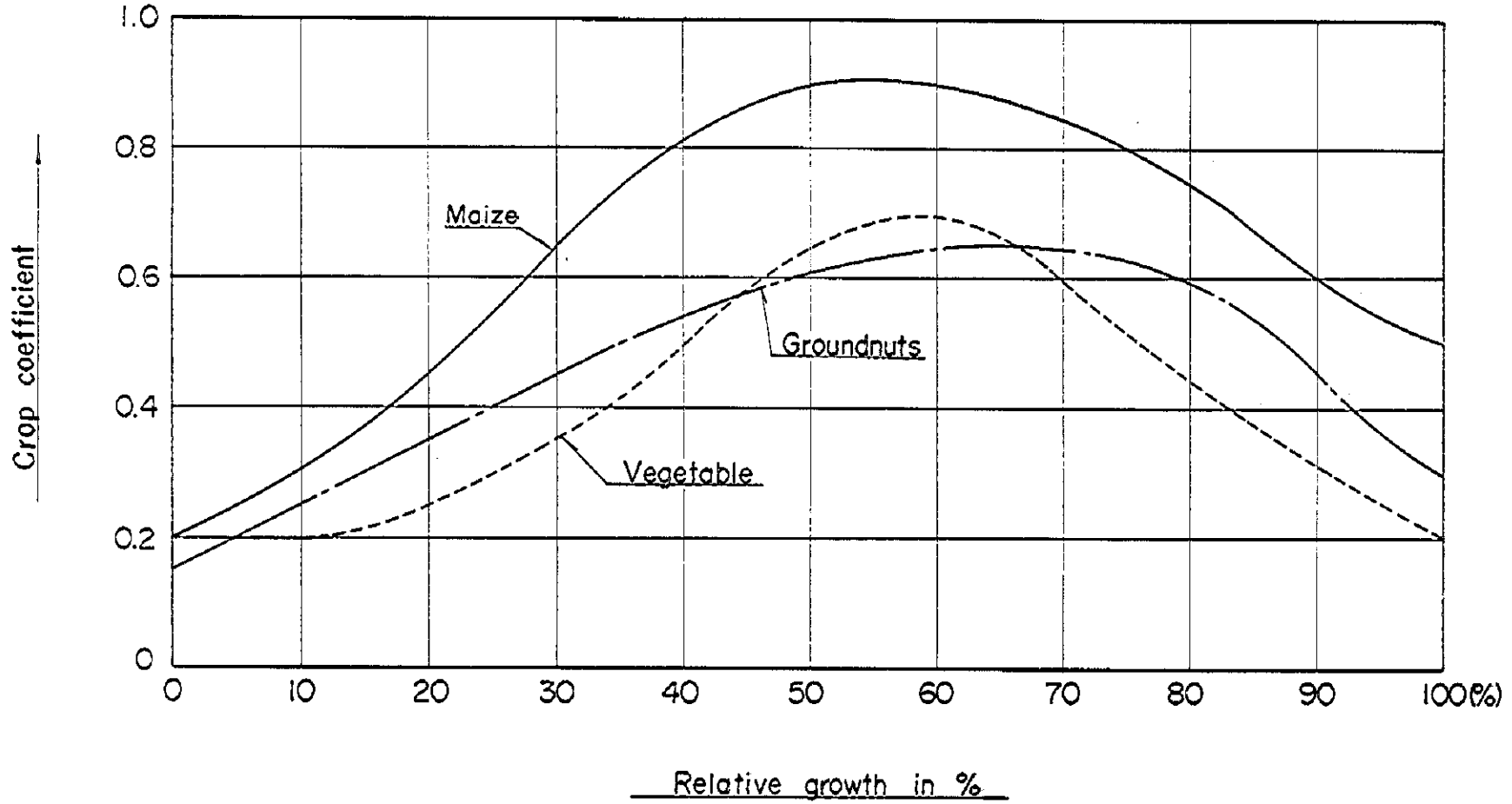
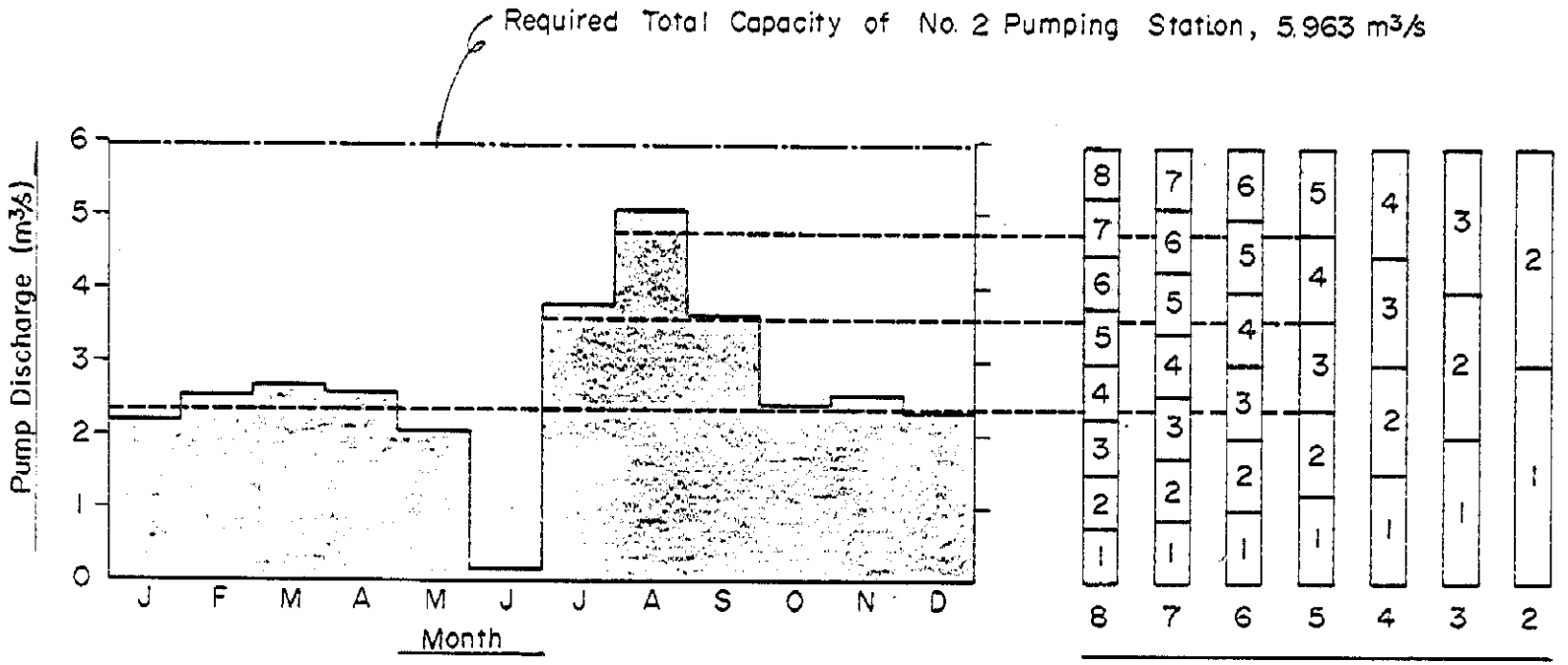


Fig. Ⅳ-3 MONTHLY VARIATION OF AVERAGE WATER REQUIREMENT

(at No.2 Pumping station , 24 hour operation)



Average Water Requirement(m³/s)⊿	J	F	M	A	M	J	J	A	S	O	N	D
	2.17	2.55	2.70	2.61	2.06	0.16	3.80	5.03	3.65	2.44	2.55	2.31

⊿= Values were estimated allowing the average monthly amount of effective rainfall.

Fig. Ⅳ - 4 IRRIGATION DIAGRAM

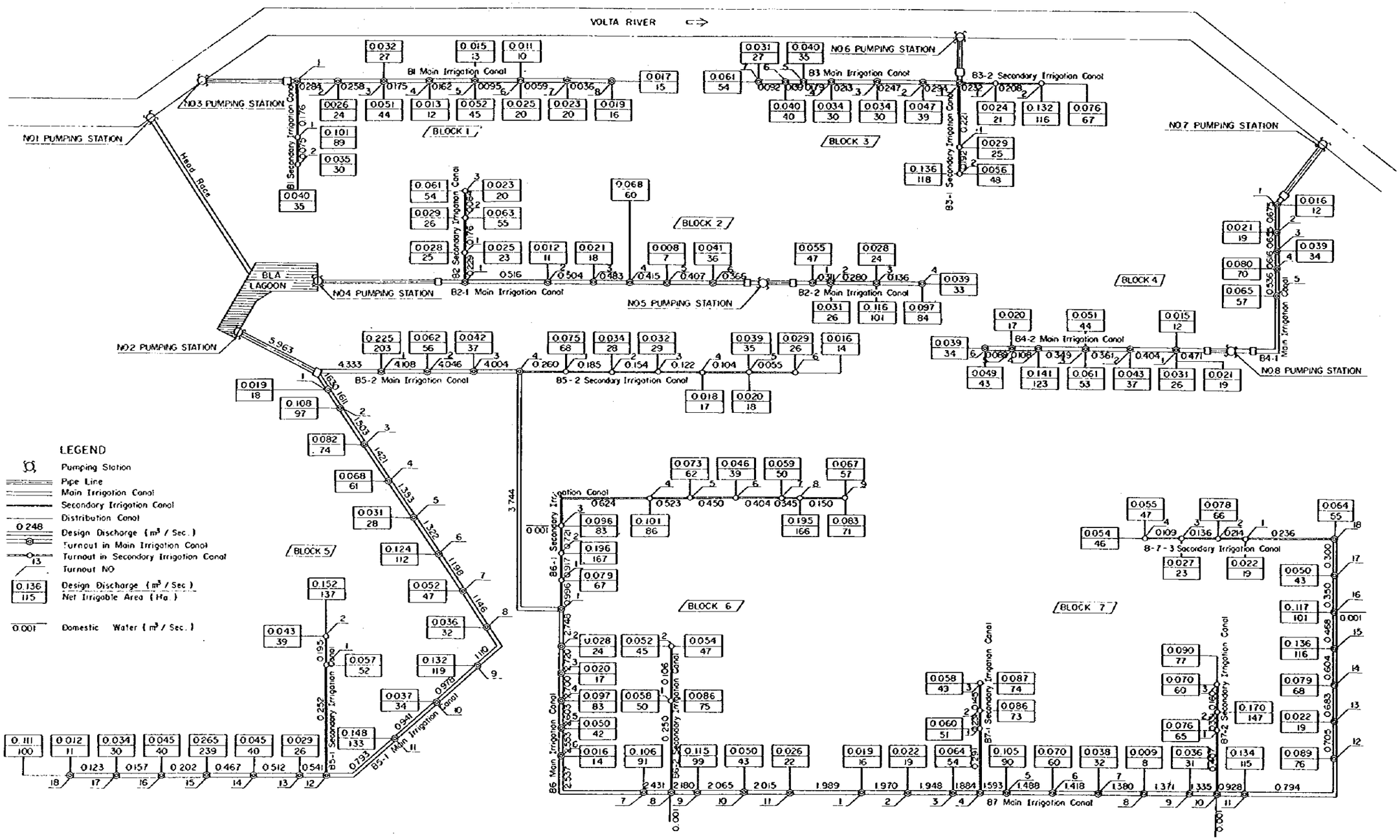


Fig IV-5 WATERSHED BOUNDARIES

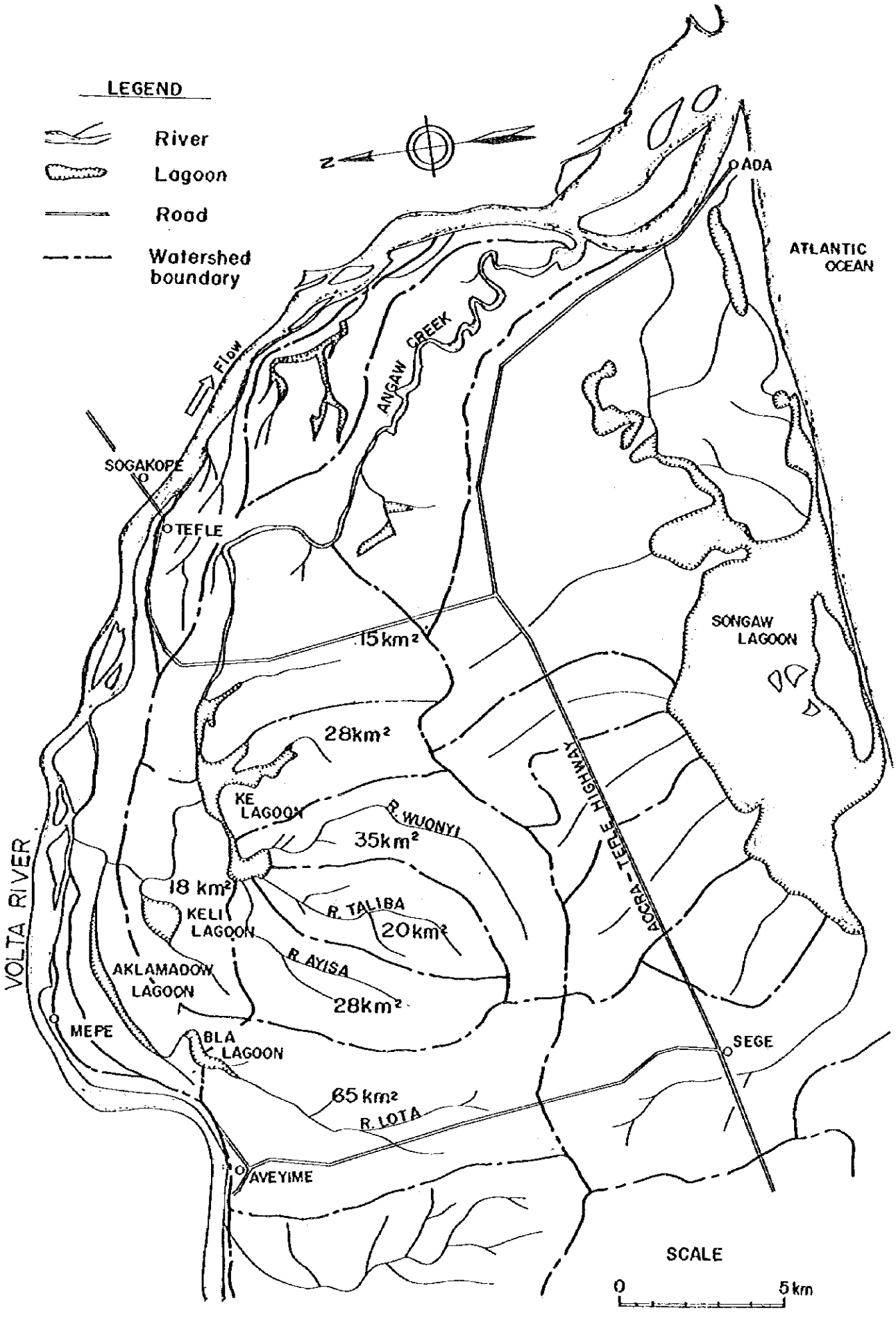


Fig.V-6 AREA AND STORAGE CAPACITY CURVES OF BLA LAGOON

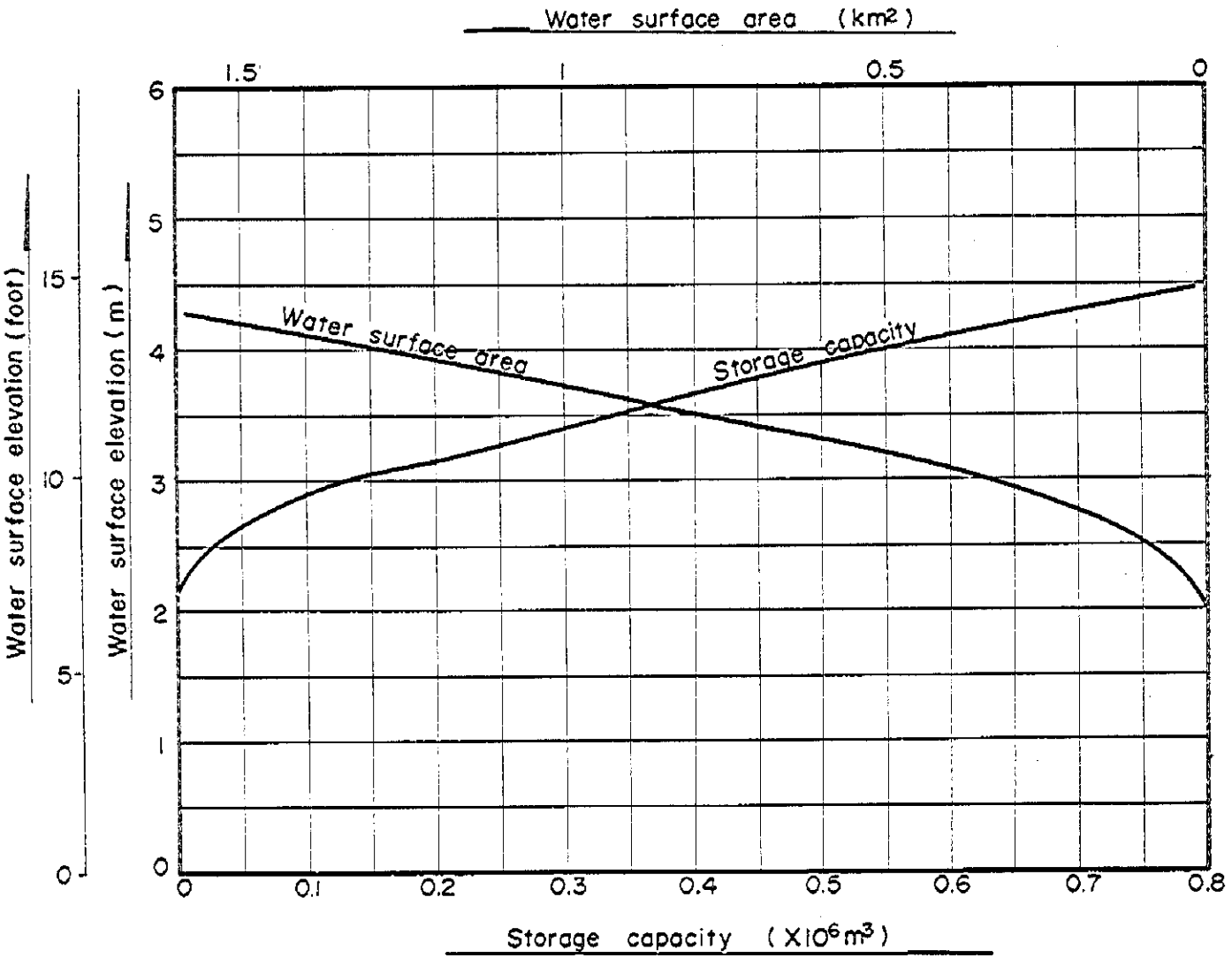


Fig.IV-7 AREA AND STORAGE CAPACITY CURVES OF AKLAMADOW LAGOON

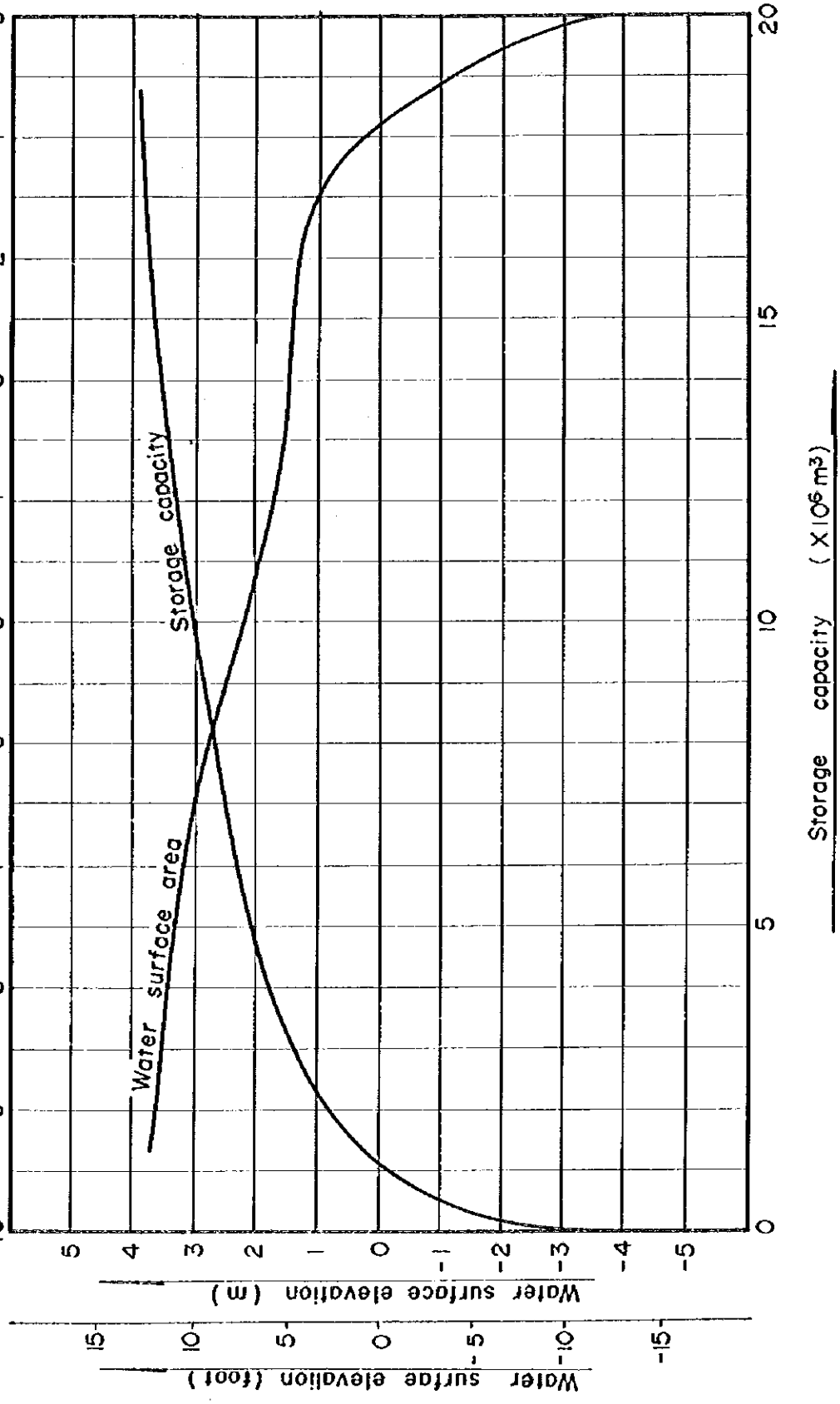


Fig. IV-8 AREA AND STORAGE CAPACITY CURVES OF KELI LAGOON

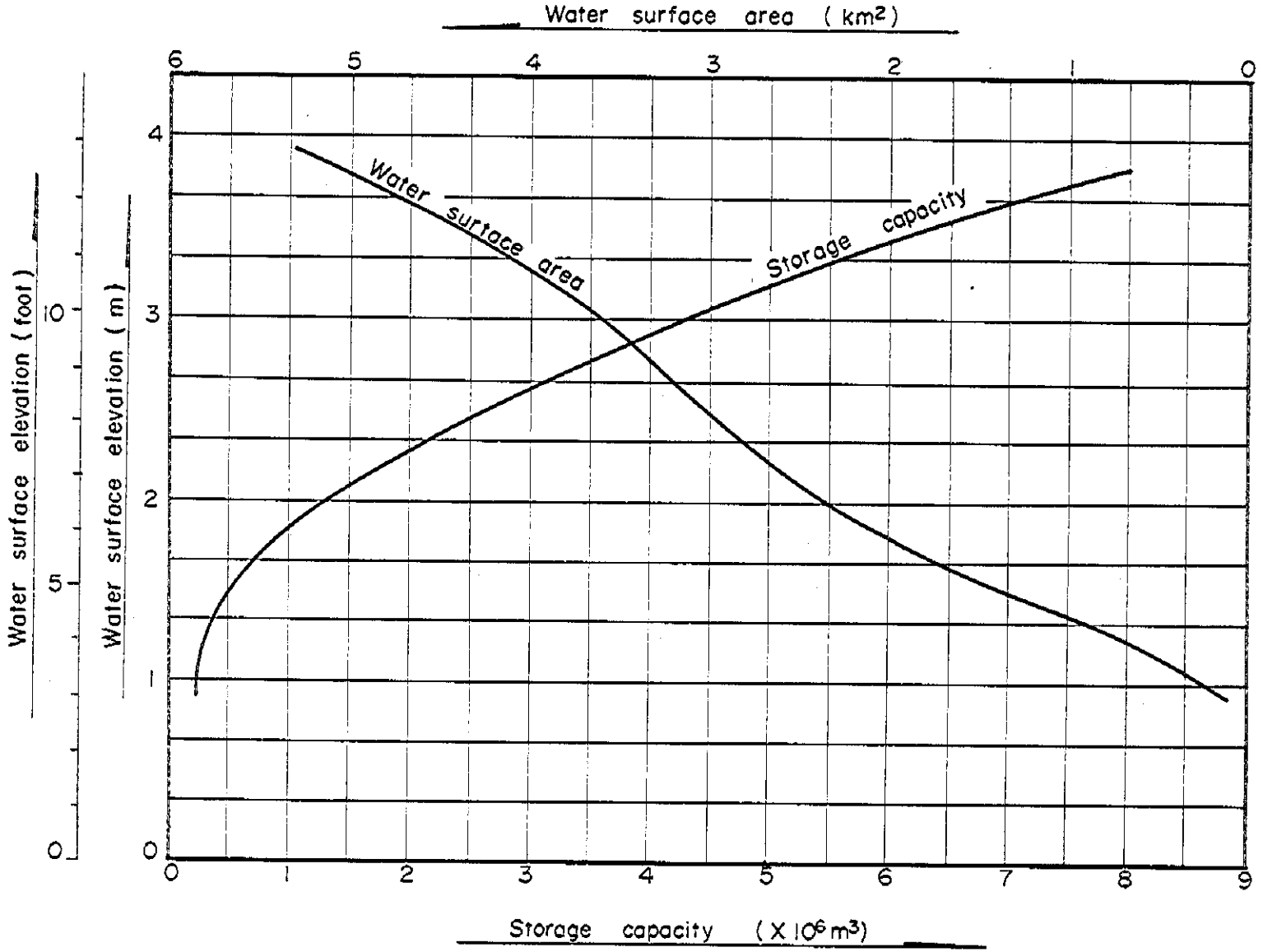


Fig. IV-9 AREA AND STORAGE CAPACITY CURVES OF KE LAGOON

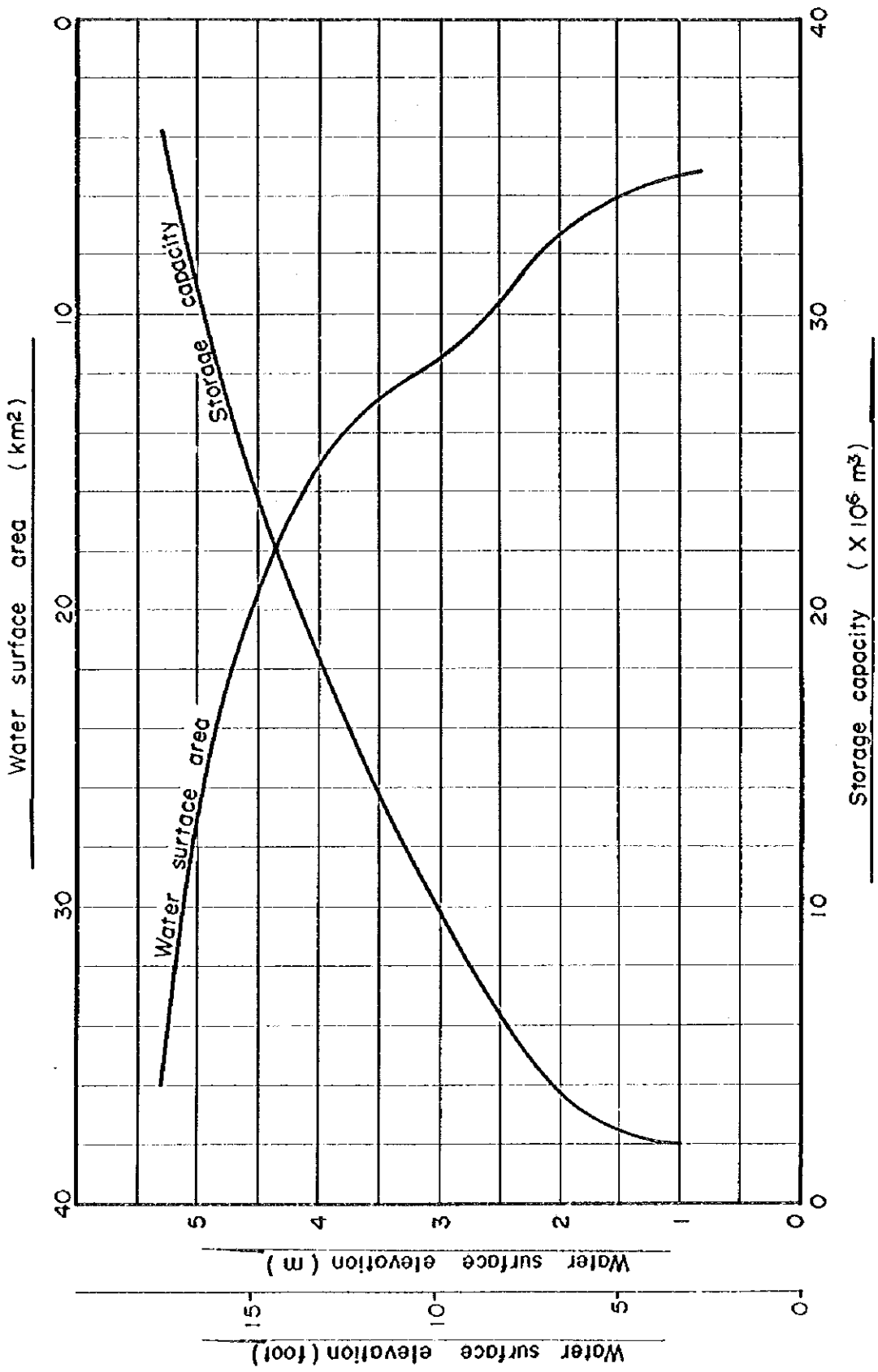


Fig. V-10 DISCHARGE CAPACITY CURVE OF THE NO.2 GATE

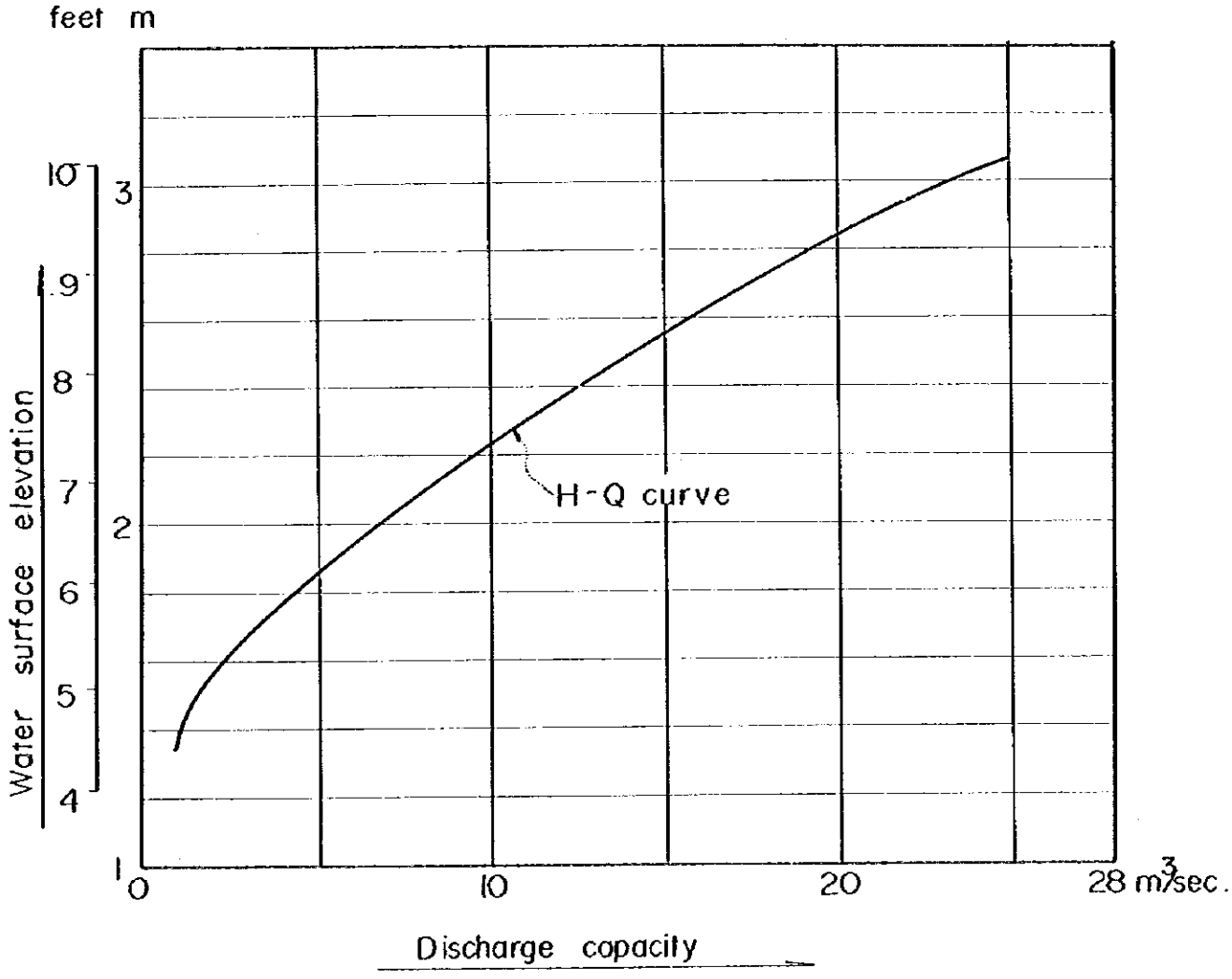
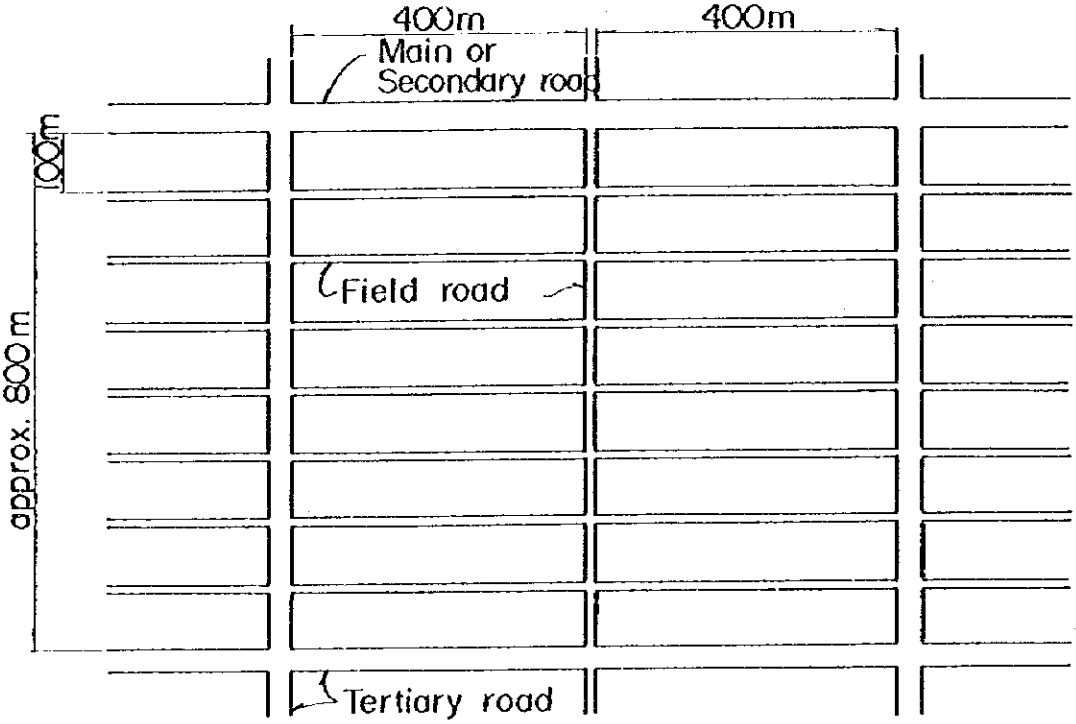


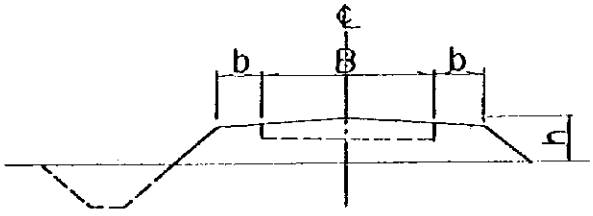
Fig. IV - 11 TYPICAL ARRANGEMENT AND TYPICAL SECTION OF ROADS

I. TYPICAL ARRANGEMENT OF ROADS



II. TYPICAL SECTION OF ROADS

(i) CROSS SECTION



(m)

Road	B	b	Pavement
Main	8.0	1.5	Gravel
Secondary	6.0	1.0	Laterite
Tertiary	4.0	1.0	〃

(ii) HORIZONTAL AND VERTICAL ALIGNMENT

Road	Slope	Local Slope	Max. Length of Local Slope	Min. Radius	Curve Length	
					More than 7°	7°~3°
Main	3%	3 %	300 m	15 m	20 m	90 - 100
Secondary		10 %	100 m	10 m	10 m	45 - 50
Tertiary						

ANNEX V

SUGAR PLANT

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX V SUGAR PLANT

CONTENTS

5.1 General

The sugar factory is planned to have a cane crushing capacity of 3,000 tons per day under 24 hour operation of the factory to produce refined sugar of 300 tons per day.

The defication process is adopted for production of raw sugar, and re-melting, carbonating, decolourizing, filtering and reboiling processes for production of refined sugar.

The sugar factory comprises the following major manufacturing divisions:

(1) Cane handling department
(2) Cane milling department
(3) Raw sugar producing department
(4) Refined sugar producing department
(5) Steam generating department
(6) Electric power generating department

The repair shop, laboratory and other appurtenant facilities are also necessary for operation of the sugar factory.

5.2 Production Capacity of the Sugar Plant

The factory plant shall have a capacity sufficient to process the whole sugar cane harvested on the sugar cane field.

At the full development stage of the project, the total harvest of sugar cane is planned to be 450,000 tons per annum and the sugar cane harvesting period is 5.5 months per year, from the begining of November to the middle of the following April.

In determining the practical cane crushing capacity of the sugar factory, the periodical factory maintenance of at least one full day every ten operation days should be taken into consideration for checking and cleaning the machinery and equipment of the factory plant. Considering this requirement, the annual net operation days are set at 150 days. Consequently, the factory plant is planned to have a practical cane crushing capacity of 3,000 tons per day under 24 hour operation.

For producing the refined sugar products in pace with the raw sugar production, the refined sugar producing department shall have a raw sugar melting capacity of 315 tons per day under 24 hour operation per day, corresponding to the production capacity of the raw sugar to be obtained from the sugar cane of 3,000 tons per day.

5.3 Outline of Manufacturing Process

5.3.1 General

The factory is planned to produce the granulated refined sugar from sugar cane harvested on the farms under the project, in an integrated production process.

The mixed juice taken from sugar cane is clarified by defication process and boiled into washed raw sugar in the raw sugar producing department. The washed raw sugar is further remelted, clarified by carbonating process, decolourized by active carbon, filtered, finished by anion exchange resin and reboiled in refined sugar in the refined sugar producing department.

Thus, the refined sugar product is sucessively obtained by processing the raw sugar produced in the same factory and the sugar production is performed during the cane crop season only. This production method is very advantageous as the type of raw sugar most suitable for refinery process can be produced in the raw sugar producing department and all returns from the refinery station are sent back to the own raw sugar producing department for efficient processing together with the fresh incoming syrup. Furthermore, the produced raw sugar for refinery process is always fresh and makes refinery operation easy.

Though the defication process is employed as a standard processing method in the world sugar industry for the raw sugar production, there are various processing methods widely employed for the refined sugar production. The typical processing methods are compared hereunder. Purification of the raw liquor obtained by melting the raw sugar is generally performed by the combination of two or more different processing methods. The most typical combinations of the processing methods prevailing in the world are given hereunder:

Process	Affination	Melting	Cabonatation	Sulphitation	Granular Carbon	Active Carbon	Sucro-Blanc	Anion Exchange resin
Case								
A	o	o	o	o				
B	o	o	o		o			
C	o	o	o			o		o
D	o	o				o	o	

Among the above processes, the affination process can be omitted in this case as the raw sugar is washed at the last stage of raw sugar production by centrifugal machines.

Comparison of the above cases A, B, C and D are briefly summarized as described below:

Case A: Installation cost is cheapest. Operation cost is also low if the sulphur and lime as sub-materials can be obtained at low cost. Quality of product and sugar yield are somewhat low.

Case B: Installation cost is most expensive while operation cost is relatively low if the fuel oil for regenerating the granular carbon can be obtained at low cost. The quality of product is very good and the sugar yield is high. For large scale refinery with production capacity over 500 ton/day, this process is very advantageous and economical as a whole.

Case C: Installation cost is not so expensive, however operation cost is somewhat high. Operation control is very flexible. The amount of active carbon can be adjusted according to the quality of liquor not affecting the output capacity of the refinery and different carbons can be easily blended as desired for most efficent decolourization and filtration. On the other hand, the flow rate of liquor through filters is somewhat poor and large filtering area is required. The best quality product can be obtained by finishing with the anion exchange resin, however this process requires large amount of pure NaCl for rinsing the resin. The quality of product is very good and the sugar yield is also high. This process is very advantageous and economical as a whole for middle scale refinery having production capacity of around 300 ton/day.

Case D: Installation cost is not so expensive. Operation cost is very high if the quality of raw sugar is not excellent. This process has some advantages only when the very good quality of affined sugar is melted. The filtration is very easy and the process is clean and simple. The quality of product is not so good and the product by this process contains more ash than the other Cases A, B and C. This process required very high quality raw sugar and is not practical for refinery with production capacity exceeding 200 ton/day, because so many treatment tanks are needed.

From the comparison mentioned above the case C not including affination process is selected as the most appropriate process for the project.

Both of the carbonation process and phosphatation process are applicable for purification and clarification of the raw liquor, however, the former is adopted in view of superior property for colour removal, the former being 60 % and the latter being 35 to 50 % for colour removal.

Explanation of the manufacturing process is given hereunder and the flow diagram of the manufacturing process is shown in Drawing No. 700-04 (OUTLINE OF PROCESS).

5.3.2 Cane handling

The sugar cane, harvested and chopped by mechanical harvesters in the cane farms, will be transported into the factory by trailer-trucks during the day time.

After being weighed by the truck scales, the chopped cane will normally be unloaded directly on the cane feeding table by means of tipping the trailers by the tipping table which will be installed at a side of the cane feeding table. The surplus cane will be once unloaded in the cane yard using the other tipping tables and stockpiled using the cane stackers. The sugar cane thus stored will then be carried to the cane feeding table using the cane stackers during the night time when sugar cane is not transported into the factory.

5.3.3 Raw sugar production

The sugar cane thus unloaded on the cane feeding table, will then be transferred to the cane carrier by the moving chain of the cane feeding table. The sugar cane will be washed with water for removing sand, soil, soot and other dirt adhered on the cane surface and will then be cut into smaller pieces by two sets of the cane cutter installed on the cane carrier, shredded by the cane shredder installed in front of the milling tandem and further delivered to the milling tandem.

Juice containing sucrose in the sugar cane will be extracted by the milling tandem. Compound maceration system will be adopted and the sucrose extraction will at least amount to more than 93 % when the sugar cane of good quality is supplied. The moisture content of the extracted bagasse will be kept at less than 50 %.

The bagasse will be supplied to the steam boiler by the bagasse elevator and the bagasse carrier, and burnt as fuel.

The mixed juice, obtained from the milling tandem, will at first be cleaned by removing cush-cush by the strainer and then, boosted up to the clarifying station.

In the clarifying station, the cleaned mixed juice is weighed at first by the automatic juice scale and limed in the lime-dosing equipment after being heated in the juice heater. The limed juice will be heated again in the juice heater up to 105°C and conveyed to the Rapi-Dorr type continuous clarifier, in which the limed juice will be continuously separated into the clear juice and the mud as a form of sedimentation of impurities.

The clear juice will then be transferred to the first vessel of the evaporator. The sedimented mud will be filtered by the rotary vacuum filter and filtrate will be fed back to the mixed juice tank. The bagacillo, obtained from bagasse through the Rotex screen, will be used as filter aid.

In the evaporation station, the clear juice of Bx 14 will be concentrated by the multi-effect evaporator into the syrup of Bx 60. Then, the syrup will be led to the vacuum pan station.

In the vacuum pan station, the syrup is boiled up to massecuite through the three-stage boiling system with triple seed system, the most practical method for producing the high purity raw sugar suitable for the raw sugar refining not including affination process for the refined sugar production. In this boiling system, C sugar is used as the seed for B massecuite boiling and B sugar as the seed for A massecuite boiling, then high quality A sugar only will be taken out as raw sugar product.

The C massecuite, discharged from the C vacuum pans, will be once received in the crystallizers, for crystallizing by cooling with water and will then be separated into the C sugar and the molasses by the continuous centrifugal machines. The C sugar is to be double cured. The C sugar thus obtained will be sent to the C seed magma mixer for preparing the seed magma for B sugar boiling. The A and B massecuite, discharged

from the A and B vacuum pans, will be separated into the sugar crystals and the molasses by the centrifugal machines. The all quantity of B sugar will be sent to the seed magma mixer through the magma mingler for preparing the B seed magma for A massecuite boiling. The A sugar will be sent to the refinery station, after being directly washed in the A centrifugal machines to a purity above 99 % to obtain a favourable condition for successive processing in the refinery station.

The final molasses purged from the C centrifugal machines will be once stored in the exhaust molasses tanks and will then be delivered to the users by tank lorries.

5.3.4 Refined sugar production

The washed raw sugar, as the final product of the raw sugar production department, will be melted again, eliminating affination process, with hot water or sweet water in the continuous melter. Concentration of the melted liquor will be regulated to Bx 60 by the regulating tank. The liquor prepared as above is called raw liquor. The raw liquor will then be pumped up to the carbonation towers.

After being limed by means of the automatic proportional dosing apparatus, the raw liquor will be continuously and constantly carbonated in the carbonation towers for coagulating the various impurities contained in the raw liquor. CO_2 gas contained in boiler flue gas will be used for carbonation process. The flue gas will be cleaned by the dust collector and scrubbers and delivered to the carbonation towers through the CO_2 gas pump.

The carbonated raw liquor will be filtered with the auto filters in which the coagulated inspurities from the liquor will be removed. The colour value of the filtered liquor is expected to be less than 7° Stammer. The brown liquor thus obtained will be pumped to the decolourizing station.

In the decolourizing station, the brown liquor will be decolourized by adding active carbon and filtering the carbon mixed liquor. In the decolourization tanks, the liquor will be mixed with a proper quantity of active carbon and kept for about 1 hour, and then filtered by the Sweetland type filters using kieselguhar as a filter aid. The clear liquor will be obtained, after filtering again by the check filter. Coulour value on this clear liquor is expected to be around 1.5° Stammer.

The clear liquor obtained as above will be transferred into the anion exchanging resin tower for final clarification, in which the final step of the purification and decolourization process of the liquor will be performed. After being treated in the ion exchanging resin tower, the fine liquor with the colour value of 0.15° to 0.2° Stammer will be obtained and then pumped up to the vacuum pan station for refined sugar boiling.

In the refined sugar boiling station, the fine liquor will be boiled up to the massacuite by four-stage straight boiling system. The massacuite will be further crystallized in the receiving massecuite crystallizers and separated into the refined sugar srystal and the molasses using the centrifugal machines. Powdered sugar will be used for seeding in each massecuite boiling.

The molasses exhausted from the centrifugal machines of the forth stage boiling will be transferred back to the raw sugar boiling station, and mixed with the syrup for the raw sugar boiling. Thus the sucrose contained in the molasses will be recovered into the raw sugar. As the refined sugar boiling is carried out in conjunction with the raw sugar boiling as mentioned above the refinery process is much more simple compared with the independent refinery plant operation, which shall involve a complicated six or seven stages boiling process for recovery of sucrose.

The refined sugar thus obtained will be temporarily kept in the sugar bins after being dried in the sugar dryer and cooler, and sieved by the sugar screen. The refined sugar will be packed with polyethylene leminated paper bag containing 30 and/or 50 kg of sugar, and stored in the sugar warehouse, and then delivered to the market as commercial granulated refined sugar product.

5.4 Plant Layout

The layout of the sugar factory plant is generally classified into two types; one is the two-storied factory and the other three-storied factory.

The three-storied system is adopted for the proposed plant layout as this type is considered to be convenient enough to ensure the smooth operation of the factory.

As shown in Drawing No. 700-01, the milling station and the boiler room are arranged in a straight line neighbouring each other. The other stations such as the clarifying and evaporation stations, and the vacuum pan and sugar stations are arranged in the direction rectengular to the above line. Viewing from the flow of the processing, such arrangement is considered to be desirable.

The power station is located conveniently both for receiving the steam from the boilers and for supplying the exhaust steam to the production processes such as the vacuum pan, clarifying and evaporation stations. The power station shall also be located for convenience of distribution of the electric power to every portion of the factory.

The vacuum pan and sugar stations are of three-storied arrangement. The vacuum pans are installed on the second floor. The crystallizers are installed on the first floor and centrifugal machines on the ground floor. Therefore, the flow of the massecuite will be performed by gravity and will not require to boost up by massecuite pumps, which is necessary in the case of the two-storied arrangement.

5.5 Electric Power Supply System

Maximum power consumption of the sugar factory during the crushing period is about 3,000 kW.

The power necessary for the factory operation is available by extending the existing power transmission system to the project area connected to Akosombo hydro-electric power station. However, it is more economical and practical to generate the necessary electric power by back-pressure type steam turbine generators. The process steam is necessary for the factory operation and bagasse as fuel is also available in enough quantity for steam generation. By utilizing the generated steam effectively for power generation, the electric power necessary for factory operation can be obtained at low cost. Two sets of steam turbine generator of 1,600 kW capacity are planned to be installed to supply electric power to the factory.

The power receiving facilities for receiving the public electric power corresponding to one unit of steam turbine generator is planned to be installed in parallel with the generated power system for the power supply for starting up the factory, in an emergency case when one unit of steam turbine generator is out of service and when the factor is out of the crushing operation.

5.6 Brief Description of Factory Plant

5.6.1 General

The factory plant are planned based on the conditions given hereunder:

(1) Production capacity

Cane crushing capacity	:	3,000 tons per day under 24 hour operation
Raw sugar melting capacity	:	315 tons per day under 24 hour operation

(2) Quality of cane

Fibre content in cane	:	13.0 %
Sucrose content in cane	:	13.0 %
Purity of absolute juice	:	82.0 %

(3) Mixed juice

Brix of mixed juice	:	14.0 %
Sucrose extraction	:	94.0 %
Quantity of mixed juice	:	85.0 % of cane weight

(4) Sugar product

Kind of sugar	:	Granulated refined sugar		
Quality of sugar (expected)	:	Polarization	:	99.90
		Invert sugar	:	0.02
		Humidity	:	0.02
		Ash	:	0.02
	:	Laminated paper bag containing sugar product of 50 and/or 100 kg		

5.6.2 Cane handling department

The major equipment in this department are as given hereunder:

4 - Weighing bridges

For weighing the cane transported by trailers or trucks.
Weighing capacity: 20 tons

3 - Trailer tipping tables

For unloading the cane from the trailers on the cane feeding table or in the cane yard.

3 - Cane stackers

For handling the cane in the cane yard.
Loading capacity: 2.5 tons of cane

1 - Cane feeding table with cane leveller

For feeding the cane to the cane carrier.
Size: 5,000 mm wide x 10,000 mm long
Driving motor: 7.5 kW

1 - Cane washing facilities

5.6.3 Cane milling department

The major equipment in this department are as follows:

1 - Cane carrier

For carrying the cane to the cane shredder.
Type: Apron type
Size: 1,980 mm wide x approx. 45,000 mm long
Driving motor: 37 kW

2 - Cane cutters

For cutting the cane.

Type:	Revolving knife type
Size:	1,340 mm dia. x 1,830 mm long
Revolution:	600 rpm
Driving motor:	For first cutter 110 kW
	For second cutter 190 kW

1 - Cane shredder

For shredding the cane.
Type: Searby's swing hammer type
Size: 1,067 mm dia. x 1,830 mm long
Revolution: 1,200 rpm
Driving steam turbine: 450 kW

5 - Three roller mills

For milling the cane
Type: King and queen boltless three roller mill
Roller size: 915 mm (36") dia. x 1,830 mm (72") long with compound gearing

5 - Steam turbines for cane mill

Type: Non-condensing, back pressure, impulse and single stage type, with reduction gear
Output: 350 kW

2 - Mixed juice pumps (one as stand-by)

For pumping up the mixed juice to the juice weighing scale

Type:	Non-clog centrifugal type
Capacity:	2,500 ℓ/min
Head:	15 m
Driving motor:	11 kW

1 - Cush-cush strainer

For removing the bagacillo from the mixed juice

Type:	perforated plate screen with drag conveyer type
Size:	915 mm wide x 18,000 mm long
Driving motor:	3.7 kW

1 - Maceration apparatus

Pump, tank, cooling apparatus, flow meter, etc.

1 - Overhead travelling crane

For maintenance works of the cane mill

Type:	Overhead travelling type
Capacity:	Main 20 tons Auxiliary 5 tons

All other necessary auxiliary equipment such as pumps, conveyors, tanks, etc. shall also be furnished to complete the process.

5.6.4 Raw sugar producing department

The department consists of the juice clarifying station, concentrating station and boiling and curing station. The major equipment in this department are as given hereunder:

For juice clarifying station

1 - Juice weighing scale

For weighing the mixed juice
Type: Maxwell-Boulogne type
Weighing capacity: Max. 150 tons/hr

2 - Mixed juice pumps (one as stand by)

For pumping up the mixed juice to the liming tank through the first juice heater.
Type: Non-clog centrifugal type
Capacity: 2,500 ℓ/min
Head: 15 m
Driving motor: 11 kW

5 - Juice heaters
For heating the mixed juice
Type: Vertical, shell and tube type
Heating surface: 150 m^2

2 - Liming tanks

For liming the mixed juice
Type: Cylindrical type with stirrer
Capacity: 12 m^3

2 - Limed juice pumps

For pumping up the limed juice to the juice clarifier through the second juice heater
Type: Non-clog centrifugal type
Capacity: 2,500 ℓ/min
Head: 35 m
Driving motor: 30 kW

1 - Continuous juice clarifier with auxiliaries

For clarifying the juice continuously by sedimentation process
Type: Rapi-Dorr four compartment type
Size: 8,500 mm (28'-0") dia. x 6,100 mm (20'-0") high

1 - Rotary vacuum-filter with auxiliaries

For filtering the mud exhausted from the juice clarifier

Type:	Oliver Campbell type
Drum size:	3,050 mm (10'-0") dia. x 5,490 mm (18'-0") long
Filtering area:	52.4 m^2

<u>For concentrating station</u>

1 - Evaporator with auxiliaries

For concentrating the clear juice
Type: Standard centerwell calandria vapour bleeding and quadruple effect type evaporator
Heating surface: 3,600 m^2 in total

1st vessel	1,500 m^2
2nd vessel	900 m^2
3rd vessel	600 m^2
4th vessel	600 m^2

1 - Condenser for evaporator

For condensing vapour from the last vessel of the evaporator.
Type: Water multi-jet type
Capacity: 12 tons of vapour/hr

1 - Injection water pump for condenser
Type: Centrifugal type
Capacity: 10,000 ℓ/ min
Head: 35 m
Driving motor: 95 kW

2 - Syrup pumps

For extracting the syrup from the last vessel of the evaporator and pumping up to the syrup tank in the boiling station.
Type: Self-priming centrifugal type
Capacity: 500 ℓ/min
Head: 35 m
Driving motor: 7.5 kW

For boiling and curing station

9 - Syrup and molasses storage tanks

For storage of the syrup and molesses, five tanks for syrup and four tanks for molasses.
Type: Rectangular shape type
Capacity: 25 m^3 for each

5 - Vacuum pans

For boiling A, B and C massecuite, two for A, one for B and others for C massecuite boiling
Type: Low head and calandria type
Capacity: 50 tons of massecuite
Heating surface: 200 m^2

5 - Condensers for vacuum pans

For condensing the vapour from the vacuum pans
Type: Water multi-jet type
Capacity: 10 tons of vapour/hr

1 - Injection water pump for condenser

Type: Centrifugal type
Capacity: 25,800 ℓ/min
Head: 35 m
Driving motor: 170 kW

2 - Seed magma mingler

One set for preparing seed magma for A boiling and the other for B boiling
Type: Horizontal U-shape type
Size: 800 mm wide x 3,000 mm long
Driving motor: 3.7 kW

3 - Seed magma mixers

For mixing seed magma, one set each for A, B and C boiling

Type:	Horizontal U shape type
Capacity:	40 tons of magma for A and B boiling
	20 tons of magma for C boiling

8 - Crystallizers

For receiving, cooling and reheating of C massecuite

Type:	Horizontal U shape and rapid cooling type
Capacity:	50 tons of massecuite
Size:	2,400 mm wide x 6,600 mm long
Driving motor:	5.5 kW

2 - Distributing mixers

For mixing and distributing the massecuite to the centrifugal machine
One set each for A and B massecuite boiling

Type:	Horizontal U shape type

5 - Centrifugal machine

For separating sugar crystal and molasses from A and B massecuite
Three sets for A massecuite and two sets for B massecuite

Type:	Top suspension and fully automatic type
Basket size:	1,219 mm (48") dia. x 762 mm (30") deep
Operation cycle:	20 cycles/hr
Revolution:	Max. 1,500 rpm

2 - Distributing mixers

For mixing and distributing C massecuite to the centrifugal machines. One for C fore-worker and another for C after-worker

Type:	Horizontal U shape type with heating coil

5 - Centrifugal machines

For separating sugar crystal and molasses from C massecuite.
Three sets for C fore-worker, one set for C afterworker and another for common use for fore-worker and after-worker

Type:	Vertical conical basket and continuous type
Basket size:	850 mm dia. at the upper part of the basket

1 - Magma mingler

For preparing the C magma for after-worker

Type:	Horizontal U shape type
Size:	800 mm wide x 3,000 mm long
Driving motor:	3.7 kW

All other necessary auxiliary equipment such as pumps, conveyers, elevators and tanks, etc. shall also be furnished to complete the process.

5.6.5 Refined sugar producing department

The department consists of the melting and liquor purifying station, CO_2 gas and lime milk preparing station, boiling and curing station, and drying and packing station.

The major equipments of this department are as given hereunder:

For melting and liquor purifying station

1 - Weighing scale

For weighing the washed raw sugar
Type: Meric type
Capacity: Normal 13 tons/hr
Maximum 20 tons/hr

1 - Melter

For melting the washed raw sugar
Type: Horizontal U shape and continuous melting type
Size: 700 mm wide x 7,500 mm long
Motor: 5.5 kW

1 - Regulating tank

For regulating brix concentration and temperature of the raw liquor
Type: Vertical cylindrical type
Capacity: 6 m^3

2 - Raw liquor pump

For feeding the raw liquor to the carbonating tower.
Type: Non-clog centrifugal type
Capacity: 400 ℓ/min
Head: 25 m
Driving motor: 5.5 kW

1 - Lime milk dosing apparatus

For dosing lime milk in the raw liquor
Type: Wheel type proportional feeder

3 - Carbonation towers

For carbonating the raw liquor
Type: Vertical cylindrical type
Size: 1,250 mm dia. x 6,000 mm high
Heating surface: 0 m^2 for 1st tower
5 m^2 for 2nd tower
10 m^2 for 3rd tower

1 - Carbonated liquor pump

For feeding the carbonated liquor to the first filters
Type: Non-clog centrifugal type
Capacity: 400 ℓ/min
Head: 40 m
Driving motor: 7.5 kW

3 - First filters

For filtering the carbonated liquor
Type: Rotary leaf auto-filter
Filtering area: 84 m^2

1 - Proportional feeder

For feeding the brown liquor and active carbon to the decolourizing tank at an appropriate ratio
Type: Wheel type
Capacity: 400 ℓ/min

4 - Decolourizing tanks

For decolourizing the brown liquor by mixing with active carbon
Type: Vertical cylindrical tank with heating devices and stirrer
Capacity: 5 m^3

2 - Active carbon mixing tank

For preparing the active carbon liquor
Type: Vertical cylindrical tank with stirrer
Capacity: 3 m^3

2 - Carbon mixed liquor pump

For feeding the carbon mixed liquor to the second filter
Type: Non-clog centrifugal type
Capacity: 400 ℓ/min
Head: 40 m
Driving motor: 7.5 kW

3 - Second filters

For filtering the carbon mixed liquor
Type: Sweetland type
Filtering area: 85 m^2

1 - Cake filter

For re-filtering the cake for recovering the sucrose remaining in the cake
Type: Filter press type
Filtering area: 52 m^2

2 - Check filter

For check filtering the clear liquor
Type: Ceramic filter
Filtering area: 35 m^2

2 - Clear liquor pumps

For feeding the clear liquor to the ion exchange towers

Type:	Centrifugal type
Capacity:	400ℓ /min
Head:	20 m
Driving motor:	3.7 kW

3 - Ion exchange towers

For finally decolourizing the liquor
Type: Batch system and anion exchange resin type
Volume of resin: 3 m^3/1 tower

2 - Fine liquor pumps

For pumping up the fine liquor to the boiling station

Type:	Centrifugal type
Capacity:	400 ℓ/min
Head:	25 m
Driving motor:	5.5 kW

1 - Sodium chloride melting tank with pump

For preparing sodium chloride liquor used for re-generating the anion exchange resin

For lime milk and CO2 gas preparing station

1 - Lime slaker

For slaking the quick lime
Type: Horizontal revolving drum type
Size: 1,160 mm dia. x 4,800 mm long
Driving motor: 3.7 kW

2 - Lime milk tanks

For preparing the milk of lime
Type: Cylindrical type with stirrer
Capacity: 3 m^3

1 - CO_2 gas washing apparatus

For washing and cooling the flue gas from the chimney of boiler.

1 - CO_2 gas pump

For supply of CO_2 gas, extracted from the chimney, to the carbonation towers

Type:	Nash type
Capacity:	40 Nm^3/min
Delivery pressure:	0.8 kg/cm^2G

For boiling and curing station

1 - Fine liquor and molasses storage tank
Type: Rectangular shape type
Number of compartment: 4
Capacity: 40 m^3 in total

2 - Vacuum pans

For boiling the refined sugar massecuite
Type: Low head and standard centerwell calandria type
Capacity: 50 tons of massecuite
Heating surface: 200 m^2

2 - Condenser for vacuum pans

For condensing the vapour from the vacuum pans
Type: Water multi-jet type
Capacity: 10 tons of vapour/hr

1 - Injection water pump for condenser

Type: Centrifugal type
Capacity: 13,000 ℓ/min
Head: 35 m
Driving motor: 110 kW

1 - Massecuite receiving mixer

For receiving the massecuite discharged from the vacuum pans.
Type: Horizontal U shape type with stirrer
Capacity: 50 tons of massecuite
Driving motor: 5.5 kW

1 - Distributing mixer

For mixing and distributing the massecuite to the centrifugal machines

3 - Centrifugal machines
Type: Top suspension and fully automatic type
Basket size: 1,219 mm (48") dia. x 762 mm (30") deep
Operation cycle: 20 cycles/hr
Revolution: Max. 1,500 rpm

For drying and packing station

1 - Sugar dryer and cooler

For drying the wet refined sugar
Type: Horizontal rotary drum type
Capacity: 16 tons of sugar/hr
Drum size: Dryer 2,200 mm dia. x 8,000 mm long
Cooler 2,000 mm dia. x 7,000 mm long
Driving motor: 15 kW for each

1 - Sugar sieve

For screening the refined sugar
Capacity: 16 tons/hr

2 - Sugar bins

For storing the refined sugar product
Type: Cylindrical shape with conical bottom
Capacity: 100 metric tons of sugar

4 - Sugar scales

For weighing the sugar product
Type: Portable platform
Capacity: Normal 50 kg

4 - Bag closing machines

For closing the paper bag
Type: Automatic and tape sealing type
Capacity: 50 - 300 bags/hr

All other necessary auxiliary equipments such as pumps, conveyors, elevators, tanks, etc. shall also be furnished to complete the process.

5.6.6 Steam generating department

1 - Bagasse elevator

For conveying the bagasse from mill station to the cane carrier
Type: Drag type
Size: 1,600 mm wide x 15,000 mm long
Driving motor: 7.5 kW

1 - Baggage carrier with return carrier

For conveying the bagasse to the steam boilers
Type: Paddle type
Size: 1,600 mm wide x 60,000 mm long
Driving motor: 37 kW

2 - Steam boilers with auxiliaries

Type: Two drum and water tube, and baggasse and oil burining type
M.C.R. evaporation: 45,000 kg/hr
Steam pressure: 21 kg/cm^2G
Steam temperature: 350^oC

4 - Steam pressure reducing and de-superheating apparatus

1 - Water softener

For softening the boiler feed water
Type: Ion exchange type
Capacity: 10 tons/hr

All other necessary auxiliary equipments such as pumps, tanks, etc. shall be furnished to complete the process.

5.6.7 Electric power generating department

2 - Turbo generators

Turbine

Type: Multi-stage horizontal impulse type, back pressure and geared type
Output: M.C.R. 1,600 kW at generator terminal
Steam condition at turbine inlet: 19 kg/cm^{2}G, 340°C
Back pressure: 1 kg/cm^{2}G
Revolution: 9,000 rpm at turbine rotor
1,500 rpm at reduction gear output end

Generator

Type: Self ventilated, salient pole and revolving field type alternator
Rating: Continuous
Output: 2,000 kVA
Phase: 3
Voltage: 3,300 V
Frequency: 50 Hz

Exciter

Type: Static type

1 - Public power supply receiving facilities

Capacity: 2,000 kVA

1 - Diesel generator

Output: 400 kW

1 - Overhead travelling crane

For maintenance of the turbine generators and diesel generator
Capacity: 5 tons

All other necessary auxiliary equipment such as panels, switchgear, transformer etc. shall be furnished to complete the power system.

5.6.8 Other auxiliaries

3 - River side pumps (one as stand-by)

Four pumping up the river water to the water reservoir
Type: Vertical centrifugal type
Capacity: 20,000 ℓ/min
Head: 15 m
Driving motor: 55 kW

2 - Final molasses storage tanks

For storage of the final molasses.
Type: Vertical cylindrical shape with conical roof and outdoor type
Storage capacity: 1,500 m^3

1 - Final molasses loading pump

For loading the final molasses to the tank lorry.
Type: Rotary displacement type
Capacity: 25 m^3/hr
Delivery pressure: 1 kg/cm^2G
Driving motor: 15 kW

1 - Heavy oil storage tank with transfer pump

For storage the heavy oil for steam boilers.
Type: Vertical cylindrical shape with conical roof and outdoor type
Storage capacity: 500 m^3

1 - Fuel oil storage tank with transfer pump

For storage the fuel oil for the diesel engine
Type: Vertical cylindrical shape with conical roof, and outdoor type
Holding capacity: 500 m^3

5.6.9 Piping and electric wiring materials

For piping

All necessary pipes, valves, chutes, gutters and other accessories shall be provided.

For electric wiring

All necessary wiring materials for the whole factory shall be provided.

5.6.10 Repair shop

For maintenance and repairing of the machinery is and equipment in the factory.

1 - Mill roll lathe
1 - Lathe
1 - Shaper
1 - Planer
1 - Radial drilling machine
1 - Milling machine
Other tools

5.6.11 Laboratory apparatus

Necessary laboratory apparatus and chemicals.

5.6.12 Spare parts

Spare parts necessary for two crushing seasons.

5.6.13 Buildings

1 - Main factory building

Steel structure construction with corrugated slate roof and wall.

Cane carrier room	8.5 m x 36 m
Mill room	22 m x 42 m
Processing room	42 m x 48 m x 2 stories
	18 m x 48 m
	12 m x 12 m
	6 m x 24 m
Boiler room	22.5 m x 54 m
Power room	18 m x 24 m
Repair shop	18 m x 24 m
Miscellaneous warehouse	18 m x 18 m
Total floor area	8,817 m^2

1 - Chemical store

For storing the chemicals such as lime, active carbon, etc. Reinforced steel concrete and brick construction.
Floor area: 144 m^3 (6 m x 24 m)

1 - Factory office and laboratory

Concrete and brick construction.
Floor area: 192 m^2 (8 m x 24 m)

1 - Garage for cane stacker

Steel structure with corrugated roofing.
Floor area: 90 m^2 (10 m x 9 m)

2 - Weighing house

Reinforced concrete and brick construction.
Floor area: 12 m^2 (3 m x 4 m)

1 - Product sugar warehouse

Steel structure construction with corrugated slate roof and wall. The lower inside part of the wall is lined with wooden plate.
Storage capacity: 6,500 tons of bagged sugar
Total floor area: 2,520 m^2 (60 m x 42 m)
Effective floor area: 1,650 m^2

ANNEX VI

ORGANIZATION AND MANAGEMENT

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX VI ORGANIZATION AND MANAGEMENT

CONTENTS

LIST OF FIGURES

6.1 Project Organization

6.1.1 General

In order to unify the various activities regarding sugar industry the Sugar Industry Board was established in 1973. Its function is to monitor the sugar industry and advice the Government on: (1) the price of sugar cane to be paid to the grower; (2) the prices of sugar and its by products; (3) extension of the sugar industry including size and location of new factories; (4) the import and export of sugar and the co-ordination of production and distribution; (5) the protection of the local sugar industry by means of duties, levies, licencing and other necessary measures; (6) the promotion and co-ordination of research activities on sugar cane growing and processing; (7) the promotion and encouragement of extension services to the sugar cane farmers; and (8) any other matters affecting the sugar industry.

Under the advice of the Sugar Industry Board, Ghana Sugar Estate Limited (GHASEL), a limited liability company has made operation and management of the existing two factories and estates. The Ghana Government has 95 % of shares in GHASEL and H.V.A. International B.V. Amsterdam having the remaining shares has been entrusted with actual day-by-day management of the company.

Presently there is no other organization than the Sugar Industry Board and GHASEL in Ghana.

As mentioned in the main report, the Aveyime Sugar Production Project is a large scale sugar production pioneer project in the Accra plains. At the full stage this project will produce 45,000 tons of sugar that plays an important role in foreign currency saving, US$18 million which corresponds to 5 % of total present imported amount. Besides, this project contains the largest scale of land settlement programme for the purpose of raizing and stabilizing local farmers standard of living by mechanized irrigation farming. Accordingly this project will bring about strong influence on the economy at national level as well as elevation of local farmer's living standard at regional level. Thence this project should not be operated by private joint stock system but a governmental organization. It is recommended in view of above that Governmental Project Authority should be newly established to make effective and functional management of this project. As for the proposed cane fields, the fields consist of two parts. One is estate farm managed by the Project Authority and the other is settlement farm managed by the farmers themselves.

The settlement farm principally operated by a cooperation of farmers, however, at the initial stage of the settlement, the Project Authority should be responsible for the management of the settlement farm land as well because of farmers' lacking in experience of sugar cane cultivation.

6.1.2 Staff and function of the Project Authority

The organization institution is set on the basis that the financial and legal arrangement for the project will be finished by the end of June, 1976.

The Project Authority, "Aveyime Project Authority" which is outlined in the organizational chart, Fig. VI-1 will be established in July, 1976.

The proposed Project Authority functually consists of three departments and a office, namely, Administration, Factory and Sugar Cane Production Departments and the Construction Office under the Board of Directors. These departments and the office are furthermore subdivided into thirteen sections. The Administration Department consists of three sections; Operation, Personnel and Accounting Sections. The Factory Department has two sections; Processing and Mechanical & Maintenance Sections. The Sugar Cane Production Department consists of three sections; Operation & Maintenance, Farm Operation and Cooperative & Research Sections. The Construction Office consists of five sections; Land Acquisition, General Engineering, Construction, Electric & Mechanical and General Affairs Sections.

The Board of directors of the Aveyime Project Authority will be made up four directors who would be nominated by the Government. In the Board, chairman will be the president and the other directors will be concurrent department heads. The Board will determine the project policy which needs the governmental approval. The independent profit system will be applied to the Project Authority. Annual budget and audit of the Project Authority will be approved by the Government.

Under general policy direction of the Board, the president will have complete executive charge of all activities of the Project Authority. He will be responsible for all aspects of external liaison, direction, planning, implementation, administration, expenditure, budgeting and accounting. He will decide all personnel appointment of the Project Authority except the member of Board. He will have a right to delegate his duties to the respective department heads. All actions taken by president will be executed in the name of the Project Authority. It is recommended that the Government give a seat in the Sugar Industry Board to the president of the Authority, in view that the project exert a large impact on the sugar market.

Department heads and the office head will have complete executive charge of their department and the office in accordance with the policy and plan made by the president. Also they will control the respective section heads. The Administrative Department head will ensure smooth administrative junctioning of the Project Authority. The Factory Department head and a Sugar Cane Production Department head will direct routine business of their departments. The Construction Office head will control the construction works of the project. The respective section heads will have complete executive charge of their sections under the overall directions of departmental or office head. The respective junior section heads will be appointed to take complete charge under the control of a respective section head. The professional staff will do their respective professional works under control of junior section heads.

6.1.3 Function of each department and the Construction Office in the Project Authority

Functions of each department and the office are summarized below.

The Administration Department will be responsible for the coordinations among the three departments and the office concerning personnel, archives, general affairs as well as clarification of financial and managerial status. This department will carry out works concerning purchase of materials. This department is functually subdivided into three sections, of which functions are summarized below.

Personnel Section

- Personnel management
- Secretariate services
- Archives keeping
- Legal aspects
- Education programme
- Contract administration
- Public welfare
- General affairs
- Building & residence

Accounting Section

- Budget programme
- Financial programme, arrangement and control
- Daily & annual accounts and their keeping
- Internal & external audit
- Payment
- Collection of water charge from settlers

Operation Section

- Sales work of sugar
- Purchase of farm inputs, cars, equipment, etc.
- Treasury control
- General affairs for the Factory & the Sugar Cane Production Departments
- Warehouse control

These sections will function as soon as the Project Authority is set.

Sugar Cane Production Department will be responsible for smooth supply of sugar cane as the raw material to the factory. This department will carry out the operation and maintenance of irrigation and drainage facilities and all farm operation accruing from sugar cane production process for the area both estate and settlement area. Furthermore this department plays an important role in good quality seed cane supply and the promotion of farmer's cooperative. This department is subdivided into three sections, of which functions are summarized below.

Operation & Maintenance Section

- Planning of irrigation programme
- Operation & Maintenance of irrigation, drainage and road networks
- Control of operation of pumping stations and gates at each turnout
- Training of farm settlers and Authority's personnel for watering
- Collection and recording of data on actual water-flow in canal

Farm Operation Section

- Planning of cropping calendar & its mechanized operation programme
- Planning of annual sugar production programme
- Planning of annual requirements of farm inputs
- Mechanized farm operations from ploughing to harvest-to-mill process
- Mechanical maintenance & repair of agricultural equipment & vehicles
- Operation of workshop
- Collection and recording of data on sugar cane production
- Training of Authority's personnel for farm operation
- Transportation of sugar cane

Cooperative & Research Section

- Operation of pure-line reserved nersery (30 ha)
- Operation of research farm (20 ha) to clarify optimum farming techniques (variety test, fertilizer test, plant protection trial, etc.)
- Assistance and guidance for the cooperatives which will be organized by settlers

The Cooperative & Research Section will start its function from August 1977 and will operate pilot farm in order to clarify most suitable mechanized irrigation farming.

According to the construction schedule 200 ha among 7,500 ha of total irrigable area will be used for the cultivation of sugar cane from the beginning of 1979. By the beginning of 1983, sugar cane cultivation will be extended to the envisaged total area of 7,500 ha. Accordingly the Farm Operation and the Operation & Maintenance Sections will operate actual their functions from 1979.

Factory Department will be responsible for all the works accruing in the process that sugar is manufactured from sugar cane supplied by the Sugar Cane Production Department. Functually this department is composed of two sections of which works are shown below.

Processing Section

- Operation and control of a manufacturing process
- Check and control of sugar quality

Mechanical & Maintenance Section

- Maintenance of process machinery and related machinery

The operation of the sugar factory will start at the end of 1980 according to the cropping calendar and its full operation will be reached in 1986. Then these two sections will function in 1980.

The Construction Office will be responsible for all the construction works accruing in the process of the construction of sugar factory and infrastructual facilities. This office functionally consists of five sections, of which works are shown as follows.

Land Acquisition Section

- Acquisition of the land necessary for the project
- Provision of services in allocation and registration of land settlers

General Engineering Section

- Preparation of proposal for progress payment to the contractors
- Check of the progress of all construction works
- Tender notice, briefing to bidders, evaluation of bids
- Preparation of annual budget and revised budget proposal related to the construction works

Construction Section

- Supervision of all civil engineering construction works of the sugar factory and infrastructure of the sugar cane field

Electric & Mechanical Section

- Supervision of all the electric and mechanical installation and construction works

General Affairs Section

- General affairs in the construction office

The Land Acquisition and the General Affairs Sections will operate its functions as soon as the Project Authority is set. The General Engineering Section will operate from the middle of 1977 in close coordination with the Administration Department. The Construction and Electric & Mechanical Sections will start to function from the end of 1977. These sections would be phased out by the end of 1982 when all construction activities are completed.

The staff required for the Project Authority which operates its full functions are as follows.

Staff Required for the Project Authority

Board of Directors

1 - President
3 - Directors

Construction Office

1 - Office head
5 - Section heads
4 - Architects
4 - Civil engineers
4 - Irrigation engineers
2 - Mechanical engineers
2 - Electric engineers
8 - Plant engineers
10 - Accountants
10 - Legal officers

Administration Department

1 - Department head (concurrent director)
3 - Section heads
10 - Junior section heads
25 - Clerks & drivers
36 - Permanent labourers
4 - Nurses

Factory Department

1 - Department head (concurrent director)
2 - Section heads
7 - Junior section heads
15 - Processing engineers
6 - Mechanical engineers
6 - Electric engineers
4 - Chemists
5 - Draftsmen
127 - Operators and mechanics
93 - Foremen
140 - Permanent labourers

Sugar Cane Production Department

1 - Department head (concurrent director)
3 - Section heads
17 - Junior section heads
2 - Mechanical engineers
1 - Irrigation engineers
1 - Farm machinery expert
2 - Assistant agronomists
17 - Ancillary workers

34 - Foremen
256 - Operators
386 - Permanent labourers
4 - Legal officers
1 - Accountant
14 - Mechanics
4 - Electricians
93 - Technicians

6.1.4 Expatriate assistance

For the effective operation and management of a large intensive agricultural development project, experienced professional experts will be required at all levels of the responsible organization as a whole.

Major works done by expatriate staff would be the detailed survey, detailed design including preparation of contract documents, advice and assistance to supervision of the project construction works by the Project Authority and technical & managerial assistance and guidance to operation and management of the project including pilot farm.

The expatriate staff required for above works are shown as follows.

1) Detailed survey period (from July, 1976 to October, 1976)

1 - Resident engineer
1 - Soil mechanical engineer
1 - Sugar plant engineer
4 - Surveyors
1 - Soil chemist
1 - Agronomist
1 - Geologist
1 - Drilling expert

2) Detailed design period (from November, 1976 to April, 1977)

1 - Resident engineer
1 - Irrigation engineer
1 - Sugar plant engineer
1 - Soil mechanical engineer
5 - Assistant irrigation engineers
4 - Surveyors
1 - Construction engineer
1 - Mechanical engineer
1 - Architect
1 - Specification writer
1 - Electrical engineer
1 - Soil chemist
1 - Agronomist
1 - Geologist

3) Construction supervision period (from November, 1977 to December, 1982)

1 - Resident Engineer

(1) Infrastructure	(2) Sugar Factory
2 - Civil engineer	1 - Sugar Plant engineer
2 - Mechanical engineer	1 - Mechanical engineer
1 - Electrical engineer	1 - Electrical engineer
	1 - Mill operation engineer
	4 - Processing engineer
	1 - Chemist
	1 - Civil engineer

4) Operation and management period (from the beginning of 1978 to 1986)

(1) Managerial guidance works

1 - Farm management specialist

(2) Research guidance works in the pilot farm

1 - Research agronomist
1 - Water management expert
1 - Farm machinery expert

(3) Technical guidance works

a) Farm

1 - Agronomist
1 - Farm machinery expert
1 - Water management expert
1 - Mechanic

b) Sugar factory

1 - Processing expert
1 - Electrical expert
1 - Mechanical expert

During detailed survey and detailed design period, the resident engineer would control all other expatriate staff. During supervision of the construction the resident engineer would control all other expatriate staff and give assistance and advice to the construction office head. All expatriate staff except the resident engineer would be responsible for technical advice and assistance to respective section heads of the office.

As for the operation and management of the project after implementation of construction, the farm management specialist would assist president of the Authority as Co-president in the overall projects.

Thence he would be an experienced agronomist with sound knowledge of the whole undertaking. He would attend all meetings of the Board of directors. Three experts engaged in the pilot farm operation would be responsible for technical research guidance in order to search most optimum mechanized irrigation farming for three years from 1978. Three expatriate staff members engage in the sugar factory operation would give technical guidance for two factory operation periods in 1981 and 1982. Four expatriate staff members engaged in farm operation of the sugar cane field would give technical guidance to get the best results of sugar cane production.

All the expatriate staff except the farm management specialist would be responsible for technical guidance to respective department heads of the factory and the sugar cane production departments. These expatriate staff would be controlled by the Co-president. All the expatriate staff would be appointed by the Authority at the right time of the project schedule.

6.2 Settlement Programme

6.2.1 Settlement area

As mentioned in Annex IV, the project area, 7,500 ha, consists of Irrigation Block 1 to 7. These blocks are approximately developed in their order number.

In case of the sugar production project, smooth supply of sugar cane to the factory is essential and a failure in smooth supply may spoil the feasibility of the whole project, once a factory is constructed.

In view of raizing and stabilizing local farmers' standard of living, it is desirable that most of the project area, 7,500 ha are cultivated by the settlement farmers themselves. However the farmers in the project area have not any experience on sugar cane growing even under the rainfed condition. The farmers could produce sufficient sugar cane only after a tight technical training. In this sence, a certain area of sugar cane field would be required to be undividedly managed by a single body, the Project Authority which is also responsible for the operation of factory, and the remaining area would be apportioned to the settlers.

In selecting the settlement area, the following conditions are taken into consideration.

(1) It is desirable to locate the settlement area at one consolidated place rather than several scattered places for the convenience of community development and efficiency of farming and management of cooperatives.

(2) A irrigation block containing both the estate and settlement farms would complecate the water management and farm operation.

(3) Technical trainings for settlers should be done in the estate farm before settling. It is therefore desirable that the settlement area be alloted to the Irrigation Blocks to be developed in the later stage of construction.

In consideration of above-mentioned conditions, Irrigation Blocks 6 and 7, 3,200 ha, which are constructed in the final construction stage are most suitable area for the settlement area.

6.2.2 Farm size for the settlers and number of settlers

Based on the natural elements and socio-economic conditions in the project area and in view of equal distribution of national property, "small holding intensive farming system" is envisaged for the project area.

As mentioned in Annex III, mechanized operation services are given to the settlement land by the Project Authority. According to Annex III, the peak farm labour requirement in the proposed settlement farm is estimated to be 0.6 person per ha, and the number of available family labour force for a standard farming family is estimated at 2.5 persons. Then the maximum land holding which is cultivated by the family labour force would be about 4 ha.

On the other hand, the net farm reserve after paying water charge in the case of 4 ha of holding size is calculated to be US$2,070 equivalent. This is about six times higher than the present average farm income in the project area and would be enough for giving incentive to the proposed settlers.

Taking into consideration the situation mentioned above and other functions such as availability of manpower resources, nature of the project and the Government policy, etc., the average size of holding in the project area is proposed to be 4 ha for each settlement farm family. Accordingly 800/1 farmers will be settled in the project area.

6.2.3 Selection of the settlers

The Project Authority would invite applicants after publicity to the inhabitants in and around the project area, and the selection would be made by a Selection Committee consisting of representatives of the departments concerned and several local leaders.

For the successful implementation of the settlement programme, it is desirable to select as many as possible the enthusiastic farmers with high ability for sugar cane growing. Of course, it is not easy to find out such farmers within a short period, however, the Project Authority should endeavor to select suitable candidates on the basis of the following qualifications of the settlers as a minimum standard.

i) Citizenship; Candidate shall be a Ghanaian in nationality.

ii) Age; Candidate shall be between 21 and 40 years of age.

iii) Education; No formal degree or diploma is necessary, but it is desirable that at least a member of the family should be literate.

iv) Health; Candidate shall have sound physical and mental health.

v) Farming ability; Candidate and one or more members of the family shall be capable of doing the farming.

vi) Membership; Candidate shall be a member of the proposed co-operative.

vii) Residence; Candidate must shall stay in the project area in order to carry out various farm operation on schedule.

6.2.4 Community development

Four villages would be newly established. The location of the villages is planned with considerations of smooth transportation of agricultural supplies and products into and from the field, communication between villages and distance from the homestead plot to the field. LOCATION MAP AND GENERAL LAYOUT (Drawing No. 000-01) shows the location of the villages projected. The following table shows number of households in respective villages.

/1 3,200 ha/4 ha/farmer

Village	No. of household of settler
I	200
II	200
III	250
IV	150

It is considered that necessary facilities for community development are required for all four villages as follows.

4 - Meeting hall
4 - Sports and Recreation field
1 - Primary school
1 - Secondary school
4 - Religious building
4 - Post office
1 - Clinic
40 - Residence for officials and teachers
4 - Market and shop
4 - Cooperative office

The cost of these community construction works are estimated at US$2.5 million. It is recommended that these construction work should be made in parallel with project construction works by the Government subsidy.

6.2.5 Farmers' organization

It is proposed to establish 4 cooperatives with 800 farm families in the project area from 5th to 6th year of construction period on the basis of land settlement schedule as will be mentioned later. The major functions of the cooperatives would be to perform the collective farm operations, water management, supply of farm requisites, etc.

The main income resources of the cooperatives are the sales of sugar cane. The cooperatives will sell the sugar cane to the factory at the fixed price of ¢20.0 per ton of cane and then net farm income deducted the farming cost which includes costs of seedling, fertilizer, insecticides, water charge, membership fee and taxes from the sales, would be divided to each member according to the harvested amount of sugar cane.

During the initial stage of the settlement, all the activities of the cooperatives should be carried out under the direction of the Aveyime Project Authority. At the beginning of the initial stage, all the candidates will be organized by each 50 farm families group as a minimum unit of proposed cooperative system. It may tentatively be named a cooperative branch, and 4 branches will make a cooperative. The branch will be further subdivided into 5 farming groups comprising 10 farm families on an average. The leaders of each farming group and the chief of each cooperative branch will be initially appointed by the Project Authority. At the end of the initial stage, the cooperative will have its own executive body which will be comprised by a chairman, a vice chairman and at least 4 executive directors in charge of farming, water management, farm requisites supply, and accounting, respectively, who will be elected from among the representatives of each branch. The proposed organization of the cooperative is shown in Fig. VI-2.

When it is recognized by the Project Authority that the executive body of the cooperative may have sufficient ability to handle the management of the cooperative by the farmers themselves, the responsibility of the management will be handed over to the executive body of the cooperative from the Project Authority.

6.2.6 Settlement procedure and schedule

The settlers would not have any previous experience on the mechanized irrigation farming at the time they will be selected. It would be necessary to give some training in the practical farm operation and the cooperative activities before settling. In order to master the mechanized irrigation farming the settlers should be engaged in the farm operation of the estate farm as the hired labourers, at least for one year before the commencement of cooperative farm operation.

During the training period, the operation techniques or daily farm practices would be taught by the Authority, using "learn-by-doing" technique. Special lecture, practical demonstration and discussion would also occasionally be arranged for them. The trainees would be organized as a small task group so as to be accustomed with various group operation practices. This training would be continued to the initial stage of settlement under the guidance and instruction of the Authority staff. The Authority should evaluate during the training period whether or not each candidate would have adequate the ability as the proposed cooperative member and the should submit the evaluation report to the Selection Committee as mentioned section 6.2.3.

When it is recognized by the Authority that the most of candidates have sufficient ability to handle the cooperative farms by themselves, each candidate approved by the Selection Committee is registered as the authentic settler and granted a possessary or usufructuary title of allocated land.

According to the proposed construction and farm operation schedule of the project, the settlement programme of 800 settlers would be started at the beginning of the 3rd year after the commencement of the construction as follows.

i) Preparatory works; During the first 6 months, the preparatory works for the settlement programme such as detailed planning, making of basic regulation, preparation of application form and registrations cards, etc. would be carried out by the staff of the Project Authority.

ii) Publicity, invitation and selection; From the beginning of the 4th year, the main activities of the department would be concentrated to the publicity and invitation for settlers. Selection of the candidates for settlers should be finalized until the end of June in 5th year.

iii) Training in the estate farm; The training in the estate farm would be held one year prior to the commencement of farm operation on the settlement farm.

iv) Openning of the cooperative offices; Before the commencement of cooperative farm operation, four cooperative offices would be established by the beginning of June in 5th year. The offices would prepare the candidate registration cards, annual cultivation plan, working schedule for candidates, contract of mechanized farm operation, etc. of respective cooperative unit.

v) Commencement of cooperative farm operation; The farm operation would be commenced from August in 5th year. All the candidates would be engaged in the daily farm operation according to the annual cultivation schedule under the control of the respective Cooperative Offices. The Cooperative Offices would carry out the daily co-operative guidances in close coordination with the Corporation.

Fig.VI-1 ORGANIZATION OF THE AVEYIME PROJECT AUTHORITY

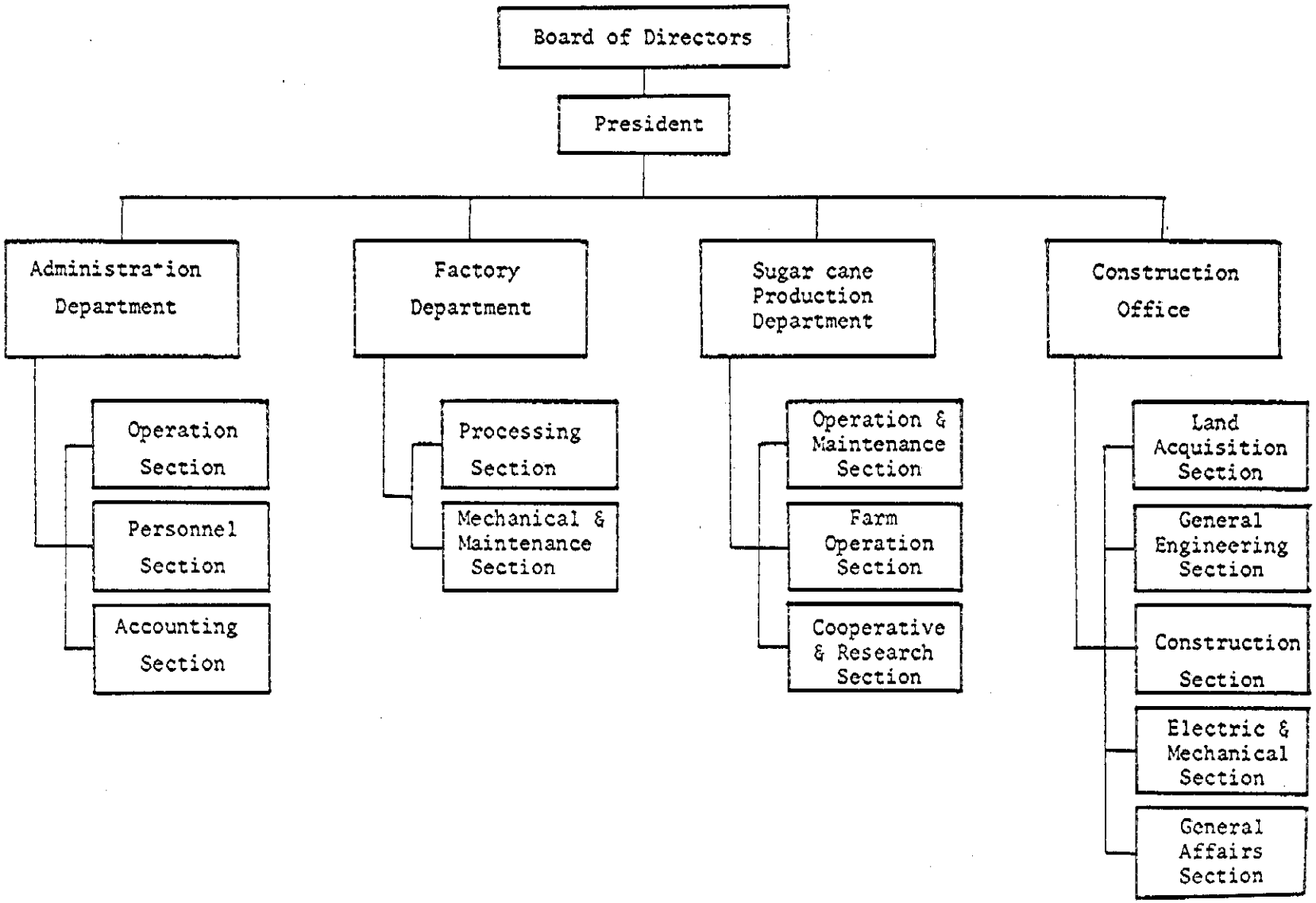
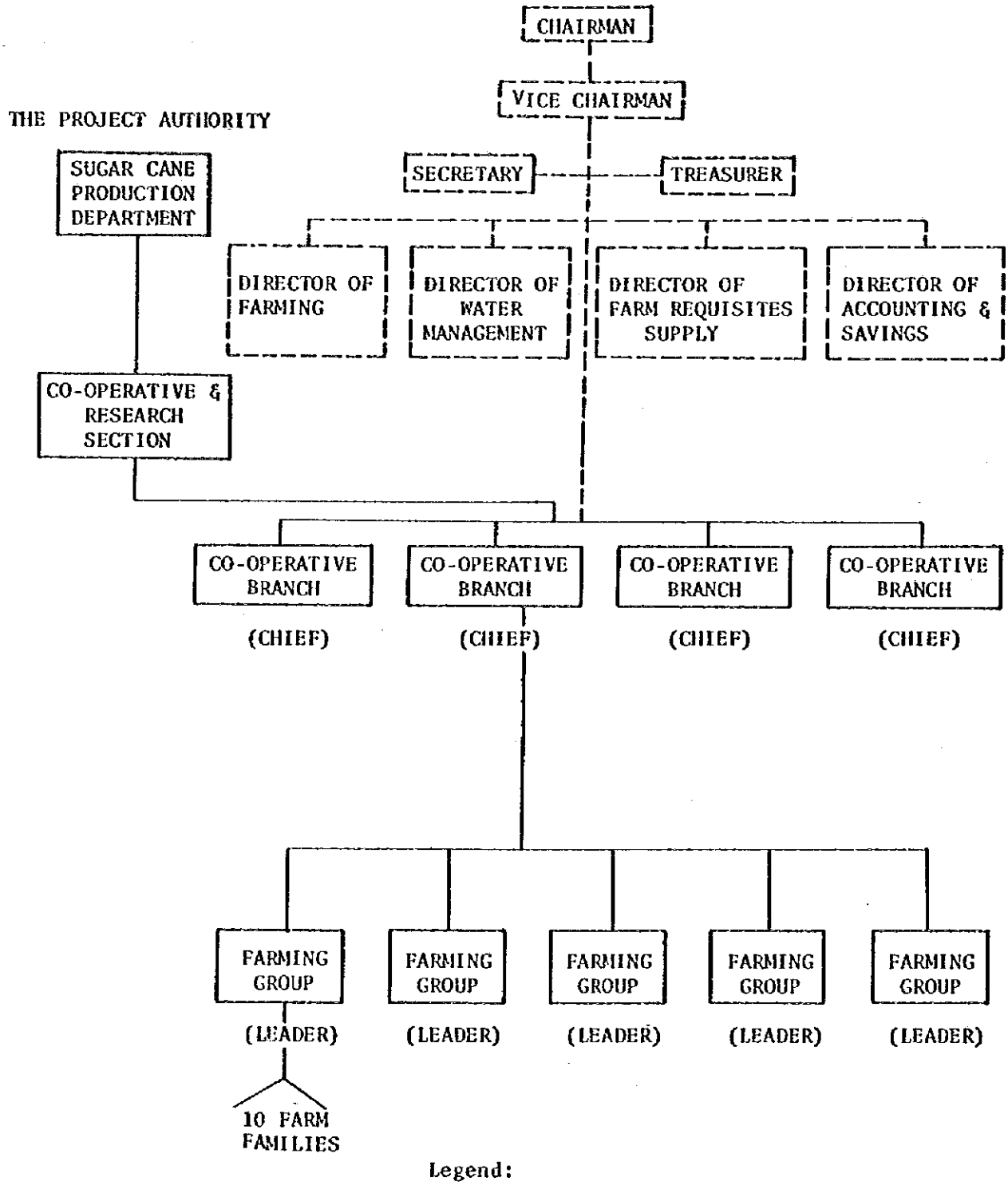


Fig.VI-2 ORGANIZATION OF CO-OPERATIVE



Legend:

——— Initial stage of the settlement

------- Indipendent stage of the settlement

ANNEX VII

CONSTRUCTION COST ESTIMATE

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX VII CONSTRUCTION COST ESTIMATE

LIST OF TABLES

Table VII-1 Prices of Materials and Labour Cost
(July 1975, at Aveyime)

Item	Unit	Unit Price (US$)
Construction Materials		
1. Portland cement	tons	80.00
2. Reinforcement bars	tons	636.00
3. Gravel for concrete	m^3	28.40
4. Sand for concrete	m^3	6.00
5. Laterite for pavement	m^3	6.00
6. Concrete block for houses	m^3	62.50
7. Timber, hard wood	m^3	200.00
8. Timber, soft wood	m^3	131.00
Fuel and lubricant		
9. Petrol, regular	ℓ	0.27
10. Petrol, super	ℓ	0.31
11. Engine oil	ℓ	0.86
12. Diesel oil	ℓ	0.21
13. Kerosene	ℓ	0.19
14. Mobil oil	ℓ	0.84
15. Grease	kg	2.50
Labourer		
16. Foreman	man-day	3.50
17. Unskilled labourer	man-day	2.10
18. Carpenter	man-day	2.90
19. Mechanic	man-day	2.90
20. Welder	man-day	2.90
21. Pipe layer & Jointer	man-day	2.54
22. Steel bar bender	man-day	2.22
23. Driver, extra heavy vehicle	man-day	3.32
24. Driver, common	man-day	2.54
25. Mason	man-day	2.90

Table VII-2 Unit Consturction Cost
(July 1975, at Aveyime)

Unit: US$

Work	Unit	Unit Price		
		Foreign Currency	Local Currency	Total
1. Site clearing for forest	ha	374.0	242.0	616.0
2. Stripping of top soil	m^3	0.9	0.6	1.5
3. Excavation, common				
Type A(for canal & structure)	"	0.7	0.8	1.5
Type B(for head race & P.S.)	"	1.2	1.0	2.2
Type C(for swamp area)	"	2.0	0.4	2.4
4. Embankment				
-Type A(by excavated materials including compaction)	"	0.9	0.7	1.6
-Type B(by borrowed materials including compaction)	"	2.0	1.4	3.4
5. Backfilling for structure	"	0.3	0.5	0.8
6. Sod facing	m^2	-	0.2	0.2
7. Pavement				
Gravel (t = 15 cm)	m^2	0.5	2.8	3.3
Laterite (t = 15 cm)	"	0.5	0.8	1.3
8. Gravel for foundation	m^3	2.7	21.6	24.3
9. Concrete				
-Type A (350 kg)	"	0.6	81.0	81.6
-Type B (300 kg)	"	0.6	75.4	76.0
-Type C (250 kg)	"	0.6	69.8	70.4
-Type D (180 kg)	"	0.6	61.8	62.4
10. Mortar	"	-	55.1	55.1
11. Reinforcement bars, cut, bend and fix	tons	-	910.0	910.0
12. Forms for concrete	m^2	-	4.7	4.7
13. Concrete block lining	nos.	0.13	1.12	1.25
14. Stoplog	m^3	-	250.0	250.0
15. Concrete pipe including installation				
ϕ 12" (ϕ300 mm)	m	-	11.0	11.0
ϕ 15" (ϕ400 mm)	"	-	14.7	14.7
ϕ 18" (ϕ450 mm)	"	-	16.5	16.5
ϕ 21" (ϕ500 mm)	"	-	18.4	18.4
ϕ 24" (ϕ600 mm)	"	-	22.8	22.8
ϕ 30" (ϕ800 mm)	"	-	37.0	37.0
ϕ 33" (ϕ850 mm)	"	-	43.4	43.4
ϕ 36" (ϕ900 mm)	"	-	49.6	49.6
ϕ 42" (ϕ1100 mm)	"	-	71.3	71.3
ϕ 48" (ϕ1200 mm)	"	-	88.9	88.9

Table VII-3 Breakdown of Construction Cost for Preparatory Works

Item No.	Description	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
A.	Construction of unloading facilities and stock yards		L.S.	12,000	5,000	17,000
B.	Installation of power supply system		L.S.	16,000	9,000	25,000
C.	Construction of water supply system		L.S.	20,000	30,000	50,000
D.	Rehabilitation of existing road and bridge		L.S.	80,000	270,000	350,000
E.	Construction of access road	km	5.0	70,000	140,000	210,000
F.	Miscellaneous		L.S.	12,000	26,000	38,000
	Total			210,000	480,000	690,000

Table VII-4 Breakdown of Construction Cost of Pumping Stations

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
No. 1 Pumping Station						
A.	Cofferdam and care of water		L.S.	-	70,000	70,000
B.	Earthworks					
B.1	Excavation	m^3	4,000	4,400	3,700	8,100
B.2	Embankment and backfilling	m^3	700	100	300	400
	Sub-total			4,500	4,000	8,500
C.	Substructure of building					
C.1	Foundation pile	m_3	450	500	13,000	13,500
C.2	Concrete	m^3	1,624	1,000	128,200	129,200
C.3	Reinforcement bars	tons	194	-	176,600	176,600
C.4	Forms for concrete	m^2	4,480	-	21,100	21,100
C.5	Gravel for foundation	m^3	23	100	500	600
	Sub-total			1,600	339,400	341,000
D.	Building works		L.S.	-	131,000	131,000
E.	Mechanical and electrical works					
E.1	Pump and motor	sets	7	476,000	-	476,000
E.2	Control panel and other equipment		L.S.	135,000	-	135,000
E.3	Crane	set	1	27,000	-	27,000
E.4	Discharge pipe and valve	sets	7	30,000	-	30,000

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
E.5	Installation of equipment			164,000	40,000	204,000
	Sub-total			832,000	40,000	872,000
F.	Miscellaneous		L.S.	71,900	85,600	157,500
	Total			910,000	670,000	1,580,000
	No. 2 Pumping Stations					
A.	Earthworks					
A.1	Excavation	m^3	2,000	2,500	2,100	4,600
A.2	Embankment and backfilling	m^3	600	600	500	1,100
	Sub-total			3,100	2,600	5,700
B.	Substructure of building					
B.1	Foundation pile	m	430	500	12,500	13,000
B.2	Concrete	m^3	663	500	52,300	52,800
B.3	Reinforcement bars	tons	80	-	72,800	72,800
B.4	Forms for concrete	m^2	1,860	-	8,800	8,800
B.5	Gravel for foundation	m^3	20	100	400	500
	Sub-total			1,100	146,800	147,900
C.	Building works			-	130,000	130,000

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
D.	Mechanical and electrical works					
D.1	Pump and motor	sets	6	600,000	-	600,000
D.2	Control panel and other equipment		L.S.	290,000	-	290,000
D.3	Crane	set	1	27,000	-	27,000
D.4	Installation		L.S.	228,000	57,000	285,000
	Sub-total			1,145,000	57,000	1,202,000
E.	Inlet canal (300 m)					
E.1	Excavation	m^3	6,000	7,200	6,100	13,300
E.2	Embankment	m^3	1,200	1,100	800	1,900
	Sub-total			8,300	6,900	15,200
F.	Penstock (800 m)					
F.1	Excavation	m^3	3,000	2,000	2,500	4,500
F.2	Concrete	m^3	3,630	2,200	294,000	296,200
F.3	Reinforcement bars	tons	202	-	183,800	183,800
F.4	Forms for concrete	m^2	13,200	-	62,000	62,000
F.5	Minor works		L.S.	200	16,300	16,500
	Sub-total			4,400	558,600	563,000
G.	Miscellaneous		L.S.	118,100	88,100	206,200
	Total			1,280,000	990,000	2,270,000

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
No. 3 Pumping Station						
A.	Cofferdam and care of water		L.S.	-	40,000	40,000
B.	Earthworks					
B.1	Excavation	m^3	1,000	1,200	1,000	2,200
B.2	Embankment and Backfilling	m^3	300	200	200	400
	Sub-total			1,400	1,200	2,600
C.	Substructure of building					
C.1	Foundation pile	m	140	200	4,100	4,300
C.2	Concrete	m^3	196	200	15,200	15,400
C.3	Reinforcement bars	tons	21	-	19,100	19,100
C.4	Forms for concrete	m^2	490	-	2,300	2,300
C.5	Gravel for foundation	m^3	12	100	300	400
	Sub-total			500	41,000	41,500
D.	Building works			-	25,000	25,000
E.	Mechanical and electrical works					
E.1	Pump and motor	sets	3	18,000	-	18,000
E.2	Control panel and other equipment		L.S.	26,000	-	26,000
E.3	Crane	set	1	5,000	-	5,000
E.4	Installation		L.S.	9,000	4,000	13,000
	Sub-total			58,000	4,000	62,000
F.	Penstock construction		L.S.	9,000	5,000	14,000

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
G.	Miscellaneous		L.S.	11,100	13,800	24,900
	Total			80,000	130,000	210,000
	No. 4 Pumping Station					
A.	Cofferdam and care of water		L.S.	-	4,000	4,000
B.	Earthworks					
B.1	Excavation	m^3	800	900	800	1,700
B.2	Embankment and Backfilling	m^3	300	200	300	500
	Sub-total			1,100	1,100	2,200
C.	Substructure of building					
C.1	Foundation pile	m	180	200	5,200	5,400
C.2	Concrete	m^3	160	100	12,400	12,500
C.3	Reinforcement bars	tons	18	-	16,400	16,400
C.4	Forms for concrete	m^2	410	-	2,000	2,000
C.5	Gravel for foundation	m^3	12	100	300	400
	Sub-total			400	36,300	36,700
D.	Building works			-	28,000	28,000
E.	Mechanical and electrical works					
E.1	Pump and motor	sets	3	18,000	-	18,000
E.2	Control panel and other equipment		L.S.	31,000	-	31,000

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
E.3	Crane	set	1	5,000	-	5,000
E.4	Installation		L.S.	10,000	5,000	15,000
	Sub-total			64,000	5,000	69,000
F.	Penstock construction		L.S.	41,000	12,000	53,000
G.	Miscellaneous		L.S.	13,500	13,600	27,100
2	Total			120,000	100,000	220,000
	No. 5 Pumping Station					
A.	Earthworks					
A.1	Excavation	m^3	700	900	700	1,600
A.2	Embankment and Backfilling	m^3	300	200	200	400
	Sub-total			1,100	900	2,000
B.	Substructure of building					
B.1	Foundation pile	m	180	200	5,200	5,400
B.2	Concrete	m^3	158	200	12,200	12,400
B.3	Reinforcement bars	tons	16	-	14,600	14,600
B.4	Forms for concrete	m^2	390	-	1,900	1,900
B.5	Gravel for foundation	m^3	24	100	500	600
	Sub-total		-	500	34,400	34,900
C.	Building works			-	28,000	28,000
D.	Mechanical and electrical works					

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
D.1	Pump and motor	sets	3	9,600	-	9,600
D.2	Control panel and other equipment		L.S.	21,400	-	21,400
D.3	Crane	set	1	5,000	-	5,000
D.4	Installation		L.S.	8,000	3,000	11,000
	Sub-total			44,000	3,000	47,000
E.	Penstock construction		L.S.	25,000	6,000	31,000
F.	Miscellaneous		L.S.	9,400	7,700	17,100
	Total			80,000	80,000	160,000
	No. 6 Pumping Station					
A.	Cofferdam and care of water		L.S.	-	35,000	35,000
B.	Earthworks					
B.1	Excavation	m^3	1,200	1,500	1,300	2,800
B.2	Embankment and Backfilling	m^3	400	200	300	500
	Sub-total			1,700	1,600	3,300
C.	Substructure of building					
C.1	Foundation pile	m	140	200	4,100	4,300
C.2	Concrete	m^3	188	200	14,600	14,800
C.3	Reinforcement bars	tons	20	-	18,200	18,200
C.4	Forms for concrete	m^2	470	-	2,200	2,200
C.5	Gravel for foundation	m^3	12	100	300	400
	Sub-total			500	39,400	39,900

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
D.	Building works			-	28,000	28,000
E.	Mechanical and electrical works					
E.1	Pump and motor	sets	3	26,100	-	26,100
E.2	Control panel and other equipment		L.S.	31,500	-	31,500
E.3	Crane	set	1	5,000	-	5,000
E.4	Installation		L.S.	11,400	5,000	16,400
	Sub-total			74,000	5,000	79,000
F.	Penstock construction		L.S.	32,000	9,000	41,000
G.	Miscellaneous		L.S.	11,800	12,000	23,800
	Total			120,000	130,000	250,000
No. 7 Pumping Station						
A.	Cofferdam and care of water		L.S.	-	35,000	35,000
B.	Earthworks					
B.1	Excavation	m^3	1,100	1,400	1,200	2,600
B.2	Embankment and Backfilling	m^3	400	300	300	600
	Sub-total			1,700	1,500	3,200
C.	Substructure of building					
C.1	Foundation pile	m	140	200	4,100	4,300
C.2	Concrete	m^3	204	200	15,600	15,800

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
C.3	Reinforcement bars	tons	21	-	19,100	19,100
C.4	Forms for concrete	m^2	500	-	2,400	2,400
C.5	Gravel for foundation	m^3	12	100	300	400
	Sub-total			500	41.500	42,000
D.	Building works			-	28,000	28,000
E.	Mechanical and electrical works					
E.1	Pump and motor	sets	3	24,000	-	24,000
E.2	Control panel and other equipment		L.S.	30,000	-	30,000
E.3	Crane	set	1	5,000	-	5,000
E.4	Installation		L.S.	10,000	5,000	15,000
	Sub-total			69,000	5.000	74.000
F.	Penstock construction		L.S.	12.000	3,000	15.000
G.	Miscellaneous		L.S.	6,800	16.000	22.800
	Total			90,000	130,000	220,000
	No. 8 Pumping Station					
A.	Earthworks					
A.1	Excavation	m^3	700	800	700	1,500
A.2	Embankment and Backfilling	m^3	300	200	200	400
	Sub-total			1.000	900	1,900

Item No.	Work	Unit	Quantity	Cost (US$) Foreign Currency	Local Currency	Total
B.	Substructure of building					
B.1	Foundation pile	m	180	200	5,300	5,500
B.2	Concrete	m^3	153	100	11,800	11,900
B.3	Reinforcement bars	tons	16	-	14,600	14,600
B.4	Forms for concrete	m^2	380	-	1,800	1,800
B.5	Gravel for foundation	m^3	12	100	300	400
	Sub-total			400	33,800	34,200
C.	Building works			-	28,000	28,000
D.	Mechanical and electrical works					
D.1	Pump and motor	sets	3	12,000	-	12,000
D.2	Control panel and other equipment		L.S.	24,000	-	24,000
D.3	Crane	set	1	5,000	-	5,000
D.4	Installation		L.S.	8,000	3,000	11,000
	Sub-total			49,000	3,000	52,000
E.	Penstock construction		L.S.	11,000	3,000	14,000
F.	Miscellaneous		L.S.	8,600	11,300	19,900
	Total			70,000	80,000	150,000
	Grand total			2,750,000	2,310,000	5,060,000