REPUBLIC OF INDONESIA
Ministry of Public Works
Directorate General of Water Resources Development

FEASIBILITY STUDY ON THE KOMERING-I IRRIGATION DEVELOPMENT PROJECT IN THE UPPER KOMERING RIVER BASIN

PLANNING CRITERIA

JUNE 1981

Japan International Cooperation Agency
Tokyo, Japan

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IRRIGATION AND DRAINAGE DEVELOPMENT

1. Introduction

This report sets forth procedures and criteria to be followed in the forming and appraisal of the Komering-I Irrigation Development Project in the Upper Komering River Basin. The overall objective is to promote uniformity in planning the project to the planners and design engineers concerned.

This report stresses engineering matters particularly for the irrigation and drainage planning and the basic engineering consideration for the preliminary design of project facilities. This report does not present detailed discussion of technics and procedures which are available in many text books and other publications, and with which the planners and design engineers should be thoroughly familiar.

In this report, Chapter 2 explains the criteria for irrigation planning with main emphasis on the selection of irrigation development area, availability of water resources and calculation procedure of irrigation water requirements. Chapter 3 describes the criteria for drainage planning dealing with the standard of drainage plan and calculation procedure of drainage requirement. Chapter 4 deals with the general considerations for the planning and preliminary design of project facilities such as Ranau regulating dam, headworks, irrigation and drainage canal systems and tertiary development.

2. Irrigation Planning

2.1 Selection of Area for Irrigation Development

2.1.1 General

Various complex and interrelated land data are collected and analyzed in selecting the area for irrigation development. Systematic appraisal of the soil and substrata, topography, and drainage conditions are conducted as a basic study integrated with economic, engineering and other disciplines. This chapter describes the criteria for the delineation of the irrigation development area to meet the technical conditions of the scope of works, as a part of the overall development plan of the project area of around 60,000 ha.

2.1.2 Consideration Affecting Selection

(1) Land Suitability

The land suitability classification survey related to the soil, topography and drainage characteristics will reveal the grade of irrigation suitability. The grade of land suitability is assessed taking into consideration the following major limiting factors to land suitability for irrigation development:

i) Topography (slope, macro and micro relief location and size)
ii) Erosion
iii) Wetness
iv) Inundation
v) Soil (acidity, fertility, texture and effective depth)

Through the study on the above limiting factors, the land is classified into five classes, in accordance with the system of land suitability classification prepared by FAO, i.e., Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), Currently Not Suitable (N1) and Permanently Not Suitable (N2).

(2) Crop, value, etc.

The land classification supplemented by overall agricultural studies will make it possible to assess the crop suitability of the soil. In determining crop values to be adopted for the Project, within the framework of marketing system, the estimate of the output from crops is conducted taking into account not only the gross value of the products but also the international market prices, national demand, the capacity of the existing processing factories available, etc.

(3) People, social and economic conditions

The field survey covers the population of the area and their social and economic conditions. Their farming experience, farming practices, family labor forces, land holding size, land tenure, agricultural supporting services, etc. are taken into account in establishing the future successful development program.

(4) Government's policy

The Indonesian Government's development policy is one of the major important factors in formulating the Project. The areas which have been selected for transmigration program or irrigation development program are preferentially considered in the selection of project area.

2.2 Establishment of Cropping Pattern

Prior to the framework of an optimum cropping pattern, selection of crops will be carried out on the basis of the results from the following considerations:

(1) Forecast of demand and supply of crops on the national level, taking into account the government policy,

(2) Forecast of demand and supply of crops from a standpoint of regional level,

(3) Study on the present farming technics and farmer's intension on cultivation of crops from the farmer's viewpoint,

(4) Forecast and estimate of ceiling prices and floor prices of crops,

(5) Estimate of consumption pattern in foodstuff,

(6) Assessment of farmer's living standard to be raised from the project irrigation farming, and

(7) Assessment of the crop suitability of soil.

Through various alternative study on cropping patterns in consideration of the above items, the most optimum cropping pattern is determined as the proposed cropping pattern.

During the above study, cropping calendar is studied taking into account the following conditions:

(1) Climate,
(2) Availability of irrigation water,
(3) Labor force, and
(4) Agronomic characteristics of crops to be selected.

2.3 Water Resources

In the study area, there flow four major rivers, i.e. the Komering, Macak, Belitang and the Pisang. The hydrological analysis indicates that the Komering gives an ample perennial flow and its water stage can cover the elevations up to 80 meters, below which most of the fertile flat land exist. Accordingly, it is enough in the study that only the Komering river is taken as an irrigation water source for the Project.

The Komering river has functioned since old time as the main water source for the living of riparian people and farm land and as a navigation route. But the occurrence patterns of the river flow coincide with that of the rainfall: the river has ample discharge in the rainy season but loses its strength in the dry season. In order to utilize its potential to maximum extent, the regulation of the river flow by means of reservoir is needed according to the seasonal demands. For this, thorough water balance study is done between the river discharge and water demands for irrigation, navigation and living.

2.4 Irrigation Water Requirements

2.4.1 General

In order to determine the capacity of irrigation system, peak water requirement by crop is needed. It is also indispensable to estimate the seasonal pattern of irrigation water demands for assessment of the dependability of the river flow through the farming operation period. To meet the above requirements, the estimate of water requirement is made with the following consideration and procedures.

Since field measurement of consumptive use of water by crops was not carried out in the study period due to limited time of field investigation, the study mainly depends on the field measurement results obtained in adjacent projects such as, the "Belitang Extension Area, Agricultural Development Project" by FAO/UNDP in 1974, "Way Sekampung Irrigation Project" by Lampung Provincial Public Works in 1978 and "Way Seputih Irrigation Project" by I.P.B. in 1973. The empirical and theoretical formulas developed in the past by various experts are supplementally used in this study.

2.4.2 Consumptive Use of Water

The consumptive use of water is the sum of the volume of water used by vegetative growth in the transpiration or building of plant tissue, and that evaporated from adjacent soil or intercepted precipitation on the area in any specified time. In the case of rice cultivation where a water level is maintained above the ground surface, evaporation from the water surface will be substituted for evaporation from soil surface.

Practically the consumptive use of water is obtained by multiplying the class-A pan evaporation or potential evapotranspiration by the crop coefficient.

(1) Potential evapotranspiration

In the study area, although the evaporation data are available at Belitang (1971 - 1980), there found some disturbances in these data, i.e. extremely high and low values and many blanks in the daily data, then, these data are not used in this study. The potential evapotranspiration calculated using the Modified Penman Formula is most applicable in the study among the various empirical and theoretical formulas in view of the latitudinal and altitudinal location of the study area and availability of meteorological data.

The following are potential evapotranspiration calculated using the meteorological data at Belitang.

(Unit: mm)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
118	115	140	132	124	117	124	133	132	140	126	133	1,534

(2) Crop coefficients, kc

The crop coefficient of paddy is referred to the kc-curve presented in the ANNEX-VIII of the Reconnaissance Planning Report on "Belitang Extension Area, Agricultural Development Project" prepared by FAO/UNDP in 1974. This curve is also shown in Fig. 2.1. As for the kc-values for soybeans and peanuts, the curves presented in the Technical Release No. 21 published by USDA in 1967 are used in the calculation. These curves are shown in Fig. 2.2 and 2.3.

2.4.3 Unit Irrigation Water Requirements

After knowing the consumptive use of water, the unit irrigation water requirements for each crop are calculated using the following daily water balance method.

Equation for Paddy:

$$IWD = (CU + PL + NW + PW - ER)/Ei$$

Equation for Upland Crop and Perennial Crop:

$$IWS = (CU + PA - ER)/Ei$$

where,
- IWD : unit irrigation water requirement
- CU : consumptive use of water
- PL : percolation loss (for paddy field only)
- NW : nursery water requirement (for paddy field only)
- PW : paddling water requirement (for paddy field only)
- ER : daily effective rainfall
- PA : farm application losses (for upland crop only)
- Ei : combined irrigation efficiency

(1) Percolation loss (PL)

In addition to the percolation rates observed in the project area, the values observed in the Way Sekampung Irrigation Project and Way Seputih Irrigation Project areas in Lampung Province are fully referred to. As the result, the percolation rates to be used for irrigation planning in this project area are as follows:

	Percolation Rate (mm)	
	Dry Season	Rainy Season
Elevated paddy field	4	2
Lowland paddy field	2	1

(2) Nursery water requirement (NW)

The nursery water requirement is estimated for the following assumptions:

(a) Area required for nursery bed: 1/20 of main field

(b) Nursery period: 25 days

(c) Water required for 25 days period:

- Preparation of nursery bed	150 mm
- Evapotranspiration, 5 mm/day	125 mm
- Percolation loss, for lowland area	25 mm
(for elevated area)	(50 mm)
Total	300 mm
	(325 mm)

(3) Puddling water requirement (PW)

The quantity of water required for puddling works is theoretically assessed for the soil depth to be puddled and porosity, which vary relatively from place to place. In this study, the following formula and assumptions are adopted for the approximation. In the calculation, the results of soil physical analyses to be made in the period of field work are also adopted.

(a) Formula:

$$PW = DS + WS + FL$$

where,
- PW : puddling water requirement in mm
- DS : required water depth above soil surface after puddling in mm
- WS : difference in soil moisture contents before and after puddling in mm
- FL : field loss including percolation and other application losses

(b) Assumption:

i) Water depth above soil surface after puddling is 20 mm.

ii) Porsity is 50% in both surface soil (20 cm depth) and sub-soil (10 cm depth).

iii) Vapor phase in soils after puddling is 5%.

iv) Soil moisture before irrigation is 15% in volume which corresponds approximately to the permanent wilting point.

v) Field loss is assumed to be 40% of (DS + WS) based on the soil conditions.

The calculated result is as follows:

$$PS = (20 + 300 \times (0.5 - 0.05) - 300 \times 0.15) \times (1 + 0.40)$$
$$\fallingdotseq 150 \text{ mm}$$

(4) Daily effective rainfall (ER)

The daily rainfall data have been collected from the following stations mainly:

i)	Belitang BK-IX	(1956 - 1974, 1978 - 1980)
ii)	Belitang BK-XVIII	(1972 - 1979)
iii)	Kurungan Nyawa	(1956 - 1974, 1978 - 1980)
iv)	Martapura	(1972 - 1975, 1977 - 1979)

Among them, the data at the Belitang BK-IX will be used for the estimation of effective rainfall in the project area.

On the basis of the assumptions for each crop made in the FAO series No. 25 "Irrigation and Drainage Paper", the daily rainfalls at this station are processed to calculate effective rainfalls.

for paddy

(a) About 80% of daily rainfall is used in the calculation, taking into consideration the locality of rainfall in case that the spot rainfall data is applied to the whole project area.

(b) Water depth to be stored in paddy field is taken at 30 mm. If the sum of daily rainfall and the residual water depth from the previous day exceeds 30 mm, the exceeding amount is regarded as the surplus.

for upland crop

(a) Daily rainfall less than 2 mm is not effective for the calculation.

(b) If the daily rainfall is more than 3 mm, 80% of the rainfall is used for the calculation.

(c) If the sum of daily rainfall and the residual moisture from the previous day exceeds the water depth to be available for crop growth, the exceeding amount is regarded as the surplus. The water depth to be stored in soil is governed by holding capacity of soil and effective root zone depth of crop. The water depth to be stored in soil is calculated for each crop as follows.

- for soybeans : 70 mm
- for peanuts : 40 mm

The effective rainfall for each crop is determined with 80% probability of exceedance of drought year.

(5) Farm application losses (FA)

Farm application losses in upland irrigation include deep percolation, surface run-off, etc. Taking into account the soil characteristics, topography, climate, irrigation practice and experience, etc., the application efficiency is assumed to be 70% of (CU - ER) on an average over the whole study area.

(6) Combined irrigation efficiency (Ei)

Certain losses are unavoidable for conveying water and applying it to the farm. Irrigation water requirements are obtained by dividing the farm requirements by the canal conveyance and operation efficiencies. In this study, the canal conveyance efficiency is estimated to be 85% and canal operation efficiency to be 70% of the diversion requirements. Those make combined irrigation efficiency of 59.5% (≑ 60%).

2.4.4 Design Diversion Requirements

The design diversion requirements is defined as the peak diversion discharge and used for the design of main works such as headworks and headreach. The peak diversion discharge will be calculated by multiplying the irrigation area by the peak unit irrigation water requirements mentioned in the preceding section.

3. Drainage Planning

3.1 Standard for Drainage Plan

About 30% of the project area extends over low-lying and flat plain and suffers from illdrainage in every rainy season. If the land is not drained well within a feasible range, the productivity will not go up even after the provision of well-designed irrigation facilities.

From the past experiments and observations in Japan/1 on the relation between the yield reduction rate of paddy and depth and duration of submergence at different growing stages of paddy, the following considerations is made:

(a) The submergence at the growing stage of young panicle formation gives the serious damage to the yield of paddy, on the contrary, damage due to submergence at the stage of maturing is insignificant.

(b) The duration of submergence within 1 to 3 days is not significant, but in case of submergence beyond 3 days, damage of paddy remarkably increases.

(c) When a part of leaves still remains above water surface, the damage to paddy is lower than the complete submergence of leaves.

While, the rainy season in the project area occurs between November and April. The sensitive growing stage to submergence from a middle stage of tillering to a beginning stage of panicle formation corresponds to the midest rainy season.

Taking into account the above considerations, the following design standard is applied for making the drainage plan in the project.

(1) The allowable depth of submergence in the paddy fields should be 30 cm, and duration of submergence should not exceed 3 days.

/1: These are presented in "Head Book on Yield Reduction Rates of Summer Crop due to Various Causes" published by the Ministry of Agriculture, Forestry and Fisheries of Japan in 1975.

(2) The submergence more than 30 cm in depth should not last more than 24 hours.

3.2 Drainage Requirement

In general, the criteria for the calculation of unit drainage requirement defines the rainfall intensity with certain probability and a drain period necessary for removal of excess water to an allowable extent. In the on-going irrigation projects in Indonesia, drainage requirements have been estimated by applying their own ways considering the natural and physical conditions prevailing over the project area.

In this study, the following assumptions and procedures are established to estimate the drainage water requirement:

(1) Since long term and reliable daily rainfall data are available at Belitang, the daily rainfall data at Belitang (1956 - 1980) are used for this study, and applied to all the project area.

(2) 3 days consecutive rainfall at Belitang with a 10-year return period is applied and it is 245 mm.

(3) Based on the average rainfall distribution pattern, the distribution percentage of the design daily rainfall is estimated as follows:

Distribution Percentage

Day	Pattern
1st day	33 %
2nd day	31 %
3rd day	36 %

(4) Relationship between rainfall and runoff distribution is assumed as follows:

Relationship between Cumulative Rainfall and Total Runoff

Cumulative Rainfall (mm)	Runoff Coefficient (f)
less than 10	0
10 - 30	0.1
30 - 50	0.3
50 - 100	0.5
100 - 300	0.8

Relationship between Rainfall and Runoff Distribution

Rainfall (mm)	1st day	2nd day	3rd day	4th day
less than 30	100	-	-	-
30 - 50	70	30	-	-
50 - 100	60	30	10	-
more than 100	50	30	15	5

(5) Based on the above assumptions, the drainage requirements are estimated as follows:

Design Rainfall (mm)	Cumulative Rainfall (mm)	f	Runoff (mm)				
			1st day	2nd day	3rd day	4th day	5th day
81	81	0.5	24.3	12.1	4.1	-	-
76	157	0.8	-	36.5	18.2	6.1	-
88	247	0.8	-	-	42.2	21.1	7.0
Total:			24.3	48.6	64.5	27.2	7.0
lit/sec/ha			2.8	5.6	7.5	3.1	0.8

4. Planning and Preliminary Design of Project Facilities

4.1 General

The central feature of the Komering-I Irrigation Development Project is to supply irrigation water of 44 m^3/sec/1 at the maximum to the area of 36,700 ha from the Komering river. The facilities required for the project include a regulating weir, headworks, headreach, canals and their relevant structures, drainage facilities and farm roads.

The basis for determining the facility requirements for each function is that enough project 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. Based on the above requirements, the following criteria for planning and preliminary design of project facilities are prepared.

4.2 Ranau Regulating Dam

4.2.1 General

The main function of this dam is to augment the discharge from Lake Ranau during the dry season. The lake is located in the uppermost of the Komering river. It has 127 km^2 of water surface area at HWL. 542.5 m from the mean sea water level and about 508 km^2 of a catchment area. Active storage capacity of the lake would be around 300 million m^3 using 2.5 m of the operating depth.

In order to utilize this large water body efficiently for irrigation and other purposes, the present outflow pattern of the lake should be regulated to the following pattern as mentioned in the comprehensive study made by JICA in 1980.

(Unit: m^3/sec)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
12	12	12	12	12	30	50	20	15	12	12	12

/1 : If the future development area of around 56,000 ha (the Tulangbawang and Lempuing areas) is included, design discharge would be around 107 m^3/sec.

4.2.2 Selection of Site

For the selection of the regulating dam site, the following items are surveyed and checked on the preliminary basis:

(a) Topography and geology of the site

i) Narrow portion of the river course will first be selected.

ii) The site underlying stable rock foundation is preferable.

iii) The river course of the site should be stable.

iv) Considering the Ranau hydropower project in future, the dam site should be suited for the hydropower project also.

(b) Construction

The site should ensure easy and cheap construction work.

(c) Operation and Maintenance

The site should provide good access for operation and maintenance.

4.2.3 Basic Conditions for Design

Based on the results of reconnaissance survey and water depth sounding of Lake Ranau, the following basic design conditions are established:

(1) Hydrological and hydraulic conditions

Regulation of outflow: The regulation of the outflow from the lake will be made using the active capacity of around 300 million m^3 which will be created by providing the drawdown of 2.5 m from the WL. 543.0 m to 540.5 m.

Design discharge: Considering the future regulation pattern of outflow mentioned in the section 4.2.1 hereof, the peak discharge of 50 m^3/sec is taken as the design discharge.

Design water level: Following the regulation method mentioned above, EL. 543.0 m and EL. 539.0 m are taken as design high water level and design low water level for the design of regulating dam, respectively.

Design flood: There is no need of consideration for design flood, because the outflow pattern from the lake varies only within the range from 15 m^3/sec to 20 m^3/sec throughout the year.

(2) Geological conditions at the site

Geological exploration of dam sites should be carried out to examine the adequacy of the site and obtain sufficient information for preparation of reliable designs. Water pressure test is also needed for the design of foundation.

4.2.4 Specific Design Conditions

The regulating dam consists of concrete dam portion, gated weir and stilling basin. In order to provide the flow capacity of 50 m^3/sec to the Selabung river at the design low water level, the expansion of the river is required particularly between the outlet of Lake Ranau and the rapid located 0.6 km downstream from the dam site. The following are specific conditions for the design of respective portions of the dam.

(1) Concrete dam portion

(a) Since there exists good rock foundation at the site, the dam is of gravity type supported by rock foundation.

(b) The dam crest is one meter higher than the design high water level.

(c) The weir is stable against the overturning, sliding and over-stressing.

(2) Gated weir portion

(a) The weir portion is of overflow type to simplify the operation and maintenance of the gates.

(b) The length and height of weir is so determined as to give a design flow capacity at the design low water level. The length of weir is taken to be the same as the width of the upstream channel.

(c) Since the gate is manually operated, the weight of gate is limited to 2.5 - 3.5 tons/unit.

4.3 Headworks

4.3.1 General

The main function of headworks is to introduce required quantity of irrigation water from river to project area at every stage of river water. In order to fulfil this purpose, the structure should be stable against floods and other forces, and should not hamper the river flow, navigation and others.

The headworks consist of various components such as fixed weir, movable weir, intake, miscellaneous structures and operating facilities (for the detail, vide Fig. 4.1 and Fig. 4.2). For the well functioning as the headworks, each function mentioned above should be combined with and fully compatible with each other.

4.3.2 Selection of Site

For the selection of headworks site, the following items are surveyed and checked on the preliminary basis.

(a) Relation between the height of weir crest and the length of headreach:

In order to attain the designed intake water level, if the headworks site is selected upstream, the height of weir crest is less but the length of headreach is more.

Whereas, if the headworks site is selected downstream, the crest height is more but the length of headreach is less.

For the selection, rough cost comparison is required.

(b) Topography and geology of the site:

(i) Narrow portion of river course will first be selected.

(ii) The site with stable rock foundation is preferable.

(iii) The river course at the site should be stable.

(c) Affection of backwater to upstream reaches:

Due to construction of weir, backwater will occur in the upstream of the weir and sometimes give damage to farmland, houses, bridges and other structures along the river. This should carefully be examined.

(d) *Affection of structure to sediment transport in the river:*

Due to construction of weir, sediment transport in the river will be examined, which will cause the river bed errosion in the downstream of the weir and may give damage to the existing bridges and intake structure in the downstream reaches of the river. Careful survey and study are required for this matter.

(e) Construction:

The site should ensure easy and cheap construction work.

(f) Operation and maintenance:

The site should provide good access for operation and maintenance.

During the comprehensive study period in the last year, there found two attractive sites for the construction of headworks, i.e. at Pracak and Perjaya. The advantages and disadvantages between these two sites are compared as follows:

(a) The river width is more narrow at the Pracak site (130 m) than the Perjaya site (170 m).

(b) A long deep-cut headreach, around 18 km, is required, if the Pracak site is selected. Whereas, a 8 km long shallow-cut headreach is required, if the Perjaya site is selected.

(c) If the Pracak site is selected, the canal water level can be maintained by 4 - 6 m higher than the Perjaya case. The difference of canal water level can increase the irrigable area to great extent, in the order of 500 - 1,000 ha.

Taking into account the abovementioned advantages and disadvantages, and furthermore based on the detailed topographical and geological survey, both of which are being carried out, elaborate technical and economical comparisons are made. Particularly, the economical comparison is made through the following procedure.

(a) Construction costs for two sites are calculated (the Pracak case should be more costly than the Perjaya case).

(b) Construction costs of headreaches for two sites are estimated.

(c) O & M cost of the headworks and headreaches for two sites are estimated.

(d) For the construction costs calculated in the above (a) and (b), the annual equivalent costs are calculated assuming the economic interest rate and useful life of the project.

The recommended economic interest rate and the project useful life are 8% and 50 years, respectively.

(e) Irrigation areas for two sites are estimated.

(f) The comparison is made using the annual equivalent costs (including the O & M costs) per unit irrigation area. If the annual equivalent cost per unit irrigation area is cheapest, its case is most economical.

4.3.3 Basic Conditions for Design

For the preliminary design of headworks, the following conditions are established.

(1) Hydrological and hydraulic conditions

Design intake discharge: The sum of peak diversion requirements for the development area is taken as design intake discharge.

Design intake water level: For the determination of design intake water level, the following two water levels at the intake structure are first calculated and the higher value of them is taken as the design intake water level.

(a) Water level to be required for the irrigation of total project area.

(b) Water level to be required for the prevention of inflow of river bed load into the intake structure. In this case, the required water level will be obtained by adding the required intake water depth to the bottom height of intake structure which will be enough high for the prevention of river bed load inflow.

Design flood discharge: The biggest flood discharge in the past is taken as design flood discharge. In this study, the biggest flood discharge will be estimated based on the observation result of the highest flood mark and the result of river cross section survey. The flood discharge thus estimated will be cross-checked using the discharge record.

Design flood water level: By using the non-uniform flow formula and the natural river gradient and cross section, the river water level at the headworks site for the design flood discharge is calculated. By adding the back-water affection, the design flood water level is obtained, which will not give any damages to the houses, farmland and bridges along the upstream reaches.

Sediment load: A reliable information on the volume and nature of the sediment of the river is needed in the design. Since satisfactory data are not available on the Komering river, an adequate sampling program should be instituted early in the project investigation. The sampling station should be at the Martapura gauging station in order that the records on each may be completely coordinated. Standard sampling methods and equipment should be employed which will ensure the acquisition of representative data on both suspended and bed load sediments. This will permit comparison with data from other sources. Sampling should be at sufficient frequency to represent sediment loads at all stages of stream flow. Particular attention should be given to sampling during flood stages. For the sampling purposes, the sediment discharge should be expressed in terms of weight or volume of sediment per unit of time. A knowledge of the nature of the sediments as determined from size analyses is needed for the design of scouring sluices and desilting basin.

(2) Geological conditions at the site

Geological exploration of the headworks site should be carried out to supplement surface observation to establish the adequacy of the site and provide sufficient information for preparation of reliable designs and estimates. Results of water pressure tests will give important information for the design of structural foundation particularly for leakage protection through the foundation.

(3) Required facilities on headworks

Other than the intake structure, flood way, scouring sluice and desilting basin, the headworks is provided with a raft way and fish ladder according to the requirements.

4.3.4 Specific Design Conditions

Headworks is composed of diversion weir, intake structure, driving channel and settling basin. The diversion weir is provided with a raft way, a fish ladder and a operation bridge as well as the fixed weir and movable weir. The following specific conditions are established for the design of respective structure.

(1) Movable weir

(a) The structure is designed for super critical flow in order to flush out the bed load.

(b) Net width of movable weir is so determined as to keep the back-water level below the design flood water level.

(c) Top elevation of gates for movable weir is set to include an allowance of around 10 cm above the design intake water level.

(d) Height of base floor of the movable weir is so determined as to give smooth flushing-out of river bed loads.

(e) The gates are operated by motor, considering the heavy weight of the gates and frequency of operation.

(f) The gate width and number are determined after economic comparison and further taking into consideration the passing of drift wood between the gate piers.

(g) Height of gate pier is determined using the following equation:

$$EP = FWL + HG + h1 + H2$$

where,

EP : Required height of gate pier

FWL: Design flood water level

HG : Height of gate

H1 : Clearance between the design flood water level and the bottom of gate in the full open position ($\doteqdot$ 1.0 m)

H2 : Allowance between the crest of gate and the top of pier ($\doteqdot$ 1.0 m)

(h) Thickness of gate pier is determined using the following empirical formula:

$$Tp = 0.12\ (Hp + 0.2\ Bi) \pm 0.25$$

Where,

Tp : Required thickness of gate pier

Hp : Height of gate pier

Bi : Span length between piers

(2) Fixed weir

(a) Height of fixed weir is determined by the following equation:

$$Hw = DWL - Do$$

where,

Hw : Required height of fixed weir

DWL: Design intake water level

Do : Flow depth over the weir crest

(b) The weir should be stable against the overturning, sliding and overstressing. The following forces act on the weir:

- self-weight of weir
- water pressure (hydrostatic pressure plus dynamic water pressure)
- uplift pressure

- silt pressure

- earthquake (ke = 0.12)

(c) The shape of weir should be hydraulically favorable.

(3) Raft Way

(a) This structure is provided only for raft passing.

(b) Width of the raft way is 8 meters.

(c) The raft way is of chute type with a draft of 1 meter.

(4) Apron

(a) Apron is provided to protect the river bed erosion and to increase the creep length.

(b) Required length of rear apron is calculated using the following equation:

- for the downstream apron for fixed weir

$$\ell = 0.6\ C\sqrt{Ha}$$

- for the downstream apron for movable weir

$$\ell = 0.9\ C\sqrt{Ha}$$

where,

ℓ : Required length of downstream apron

c : Coefficient after Bligh's formula

Ha : Difference of height between the top of weir crest (top of gate height in case of movable weir) and downstream apron.

(c) For the protection of downstream apron, the gabion is installed at the downstream of apron

(5) Intake structure

(a) Bottom height of intake structure should filfil the following two conditions:

(i) $ELi \geq ELs + 1.50$

(ii) $ELi \geq (FWL - ELs) \times 1/6$

where,

Eli : Required bottom height of intake structure

Els : Height of base floor of scouring sluice

FWL : Design flood water level

(b) Flow velocity at the intake gate should be from 0.6 m/sec to 1.0 m/sec.

(c) Net width of intake structure is calculated using the following formula:

$$B = Q/hl \cdot vl$$

where,

B : Required net width of intake structure

Q : Design intake discharge

hl : Intake water depth

vl : Intake water velocity

(d) The operation of gates is done combinedly by motor and manual. The size of gates is decided after cost comparative study among the various sizes.

(6) Driving Channel

The driving channel between the intake structure and settling basin is so designed as to keep a flow velocity enough for the transportation of sediment loads into the canal.

(7) Settling Basin

(a) The location of settling basin should be selected near the intake structure as much as possible.

(b) The maximum daily sediment load is estimated as follows.

$$Vs = Ds \times Q \times 86{,}400 \ (m^3/day)$$

where,

Vs : Daily sediment load

Ds : Sediment production rate
(3×10^{-4} m^3 per 1 m^3/sec of irrigation water/1)

Q : Design discharge

(c) The minimum particle size of sediment loads adopted in the design is 0.3 mm.

(d) The required length of settling basin is calculated using the following equation:

$$L = K \frac{H \cdot V}{Vg}$$

Where,

L : Required length of settiing basing

K : Safety ractor (≒ 1.5)

H : Design water depth in the settling basin (2.0 m)

v : Design flow velocity in the settling basin (0.3 m/sec)

Vg : Sinking speed of 0.3 mm suspended load (0.03 m/sec)

(e) The required width of settling basin is calculating using the following equation:

$$B = \frac{Q}{H \cdot v}$$

Where,

B : Required width of settling basin

Q : Design discharge in the settling basin

H : Design water depth in the settling basin (2.0 m)

v : Design flow velocity in the settling basin (0.3 m/sec)

(f) Sediment load in the settling basin is flushed out to the Komering river with gravity flow within four hours.

/1: This figure is estimated based on the observation results in the Belitang Irrigation Canal.

(8) Foundation work

(a) The foundation of gate pier and weir body is of floating type supported by piles.

(b) Particular foundation treatment is not needed for the construction of apron.

(c) The foundation of intake structure is independent from those of other structures.

4.4 Irrigation Canal System

4.4.1 Function and Requirement of Canal

Irrigation canal system in the project area includes headreach, main canals, secondary canals, and tertiary systems. The layout planning of these canals will be done after understanding their respective function and requirement mentioned below.

(1) Headreach

A headreach is constructed between the headworks and a bifurcation structure to lead irrigation water to South and North Main canals. Before the design is made, it is necessary to make cost comparative study between unlined and lined cases. For the lined case, canal section will become smaller and excavation volume will be reduced to great extent, though lining cost will be high. Furthermore, for the selection of lining materials, comparative study among concrete lining, masonry lining and other materials is made for their technical and economical merits.

(2) Main canals

In the project area, there are three main canals: South Main Canal, North Main Canal and Pisang Main Canal. The main function of the main canal is to deliver irrigation water from the headreach to development area in the shortest or in the most economical way. The canals is basically unlined and trapezoidal. The raised portion is lined with concrete.

(3) Secondary canal

This canal is branched off from the main canal to distribute water up to the secondary unit area. The size of secondary unit area varies from 500 to 2,000 ha which is divided into around 5 to 20 tertiary blocks. The canal is principally unlined, but the raised canal portion is lined with concrete.

(4) Tertiary system

The tertiary block includes one tertiary canal and 10 - 15 quaternary canals. The maximum size of tertiary block is 150 ha. Whereas, a quaternary canal covers 10 - 15 ha (for details vide Section 4.7 hereof).

4.4.2 Layout Planning of Canal

The layout planning of canals is done through the following procedure.

(1) Layout planning on map

Before start of field survey, a layout planning of canals is made on the map. For this work, the map on a scale of 1/1,000 to 1/5,000 is preferable. In the planning, the following matters should be taken into consideration.

(a) Canal alignment should be straight and short as much as possible.

(b) The alignment should be planned so as not to pass through village areas and not to give damages to public facilities.

(c) Embankment portions should be minimized as much as possible.

(d) Canal construction cost should be minimized by selecting the proper alignment.

(e) Canal water level should be kept comparatively high for easy operation of canal system.

(f) The canal layout should be convenient for the grouping of future water users' association.

(2) Field survey

(a) Based on the layout planning prepared on the map, the detailed field reconnaissance is made along the alignments to know the micro-topography, hydrological conditions and soil conditions, and to collect farmers' opinion toward the development plan.

(b) The following topographic surveys are necessitated for the proper planning and preliminary design:

- check levelling for existing benchmarks,
- plan table survey at the improtant structure sites on a scale of 1/200 to 1/1,000,
- route survey along such major canals as headreach and main canals,
- check levelling at the key points of secondary canals such as intersectional point and major structure sites.

(c) Geological investigation including drilling, field penetration tests and water pressure tests are carried out at the major structure sites along the headreach.

(d) Soil mechanical survey includes:

- penetration tests at main structure sites,
- soil mechanical survey along the headreach and main canals and soil mechanical tests in laboratory,
- measurement of groundwater table along the major canal routes.

(e) The construction material survey is made for their availabilities and prices.

(f) For the layout planning, agricultural, economical and sociological data are also collected.

(3) Preliminary study of canal layout

The primary objective of preliminary study is to attain the basic idea of detail design and to grasp the scale of investment cost of the project. The preliminary study would therefore possess a vital importance to establish the economical and efficient development plan of the project. The main items to be studied in the preliminary study stage are mentioned below.

(a) Irrigation water requirements, irrigation method, required canal elevations at key points and general layout of the canal system should first be confirmed.

(b) Modification of canal layout is made based on the field survey results mentioned in the above.

(c) Shape of canal cross section, canal gradient, and necessity of canal lining is also studied based on the field survey results.

(d) Alternative study will be made to assure the suitable alignment. In this alternative study, the kind, type and configuration of major structures will also be incorporated fully.

(e) The canal alignment thus obtained is confirmed whether the alignment will satisfy the operational and social requirements or not.

(f) Preliminary construction cost estimate will be made for determination of the final layout of the canal system.

4.4.3 Function and Configuration of Related Structures

A number of canal structures of various type are required in conjunction with the irrigation canals. The configurations of these structures should be selected properly considering their functions, canal layout, operational program and social conditions in the project area.

(1) Bifurcation structure

A bifurcation structure is constructed at the end of headreach to distribute irrigation water strictly to the South and North Main Canals in accordance with the design water requirements. The structure is partitioned into two channels by concrete wall and these channels will lead irrigation water to the South and North Main Canals respectively. Each channel is provided with steel gates for the control of discharge to the main canal.

(2) Check gate

In order to maintain the required water level at the site of diversion or off-taking even during periods of partial discharge, a check gate is provided where a number of turnouts is densely provided or where fairly large discharge is diverted. Over the project canals, two types of check gates is constructed depending on the topography along the canal. One type simply has a function as a check gate and the other type is of combined type with drop structure.

At the sites where farm road crossings are required from the viewpoint of canal and road layouts, concrete slabs are provided on the check gates. Other check gates will be provided with only foot path crossings.

(3) Turnout

Turnout is constructed to divert the required water from a parent canal to its branch canal. The free flow type of turnout is introduced for this project. The rectangular box barrel or precast concrete pipe to cross the road or canal embankment is adopted depending on the discharge. The rectangular box barrel is applied for discharge more than 0.6 m^3/sec. All the turnouts are designed for full capacity at every water surface regulated by the check gate.

(4) Aqueduct

An aqueduct is constructed to transport irrigation water across a canal or river. For the aqueduct on the North Main Canal to cross over the Belitang Irrigation canal, a free flow type of aqueduct is constructed so as not to change the present hydraulic condition.

(5) Bridge and culvert

A bridge or culvert is constructed where a road crosses over the canal. These bridges and culverts are strong enough for the increase of heavy trafic after the project implementation. For selection of bridge or culvert, a comparative study of construction cost is made between them considering the cutting depth of canal and canal width.

(6) Spillway

A spillway is constructed in the canal system for the purpose of flushing off all the water in the canals or spilling out excess flow in case of emergency and clearing and repairing canals. This structure is provided in the mid-course of respective main canal and at the end of secondary canal. All the spillways are equipped with slide gates (waste-way) and connected to the nearby drainage canals.

(7) Crossdrain

A crossdrain is constructed at the site where the irrigation canal runs across a depressed land or natural stream. As the crossing structure, a rectangular-shaped barrel or precast concrete pipe is laid under the irrigation canal.

(8) Water meansuring device

There is no doubt that the conventional use of water for agriculture is, to some extent, wasteful. There is considerable room for economy in water use, and effort should increasingly be made toward eliminating waste and harmful irrigation practices which give rise to waterlogging. For this, accurate and reliable measurement is essential, as this can be accomplished by knowing with reasonable accuracy; the amount of water being diverted and delivered. Water measurement is also needed to establish charges to water users, if required. In this context, the installation of following measuring devices is proposed for the respective canal system.

Place of installation	Measuring devices
- for intake structure	Gauging staff
- for bifurcation structure	Broad crested weir type
- for main canal	1. Gauging staff at check gate 2. Broad crested weir type at check gate
- for secondary canal	1. Romijn gate at turnout (upto 1 m^3/sec) 2. Cipolletti weir at turnout
- for tertiary canal	1. Romijn gate at turnout 2. Cipolletti weir at turnout

4.5 Drainage Canal System

4.5.1 Function and Requirement of Drainage Canal

The drainage canals are classified by function as follows:

(a) Quaternary drain is provided to drain out excessive water in fields and to lower or control the subsurface water level.

(b) Tertiary drain is provided to drain out the excessive water and subsurface water collected by the quaternary drain to secondary drain or directly to river.

(c) Main and secondary drains transport water from field drains and collector drains to outlets or disposal points.

The layout of the irrigation system and topography are the main factors determining the location of all the drainage canals.

Quaternary and tertiary drain: Detailed description will be made in Section 4.7 hereof.

Secondary drain: These drains are designed to collect water from quaternary drains and tertiary drains and to transport to main drains or rivers. Depressed areas or old stream beds are used for location of the secondary drains.

Main drain: The location of main drain is dominated by natural streams and rivers crisscrossing in the development area. These natural streams and rivers are used as much as possible as the main drains.

4.5.2 Layout Planning of Drainage Canal

The layout planning of drainage canals is carried out through the following procedure.

(1) Establishement of basic concepts

First of all, the following basic concepts for planning the drainage system are confirmed.

(a) What extent should the area be protected against the floods from the river?

(b) Where should the main drainage canal or disposal points be located?

(c) How will the excessive water in the area be collected and transported to the disposal points ?

(d) Is there any necessity of mechanical drain?

(e) What extent can the drainage benefit be expected after the project implementation ?

(2) Field Survey

(a) Field damage due to floods and mal-drainage is surveyed for its extent and magnitude.

(b) Present drainage mechanism is observed in the project area and in its vicinal areas.

(c) Reconnaissance along the rivers is made to check the highest flood water level in the past and their present flow capacities.

(d) Sub-surface water level is observed in both the dry and rainy seasons by digging several pits in the representative sites.

(e) Rainfall data is analyzed on the intensity and duration of rainfall in the area and estimation of drainage requirements.

(f) Present land use in the area is surveyed for the use of analysis on drainage requirements.

(g) Soil characteristics in the area are surveyed on the reconnaissance basis.

(h) Present farming practices and socio and agro-economic surveys are carried out in the project area and in its vicinal areas.

(3) Preliminary study of drainage canal layout

Based on the result of field survey mentioned above, preliminary layout of the drainage canal system is planned on the topographic map, preferably with a scale of 1/5,000 to 1/10,000. In the planning, the following matters are fully taken into consideration.

(a) Drainage water requirements, drainage method, required canal elevations at key points and general layout of drainage system should first be confirmed.

(b) Drainage alignment should be planned along the lowest land and as straight as possible.

(c) The alignment should be planned so as not to pass through village areas and not to give damages to public facilities.

(d) Raised portions of drain should be minimized in order to keep canal water level below ground surface as much as possible.

(e) Alternative study will be made to assure the suitable alignment. In this alternative study, canal slope, kind, type and configuration of related structures will be incorporated.

(f) The canal alignment thus obtained is confirmed whether the alignment will satisfy the operational and social requirements or not.

(g) Preliminary construction cost estimate is made for determination of the final layout of the drainage system.

4.5.3 Function and Configuration of Related Structures

The structures related to the drainage network are bridges, culverts, drops and drainage outlets.

The bridges and culverts are planned and designed with the same principles as mentioned in Section 4.4.3. For drainage culverts, two types are provided depending on their design capacities; i.e. rectangular box barrel type and precast concrete pipe type. The former is applied for the design capacity of more than 1.0 m^3/sec. The drops are of vertical type with rectangular cross section. The drainage outlets are provided at the end of drainage canals, which will flow directly into the rivers or streams, to prevent the river bed erosion and retrogressive erosion in the drainage canals.

4.6 Inspection Road

For the proper operation and maintenance of project facilities, well arranged inspection roads are of vital importance. Since these road will be used as village roads and farm roads after the project implementation, the arrangement of the inspection roads should be made considering the existing and planned road networks.

(1) Main inspection road

The main inspection roads are required for inspection, operation and maintenance of the headreach and main canals. Considering the future increase of vehicles for the inspection and operation and heavy construction equipment to be required for the canal maintenance and repair, all the main inspection roads are so designed as to have an effective width of 7 meters and to be gravel-metalled. These roads will also be used for the movement of agricultural products and equipment and for the day-to-day services between villages and from them to the highway and railway station.

(2) Secondary inspection road

The secondary inspection roads are mainly provided alongside the secondary canals. All these roads have an effective width of 5 meters and are paved with gravel or laterite soil. These roads link the cultivable areas to population centers in the area and also be used for the purpose of farm operation, particularly for harvesting.

(3) Tertiary inspection road

For the same purpose as that of the secondary farm roads, the tertiary farm roads are constructed along one side of all the tertiary canals. These roads have an effective width of 3 meters and are of earth without any metalling.

4.7 Tertiary Development

4.7.1 General

Tertiary development program aims at efficient water management by establishing the well organized tertiary system and through refined rotational irrigation program. For this subject, the Directorate of irrigation of P.U. has prepared the report titled as "Guideline Manual for Planning of Tertiary Network". For the details of criteria and standards for the design and operational programming, this guideline manual is referred to.

4.7.2 Definition and Recommended Size of Irrigation Block

The teritiary development program is prepared for every tertiary block. This tertiary block is further divided into several subordinate blocks like sub-tertiary blocks and quanternary blocks. The definition and recommended size of each irrigation block is briefed as follows:

(1) Tertiary block

The tertiary block is covered by one tertiary canal. The distribution of irrigation water in the tertiary block is managed by farmers themselves. In some cases, however, it is difficult for the farmers to manage the distribution of water to vast lands and large number of farmers equally. The past experiences in Indonesia showed that the suitable size to be covered by one tertiary canal would be in the order of 50 ha. Considering the appropriate organization of water users' group in future, the maximum size of tertiary block is proposed to be 150 ha.

(2) Sub-tertiary block

In case that the tertiary block can not be formed within one village: in many cases, the boundary of teritary block crosses the administrative boundaries of villages, a sub-tertiary block is formed in each village to simplify the organization of water users' group.

(3) Quaternary block

In order to distribute irrigation water equally and efficiently to all parts of the fields through more intensive water control, it is advisable to sub-divide the tertiary block into several subordinate blocks: the quaternary blocks. The quaternary block is served by respective quaternary canal. The recommended size of one quaternary block is 10 to 15 ha. The rotational irrigation is practiced on the quaternary basis.

4.7.3 Irrigation Canal System

(1) Canalization system

The tertiary system consists of tertiary canal, sub-tertiary canals and quaternary canals which respectively cover the tertiary block, sub-tertiary blocks and quaternary blocks as mentioned above in layout planning of these cansls, the following respective function and design principle are taken into consideration.

(a) Tertiary canal

The tertiary canal delivers irrigation water from secondary irrigation canal or sometimes directly from main canal to the sub-tertiary canals and/or quaternary canals. The irrigation water should not be taken directly from the tertiary canal into fields. For the alignment of these canals in the area with steep topography: more than 1% of land slope, the canal should be in perpendicular to the contour line (perpendicular type)

(b) Sub-tertiary canal

The sub-tertiary canal leads irrigation water from the tertiary canal to the quaternary canals. In this case also, irrigation water should not be taken directly from this canal to fields. In principle, the alignment of this canal is made in the same manner as that of the tertiary canal.

(c) Quaternary canal

The quaternary canal is terminal system. Irrigation water to be carried by this canal flows in fields directly or through sub-quaternary canals (branch of quaternary canal). The end of quaternary canal is connected to nearby drainage canal so as to drain off excess water in the canal Especially in steep-slope area, more than 1% of land slope, the canal should be aligned in parallel to the contour line (contour type). In order to avoid irrigation water from spilling-out from one paddy field to the next field, the width of one plot of quaternary sector should be limited to 200 m at maximum. Furthermore, in order to minimize the area to be occupied by the canal alongside the drainage canal should be avoided as much as possible. Instead, all the quaternary canals except the canal to be constructed in the highest position in the respective area are so designed as to have dual functions; irrigation and and drainage functions, where possible.

The typical layout of tertiary system are illustrated in Fig. 4.3.

(2) Related structurs

In order to attain its primary objective, the canalization system thus aligned requires the following structures.

(a) Tertiary division box

Many division boxes are constructed on the tertiary canals and all of them are equipped with gates to regulate irrigation water in accordance with the rotational irrigation program.

(b) Quaternary division box

All the division boxes to be constructed on the quaternary canal are not equipped with gates.

(c) Measuring device

The measuring device such as Romijn gate, Cipolletti weir, etc. is installed at the head of tertiary block.

(d) Drop structure

A drop structure is provided where the ground surface slope is steeper than the required canal gradient In principle, the division box is not provided on the canal system as an independent structure but as a supplementary structure of division box. Especially for the fall height of less than 30 cm, in case of the quaternary canal, the drop structure are not constructed independently.

(e) Culvert

A culvert is constructed at the crossing point of canal with road. This structure is of combined type with the division box as far as possible.

(f) Crossdrain

A crossdrain is provided at the site where the irrigation canal has to cross over the drainage canal.

4.7.4 Drainage Canal System

(1) Drainage canalization system

In the tertiary block, quaternary drains and tertiary drains are required to evacuate excess water from the block. In the layout planning of these drainage canals, the following respective function and design principle are taken into consideration.

(a) Quaternary drain

Quaternary drain is excavated to collect excess water in the quaternary block and drain off the water to the tertiary drain. In case the quaternary canal has dual functions, the quaternary drain is not excavated.

(b) Tertiary drain

Tertiary drain is provided to lead the excess water to be collected by the quaternary in the tertiary block to the secondary drain or directly to the river. In the typical layout, the tertiary drain is aligned alternately with the tertiary canal.

(2) Related structure

In order to facilitate the proper function to the drainage system mentioned above, the following structures are required on the canals.

(a) Drainage drop structure

This structure is placed where the natural ground slope is steeper than the designed gradient of drain bed.

(b) <u>Drainage culvert</u>

A drainage culvert is provided at the site where the drainage canal will cross under the road. For crossing, the precast concrete pipe is installed.

4.7.5 <u>Road Networks</u>

For the purpose of canal inspection and farm operation, two types of road; tertiary inspection road and farm road, are required in the tertiary block. The respective function and design principle are mentioned below:

(a) <u>Tertiary inspection road</u>

A tertiary inspection road is required alongside the tertiary canal and the sub-tertiary canal. This road is used only for the inspection of canals and farm operation.

(b) <u>Farm operation road</u>

This road suitable for trucks and tractor is required throughout the tertiary block for the purpose of farm operation particularly for harvesting. This road is provided for the connection of tertiary inspection road to other roads. This is used only for farming operation.

(c) <u>Related structures</u>

Farm approaches are provided at the entrances from the tertiary road into the field plots.

4.8 <u>Water Management</u>

Water management up to secondary canals will be done by the Government, whereas water management of tertiary system will be done by the farmers themselves.

Generally, three cases of rotational irrigation operation can be considered, i.e. on the secondary canal basis, tertiary canal basis or quaternary canal basis. In this project, the rotation on the quaternary canal basis is proposed, because the canal construction cost will be minimized in the case of quaternary canal basis, and the operation will be more simple than other cases and easily practiced even by the farmers who are not familiar to irrigation practices.

For the preparation of detailed rotation program, various data and studies such as climatological data, pedclogical data, cropping pattern, seasonal irrigation water requirements and layout planning of the tertiary system, are required to much extent.

4.9 O & M Facilities

For the proper operation and maintenance of the project facilities, the arrangement of the O & M facilities will be essential. Office and quarters will be required for the persons to be engaged in the project implementation and in the operation and maintenance of the project facilities. Operator houses will be also constructed at the check gate sites along the main and secondary canals.

The communication system such as the wire telephone system will be facilitated for the efficient and smooth communication. The wire telephone system will be provided so as to network the operation houses at head works site, head office and operation houses along the canals.

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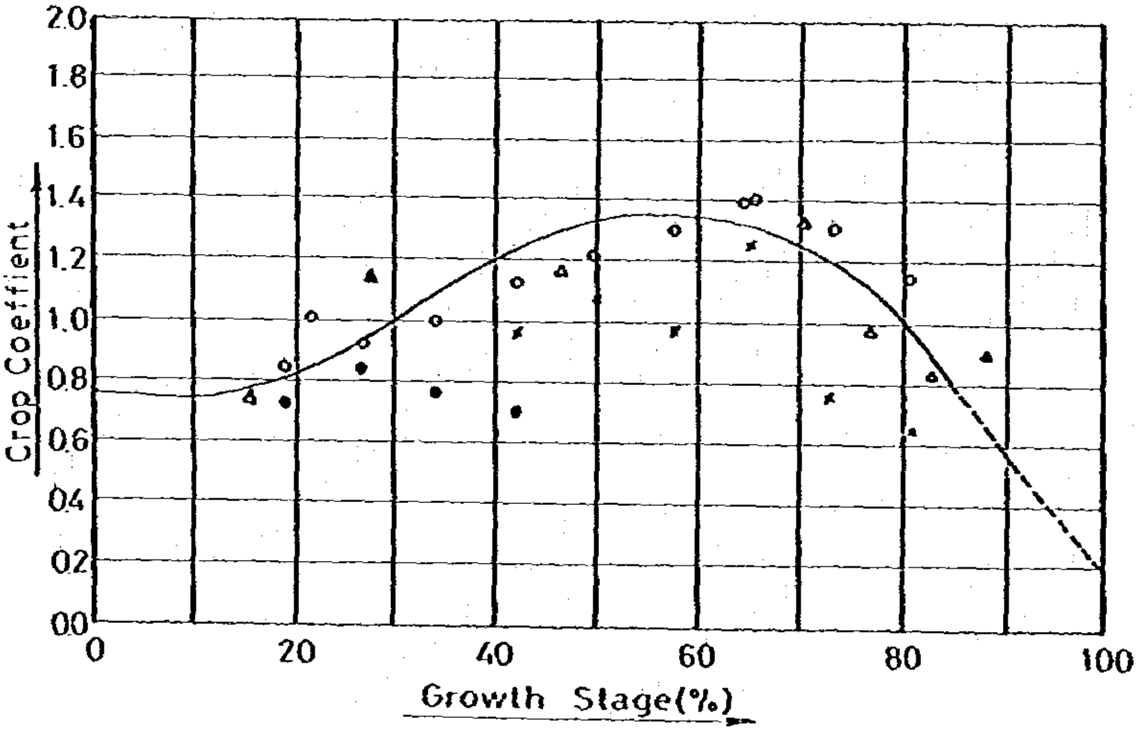
Fig. 2.1 CROP COEFFICIENT CURVE FOR PADDY



x Observed at Cintamanis (Wet seaseon)

• - do - (Dry seaseon)

o Observed at Belitang (Wet seaseon)

▲ - do - (Dry seaseon)

Fig. 2.2 CROP COEFFICIENT CURVE FOR SOYBEANS

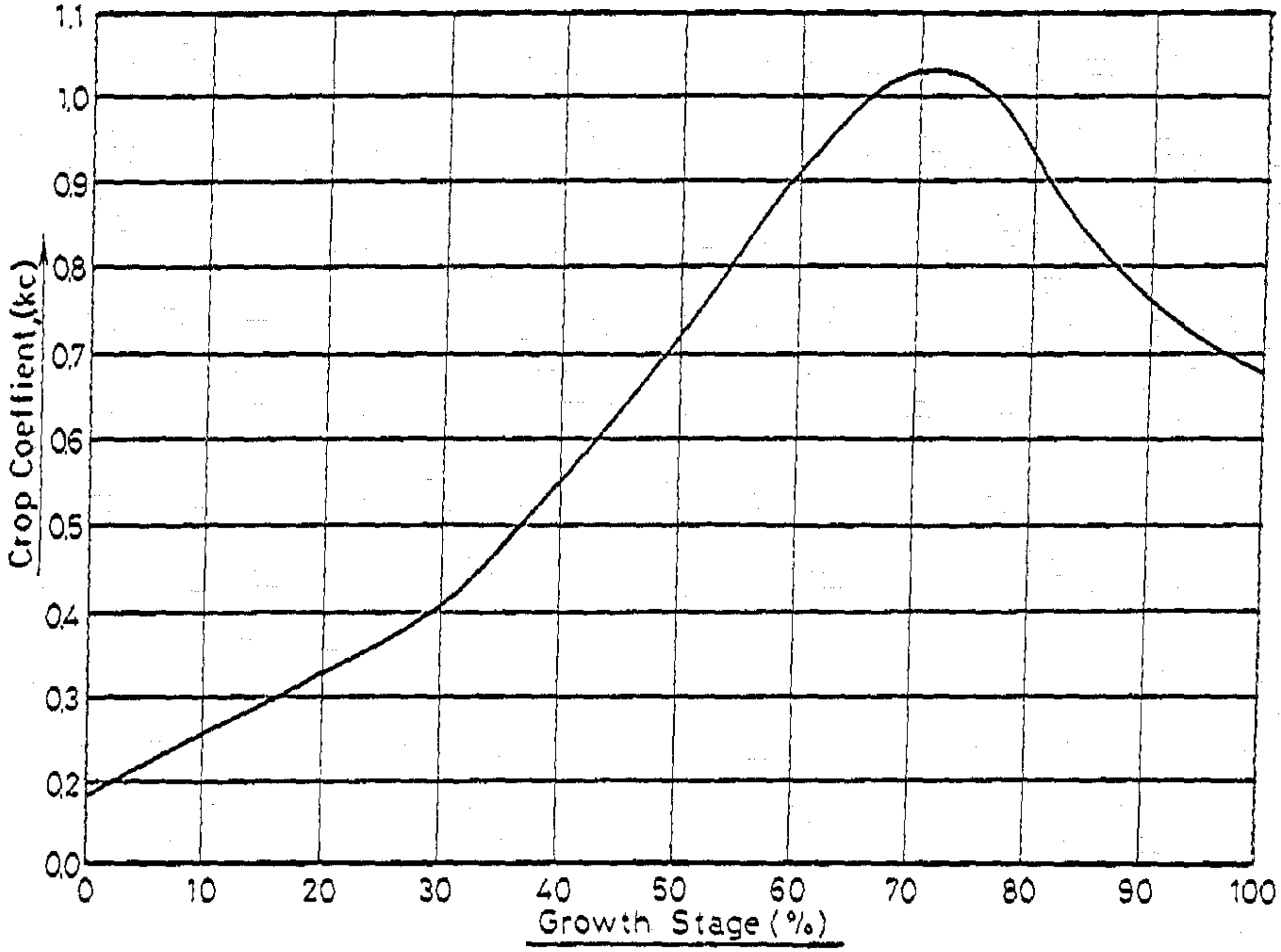


Fig. 2.3 CROP COEFFICIENT CURVE FOR PEANUTS

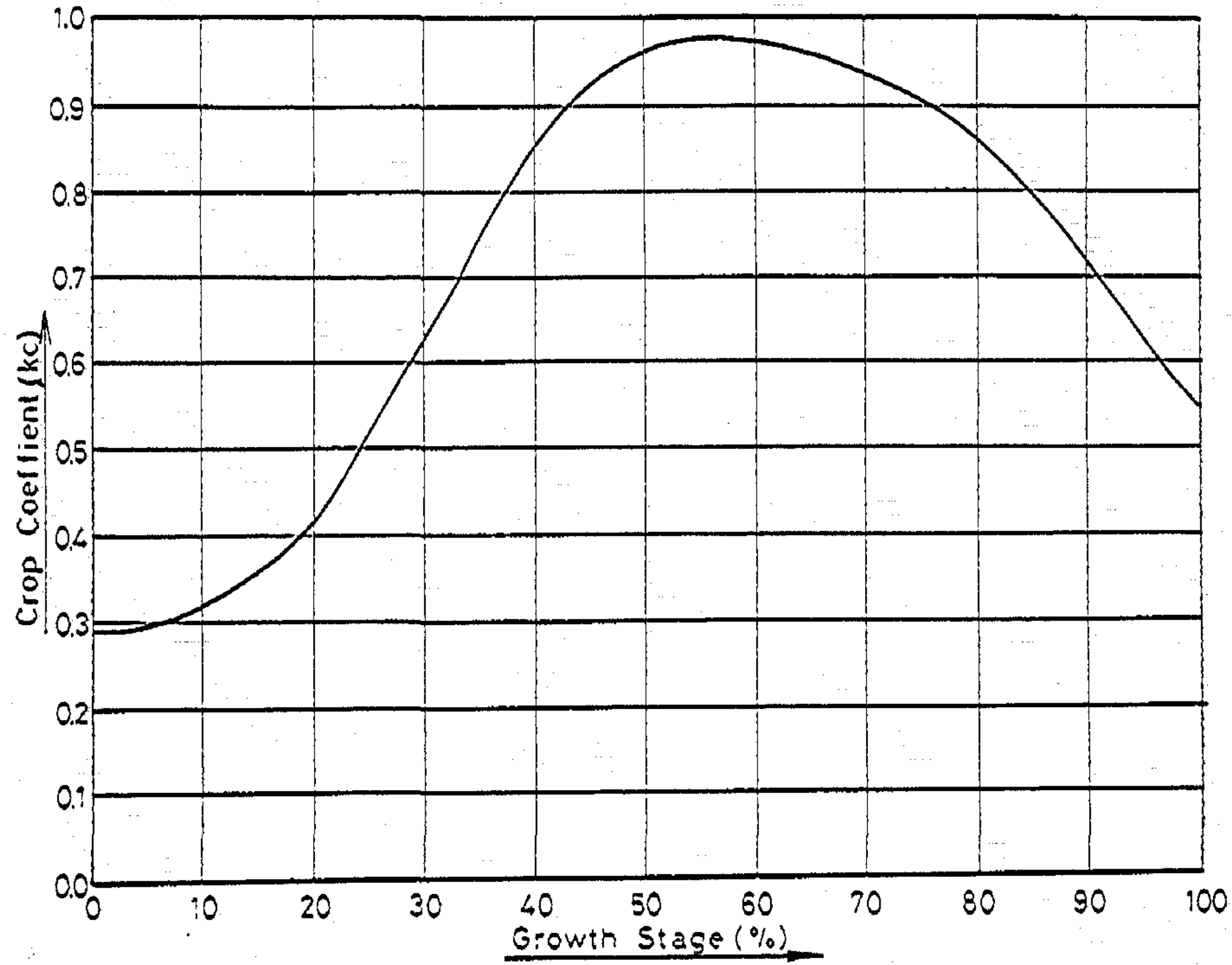


Fig. 4.1 COMPONENT OF HEADWORKS

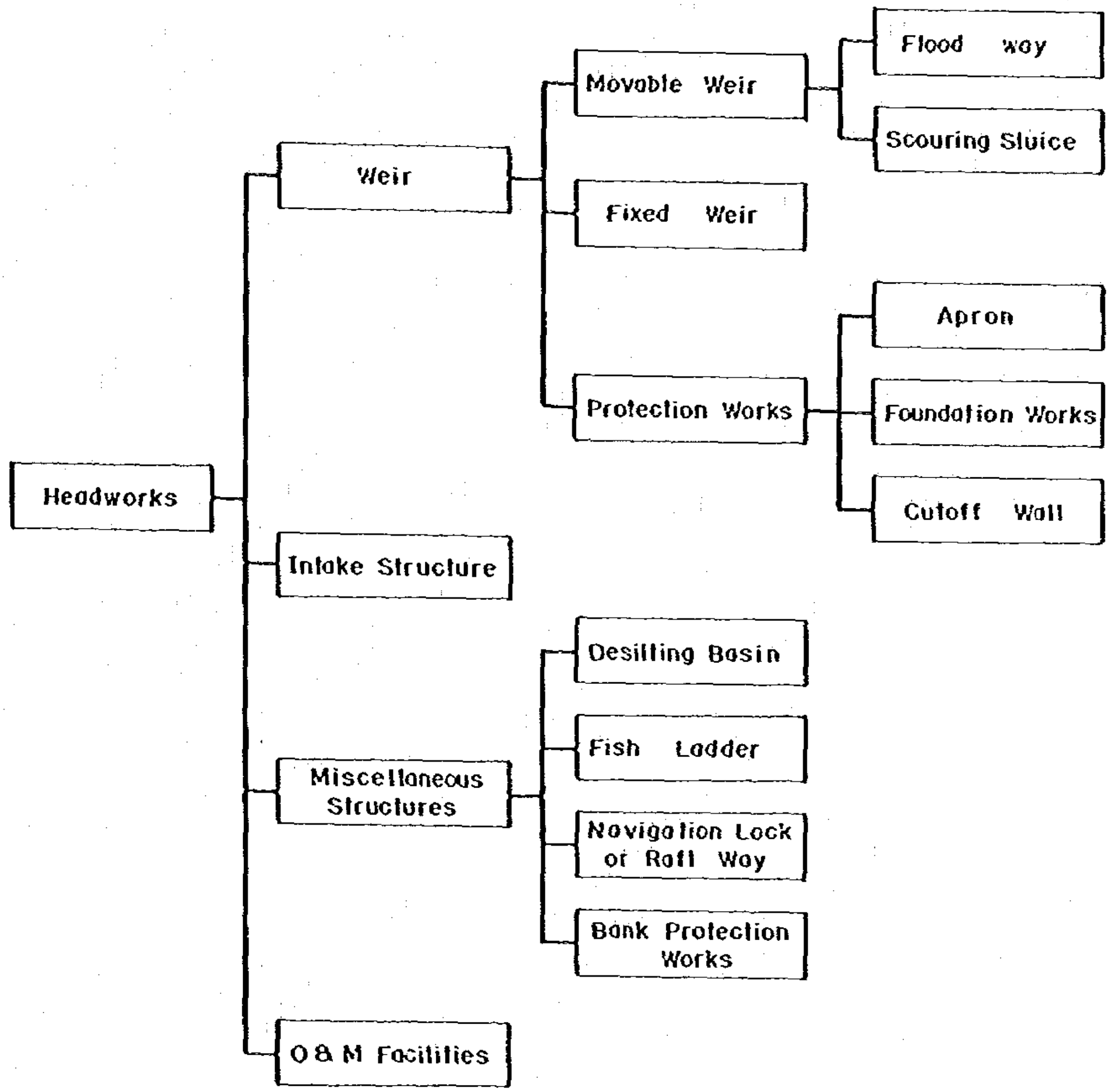
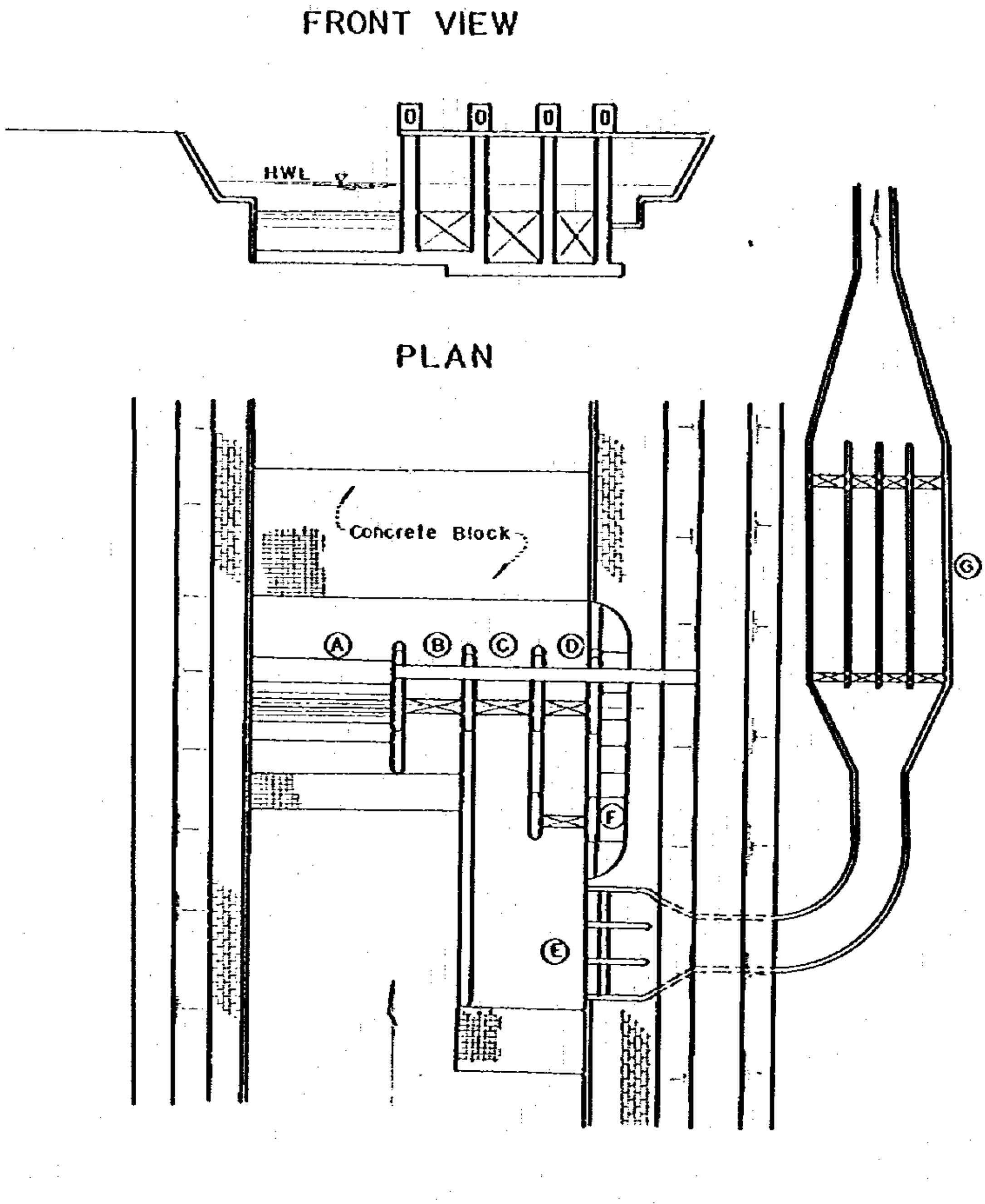
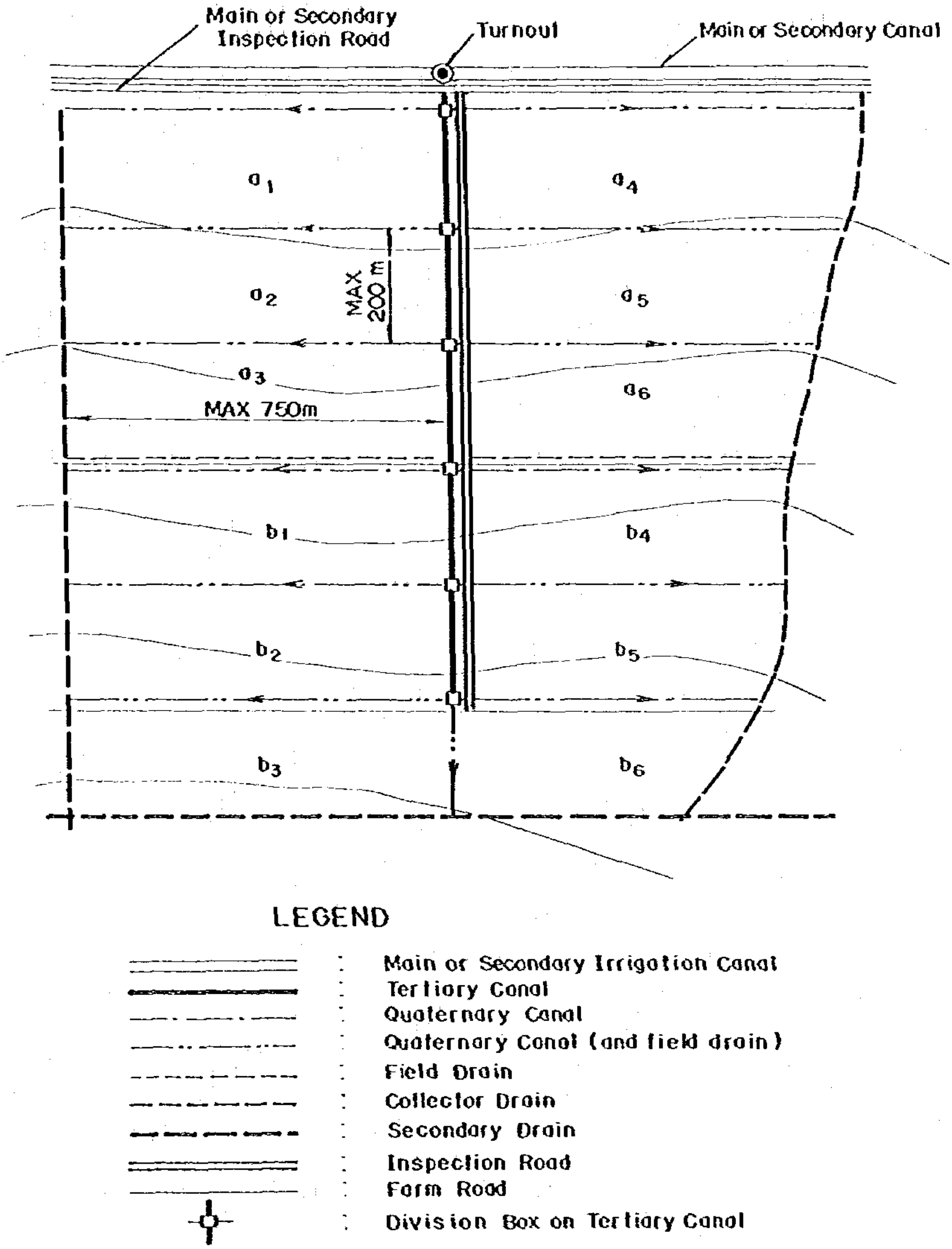


Fig. 4.2 LAYOUT OF HEADWORKS



A : Fixed Weir
B : Flood Way
C : Scouring Sluice
D : Navigation Lock or Raft Way
E : Intake Structure
F : Fish Ladder
G : Desilting Basin

Fig. 4. 3 TYPICAL LAYOUT OF TERTIARY SYSTEM



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