THE KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
DEPARTMENT OF LAND DEVLOPMENT

THE STUDY ON AGRICULTURAL LAND CONSERVATION FOR INTEGRATED RURAL DEVELOPMENT IN THE EAST

Vol. VI GUIDELINE FOR PLANNING, DESIGN AND CONSTRUCTION OF LAND AND WATER CONSERVATION

SEPTEMBER 1988

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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ABBREVIATIONS AND UNIT

Agencies

AC	Agricultural Cooperative
ADB	Asian Development Bank
ALRO	Agricultural Land Reform Office, MOAC
ARDO	Accelerated Rural Development Office, MOI
BMA	Bangkok Metropolitan Administration, MOI
DA	Department of Agriculture, MOAC
DH	Department of Health, MPH
DLD	Department of Land Development, MOAC
DMR	Department of Mineral Resources, MI
DOAE	Department of Agricultural Extension, MOAC
DTEC	Department of Technical and Economic Cooperation
EGAT	Electricity Generating Authority of Thailand
FAO	Food and Agriculture Organization of the United Nation
JICA	Japan International Cooperation Agency
LWCB	Land and Water Conservation Board
MD	Meteorology Department
MI	Ministry of Industry
MOAC	Ministry of Agriculture and Cooperative
MOI	Ministry of Interior
MPH	Ministry of Public Health
MWWA	Metropolitan Water Works Authority
NESDB	National Economic and Social Development Board, PMO
PMO	Prime Minister's Office
PWD	Public Welfare Department, MOI
RFD	Royal Forestry Department, MOAC
RID	Royal Irrigation Department, MOAC

Other abbreviations

CS	Chachoengsao
CN	Chonburi
RY	Rayong
CT	Chanthaburi
B/P	Basic Plan
F/S	Feasibility Study
GDP	Gross Domestic Product
GRP	Gross Regional Product
GPP	Gross Provincial Product
HYV	High Yield Varieties
LV	Local Varieties
EIRR	Economic Internal Rate of Return
NPV	Net Present Value / Net Production Value
B/C	Benefit Cost Ratio
GPV	Gross Production Value
F. C	Foreign Currency
L. C	Local Currency
C. I. F	Cost, Insurance and Freight
F. O. B	Free on Board
O & M	Operation and Maintenance
H. W. S	High Water Surface
N. W. S	Normal Water Surface
L. W. S	Low Water Surface

Glossary

Park	Region
Changwat	Province
Muang	Capital of Province
Amphoe	District
Tambon	Sub-district
Muban	Village
Mae Nam	Large river
Nam	A medium-size river
Lam	A small river
Kwae	A tributary of a river
Huai	A rivulet

Unit

Rai	Unit of land measurement
Baht	Unit of Thai Currency
mm	Millimeter
cm	Centimeter
m	Meter
cu. m	Cubic meter
MCM	Million Cubic Meter
cu. m/s	Cubic meter per second
km	Kilometer
sq. km	Square kilometer
g	Gram
kg	Kilogram
ton	Metric ton
ha	Hectare
El	Elevation above mean sea level
MSL	Mean Sea Level
°C	Degree Centigrade
mmho/cm	Millimho per centimeter
HP	Horsepower
ppm	Parts per million

Units of Measurement

Rai	= 0.16 hectares = 1,600 sq.m
Hectare	= 6.25 rais = 10,000 sq.m

Currency Equivalents (Average of March. 1988)

US Dollar	US$ 1.00 = 25.52 Baht = ¥ 128.92

Definition of Words

The Sixth Plan or the Sixth NESD Plan	The Sixth National Economic and Social Development Plan (1987~1991) published by NESDB
Survey area or Study area	19,604 km^2 (12,252,500 rais) covering the whole area of 4 provinces (Chachoengsao, Chonburi, Rayong and Chanthaburi)
Project area	15,248 km^2 (9,530,000 rais) covering 3 whole provinces (Chachoengasao, Chonburi and Rayong) and a part of Chanthaburi province (approximately one third of the western side of the province)
Planning area	The net area of 8,840 km^2 (5,525,000 rais) out of the Project area excluding paddy and forest land, residential and industrial area, etc.

Chapter 1.

INTRODUCTION

Vol. VI A Guideline on Soil and Water Conservation

CHAPTER I INTRODUCTION

1-1 Preface

All over the world people are becoming more and more aware of the importance of keeping their agricultural land permanently productive. They are coming to realize that productive land is the source of human sustenance and security - that it is basic to the welfare of people everywhere at all times.

Essential foods, vegetable oils and fats, leather, fibers - these are indispensable products, and for our supply of them we are dependent entirely or largely on the soil.

In order to keep the land productive, a good conservation program is imperative. Soil and water conservation is the basis of such a program, and also helps improve land impoverished by erosion and overuse - makes it more productive so that it can support more people.

For effective conservation of soil and water, we must treat and use the various kinds of land according to their capability and need. To do this it is necessary to study the land carefully, so as to be able to fit conservation practices and structures to the various kinds of land. These measures can be used singly on some of the more stable land, but more often than not they must be used in combinations that will mutually support one another and thereby give greater strength, durability, and productiveness to the land. Moreover, they must be used within the economic limitations and in accordance with the facilities of farmers.

Soil conservation stores more of the runoff from excess rainfall in the reservoir of the soil for subsequent crop use; and this much water is kept out of streams, thereby contributing to flood reduction.

Today these techniques of soil and water conservation are being practiced in many countries with much benefit to great numbers of people. Agriculturists throughout the world now generally agree that a change-over from wasteful to protective and fruitful land-use and farming methods should be brought about as quickly as possible. It must be brought about, that is, if individual nations and the world are to build a healthy economy, with agricultural production wherever possible adequate to feed, clothe, and shelter the people and to supply materials required in time of emergency.

Soil erosion is the most serious and prevalent disease of the land. Vast areas have been so damaged that they no longer can be used to grow anything of value to human beings. Much of the good land that remains is in danger, from overuse and improper use. Populations are expanding nearly everywhere, and pressure on the land is heavier than ever before.

The primary purpose of soil and water conservation is to prevent soil erosion and heal its scars where it has not advanced too far to respond to curative methods. This involves, in many instances, changing the uses to which land is put. It has been found, in fact, as stated previously, that the first requisite to conservation of land is to fit the crop-whether cultivated crops, trees, or grazing plants-to the capabilities of the soil and the water available. Equally important is the use of mechanical and agricultural practices which, conjointly, will control and conserve water and counteract the erosive action of both water and wind on the soil.

In conjunction with these two basic principles, there must be put back into the soil what is taken out - organic matter, nitrogen, the mineral plant foods. And proper amounts of moisture for plant growth must be maintained through sound conservation measures, including irrigation where it is needed and is feasible. Also, the many machines and tools now coming into use over the world must be used according to the capability and need of the land, otherwise both the machines and the land are likely to suffer.

It is on these premises that modern soil conservation has been planned and developed. Its ultimate objective is to achieve a sustained-yield type of agriculture based on principles and that will protect and improve land while it is being used, rather than one that will further deplete or destroy its productive capacity.

This guideline describes the major soil-and water-conservation measures which, when applied to the land in correct combinations, will greatly reduce or prevent soil erosion, improve fertility, and increase yields.

Soil conservation is an international concern. Eroded and impoverished land that was formerly productive is now scattered throughout nearly all countries. Responsibility for care of the productive land rests on all the people of the country.

This guideline was prepared for the use of officials of DLD and concerned agencies and agriculturist interested in soil conservation in the East of Thailand.

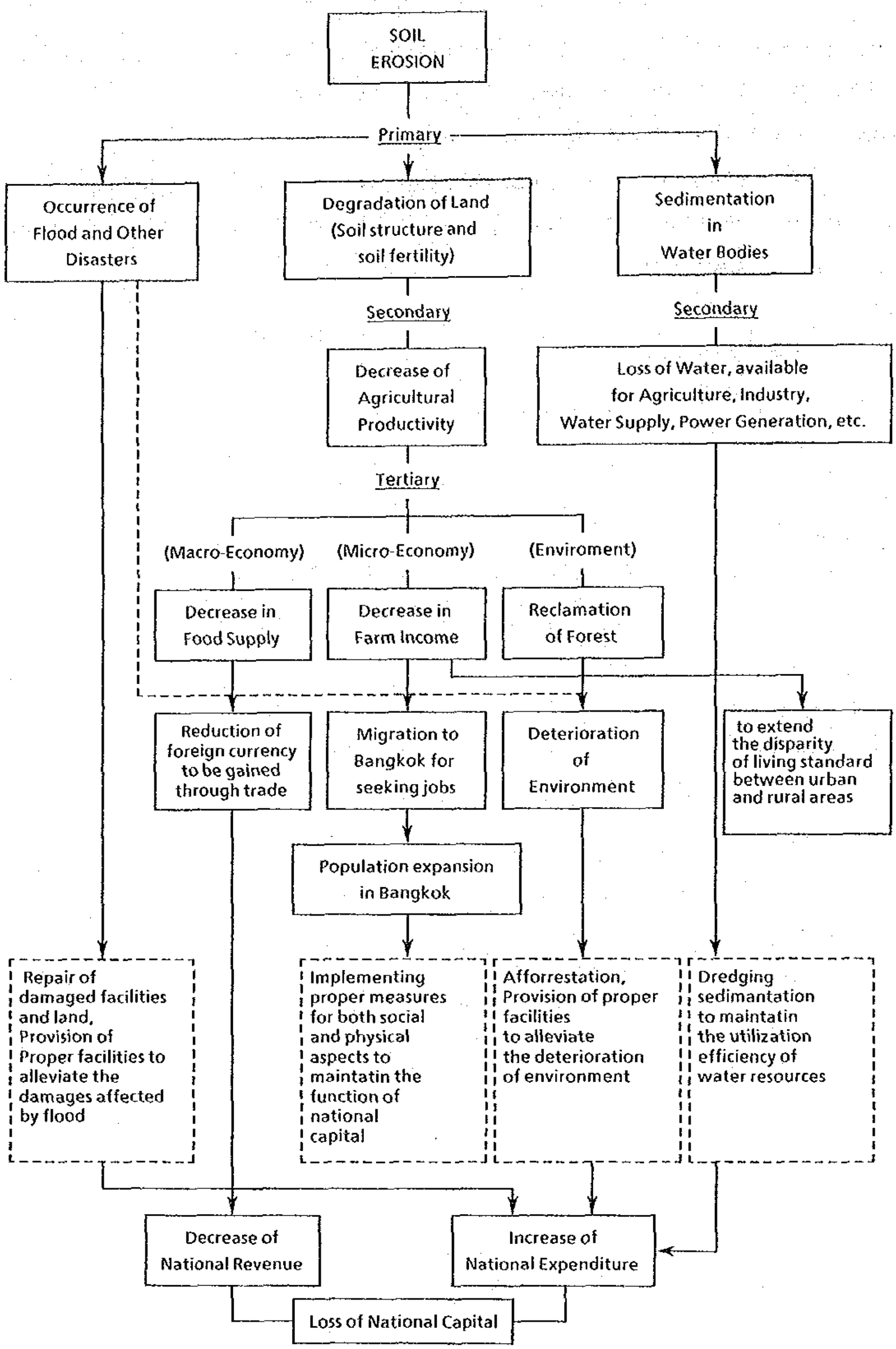


Figure 1.1-1 Diagram of Damages Caused by Soil Erosion

1-2 Objective of Guideline

By introducing land and water conservation project of total 8,840 km^2 to the region as formulated in the Basic Plan, the following targets will be achieved.

- To prevent destruction of natural resources, particularly land affected by disorderly development.
- To supply food and raw material to the industrial area especially Bangkok Metropolitan and the Eastern Seaboard from the rural area, which will also stabilize the farmer's income and improve living standards.
- To reduce the disparity in income between the people living in the industrial and rural area.

The acreage of the project area in each province is as follows ;

Chachoengsao	;	2,200 km^2
Chonburi	;	3,041 km^2
Rayong	;	2,634 km^2
Chanthaburi	;	965 km^2
total		8,840 km^2

In the feasibility study, 16 pilot areas (4 sites in Chachoengsao, 5 sites in Rayong and 2 sites in Chanthaburi, total 2,062 ha) are introduced to the project area. The rest of the project area is expected to be implemented progressively and smoothly.

Therefore, this guideline is provided aiming to introduce the basic ideas of planning, design and construction methods for land and water conservation project through the results of the feasibility study conducted.

Detailed methods can be referred to in previously published manuals.

Chapter 2.

PLANNING OF PROJECTS

CHAPTER 2 PLANNING OF PROJECTS

2-1 Act and Regulation

(1) Basic Policy Decision

Basic policy for soil and water conservation is decided under the Board of Land Development and the activities of the Board are shown below.

1) Members

Minister of Agriculture and Agricultural Cooperatives as Chairman, Permanent Secretary of Agriculture and Agricultural Cooperatives as Deputy Chairman, Secretary-General of the Office of National Economic and Social Development Board, Director-General of Land Department, Director-General of the Public Welfare Department, Director-General of the Royal Forest Department, Director-General of the Royal Irrigation Department, Director-General of the Agricultural Extension Department, Director-General of the Agricultural Department, Secretary-General of the Agricultural Land Reform Office, Secretary-General of the Office of Agricultural Economics and not more than three qualified persons appointed by the Minister as members, and the Director-General of the Land Development Department as member and Secretary.

2) The Board shall have the following powers and duties;

i) to formulate the criteria for land classification, land-use planning and land development, and to specify the area for land utilisation for submission to the Council of Ministers for approval so that they may be carried out by the State Agencies concerned.

ii) to prescribe the area for land survey.

iii) to specify measures for the improvement of soil or land or measures for the conservation of soil and water so that the state agency concerned may employ, advise and promote it among the farmers.

iv) to approve the establishment of land development agencies at various levels in any area in order to provide technical assistance, demonstration and advice directly to the farmers in cases where there are measures for the improvement of the land or the conservation of soil and water specified by the Board and where the said technique has to be employed and where it is not possible to provide the advice to farmers by other promotional activities.

v) to lay down regulations, terms or conditions relating to application for analysis of soil sample, for soil improvement or individual land development.

vi) to lay down regulations relating to the performance of duties by the sub-committees.

vii) to carry out any other works prescribed by the law or assigned to it by the Council of Ministers.

In the performance of its duties mentioned above the Board may direct the Department of Land Development to prepare and submit proposals to the Board for its consideration.

(2) Act and Regulation for proceeding Projects

In order to expand soil and water conservation projects, it is important to establish an act and regulation. The following form is recommended as the regulation to proceed the Project based on Land Consolidation.

	Land Consolidation	Soil and Water Conservation
Policy:	It should be undertaken in the irrigated area where plantation can be done all year round. In selection of the mentioned area, technological, socio-economic and political aspects should also be considered.	Land conservation area should be decided by separating reforestation area and land reform area. In selection of the mentioned area, existence of small scale water source is indispensable and technological, socio-economic and political aspects should also be considered.
Classification:	1. Intensive Development 2. Extensive Development	Based on the predicted soil loss and farmers economic condition. 1. Intensive Development 2. Extensive Development
Act:	Land Consolidation Act (1974)	Land Development Act (1983)
Committee:	Central Land Consolidation Committee (Chap.1 Sec.6) Provincial Land Consolidation Committee (Chap.1 Sec.8)	Board of Land Development (Sec.4) Sub-Committee
Office:	Central Land Consolidation Office (Chap.2 Sec.16) Provincial Land Consolidation Office (Chap.2 Sec.17)	Department of Land Development (DLD) Local Land Development Agency
Regulation to proceed the Project:	- Sec.27 & 28: Inquiring the willingness of every owner or possessors of land by the committee or its authorized person. - Sec.28: Agreement of over 50% of all the land owners	Farmers who want DLD to carry out the Project request Provincial Office to proceed to Project through Agricultural Association Agreement of over 70% of all the land owners

	Land Consolidation	Soil and Water Conservation
Regulation to proceed the Project:	- Sec.25: Declaring the area to be surveyed in the Government Gazette by MOAC	same as left
	- Sec.24: Prescribing the area of land consolidation programme in the Royal Degree	Prescribing the area of soil and water conservation program in the Royal Degree
	- Sec.29: Submitting the certificate of ownership of land to the provincial committee by the land owner etc.	same as left
	- Sec.30: Task of the provincial committee	Task of DLD
	- Sec.31 & 37: Construction works of land consolidation	same as left
	- Sec.38: Meeting of the landowners concerning the determination of land allotment	same as left
	- Sec.38: Approval by the provincial committee on the agreement of land allotment ① The value of land and any other property for common use shall not exceed 7% of the original assessed value. ② If the value exceed 7%, MOAC shall compensate by paying the amount in excess.	same as left
	- Sec.41: Issue the new certificate of land ownership	same as left

	Land Consolidation	Soil and Water Conservation
Regulation to proceed the Project:	- Sec.46: Determining the principles and procedures in collecting expenses for land consolidation by the Central Committee.	Determining the principles and procedures in collecting expenses for soil and water conservation by Board of Land Development
	- Sec.47: Paying the expenses for operation and maintenance of the land consolidation by the land owners in principle, procedures and rate prescribed by the Central Committee.	Paying the expenses for operation and maintenance of the soil and water conservation by the land owners in principle, procedures and rate prescribed by the Board of Land Development.

2-2 Project Implementation Procedure

Needless to say, DLD is the responsible agency to carry out the Project implementation and to coordinate other agencies concerned.

Project implementation procedure consists of the following items (Recommendation).

(1) Request and Implementation Procedure

① Farmers interested in soil and water conservation request farmers association according to the regulation.

② Farmers association checks its contents and requests provincial administration office. (Tambon, Amphoe, Changwat)

③ At the provincial level, soil and water conservation committee selects reasonable project due to urgency ad feasibility together with DLD staff.

④ After approval of the Project by DLD station, station request to DLD regional office.

⑤ Regional office asks LWCC to research and study the Project through station.

⑥ Regional office submits the report made by LWCC of the Project

⑦ After the approval of the Project by H.Q, H.Q asks budget setting down to Budget Bureau.

(2) Implementation Procedure

① After setting down the Budget of the Project by Budget Bureau, H.Q of DLD delivers it to Regional Office.

② Regional Office takes necessary legal measures and coordination to other agencies concerned. At the same time, Regional Office asks LWCC to prepare detailed design, final cost estimation and tender document by employing consultants firm if necessary.

③ In the case of contract basis, LWCC makes tendering to employ contractor for implementation of the Project.

④ Tender awarding is carried out by Evaluation Committee at H.Q.

⑤ After signing of contract with contractor, contractor carries out the Project under supervision by DLD station or employed consultants firm.

(3) Operation and Maintenance (O & M) of the Project

After the completion of the Project, O & M starts by the Project office assisted by DLD station, Farmers Association and related regional agencies.

In principle agricultural management and technical assistance is given by DLD and financial coordination shall be given by Farmers Association and Regional Agencies concerned.

(4) Monitoring of the Project

All input and output of the Project shall be recorded by the Project Office and shall report to LWCC through DLD station.

LWCC shall keep the record and evaluate the effectiveness of soil and water conservation measures each 2 years. This result shall be informed to the Project Office to make the Project more successful.

Monitoring items are considered as follows;

① Soil loss condition

② Unit yield of crop production

③ Input of nutrient and fertilizer

④ Usage of irrigation water

⑤ Working hour for farming

⑥ Balance sheet of farm from agricultural activities

⑦ Others

Above mentioned data shall contribute successful of the Project and new Projects.

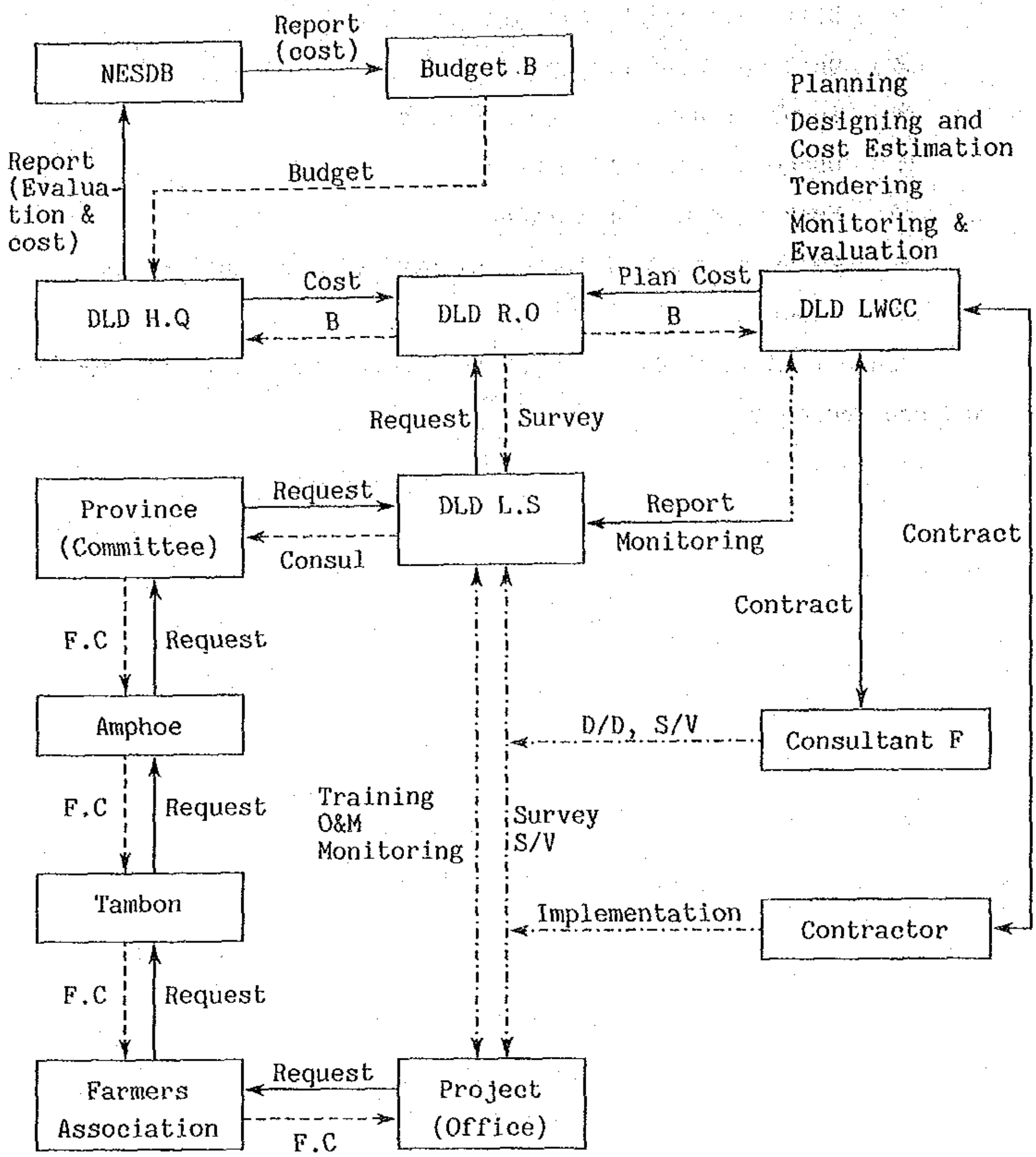


Figure 2.2-1 Procedure of the Project Formulation

Where	NESDB	:	National Economy and Social Development Board
	Budget B	:	Budget Bureau
	H.Q	:	Headquarters
	R.O	:	Regional Office
	L.S	:	Regional Station
	LWCC	:	Land and Water Conservation Center while, the Center is not exsisting now R.O shall take place the activities

2-3 Data Collection and Field Survey

Prior to planning and designing of the Project following data collection and field survey are required.

(1) Data Collection

a. Natural Conditions

- Topography and Geology
- Meteorology and Hydrology
- Soils and Land-use
- Soil Erosion
- Land and Water Resources

b. Socio-Economy

- Population Statistics
- Labor Force and Employment
- Income Level
- Nature of Title to Holdings and Size and Distribution of Holdings

c. Agriculture

- Agricultural Production
- Animal Husbandry
- Forestry
- Fishery

d. Agro-Industry and Industry

- Agro-Industry (Agricultural Products Processing)
- Industry

e. Rural Area and Infrastructure

- Roads and Transportation
- Water Supply and Electricity
- Facilities for Agriculture
- Social Services

f. Farmers Organizations

- Cooperatives
- Farmer's Associations
- Agricultural Groups
- BAAC Client Group

Details of each item are shown in Vol. III.

For understanding present conditions of the Project such data mentioned above should be prepared and arranged in computer of DLD Regional Office or LWCC (Land and Water Conservation Center under proposed).

(2) Field Survey

For carrying out detailed design and cost estimation, reconnaissance and field survey should be carried out.

Items and contents shall be explained in the following.

1) Topographic Survey

i) Target

- Scale S=1/5,000 or 1/2,000
- Contents coordinates
  contour : 1.0 m interval

ii) Procedure

① Procurement of existing topographic maps (S=1/50,000) and aerial photographs

② Ground Control Survey
Doppler positioning survey to determine coordinates and level of the Project.

③ Traversing and Leveling
Horizontal and vertical control survey by traversing and leveling are required to perform aerial photogrammetric mapping.

④ Topographic Mapping
The topographic map on a scale of 1/2,000 and 1/5,000 shall be plotted by the photogrammetric method. The results of the ground control surveys shall be used.

2) Cadastral Survey

With a view to clarify the boundary and the land right of each farmer in the Area, a cadastral survey shall be executed.

The data shall be obtained from the Regional Office of Land Department, MOI, after which confirmation of the boundaries shall be made at the site.

The boundary of each farmer and public area shall be plotted and drafted on the polyester base on a scale of 1/2,000.

3) Land-use Mapping

Present Land-use condition of each farmer shall be classified for the Project Area.

4) Erosion Mapping

The soil condition and present situation of erosion shall be surveyed by the Soil Engineers at the site.

The results of the survey shall be plotted and drafted on the polyester base on the scale of 1/2,000.

5) Groundwater survey

For development of groundwater the following field survey shall be executed.

i) Electric resistivity prospecting
   - prospected depth 50 m. 3 - 6 points/1 Project area

ii) Single well pumping test
   - recovery method 2 wells/1 Project area

iii) Well investigation
   - gauging groundwater level and well depth
   - water quality test (PH, a colon bacillus)
   - interview about wells
     (the using purpose, the existence of another water resource and the extent of drying up in the hot season, etc.)

From i), possibility of groundwater development shall be given due to layer of under ground.

From ii) and iii), capacity of exsisting shallow well shall be given.

Long term data (more than 2 years) of groundwater level shall be very useful for utilization of groundwater.

6) Hydrology

For the usage of surface water for irrigation in the dry season the following survey is very important.

- Measurement of runoff discharge
  - current meter method
  - triangulation weir method

For measurement of surface water of stream seepage, water flowing from the opposite direction and under the stream bed should be stopped.

Long term data (more than 2 years) of surface discharge shall be required to analyze available water for irrigation in the dry season.

7) Soil

Soil survey by field test, test-pit and auger boring shall be carried out and soil samples for laboratory analysis shall be taken from a representative profile in the Project area.

Items of soil analysis are as follows;

i) Physical properties (mainly relating to soil erosion)
   - Particle size distribution, Bulk density, Soil moisture, Hydraulic conductivity, Water holding capacity (1/3 bar, 15 bar)

ii) Chemical properties (mainly relating to soil fertility)
   - PH (H_2O), PH (KCl), Total-C, Total-N, Available-P, CEC Exchangeable bases (Ca. Mg. Na. K)

iii) Infiltration test by cylinder infiltrometer

Above mentioned soil investigation at the site is the most important due to the following.

The upland soils in the Eastern Region are mostly classified as Ultisols and Entisols. They are similar in surface soil humus content, clay mineral composition, soil reaction and drainage condition. Consequently, the differences of soil behavior mainly depend on the soil texture. Especially, erodibility of soil is highly influenced by the texture of surface soil.

The slopes of the pilot areas range mainly from 2 to 6 percent.

Relating to the soil erosion, LS factor of 4 percent slope is less than 1/3 of that of 10 percent slope for the same length of slope.

From the viewpoint of land slope, the degree of erosion in the soils of the East may not seem to be so severe. But actually, severe soil erosion is one of the most serious problems in the East, the causes of which may be the sandy surface soil as well as the heavy rainfall and cassava cultivation.

Most soils of the areas in the East have a SL to LS textured surface soil whose sand mostly consists of fine sand. They are highly erodible.

Moreover, as mentioned above, some soils have a very compact layer immediately below the plow layer, which will increase the runoff and soil erosion.

The soil texture is a very important property for estimating the soil erodibility in the Eastern Region. It is also one of the main properties for evaluating the soil fertility and suitability.

8) Soil Conservation

Contents of the Field Survey of the Project area are as follows;

i) Causes of soil erosion

a) Agricultural causes

b) Mechanical causes

c) Socio-Economic causes including farmers organization and regulation

ii) Proposed Countermeasures of Soil and Water Conservation

a) Agricultural measures

b) Mechanical measures

c) Irrigation facilities

d) Supporting measures

e) Organization and Management

iii) Estimated Benefit of Countermeasures

a) Physical

b) Economical

c) Mental (Intangible matters)

Since proposed project area is suffering from serious soil erosion due to many complicated causes, establishing proposed countermeasures, predicting benefits of the project and causes of soil erosion should be analyzed and classified as well as farmers needs.

Survey items concerning i) are as follows;

Agricultural causes

- mulching
- crop cultivation method contour, up-down, ridging etc.
- soil management
- others

Mechanical causes

- adopted measures
- drainage system
- structure of waterway
- road condition
- irrigation condition
- others

Socio-Economic causes

- economic condition of farmer
- history of farming
- marketing condition of each crop
- farm size and shape

- agricultural organization
- act and regulation as to soil conservation
- farmers needs

9) Irrigation

i) Water resources

a) Present conditions of water use
Irrigation area, Intake water, Capacity of facilities, etc.

b) Damage by drought
Damaged crop, area, amount, etc./Meteorological conditions of drought year/countermeasures taken by farmers

c) Water resources
Run-off, water temperature, water quality/right of water resources

ii) Irrigation plan

a) Crop root zone and crop yield

b) Soil texture, hardness, thickness of plowed soil and available soil layer

c) Proposed cropping pattern

d) Proposed irrigation method

iii) For farm pond

a) Materials for embankment

b) Foundation conditions by borehole drilling

10) Cost Estimation

i) Procurement of construction materials and labors

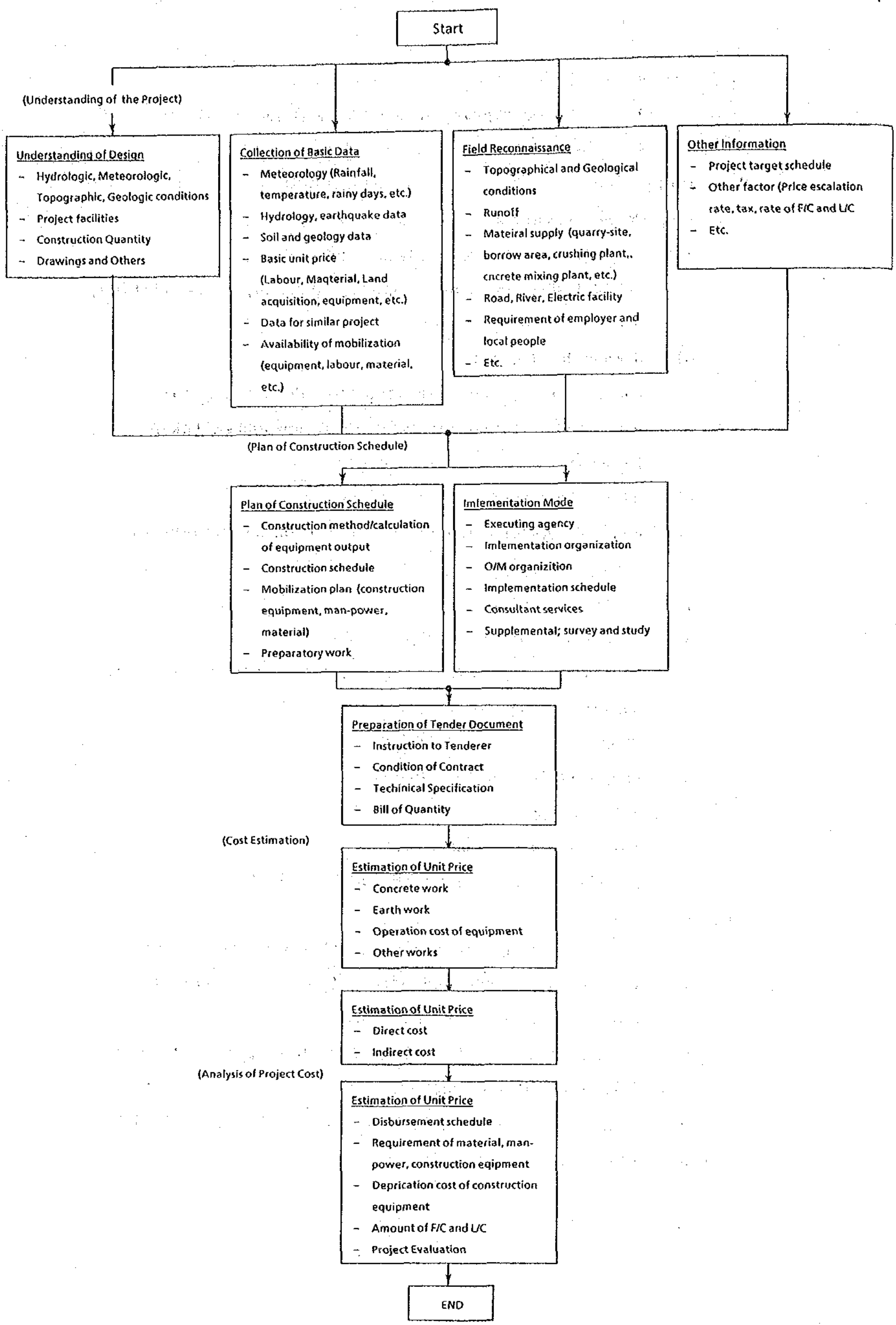
a) Procurement route and price of materials namely cement, timber, etc. by season

b) Procurement of labor force and their price by season

ii) Condition of contractors

Work plan chart for project implementation schedule and cost estimation is shown in Figure 2.3-1.

Figure 2.3-1 Work Flow Chart for Project Implementation



2-4 Predicting Soil Loss

To predict the soil loss volume of each Project Area, Universal Soil Loss Equation (USLE) is adopted. From the field survey of Project Areas, however, detailed information could be obtained concerning each factor of USLE, predicted soil loss volume could be calculated Method of calculation are explained in the following.

(1) Basic formula

$$A=P\cdot K\cdot LS\cdot C\cdot P$$

where A = Predicted total soil Loss Volume (ton/ha/hear)

R = Rainfall and Run-off

K = Soil Erodibility Factor

LS = Slope and slope-Length Factor

C = Crop Management Factor

P = Soil Conservation Practice Factor

(2) Each factor

1) Rainfall and run-off factor (R-value)

R-value shall be calculated from the following formulas ;

Chachoengsao, Chonburi and Rayong

$$R = 0.163 X$$

where X : Average annual rainfall, mm/year

R : Soil loss volume : ton/ha/year

Chanthaburi

$$R = 0.196 x - 13.4$$

quoted from DLD FAO PROJECT, TCP/THA/4408 (T), 1986

In the above, X value shall be assumed to be the maximum value form the range of each Province. This is because the possibility of soil loss is an important subject in the study.

The relation between average annual rainfall and R-value in USLE is as follows ;

Unit : mm

Province	Average annual	X-value	R-value
Chachoengsao	1,900 to 1,500	1,900	309.7
	1,500 to 1,400	1,500	244.5
Chonburi	1,900 to 1,500	1,900	309.7
	1,500 to 1,400	1,500	244.5
Rayong	2,500 to 2,100	2,500	407.5
	2,100 to 1,700	2,100	342.3
	1,700 to 1,500	1,700	277.1
Chanthaburi	2,900 to 2,500	2,900	555.0
	2,500 to 2,000	2,500	476.6

2) Soil erodibility factor (K-value)

K-value shall be set up from the texture property of top soil of each Project Area.

The relation between soil texture and K-value can be seen in the following.

Soil Texture		K-value
S	(sand)	0.05
LS	(loamy sand)	0.08
SL	(sandy loam)	0.34
SCL	(sandy clay loam)	0.23
L	(loam)	0.33
CL	(clay loam)	0.25
C	(clay)	0.21

To set up the soil texture of each Project Area, particle size distribution analysis shall be carried out in the US system.

3) Slope and slope-length factor (LS-value)

LS-value can be obtained from the following formula

$$LS = \left(\frac{L}{22.14}\right)^m (0.065 + 0.046s + 0.0065s2)$$

where L : slope length (m)

S : slope (%)

m : can be set up in the following

slope	m
≧ 5.0%	0.5
4.5 to 3.5	0.4
3.0 to 1.0	0.3
1.0>	0.2

This formula was quoted from [Predicting Rainfall Erosion Losses, A guide to Conservation Planning. United States Department of Agriculture, 1987]

Original formula is in feet and angle as follows ;

$$LS = \left(\frac{\lambda}{72.6}\right)^m (0.065 + 4.56\sin\theta + 65.41\sin^2\theta)$$

where λ : slope length in feet

θ : angle of slope

m : same as above

LS-factor can be given from Figure 2.4-1

In actual, slope-length of each Project Area is almost more than 300 m at present because of no tracing, no drainage and no road from top of the mountain to the stream only natural stream cut the slope-length.

In usual, SL-value in USLE is useful within 300 m, therefore, 300 m is used as maximum slope-length to calculate predicted soil loss of each Project Area.

4) Crop management factor (C-value)

C-value can be obtained from the following ;

crop	C-value	Note
Cassava	0.60	
Pineapple	0.50	
Sugarcane	0.45	
Maize	0.40	
Groundnut	0.50	
Cotton	0.40	
Tobacco	0.40	
Para-Rubber	0.50	young
	0.35	fully matured
Fruit tree	0.35	young
	0.10	matured
Tree	0.35	young
	0.10	matured

Data : (1) FAO PROJECT TCP/THA/4408 (T) 1986 Ⅲ/1

(2) FIFTH ASEAN SOIL CONFERENCE 1984 E 8.1

(3) SOIL CONSERVATION AND MANAGEMENT IN THE HUMID TROPICS 1985 P.180

If there are more than two type of crops in the same farm or same area, weighted means C-value shall be calculated. At present, type of trees are divided into young one and matured one. This difference shall be used to calculate predicted soil loss.

5) Conservation Practice Factor (P-value)

P-value shall be divided into agricultural measures and mechanical measures.

P-value can be obtained from the following,

Conservation measure	P-value
Agricultural measures	
· Contour Planting	0.70
· Cover Crop	
grazed	0.30
ungrazed	0.10

· strip cropping (more than 2 m)		0.25
Mechanical measures		
· Terracing	40 m interval	0.10
	50 m interval	0.15
	60 m interval	0.20
· Contour ridging		0.20
· Contour ploughing		0.50
· Sub-soiling		0.50

Data : same as c-value

When more than two types of measures shall be adopted at the same area, the most effective measures (P-value) shall be used in USLE.

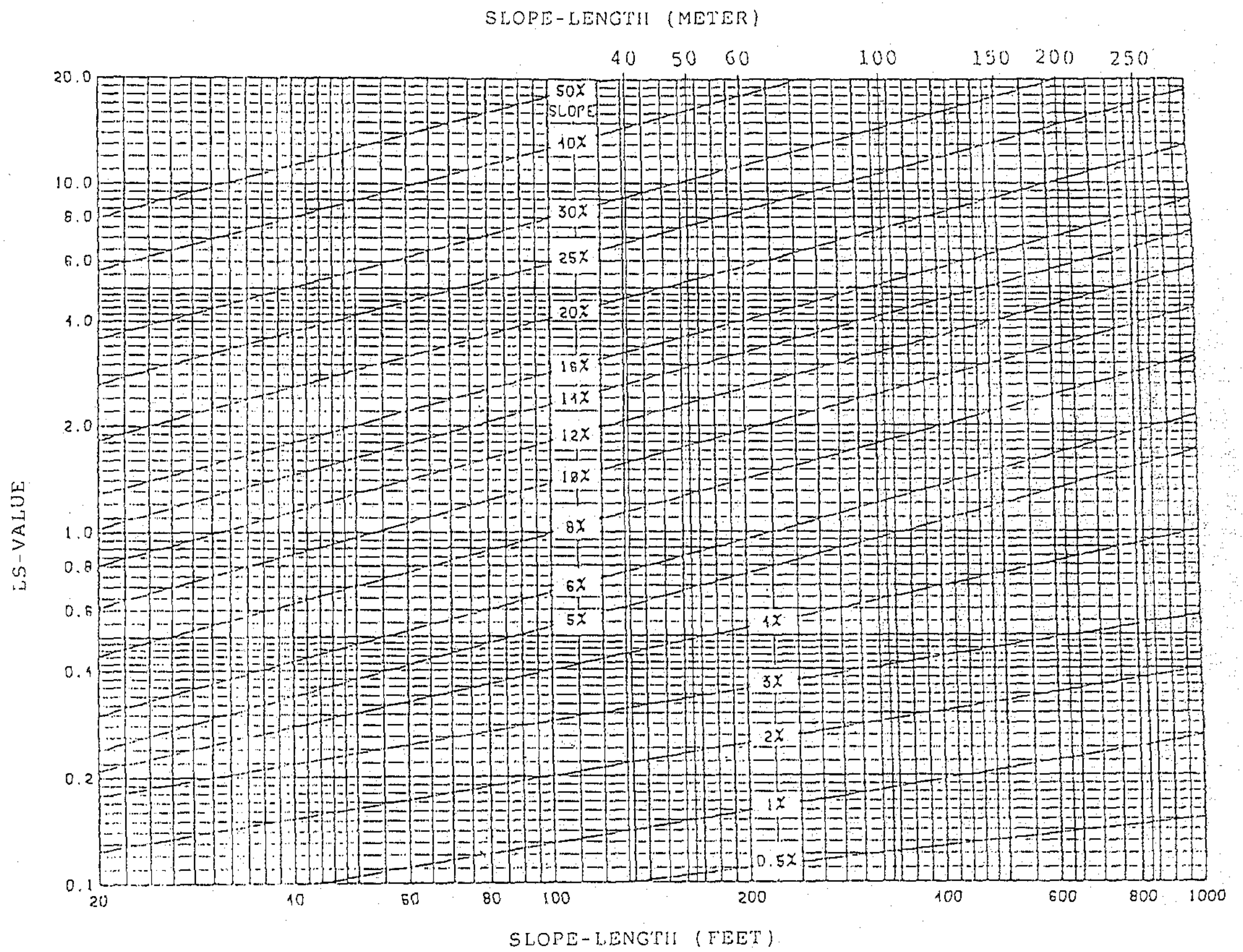


Figure 2.4-1 Slope and Slope-length Factor (LS-value)

[Reference]

USDA (United States Department of agriculture) suggests to use the following equation and nomograph for obtaining soil factor (K-value).

It seems to be very reasonable and useful, therefore, after confirmation of the result by field testing in Thailand it is recommended that DLD should extend the formula and the nomograph.

The content and method shall be explained in the following.

[Explanation]

The soil loss data show that very fine sand (0.05-0.10 mm) is comparable in erodibility to silt-sized particles and that mechanical-analysis data are much more valuable when expressed by an interaction term that describes the proportions in which the sand, silt, and clay fractions are combined in the soil. When mechanical analysis data based on the standard USDA classification are used for the nomograph in Figure 2.9-2, the percentage of very fine sand (0.1-0.05 mm) must first be transferred from the sand fraction to the silt fraction. The mechanical analysis data are then effectively described by a particle-size parameter M, which equals percent silt (0.1-0.002 mm) times the quantity 100-minus-percent-clay. where the silt fraction does not exceed 70 percent, erodibility varies approximately as the 1.14 power of this parameter, but prediction accuracy is improved by adding information on organic matter content, soil structure, and profile permeability class.

For soils containing less than 70 percent silt and very fine sand, the nomograph (Figure 2.4-2) solves the equation :

$$100K = 2.1\ M^{1.14}\ (10^{-4})(12-a) + 3.25\ (b-2) + 2.5\ (c-3)$$

where

M = the particle-size parameter defined above,

a = percent organic matter,

b = the soil-structure code used in soil classification, and

c = the profile-permeability class.

The intersection of the selected percent-silt and percent-sand lines computes the value of M on the unidentified horizontal scale of the nomograph. (Percent clay enters into the computation as 100 minus the percentages of sand and silt.)

The data indicate a change in the relation of M to erodibility when the silt and very fine sand fraction exceeds about 70 percent. This change was empirically reflected by inflections in the percent-sand curves at that point but has not been described by a numerical equation.

Nomograph Solution

With appropriate data, enter the scale at the left and proceed to points representing the soil's percent sand (0.10-2.0 mm), percent organic matter, structure code, and permeability class as illustrated by the dotted line on the nomograph. The horizontal and vertical moves must be made in the listed sequence. Use linear interpolations between plotted lines. The structure code and permeability classes are defined on the nomograph for reference.

Many agricultural soils have both fine granular topsoil and moderated permeability. For these soils, K may be read from the scale labeled "first approximation of K", and the second block of the graph is not needed. For all other soils, however, the procedure must be completed to the soil erodibility scale in the second half of the graph.

The mechanical analysis, organic matter,and structure data are those for the topsoil. For evaluation of K for resurfaced subsoil horizons, they pertain to the upper 6 in of the new soil profile. the permeability class is the profile permeability. Coarse fragments are excluded when determining percentages of sand, silt, and clay. If substantial, they may have a permanent mulch effect which can be evaluated from the upper curve of the cart on mulch and canopy effects and applied to the number obtained from the nomograph solution.

Confidence Limits

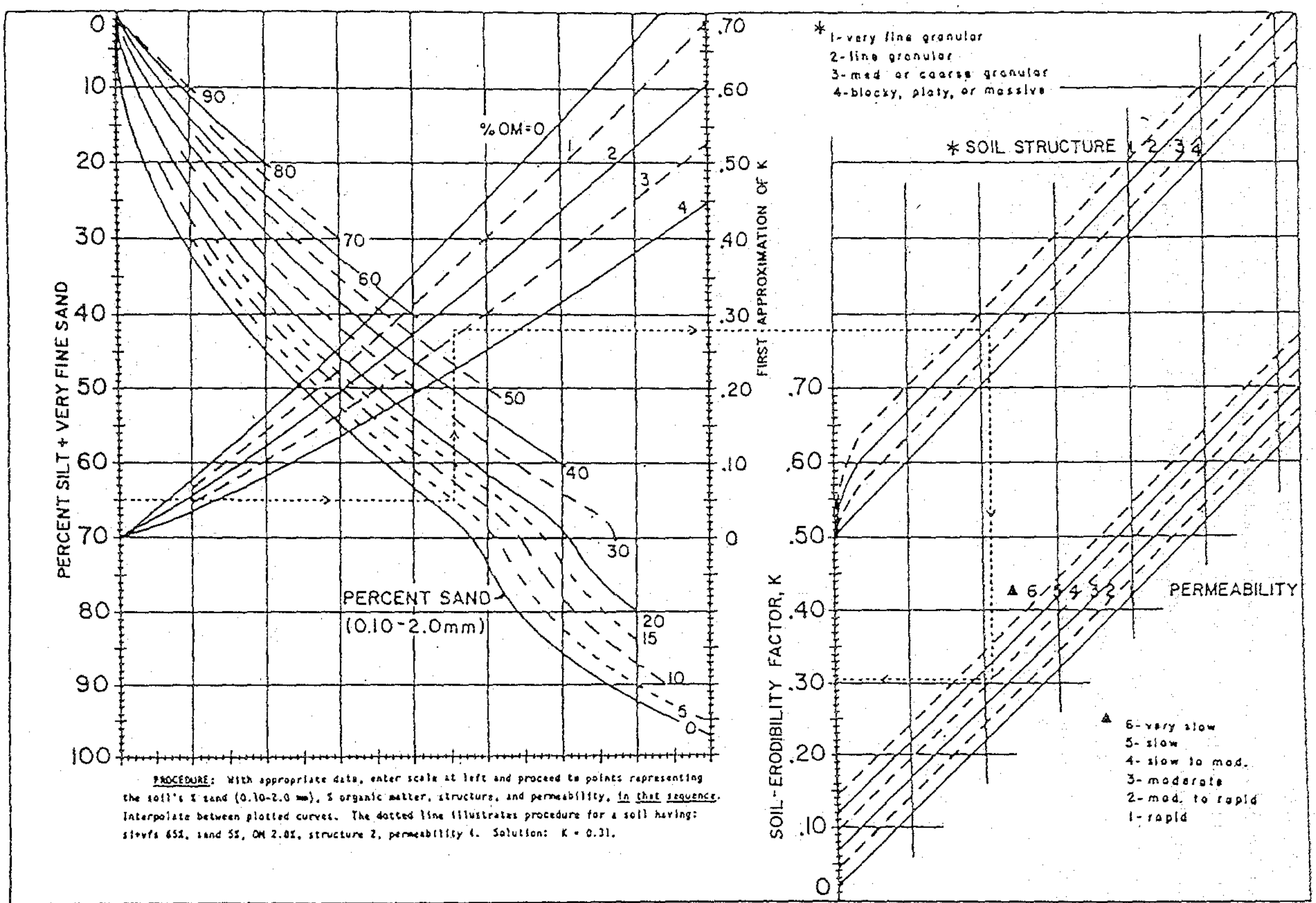
In test against measured K values raging from 0.03 to 0.69, 65 percent of the nomograph solutions differed from the measured K values by less than 0.02, and 95 percent of them by less than 0.04. Limited data available in 1971 for mechanically exposed B and C subsoil horizons indicated about comparable accuracy for these conditions. However, more recent data taken on resurfaced high-clay subsoils showed the nomograph solution to lack the desired sensitivity to differences in erodibilities of these soil horizons. For such soils the content of free iron and aluminum oxides ranks next to particle-size distribution as an indicator of erodibility.

some high-clay soils form what has been called irreversible aggregates on the surface when tilled. these behave like larger primary particles.

[Data Source]

Predicting Rainfall Erosion Losses A Guide to Conservation Planning

Science and Education Administration United States Department of Agriculture in cooperation with Purdue Agricultural Experiment Station, Dec. 1978.



Where the silt fraction does not exceed 70 percent, the equation is $100\ K = 2.1\ M^{1.14}\ (10^{-4})\ (12 - a) + 3.25\ (b - 2) + 2.5\ (c - 3)$ where M = (percent si + vfs) (100 − percent c), a = percent organic matter, b = structure code, and c = profile permeability class.

Figure 2.4-2 Soil Erodibility Nomograph

Chapter 3.

DESIGNING OF PROJECTS

CHAPTER 3 DESIGNING OF PROJECTS

3-1 Farm Management and Agriculture Measures

(1) Farm management

Basic idea for planning and designing of farm management in the project area is summarized as follows;

1) Crops to be suggested as substitutes for cassava should be unerodible and economically more stable and rewarding as well.
2) Judging from natural environment, national policy of crop diversification and economical circumstances, tree or fruit tree crops such as Para-rubber, durian and mango etc. will be the main crops for cassava. Durian will be emphasized especially where water is available because of economical reason.
3) To cope with the economical stress to farmers in the initial several years of such perennial crop's cultivation mentioned above, intercropping of annual crops such as cassava and pineapple, etc. is suggested.
4) From the viewpoint of agricultural product processing, pineapple will continue to be one of the most promising cash crops in future.
5) Though cassava is the crop to be replaced due to its erodibility and economical unstableness, it is the most adaptable crop in the natural condition of the area. It will be cultivated for a certain long time to come as the main annual cash crop. For that, improving cultivation technology e.g., application of more fertilizer, or extension of new clone "Rayong 60", is necessary. Subsidizing policy of fertilizer is strongly needed to get high productivity, not only in cassava but also in other crops.
6) No specific vegetable crop is emphasized but where water is available all the year round, such as surrounding area of pond, vegetable cultivation is economically hopeful. Demand for vegetables will increase with marketing development.

7) Covering land surface with grasses is the best way to prevent erosion and this leads to animal husbandry industry. In this case, it is necessary to test the adaptabilites of these grasses to the area at first. Even after overcoming this problem, there are some to be solved, such as technical know how of animal feeding, water resources for animal and cooperation of related agencies.

8) Marketing and crediting are two main economical problems for farmers. Though these are very urgent issues to be tackled but they are policy matter of government.

9) More cooperation among related agencies regarding agricultural improvement, especially DLD, DA and DOAE are strongly needed from agro-technical view point.

(2) Allocation of suggested crops to the area

It is rather easy to select and decide the area of crop to replace cassava. The most difficult problem will be how to allocate the crop to the present fields, which belong to each individual farmer.

Basic principle should be as follows in that respect.

1) Merits of new planting system should be shared by all the farmers in the watershed who will invest some amount of money to the project.

2) Planting of perennial crops like fruits tree or Para rubber will be along contour lines to prevent erosion.

3) Loss of farmland by making water reservoirs should be compensated by any means.

4) Exchange and consolidation of farmland is necessary for implementation of the above. This is one of the biggest problems in this project and cooperation between personnel and organizations is badly needed.

5) New organizations are suggested as follows ;

i) Water users' association

ii) Production type agricultural cooperation

i) will handle all issues related to water such as maintenance of pumps, irrigation facilities and cycle of irrigation to each plot, etc.

ii) will be in charge of crop production such as cropping pattern and marketing problem etc.

6) The idea of 1) and 2) is shown schematically in Figure 3.1-1.

(3) Agricultural measures

Since the topography of project areas is mostly undulating and not so steep farms are observed, it is suggested that no drastic countermeasures against erosion will be necessary.

As the agricultural approaches to this problem, next five items are mentioned.

1) Mulching :

This is to protect soil surface by some grassed, plant residue or some other materials against rain or wind. As line-mulching material, some cover crops are recommended. As now-line mulching material, rice straw is most suitable but it is sometimes very difficult to collect in the area.

2) Cropping method :

This includes rotation-and inter-cropping etc. to kup soil property in good condition by cultivation of different non-erodible crop or by covering base soil with intercrop, expecting mulching effect.

3) Cultivation method :

This means strip cultivation, contour cultivation, combination of these method etc. with some modification.

As mentioned earlier, the slope of almost all farmland in the area is below 10% and contour strip cultivation will be the most practical method. Needless to mention that consensus of related farmers is essential for execution of this operation and this might be the biggest problem to be tackled.

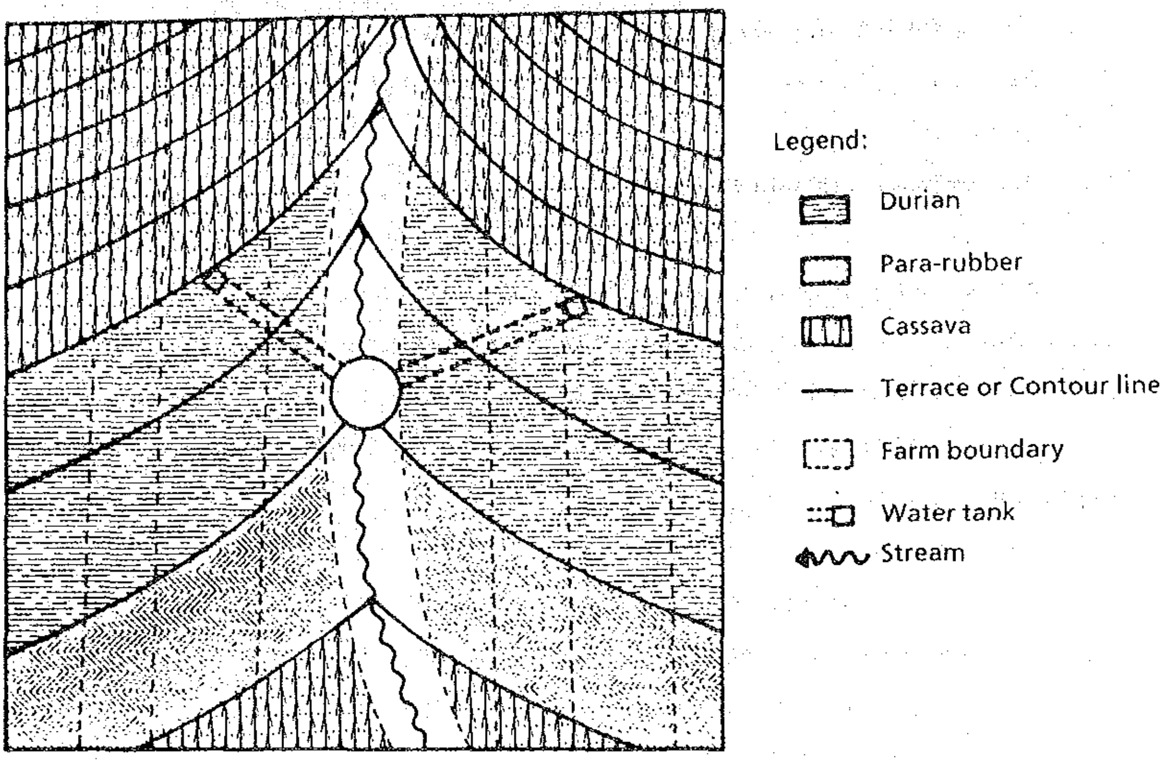


Figure 3.1-1 Schematic Map of Crop Allocation

3-2 Mechanical Measures

(1) Basic concept of mechanical countermeasures for soil conservation

Mechanical measures should be considered and established on the balance of input and output of the Project.

Assuming 30 years as the Project life, the Project should be feasible.

Basic countermeasures for soil conservation are given as follows in order of their priority.

1) Establishment of drainage system

Classification of drainage canals is as follows ;

- Catching ditch (canal)
  To catch surface runoff water, normally constructed in the direction of the contour
- Collecting ditch (canal)
  To collect discharges from catching ditches, constructed at a right angle to contour direction, discharge increases gradually
- Draining ditch (canal)
  To collect discharges from collecting ditches, there are trunk ditches and branch ditches

Velocity of the surface flow (surface laminar flow) on the soil is variable depending on slope, roughness coefficient and length. To reduce the capacity of soil transportation by flow (tractile force) shortening the water way, reducing the slope and increasing surface roughness shall be adopted. Therefore, contour cultivation (contour strip) is effective for soil conservation. However, if the collecting ditch is not strong enough damage to farm land shall occur, therefore, the structure and materials of collecting canals should be selected carefully. Figure 3.2-1 shows an illustration of the drainage system.

The establishment of a drainage system is the most important work of a farm land development project and land consolidation project.

Therefore, how to establish the drainage system shall be explained in section 3-4 in the Guideline.

2) Farm road construction

Farm roads have functions for both farm management and soil conservation.

Farm roads are divided into several grades from farm roads to trunk agricultural roads, the same as the drainage system. Normally, drainage ditches shall be constructed beside farm roads.

The conditions of farm road construction are not so limited owing to land holding areas per farm of 50 rai (8 ha) and a slope gradient of less than 10% in the East of Thailand.

Therefore, how to minimize the construction cost of farm roads shall be very important.

3) Terrace construction

From the viewpoint of soil erosion, making farm land in steep areas adapting the bench terracing method causes soil erosion and disasters and is not highly recommended since a lot of the earth works and slope protection works are very difficult and costly, particularly under sandy soil conditions in the East.

Therefore, prior to selecting this method, the land-use plan should be considered from farm land to forest or grass land.

On the contrary, graded terrace and contour terrace are very useful to prevent soil erosion because of shortening the slope length of farm land. Therefore, graded terrace shall be adopted in Project areas.

4) Farm pond (Tameike) construction

The functions and effectiveness of farm ponds are as follows ;

a. To deposit soil in the drainage system (soil conservation).

b. To be able to use storage water for irrigation and domestic use.

c. To make soil downstream of the pond moist.

In particular, to supply water to parched soil is very useful for soil conservation.

The most important merit of the Farm Pond is to use storage water for irrigation. Drop diversification and crop conversion from cassava to orchard can be realized by irrigation without failure or risk to farmers.

5) Standard field lot and farm land block

Farm land consists of farm land blocks and field lots.

Farm land blocks are enclosed by farm roads and divided in to several field lots. It is presumed that field lots shall be 100 m (length) × 20 m (width) and the length shall lie in the contour direction and the width at a right angle to the contour direction.

In general the shape of field lots and arrangement of farm roads shall be decided from crops, coefficient of farming machinery and arrangement of the drainage system for soil conservation. Figure 3.2-2 shows that there are many arrangements of farm roads. In general, for erodible areas, the interval of vertical roads (at a right angle to the contour direction) is shorter than the horizontal road (contour direction) in order to drain excess water from the field as soon as possible.

The basic plan is recommended as follows ;

a. Interval of vertical roads shall be 100 m ~ 200 m.

b. Interval of horizontal roads shall be 200 m ~ 500 m.

c. Drainage of the field shall be done using natural topographic slope to the contour direction.

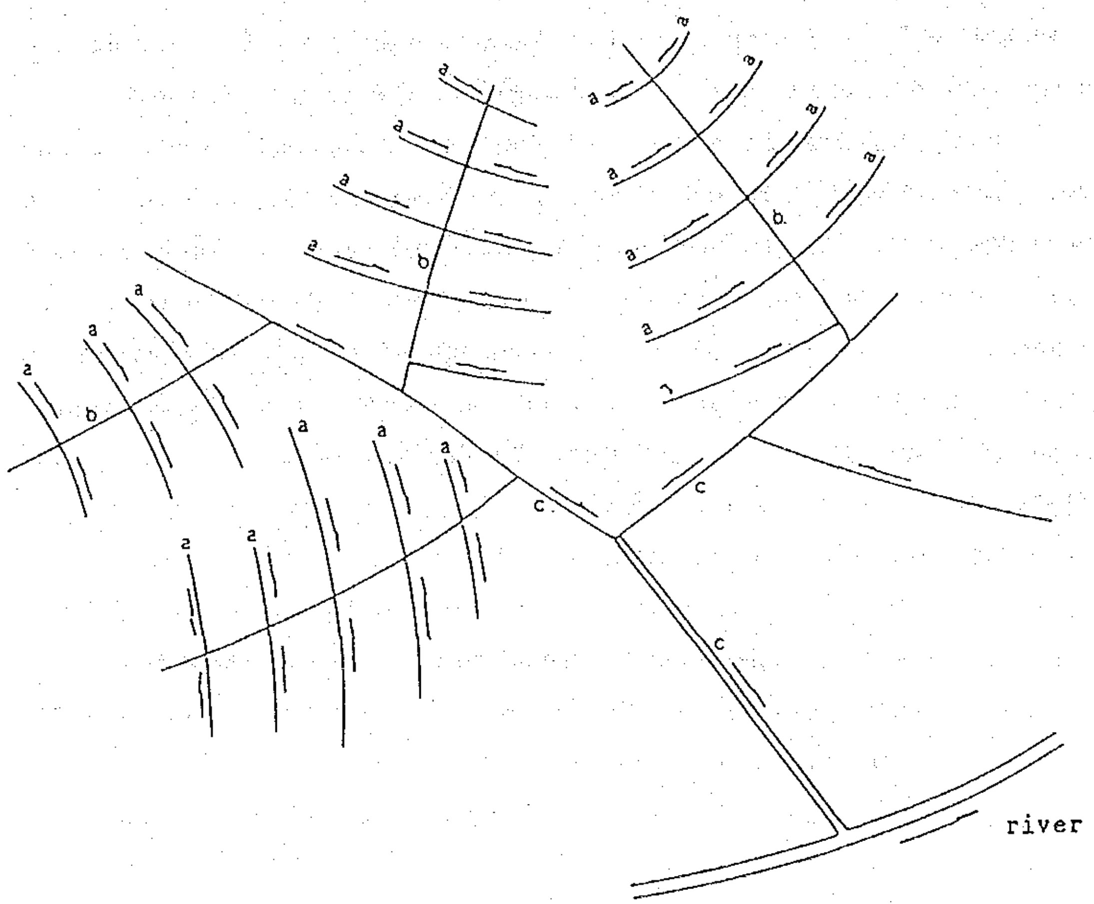
d. Drainage system shall be constructed beside farm roads in principle.

e. Vertical roads and horizontal roads cross at right angles in principle.

For soil conservation, road arrangement should be high in density as much as possible.

6) Land grading

The topographic condition in the East is comparatively flat with 3~10% slope gradient and rolling. Therefore, land grading shall be carried out according to natural slope without earthwork on a large scale.

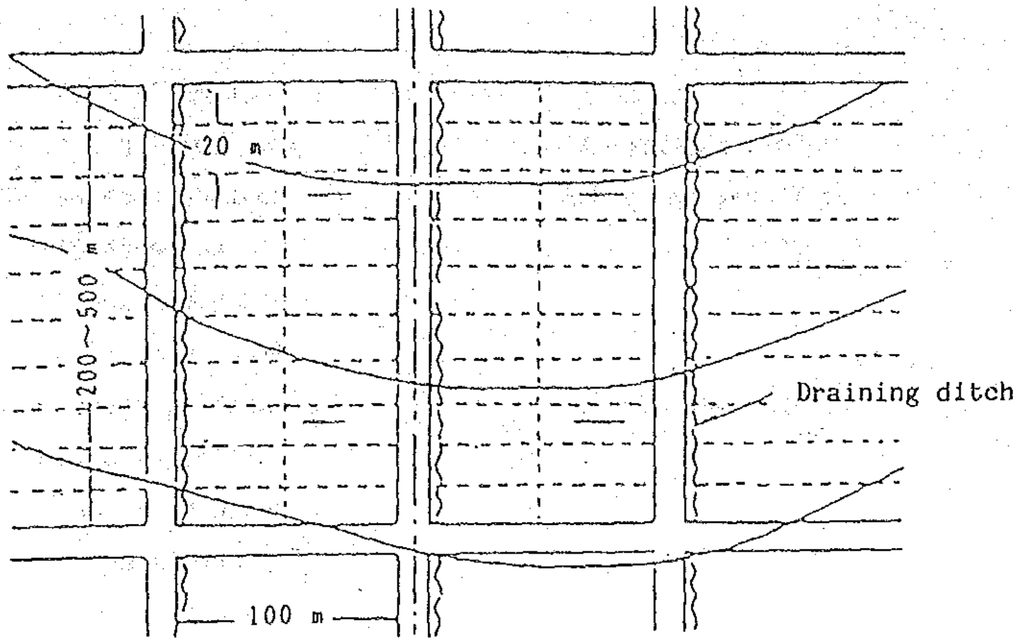


a : Catching ditch

b : Collecting ditch

c : Draining ditch

Figure 3.2-1 Drainage System Diagram



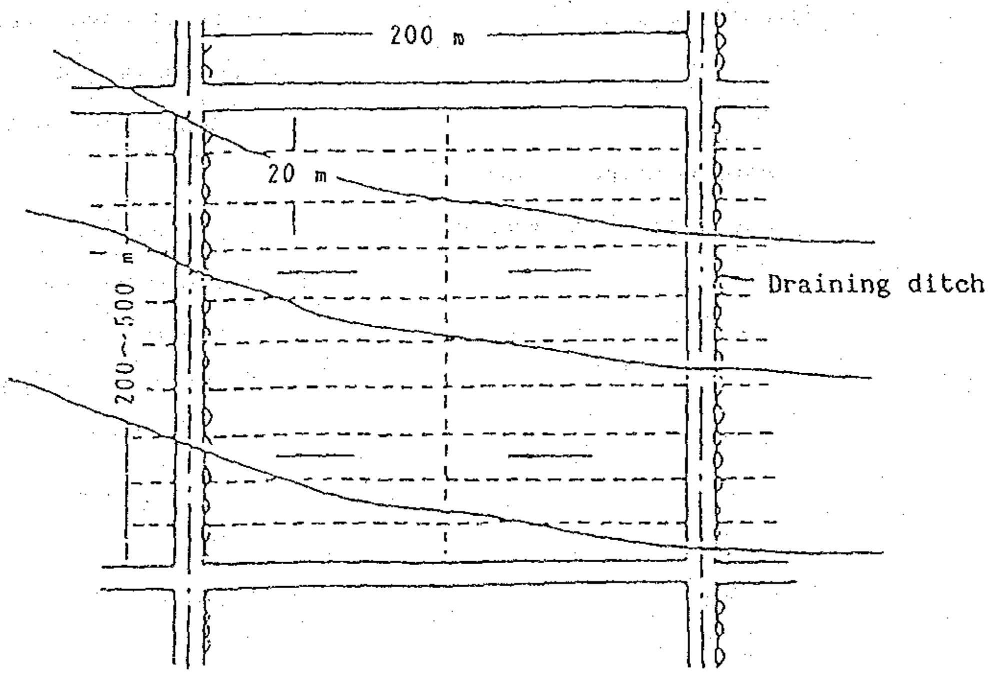


Figure 3.2-2 Plan of Farm Land Consolidation

(2) Items and types of mechanical measures

Mechanical measures shall be classified as follows;

category	items
a) Soil management system	. Sub soiling
b) Terracing system	. Contour terrace
	. Graded terrace
	. Bench terrace
	. Zing terrace
c) Drainage system	. Catching ditch
	. Collecting ditch
	. Draining ditch
	. Appurtenance
	drops
	sediment trap
	connecting pit
	rectifying pit
d) Farm road system	· lateral road, vertical and horizontal
	· trunk road (main road)
e) Farm Pond (Tameike)	
f) Check dam (Sediment pond)	· Woven-wire dam
	· Brush-wood dam
	· Loose-rock dam
	· Plank or slab dam
	· Masonry dam
	· Concrete dam
	· Earth dam
g) *Slope protection*	· *Spray method*
	· Sodding
	· Concrete wall
	· Wooden wall
h) Others	· Sand bag
	· Woven-wire mat

Each measure shall be selected depending on actual site conditions of the Project.

(3) Specification and application criteria

Specification and application of measures are explained in Table 3.2-1. In the table, Contour Terrace shall be included in the Graded Terrace and Zigg Terrace shall be omitted to avoid large earth movement.

Table 3.2-1 Specification and Application of Measures (1/4)

Measure	Specification	Application
1. Sub-Soiling	a. To break hard subsoil b. Proposed depth = 0.60 m	· Slope : 3 %~10 % · Soil : any type · Crop : any crop
2. Contour Ridging	a. To make ridge for planting b. Proposed height = 0.30 m	· Slope : 3 % ~ 10 % · Soil : any type · Crop : field crop; vegetable
3. Graded Terrace	a. To make contour bank and grass waterway b. Allowable ditch slope of waterway is 2% c. Horizontal interval = 40 m ~ 60 m	· Slope : 3 % ~ 15 % · Soil : any type · Crop : any crop
4. Bench Terrace	a. To make bench farm and catching ditch b. Surface slope 2% inversely c. Hmax = 1.0 m d. Slope protection = Sodding e. Slope = 1 : 2.0 f. All cutting method g. Farm Length = 6.0 ~ 12.0 m	· Slope : 6 %~2 % · Soil : any type · Crops : Fruit, vegetable (Note) To avoid large scale earth movement and slope protection, Hmax shall be decided as 1.0.
5. Grass Waterway	a. Vmax = 1.0 m/s (n = 0.04) b. I max = 3 % < 0.1 m^3/s 2% > 0.1 m^3/s c. Bottom W = 0.30 ~ 0.50 m H = 0.40 ~ 0.80 m Z = 1 : 1.5 ~ 2.0 d. Grass = Pangola, Bermuda	· Side ditch of Farm Road · Graded Terrace · Collecting ditch · Catching ditch
6. Masonry Waterway	a. Vmax = 2.5 m/s (n = 0.032) b. I max = 4% < 1.0 m^3/s 2% > 1.0 m^3/s c. Bottom W = 0.30 ~ 0.70 m H = 0.50 ~ 1.00 m Z = 1 : 1.0	· Side ditch of Farm Road · Collecting ditch · Draining ditch

Table 3.2-1 Specification and Application of Measures (2/4)

Measure	Specification	Application
7. Drop	a. dHmax = 1.00 m in Grass waterway and Masonry waterway b. B = 1.0 ~ 1.5 m c. L = 1.0 ~ 1.5 m d. H = 1.5 ~ 2.0 m e. Structure = Concrete Block + mortar f. Side Protection = Sand Bag	· Grass waterway (dH = 1.0 m) 4 % : 50 m interval 5 % : 34 m interval 6 % : 26 m interval · Masonry waterway (dH = 1.0 m) 4 % : no need 5 % : 100 m interval 6 % : 50 m interval (Note) Interval of drops shall be decided by hydraulic calculation considering slope of land and run off discharge.
8. Check dam (Sediment Pond)	a. H = 1.0 ~ 2.0 m b. Qmax = 3.0 m^3/s (1/10) c. Structure · Earth + Riprap · Woven-wire dam · Loose rock dam · Wood and rock · Sand bag · Others	
9. Farm Road	a. Effective width · Main = 5.0 m · Lateral = 3.0 m b. Total Width · Main = 6.0 m · Lateral = 4.0 m c. Laterite thickness = 0.2 m d. Banking = 0.10 ~ 0.30 m e. Stripping of original ground = 0.15 m	· Pavement type by shape Laterite < 10 % Gravel = 10~15 % Concrete > 15 % · Surface slope CS = 3 % CN. RY = 4% CT = 5 % (Note) Surface slope shall be decided depending on rainfall intensity at the site.

Table 3.2-1 Specification and Application of Measures (3/4)

Measure	Specification	Application
10. Canal Crossing	a. Structure	
	· Concrete Slab Bridge	$Q > 10\ m^3/s$ (1/10 Probability)
	· Concrete Paved Road	$Q = 3 \sim 10\ m^3/s$ (1/10 Probability)
	· Concrete Pipe	$Q < 3\ m^3/s$ (1/10 Probability)
11. Farm Pond Large Scale	a. Earth Dam · Height max = 6.0 m · Cut off Trench = 5.0 m · Crest Width = 5.0 m · Freeboard = 1.0 m · Slope : Upst. = 1 : 3.0 · Downst. = 1 : 2.5 · Slope Protection = Riprap and Sodding · Spillway (1/50) = Chute Type (Concrete) · Outlet = Bottom Type (steel pipe)	· Effective storage capacity (Ve) $Ve > 100{,}000\ m^3$ · Not to make farmer's house submerge
Small Scale	a. Earth Dam · Height max = 4.0 m · Cut off Trench = 4.0 m · Crest Width = 5.0 m · Freeboard = 1.0 m · Slope : Upst. = 1 : 3.0 · Downst. = 1 : 2.5 · Slope Protection = Riprap and Sodding · Spillway (1/50) = Chute Type (Masonry) · Outlet = Bottom Type (steel pipe)	· Effective storage capacity (Ve) $Ve > 10{,}000\ m^3$ · Not to make farmer's house submerge

(Note) · Type of earth dam shall be inclined one in principle because of lack of core type dam materials.
· To stop the water loss by seepage under the dam, the depth of cut off trench shall be carefully decided at detailed design stage.

Table 3.2-1 Specification and Application of Measures (4/4)

Measure	Specification	Application
12. Slope Protection	a. Spray Method · Sodding · Concrete mortar · Asphalt emulsion b. Sodding c. Stripped sodding	· Sprayed sodding terrace bank in the reservoir ditch · Concrete mortar Slope of the road · Asphalt emulsion catching canal
13. Gully Protection	a. Brush Wood Method b. Wooden pile and stem or branch of tree or bamboo shall be used. c. Sand bag (50~60 kg) cloth or vinyl bag and soil shall be used. d. Woven-wire Method (T x B x L = 0.60 m x 1.20 m x 2.4 m) woven wire and stone or rock (dia. > 10 cm) shall be used. e. Wood and Rock	(Note) This method shall be used as temporary countermeasure for disaster. However, Woven-wire method shall be used as a permanent measure to save cost sometimes.

3-3 Drainage System

(1) Basic concepts

Establishment of a drainage system is the most important mechanical measure for land and water conservation.

Excess surface water (run-off discharge) should be taken away from farm land to a stable natural river or trunk drainage canal immediately, smoothly and safely.

Such small watershed as 100~300 ha, small scale canal (same meaning as ditch and water-way) shall be required on farm land as a gutter of road, terracing and drainage canals. Therefore, in this chapter methodology for design of grass water-way and masonry water-way is explained.

More detailed design methods can be referred to in published manuals.

(2) Design discharge

To determine design discharge the following criteria shall be adopted.

1) Return period of excess probability for design discharge and its application.

5 years	:	catching canal (ditch)
10 years	:	collecting canal
		draining canal
50 years	:	spillway of dam

For the safety of facilities and to comply with unexpected matters such as sedimentation and vegetation, the above mentioned return period shall be adopted for each canal.

Data : Japanese standard of MAFF

2) Province and design discharge

From calculation of excess probability in each province based on long term daily rainfall data, specific flood discharge is as given in Table 3.4-12.

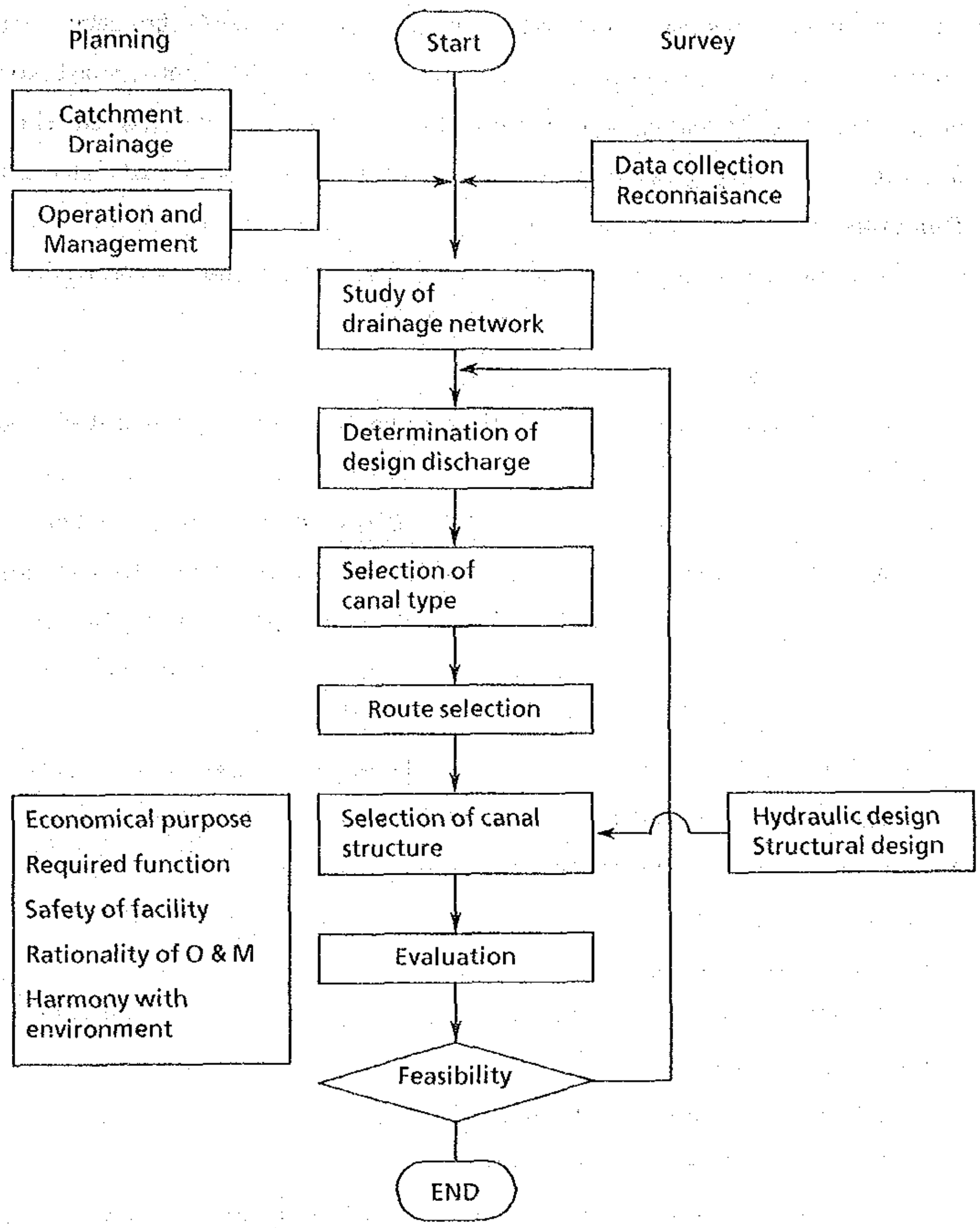


Figure 3.3-1 Procedure of the Drainage System Design

(3) Canal types and structures

The selection of the canal type greatly affects the function of the entire canal system, and also significantly affects the construction costs. It is, therefore, necessary to consider the conditions of the costs and future water management and maintenance system in the selection of the canal type, aiming at the entire fulfillment of its purpose and function.

Following canal type and structure shall be recommended for each canal.

	canal	structure
a.	Catching canal	• Grass water-way (planted sodding) • Sprayed type (sodding asphalt emulsion, concrete mortor)
b.	Collecting canal and Draining canal	• Grass water-way (planted sodding) • Masonry water-way (planted sodding) • Concrete lining water-way (planted sodding) • Concrete flume (ready made)

Types and structures shall be selected by detailed hydraulic caluculation considering the afore-mentioned factors.

(4) Hydraulic design

To determine the size and structure of canal detailed hydraulic calculation is required.

Method and formulas are explained in the following.

1) Allowable flow velocity

The design velocity of canals must be determined within the limits of two factors: the minimum allowable velocity which produces neither deposit of sand and earth nor growth of water weeds and the maximum allowable velocity which produces neither erosion of canal component materials by the flow not hydraulic conditions of flow in the canal.

i) Determination of the design velocity is one of the important factors for the design of canals and the cross sections of canal structures.

The design velocity is determined between the minimum and maximum allowable velocity taking into consideration the functions and sturucture of a canal.

ii) Minimum allowable velocity

It is not easy to determine the proper value of the minimum allowable velocity because there are undrefinable factors which place restrictions on the minimum allowable velocity. It is obtained so as not to produce sand deposits and hinder the flow capacity of the canal by the presence of water weeds.

In general, it is recognized that sand deposits are not produced at a mean velocity of 0.45 ~ 0.9 m/sec in a canal where the particle size of suspended sediment is not larger than silt, and that water weeds hindering the flow capacity of the canal will not grow when the mean velocity is more than 0.7 m/sec. Therefore, it is approvable that velocities for the most-frequent discharge and the discharge to study low water revetment should not be lower than the above values when applying them to irrigation and drainage canals.

The velocities in tunnels, culverts and siphons must be larger than those in the connecting open channels because when sand deposits are produced in these facilities, their flow capacities become constricted and it is difficult to remove such deposits.

The following velocity ratios in tunnel, culvert and siphon are generally applicable:

Tunnel, Culvert - more than 1.3 times the velocity in open channel

Siphon - more than 1.5 times the velocity in open channel

iii) Maximum allowable velocity

Since the maximum allowable velocity varies remarkably with materials used for canals and is unclear, experience and other examples must be considered.

Limited velocities found to be applicable to different types of materials used for canals are given in Table 3.3-1.

The maximum allowable velocity is required to be under 1.5 times of the value mentioned above for waterway, spillway in an irrigation canal and for structures used temporarily. In the case of a drainage canal, the above value is applied to discharges to study low water revetment.

The values indicated in the above table are not applied to chutes, drainage canals with steep slope which are protected with reinforced concrete or thick concrete and drainage canals equivalent to rivers.

In this case, the design velocity is determined after taking into account the canal structure, topography, geology and other practical case.

iv) Consideration for determination of design velocity

Hydraulic conditions in a canal must be carefully examined in determining the design velocity of an irrigation canal. Under the nearly critical flow conditions, the water surface in the canal tends to become unstable, producing waves which do not vanish quickly. These cause a lowering in the efficiency of the canal function. It is generally recognized that the stability of flow in the canal is controlled by the velocity, though it can vary owing to many factors such as discharge, velocity, change of cross-section area, bends, etc. A velocity of less than two-thirds of the critical velocity may be expected to stablize the water surface in the canal. Accordingly, the above velocity must be applied to conditions under sub-critical flow in the irrigation canal.

If a velocity larger than the above has to be adopted for any reason, necessary measures must be taken to heighten the canal wall and to provide special designs for division works, drops, etc. taking into consideration the water surface fluctuation, eccentric water surface at bend points of a canal. In addition, for facilities under supercritical flow conditions such as chutes, etc., the table is not applied and special attention must be given to the internal friction in the canal and hydraulic effects due to the changes in the cross-section of the canal such as enlargement, contraction and others.

Table 3.3-1 Maximum Allowable Velocity

Type	Flow Velocity (m s)	Type	Flow Velocity (m s)
Sandy soil	0.45	Thick concrete (approx. 18 cm)	3.00
Sandy loam	0.60		
		Thin concrete (approx. 10 cm)	1.50
Loam	0.70		
Clayey loam	0.90	Asphalt	1.00
Clay	1.00	Hollow block masonry (Buttrees less than 30 cm)	1.50
Sandy Clay	1.20		
		Hollow block masonry (Buttrees more than 30 cm)	2.00
Soft rock	2.00		
Semi-hard rock	2.50	Block masonry with concrete filled	2.50
Hard rock	3.00		
		Precast concrete pipe	2.50
		Steel pipe	5.00

2) Calculation of mean velocity

Dimensions of the cross section of a canal are determined, in principle, from the design dicharge calculated by mean of velocity formula.

The calculation of the uniform flow velocity formula for an open channel type canal and Hazer William's formula for a pipe line type canal.

i) Discharge of canal

The discharge of the canal is calculated using the following formula:

$$Q=A \cdot V$$

where, Q: Discharge (m^3/s)

A: Cross-section area (m^2)

V: Mean velocity (m/sec)

ii) Mean velocity formula of open channel type canal

The mean velocity of an open channel type canal in the above formula is calculated according to the Manning formula as a rule.

$$V = \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$$

where, V : Mean velocity (m/sec)

I : Hydraulic gradient (canal bed slope)

R : Hydraulic radius (m)

n : Coefficient of roughness

In this manual, this formula is applied mainly to open channels or culverts and siphons partially included in an open channel type canal.

For non-uniform flow condition, the energy gradient is substituted for the canal bed slope in this formula.

iii) Coefficient of roughness

Selection of coefficient of roughness

Selection of the coefficient of roughness is very important in applying the Manning formula, therefore, careful consideration is required in determining the coefficient on various influencing factors such as surface roughness, vegetation, bends, cross-section area and shape, velocity, hydraulic radius, sediment, source, suspended materials, canal conditions of operation and maintenance stage, etc.

In canals constructed with the same materials, the coefficient of roughness tends to become larger in the case of extremely slow velocity or small hydraulic radius. Standard values in the table are generally applied to design. It must also be considered that the smoothness of the internal section of the canal decreases gradually due to friction, scoure, etc. produced by the flow in the canal, and the growth of aquatic plants.

iv) Effects of bends, sedimentation and vegetation on coefficient of roughness

The following factors have an effect on the coefficient of roughness.

a) Canal bends: The coefficient of roughness (n) increases when a canal meanders because such meandering produces losses and sand deposits in the canal. In the case of low velocity, increases of n may be neglected. In general, n increases by about 0.002 as an allowance for canal bend losses when the canal has curves, and n in a natural meandering canal increases by 30%.

b) Sedimentation: n is affected by sand deposits in a canal and increases significantly in the case of non-uniform sediments such as sand-bars and sand ripples.

c) Vegetation: n increases with the growth of weeds in a canal.

Table 3.3-2 ① ~ ③ show coefficient of roughness depending on type and condition of canal.

Table 3.3-2 ① Coefficient of Roughness n

1) Lining, retaining walls, tunnels, culverts, siphons, and aqueducts

Materials and conditions of canals	Coefficient of roughness		
	Maximum value	Standard value	Maximum value
Concrete (east-in-place flume, culvert, etc.)	0.012	0.015	0.016
Concrete (shoterete)	0.016	0.019	0.023
Concrete (with precast flume, pipe, etc.)	0.012	0.014	0.016
Concrete (reinforced concrete pipe)	0.011	0.013	0.014
Concrete block masonry	0.014	0.016	0.017
Cement (mortar)	0.011	0.013	0.015
Asbestos cement pipe	0.011	0.013	0.014
Steel (locked bar or welded)	0.010	0.012	0.014
Steel (revet)	0.013	0.016	0.017
Smooth steel surface (non painted)	0.011	0.012	0.014
Smooth steel surface and pipe (painted)	0.012	0.013	0.017
Corrugated surface (steel sheet)	0.021	0.025	0.030
Cast iron (not painted)	0.011	0.014	0.016
Cast iron sheet and pipe (painted)	0.010	0.013	0.014
Chloride vinyl pipe		0.012	
Reinforced plastic		0.012	
Ceramic pipe	0.011	0.014	0.017
Earth lining		0.025	
Asphalt (smooth surface)		0.014	
Asphalt (rough stone)		0.017	
Masonry (rough stone wet masonry)	0.017	0.025	0.030
Masonry (rough stone dry masonry)	0.023	0.032	0.035
Wood (wooden gutter)	0.010	0.012	0.014
Wood (lined in thin layer, treated with creosote)	0.015	0.017	0.020
Rock tunnel with no lining on overall cross-sectional area	0.030	0.035	0.040
Rock tunnel with no lining except concrete placed on the bottom	0.020	0.025	0.030
Vegetation coverage (turfing)	0.030	0.040	0.050

Table 3.3-2 ② Excavated or Dredged Canals

Materials and conditions of canals	Coefficient of roughness		
	Maximum value	Standard value	Maximum value
Earth canals, uniform and straight			
1) No weeds (immediately after completion of the canal)	0.016	0.018	0.020
2) No weeds (after the canal has been exposed to weather)	0.018	0.022	0.025
3) Sand (no weeds)	0.022	0.025	0.030
4) No weeds except some short grases	0.022	0.027	0.033
Earth canals, non-uniform and bent			
1) No vegetation coverage	0.023	0.025	0.030
2) Some weeds	0.025	0.030	0.033
3) Weeds and aquatic plants are growing densely	0.030	0.035	0.040
4) Earth bottom and rubble at both sides	0.028	0.030	0.035
5) Earth bottom and weedy sides.	0.025	0.035	0.040
6) Cobblestones on the bottom and no weeds at either side	0.030	0.040	0.050
Drag line excavation and dredging			
1) No vegetation coverage	0.025	0.028	0.033
2) Some shrubs on shore	0.030	0.050	0.060
Rock excavation			
1) Smooth and uniform	0.025	0.035	0.040
2) Irregular	0.035	0.040	0.050

Table 3.3-2 ③ Natural flow canals

Materials and conditions of canals	Coefficient of roughness		
	Maximum value	Standard value	Maximum value
Small canals on flat land 1) Not weedy, straight. Neither cracks nor crevices are seen when	0.025	0.030	0.033
2) Weedy and stony. Neither cracks nor crevices are seen when water reaches the high water level	0.030	0.035	0.040
3) Not weedy but meandering. Some crevices and shallows are seen	0.033	0.040	0.045
4) Some weeds and stones. Meandering. Some a byses and shallows are seen.	0.035	0.045	0.050
5) Meandering. Some crevices and shallows are seen. Water level is low. The changes in gradients and cross-sections are few.	0.040	0.048	0.055
The same as 4). Somewhat stony	0.045	0.050	0.060
7) Weeds and deep crevices are seen along moderate flow areas.	0.050	0.070	0.080
8) Area where weeds grow densely, deep crevices are seen, or trees are present.	0.075	0.100	0.115
Canals in mountainous areas. No plants in canals. River banks are usually steep. The trees and shrubs along river banks are flooded when water reaches the high water level. 1) Cobblestones and gravel on river beds	0.030	0.040	0.050
2) Large cobblestones on river beds	0.040	0.050	0.070
Large canals 1) Constant cross sections without large cobblestones or shrubs	0.025		0.060
2) Rough and irregular cross sections	0.035		0.100

(5) Calculation samples

Hydraulic calculation samples for grass waterway and masonry waterway are shown in Table 3.3-3 and 3.3-4.

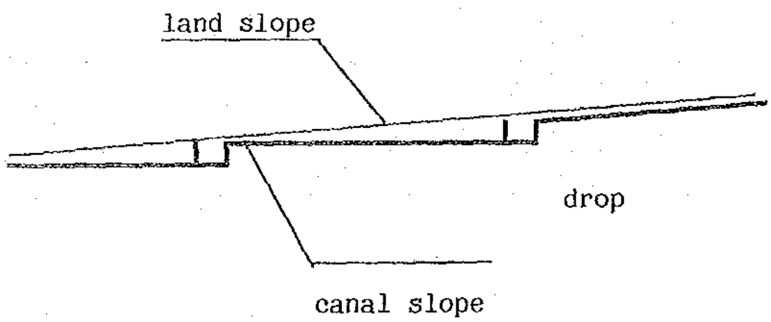
Cross section of a canal shall be mainly determined from a combination of the following three factors.

① canal bed slope (I)

② discharge (Q)

③ maximum velocity (Vmax)

The planned cross section should be determined within maximum velocity. Therefore, drops shall be used to adjust land slope and canal slope.



Vmax = 1.0 m/s

Table 3.3-3 Grass Water-way

I	Z	B_1	B_2	H_1	H_2	d	A	P	$R^{2/3}$	$I^{1/2}$	n	V	Q
		(m)	(m)	(m)	(m)	(m)	(m^2)	(m)				(m/s)	(m^3/s)
1/100	2.0	0.30	1.90	0.40	0.20	0.20	0.14	1.19	0.24	0.100	0.040	0.60	0.084
			〃			0.30	0.27	1.64	0.30	〃	〃	0.75	0.203
			〃			0.40	0.44	2.09	0.35	〃	〃	0.88	0.385
2/100			〃			0.20	0.14	1.19	0.24	0.141	〃	0.85	0.118
			〃			0.30	0.27	1.64	0.30	〃	〃	1.06	0.286
			〃			0.40	0.44	2.09	0.35	〃	〃	1.23	0.543
3/100			〃			0.15	0.09	0.97	0.20	0.173	〃	0.87	0.078
			〃			0.20	0.14	1.19	0.24	〃	〃	1.04	0.145
			〃			0.30	0.27	1.64	0.30	〃	〃	1.30	0.350
4/100			〃			0.10	0.05	0.75	0.16	0.200	〃	0.80	0.040
			〃			0.15	0.09	0.97	0.20	〃	〃	1.00	0.090
			〃			0.20	0.14	1.19	0.24	〃	〃	1.20	0.168
5/100			〃			0.10	0.05	0.75	0.16	0.224	〃	0.90	0.045
			〃			0.12	0.065	0.84	0.18	〃	〃	1.01	0.066
			〃			0.15	0.09	0.97	0.20	〃	〃	1.12	0.101
6/100			〃			0.05	0.02	0.52	0.11	0.250	〃	0.69	0.014
			〃			0.10	0.05	0.75	0.16	〃	〃	1.00	0.050
			〃			0.15	0.09	0.97	0.20	〃	〃	1.25	0.113

Cross Section

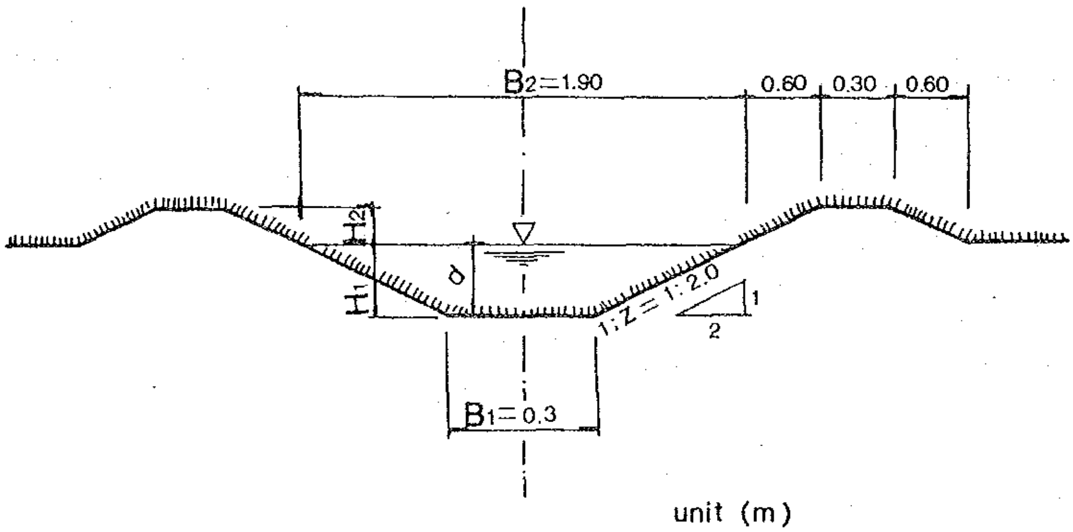


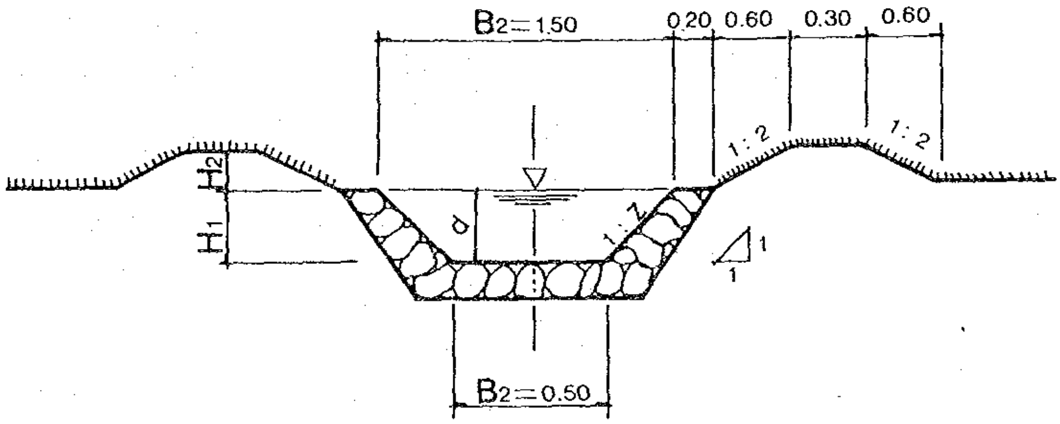
Table 3.3-4 Masonry Water-way

Vmax = 2.50 m/s

I	Z	B1	B2	H1	H2	d	A	P	$R^{2/3}$	$I^{1/2}$	n	V	Q
		(m)	(m)	(m)	(m)	(m)	(m^2)	(m)				(m/s)	(m^3/s)
2/100			1.50			0.40	0.36	1.63	0.37	0.141	0.032	1.63	0.587
			"			0.50	0.50	1.91	0.41	"	"	1.81	0.903
3/100	1.0	0.50	"	0.50	0.30	0.40	0.36	1.63	0.37	0.173	"	2.00	0.720
			"			0.50	0.50	1.91	0.41	"	"	2.22	1.108
4/100			"			0.40	0.36	1.63	0.37	0.200	"	2.31	0.833
			"			0.50	0.50	1.91	0.41	"	"	2.56	1.281
5/100			"			0.30	0.24	1.35	0.32	0.224	"	2.24	0.538
			"			0.39	0.35	1.60	0.36	"	"	2.52	0.882
			"			0.50	0.50	1.91	0.41	"	"	2.87	1.435
6/100			"			0.30	0.24	1.35	0.32	0.245	"	2.45	0.588
			"			0.32	0.26	1.41	0.33	"	"	2.53	0.657
			"			0.40	0.36	1.63	0.37	"	"	2.83	1.020
7/100			"			0.25	0.19	1.21	0.29	0.265	"	2.40	0.456
			"			0.28	0.22	1.29	0.31	"	"	2.56	0.564
			"			0.30	0.24	1.35	0.32	"	"	2.65	0.636

R = A/P

Cross Section



unit (m)

3-4 Irrigation Facilities

3-4-1 General

This text aims to introduce the basic ideas for design of irrigation facilities which will be constructed in pilot areas in the project area (8,840 km²), in accordance with the schedule of the Basic Plan established in Vol II.

Therefore, detailed design methods can be referred to from the manuals published for each specific item.

The procedure of design for irrigation facilities for upland crops is as shown in Figure 3.4-1.

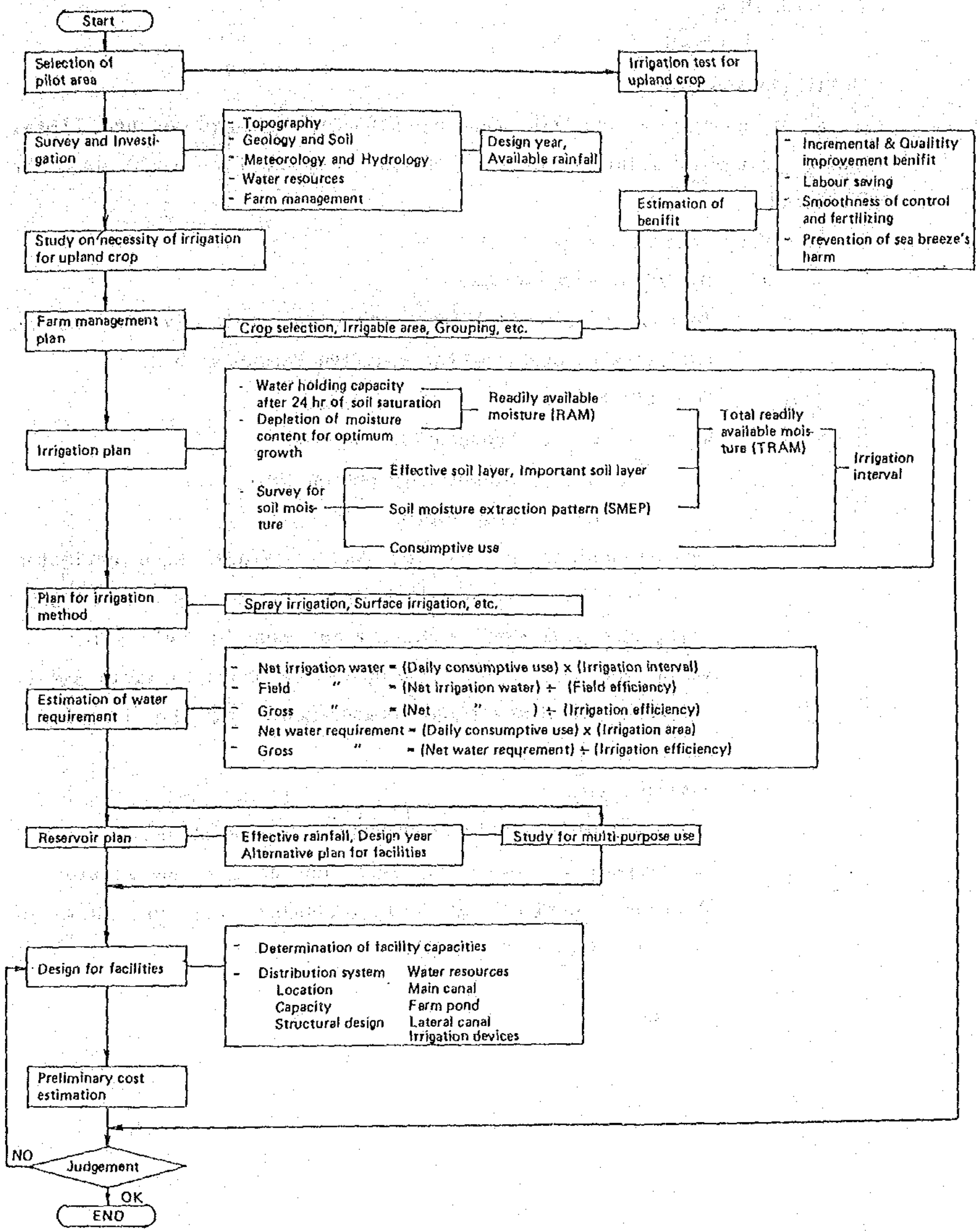


Figure 3.4-1 Flow Chart for Designing of Irrigation Facilities

3-4-2 Basic Plan

(1) Irrigation plan

After conclusion of the cropping pattern, consumptive use, total readily available moisture and irrigation interval for crops shall be determined.

1) Crop consumptive use (Cu)

i) Modified Penman Method

In case of non-effective data, crop consumptive use can be estimated by applying the modified Penman Method.

$Cu = ETo \times Kc$

Where, Cu ; consumptive use (mm)

ETo ; Evapotranspiration (mm)

Kc ; Crop factor

Evapotranspirations for the four provinces were estimated based on the climatological data for 30 years 1956~1985. which were published by M.D are as shown in Table 3.4-2. While, the crop factor is proposed as shown in Table 3.4-1, referring to the actual measurements by the irrigation station, RID.

ii) Observed data

The available data for consumptive use which were observed by irrigation research stations such as Mae-tang station in Chiangmai, Samchuk station in Suphunburi etc. are shown in Table 3.4-3 (1/3) to (3/3).

Table 3.4-1 Crop Factor (Kc) for Representative Crops

Crop / Month		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
1) Paddy													
- LV	1/	1.0	1.0	1.2	1.35	1.3	1.2	1.1					
- HYV	1/	1.0	1.25	1.35	1.3	1.1							
2) Upland Crop													
- Sugarcane	1/	0.6	0.8	1.0	1.2	1.25	1.2	1.15	1.0	0.85	0.65	0.6	0.50
- Cassava	2/	0.2	0.3	0.4	0.5	0.6	0.6	0.5	0.4	0.3	0.3	0.2	0.2
- Pineapple	2/	0.4	0.4	0.6	0.8	0.9	0.9	0.7	0.6	0.5	0.4	0.4	0.3
- Mungbean	2/	0.7	0.7										
- Soybean	2/	0.85	0.85	0.85	0.85								
- Groundnut	2/	0.8	0.8	0.8	0.8								
- Sweet corn	2/	0.8	0.8	0.8									
3) Tree Crop	2/	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Note:

1/: Based on the actual measurements by Irrigated Agricultural Section, RID in 1979 (Refer to the feasibility study report on the Mae Wang-Kew Lom Irrigated Agriculture Development Project, JICA 1980)

2/: Based on the actual measurements conducted from 1980-1983 by Irrigation's research stations, RID

Table 3.4-2 Evapotranspiration (ETo)

(unit: mm)

Month	Prachinburi Station		Chonburi Station		Sattahip Station		Chanthaburi Station	
	Day	Month	Day	Month	Day	Month	Day	Month
Jan.	4.6	143	4.2	130	4.5	140	3.7	115
Feb.	4.4	123	4.7	132	5.0	140	3.6	101
Mar.	4.8	149	5.4	167	5.6	174	3.9	121
Apr.	4.6	138	5.4	162	5.7	171	4.1	123
May	3.9	121	4.5	140	4.9	152	3.3	102
Jun.	3.4	102	4.1	123	4.9	147	2.9	87
Jul.	3.3	102	4.0	124	4.6	143	2.8	87
Aug.	3.2	99	3.7	115	4.5	140	2.7	84
Sep.	3.2	96	3.4	102	3.7	111	2.7	81
Oct.	3.9	121	3.7	115	3.6	112	3.3	102
Nov.	4.2	126	4.2	126	4.3	129	3.7	111
Dec.	4.2	130	4.3	133	4.5	140	3.8	118
Total/Average	4.0	1,450	4.3	1,569	4.7	1,699	3.4	1,232

Note: a) Climatological data for the period 1956 - 1985 published by Mateorological Department is used.

b) ETOs Chachoengsao and Chonburi provinces are applied to that of Chonburi station, ETO of Rayong province, Sttahip station, and ETO of Chanthaburi province, Chanthaburi station respectively.

Table 3.4-3 Consumptive Use for Upland Crop (1/3)

No.	Name of Plant	Period from Planting to Harvesting (day)	Average Water Consumption (mm./day)	Total Water Consumption (mm.)	Water Consumption (m³/rai/ season)
1.	Corn for feeding	110	3.5	381.2	610
2.	Millet	100-120	2.5-3.1	250-375	400-600
3.	White sesame	90	4-5	360-450	576-730
4.	Black sesame	90	3-3.9	270-350	430-560
5.	Mung bean	60-70	2.9-4.3	187.5-281.2	580-480
6.	Black bean	100-120	1.8-2.2	198-242	316-390
7.	Green gram	100-120	1.7	187	300
8.	Groundnut	100-110	2.4-3.6	250-375	400-600
9.	Soya bean	95-110	1.8-3.7	187-375	300-600
10.	Jute	120-150	4.7-5.9	634-796	1,000-1,270
11.	Hemp	120-150	3.5-4.5	480-607	770-970
12.	Cotton	150-180	1.9-3.0	312.5-500	500-800
13.	Plant	12-18 month	1.3-1.6	600-730	960-1,200
14.	Pineapple	12-18 〃	1.9	875	1,400
15.	Sugarcane	12-18 〃	2.7-4.1	1,200-1,875	2,000-3,000
16.	Cassava	10-14 〃	1.5	540	864
17.	Cauliflower	100-120	2.5	281.2	450
18.	Cabbage	100-110	2.6-3.8	280-400	450-640
19.	Spring green	45-55	4.4	220	350

Table 3.4-3 Consumptive Use for Upland Crop (2/3)

No.	Name of Plant	Period from Planting to Harvesting (day)	Average Water Consumption (mm./day)	Total Water Consumption (mm.)	Water Consumption (m^3/rai/ season)
20.	White bean	60-90	3.3	250	400
21.	French bean	55-60	3.3	188	300
22.	Corn pea	50-75	4.0	250	400
23	Pea	99-110	2.4	250	400
24.	Mange-tout	60-90	2.5	188	300
25.	Many Kind gourds	40-60	3.7-6.2	188-310	300-500
26.	White green	45-80	4.5	280	450
27.	Chinese mustard	55-75	3.4	220	350
28.	Lettuce	55-70	3.5	220	350
29.	White radish	40-65	6.0	312	500
30.	Coriander	45-60	4.2	220	350
31.	Glory	30-35	3.9	125	200
32.	Chile	70-90	4.0-6.6	312-531	500-850
33.	Green melon	90-120	2.1	220	350
34.	Pumpkin	120-180	1.4	208	333
35.	Egg plants	60-90	3.5-6.3	268-475	430-760
36.	Tomatoes	60-75	4.6-6.1	322-406	500-650
37.	Tobacco	90-120	2.4-3.6	250-375	400-600
38.	Cucumber	30-40	6.3	220	250
39.	Big cucumber	80-120	2.5	250	400
40.	Garlic	75-150	2.9	334	535

Table 3.4-3 Consumptive Use for Upland Crop (3/3)

No.	Name of Plants	Period from Planting to Harvesting (day)	Average Water Consumption (mm./day)	Total Water Consumption (mm.)	Water Consumption (m^3/rai/ season)
41	Sweet corn	70-85	4.1	318	510
42.	Yam bean	210-240	3.7	848	1,350
43.	Sweet potato	90-120	2.9-4.0	312-425	500-680
44.	Red onion	40-50	9.0	406	650
45.	Potato	100-120	2.8-3.7	312-406	500-650
46.	Onion	80-120	3.6-5.0	362-500	580-800
47.	Water melon	75-120	3.0	298	470
48.	Pepper	1 Year			
49.	Strawberry	80-100 Day			
50.	Grape	470-510 Day			

Remark

Report from Irrigation Research Station (Oct. 1987)

Mae-tang Station - Chiang Mai

Samchuk Station - Suphunburi

Petch - buri Station and Pattani Station

2) Total readily available moisture (TRAM)

Although total readily available moisture which is water consumed in the effective root zone is better to be measured through a field test, the following formula can be applied for estimation.

TRAM = (FC - ML)·D/Cp (mm)

Where, FC ; Water holding capacity after 24 hours of soil saturation

ML ; Depletion of moisture content for optimum growth

D ; Important soil layer

Cp ; Rate of soil moisture extraction pattern in important soil layer

(FC-ML) ; Available water holding capacity (refer to Table 3.4-4)

Sample soil moisture extraction patterns are shown in Figure 3.4-2

3) Irrigation interval

Irrigation interval is calculated as follows:

IN = TRAM/Cu (day)

Where, IN ; Irrigation interval (day)

TRAM ; Total reading available moisture (mm)

Cu ; Crop consumptive use (mm/day)

(2) Irrigation method

The irrigation method for field crop is mainly classified into the following;

- Surface irrigation

  (Border irrigation, Contour ditch irrigation, Furrow irrigation, Perforated pipe irrigation, etc.)
- Spray irrigation

  (Sprinkler irrigation, Drip irrigation, etc.)
- Sub-surface irrigation

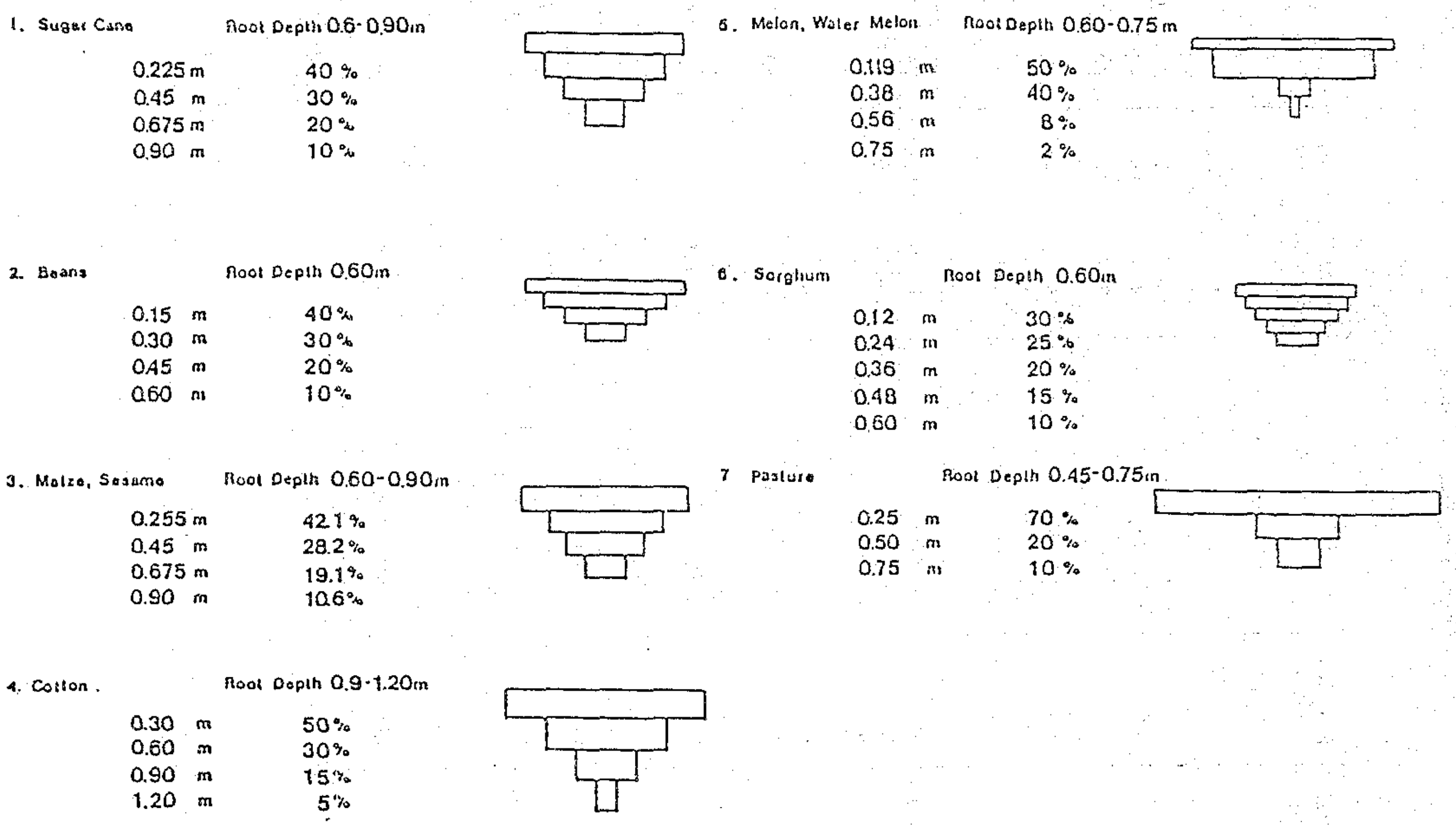
  (Open canal irrigation, Pipeline irrigation)

Table 3.4-4 Available Water Holding Capacity and Basic Intake Rate (Families) as Related to Soil Textures

Textural Class	Abbreviations	Texture	Available Water Holding Capacity cm/cm		Basic Intake Rate cm/hr	
			Range	Average	Range	Average
(H)	C	Clay	.14-.2	.17	.25- .75	.25
Fine	SIC	Silty Clay	.14-.2	.14	.25- .75	.25
	SC	Sandy Clay	.14-.2	.17	.25- 1.25	.25
(F)	SICL	Silty Clay Loam	.14-.2	.17	.25- 1.25	.75
Moderate	CL	Clay Loam	.14-.2	.17	.75- 2.5	1.25
Fine	SCL	Sandy clay Loam	.13-.19	.16	.75- 2.5	1.25
(M)	SL	Silt	.14-.20	.17	.75- 2.5	1.25
Medium	SIL	Silt Loam	.14-.20	.17	.75- 2.5	1.25
	L	Loam	.13-.19	.16	1.25- 3.75	2.5
	VFSL	Very Fine Sandy Loam	.13-.18	.15	1.25- 5.0	2.5
	FSL	Fine Sandy Loam	.10-.14	.12	2.50- 7.5	3.75
	SL	Sandy Loam	.10-.13	.11	2.50- 7.5	3.75
(S)						
Moderate	FSL	Fine Sandy Loam	.10-.14	.12	2.50- 7.5	3.75
Coarse	SL	Sandy Loam	.10-.13	.11	2.50- 7.5	3.75
(L)	COSL	Coarse Sandy Loam	.10-.13	.11	3.75- 7.5	5.0
Coarse	LVS	Loamy Very Fine Sand	.09-.12	.10	3.75-10.0	5.0
	LFS	Loamy Fine Sand	.08-.11	.09	5.00-10.0	7.5
	LS	Loamy Sand	.06-.09	.07	5.00-10.0	7.5
	LCOS	Loamy Coarse Sand	.06-.09	.07	5.00-10.0	7.5
(C)	VFS	Very Fine Sand	.05-.08	.06	7.50-10.0 +	7.5
Very	FS	Fine Sand	.05-.08	.06	7.50-10.0 +	7.5
Coarse	S	Sand	.04-.07	.05	7.50-10.0 +	10.0
	COS	Coarse Sand	.04-.07	.05	7.50-10.0 +	10.0

Source : OFWM Handbook, 1986

Figure 3.4-2 Sample Soil Moisture Extraction Pattern



Source; Feasibility study report on Aguan River-basin Agricultural Development in Honduras 1985 by JICA

Selection of irrigation method shall be made taking into account the various factors such as field and climate conditions, irrigation efficiency, construction cost, operation and maintenance methods, etc.

The irrigation method as characteristic for each type mentioned above is summarized in Table 3.4-5 (1/2) to (2/2). Application of the said irrigation methods will be conducted through a comparison study of each irrigation type as shown in Table 3.4-6 (1/2) to (2/2).

Judging from the field conditions in the project area, spot drip, sprinkler and perforated methods will be adoptable.

Table 3.4-5 Method / Characteristic of Each Irrigation Type (1/2)

Type	Method/Characteristic
1) Sprinkler irrigation	Method; - Pressure water is spread through sprinkler as rain Characteristic; - Construction and operation cost are costly but irrigation efficiency is good. - Available for multipurpose use and automatic system - Less effection by topography and soil, but affected by wind. - Small irrigation water a time. Often irrigation is possible.
2) Perforated pipe irrigation	Method; - Water is irrigated through perforated pipe lied on the ground. Characteristic; - Available for terrace field and/or small scale farm. - Available for tree crop irrigation. - Less effection by wind.
3) Furrow irrigation	Method; - Water flowing in furrow is irrigated to the root zone of plant through the side of furrow. Characteristic; - Suitable for impervious soil in the flat area. - Economical construction and operation costs but bad irrigation efficiency with comparative high maintenance cost.
4) Border irrigation	Method; - Water with shallow depth flows over the farm divided by small levee. Characteristic; - Almost same as that of furrow irrigation

Table 3.4-5 Method / Characteristic of Each Irrigation Type (2/2)

Type	Method/Characteristic
5) Contour ditch irrigation	Method; - Arrangement of main and sub-ditch is made depending on the slope of land. In case of steep slope (1/100 - 1/200), the sub-ditches are constructed along the contour and the main ones, making a right angle with the contour. By daming the sub-ditch, the water is leading to the farm. However, in case of gentle slope the opposite way shall be taken. Characteristic; - Adaptable for the sloped land by providing terrace. - Another characteristics are almost same as the furrow irrigation.

Table 3.4-6 Comparison Table between Surface and Sprinkler Irrigation (1/2)

Method / Description	Sprinkler Irrigation	Surface Irrigation
1) Land slope	No objection	Border : 3°, Furrow : 15° Contour ditch: 27°, Pipeline: No objection
2) Land leveling	Not required in most case	Required
3) Soil classification	Any kind of soils are adaptable except day	Sand with high rate of percolation water is not suitable except pipeline method.
4) Irrigation efficiency	80–90%	Less than 70%
5) Irrigation technique	Making even irrigation without skilled technique	Imbalance irrigation depending on the technique
6) Wind factor	Affected by the wind velocity Velocity (m/sec) — Equipment Pitch by sprincle diameter 0 — 65% 0 - 2.5 — 60% 2.5 - 5.0 — 50% 5.0 - — 30%	No objection
7) Land erosion	Land erosion will occur in the inclined area	Unconsolidated and/or uncompacted furrows will be eroded.
8) Water management	Management will be conducted through the farmer's group. There are less water losses.	Management is easily to be conducted by a person or family. Therefore, water losses are bigger than that of sprinkler irrigation.

Table 3.4-6 Comparison Table between Surface and Sprinkler Irrigation (2/2)

Method / Description	Sprinkler Irrigation	Surface Irrigation
9) Labour force for irrigation	As to portable type sprinkler, 1 or 2 workers are required to remove the equipment for 20 - 30 minites.	Some labours are required.
10) Construction cost	High	Low in flat plan, however, in the hill side, the construction cost might be higher than that of sprinkler irrigation owing to its lining and appartment structure costs.
11) Operation and maintenance cost	High (Operation cost for pump is required)	Low (Continuous maintenance is required for canal)

(3) Irrigation water requirement.

1) Basic concept for estimating diversion water requirements

The diversion water requirement will be estimated by the following formula;

- Net water requirement = Crop consumptive use = Percolation + Water requirement for field preparation (land preparation, etc.)
- Field water requirements = Net water requirement - Effective rainfall + Field losses.
- Diversion water requirement = Field water requirement + Conveyance and operation losses.

2) Crop consumptive use (Cu)

(See 3.4-2, (1),1))

3) Other requirements

Besides the crop consumptive use, water requirements for percolation, land preparation in paddy cropping and preparatory works in upland cropping shall be considered.

Considering the soil characteristics in the subject area, the percolation value of 2.0 mm per day will be adopted for paddy land, this is a standard value in the Northeast Region under the RID's Medium Scale Irrigation Project. Percolation in the upland area is regarded as an irrigation water loss. Such additional water requirement as land preparation water for paddy and pre-irrigation water for upland will be designed as below, referring to the data available from other similar natured projects in Thailand.

Additional Water

Crops	Requirement	Required Period
	(mm)	(days)
- Paddy	200	30
- Sugarcane	50	90
- Other upland crops	40	30

4) Effective rainfall

Effective rainfall for upland crop means rainfall which is effectively consumed by the crop growing from all rainfall in the cultivation area. Namely, effective rainfall is such rainfall retained in the effective root zone from which a crop consumes its required water or the total readily available moisture (TRAM). Rainfall beyond the effective rainfall will flow out from the field.

TRAM was assumed based on the previous effective data as follows :

Soil texture	Available Water Holding Capacity (FC-Wp)	Effective Soil layer	D	Cp	TRAM
	(%)	(cm)	(mm)		(mm)
- Sandy loam	11	120	300	0.40	73
- Loamy sand~clay loam	7~11	"	"	"	60
- Clay loam~silty clay	14~17	"	"	"	100

5) Losses

Field loss:

A part of the irrigation water to be supplied to the fields will be lost through horizontal and vertical percolation in the fields, or surface runoff. Therefore, the field water requirement should be estimated by the following equation:

$$FWR = \frac{NWR - ER}{Ef}$$

Where,

FWR : Field water requirement

NWR : Net water requirement

ER : Effective rainfall

Ef : Field efficiency

The field efficiency varies with different irrigation methods and field conditions. Based on previous studies and research carried out in Thailand and/or Japan, the following factors described below will be adopted in this study.

Field	Ef
- Paddy land	0.70
- Upland	
Surface irrigation	0.55
Spray irrigation	0.70
Spot irrigation	0.80

Conveyance and operation losses :

Some water losses take place while water is being conveyed through canals. The conveyance loss varies with the different structures of the canals concerned and the operational loss varies by operation method.

In taking these water losses into consideration, the diversion water requirements which will be required at the diversion site can be computed by the following equations:

$$FWR = \frac{FER}{Ec \times Eo} = \frac{NWR - ER}{Ef \times Ec \times Eo}$$

Where,

DWR : Diversion water requirement

FWR : Field water requirement

NWR : Net water requirement

ER : Effective rainfall

Ef : Field efficiency

Ec : Conveyance efficiency

Eo : Operation efficiency

In this study, the following losses will be adopted.

Structure	EC	Eo
- Open canal		
Lined canal	0.90	0.90
Unlined canal	0.70	0.90
- Pipeline	0.95	1.00

Since the Study Area is mostly covered with sandy soil, the canal shall be lined with concrete except for farm-ditch. From the above considerations, the overall efficiencies (Ef×Ec×Eo) are given as follows;

Soil texture	Ef	Ec	Eo	E
- Paddy land	0.70	0.90	0.90	0.57
- Upland				
Surface irrigation	0.55	0.90	0.90	0.45
Spray irrigation	0.70	0.95	1.00	0.57
Spot irrigation	0.80	0.95	1.00	0.76

6) Diversion water requirement for fruit tree

The results of estimation of diversion water requirement for durian under the following conditions is shown in Table 3.4-7.

[Conditions]

- Rainfall ; Rayong 48022 gauging station/ 1/2 year minimum rainfall (1982)
- Crop ; Durian
- Crop factor ; 0.70
- Irrigation efficiency ; 0.75
- TRAM ; 60 mm
- Irrigation interval ; 15 days
- Analysis interval ; each 5 days

Table 3.4-7 Sample Diversion Water Requirement

WATER DEMAND

PILOT AREA:RY-N02

CROP :DURIAN
C-FACTOR :0.7
TRAM :60.

INTER-IRRI:3.(5DAYS)
G-STATION :RY48022
IRR-EFFICI:0.75

MON	5DAY	RAIN-F	E-RAIN	W-CONS	W-REQU	W-DEMA
1	1	0.0	0.0	15.8	0.0	0.0
1	2	0.0	0.0	15.8	0.0	0.0
1	3	0.0	0.0	15.8	47.4	63.2
1	4	0.0	0.0	15.8	0.0	0.0
1	5	0.0	0.0	15.8	0.0	0.0
1	6	0.0	0.0	18.9	50.5	67.3
SUB-T		0.0	0.0	97.9		130.5
2	1	0.0	0.0	17.5	0.0	0.0
2	2	0.0	0.0	17.5	0.0	0.0
2	3	0.0	0.0	17.5	52.5	70.0
2	4	0.0	0.0	17.5	0.0	0.0
2	5	0.0	0.0	17.5	0.0	0.0
2	6	0.0	0.0	10.5	45.5	60.7
SUB-T		0.0	0.0	98.0		130.7
3	1	31.8	19.6	19.6	0.0	0.0
3	2	3.1	3.1	19.6	0.0	0.0
3	3	0.0	0.0	19.6	36.1	48.1
3	4	0.0	0.0	19.6	0.0	0.0
3	5	0.0	0.0	19.6	0.0	0.0
3	6	0.0	0.0	23.5	62.7	83.6
SUB-T		34.9	22.7	121.5		131.7
4	1	17.1	17.1	20.0	0.0	0.0
4	2	45.4	22.9	20.0	0.0	0.0
4	3	5.1	5.1	20.0	14.9	19.9
4	4	9.0	9.0	20.0	0.0	0.0
4	5	7.8	7.8	20.0	0.0	0.0
4	6	0.0	0.0	20.0	43.2	57.6
SUB-T		84.4	61.9	120.0		77.5
5	1	0.0	0.0	17.2	0.0	0.0
5	2	4.4	4.4	17.2	0.0	0.0
5	3	15.8	15.8	17.2	31.4	41.9
5	4	6.0	6.0	17.2	0.0	0.0
5	5	60.0	28.4	17.2	0.0	0.0
5	6	35.8	20.6	20.6	0.0	0.0
SUB-T		122.0	75.2	106.6		41.9
6	1	35.9	17.2	17.2	0.0	0.0
6	2	247.9	17.2	17.2	0.0	0.0
6	3	46.6	17.2	17.2	0.0	0.0
6	4	24.6	17.2	17.2	0.0	0.0
6	5	19.2	17.2	17.2	0.0	0.0
6	6	19.9	17.2	17.2	0.0	0.0
SUB-T		394.1	103.2	103.2		0.0

MON	5DAY	RAIN-F	E-RAIN	W-CONS	W-REQU	W-DEMA
7	1	0.0	0.0	16.1	0.0	0.0
7	2	56.8	32.2	16.1	0.0	0.0
7	3	8.1	8.1	16.1	8.0	10.7
7	4	20.6	16.1	16.1	0.0	0.0
7	5	20.7	16.1	16.1	0.0	0.0
7	6	26.1	19.3	19.3	0.0	0.0
SUB-T		112.3	91.8	99.8		10.7
8	1	7.1	7.1	15.8	0.0	0.0
8	2	8.1	8.1	15.8	0.0	0.0
8	3	0.0	0.0	15.8	32.2	42.9
8	4	96.2	15.8	15.8	0.0	0.0
8	5	32.6	15.8	15.8	0.0	0.0
8	6	11.3	11.3	18.9	7.6	10.1
SUB-T		155.3	58.1	97.9		53.0
9	1	11.5	11.5	13.0	0.0	0.0
9	2	100.4	14.5	13.0	0.0	0.0
9	3	6.3	6.3	13.0	6.7	8.9
9	4	0.0	0.0	13.0	0.0	0.0
9	5	44.9	26.0	13.0	0.0	0.0
9	6	88.3	13.0	13.0	0.0	0.0
SUB-T		251.4	71.3	78.0		8.9
10	1	11.8	11.8	12.6	0.0	0.0
10	2	64.2	13.4	12.6	0.0	0.0
10	3	32.3	12.6	12.6	0.0	0.0
10	4	0.0	0.0	12.6	0.0	0.0
10	5	17.1	17.1	12.6	0.0	0.0
10	6	10.9	10.9	15.1	12.3	16.4
SUB-T		136.3	65.8	78.1		16.4
11	1	0.0	0.0	15.1	0.0	0.0
11	2	42.0	30.2	15.1	0.0	0.0
11	3	15.9	15.1	15.1	0.0	0.0
11	4	8.2	8.2	15.1	0.0	0.0
11	5	17.9	17.9	15.1	0.0	0.0
11	6	37.1	19.2	15.1	0.0	0.0
SUB-T		121.1	90.6	90.6		0.0
12	1	9.5	9.5	15.8	0.0	0.0
12	2	0.0	0.0	15.8	0.0	0.0
12	3	0.0	0.0	15.8	37.9	50.5
12	4	0.0	0.0	15.8	0.0	0.0
12	5	0.0	0.0	15.8	0.0	0.0
12	6	0.0	0.0	18.9	50.5	67.3
SUB-T		9.5	9.5	97.9		117.8
TOTAL		1421.3	650.1	1189.5		719.1

(4) Irrigable area

Irrigable area of a pond and/or weir can be estimated through a water balance study taking into account inflow (run-off) from watershed, such water losses in the reservoir as evaporation and seepage, and outflow (water requirement) to the irrigation area.

1) Run-off water

Since there are no effective run-off data for small watersheds, the run-off water is estimated applying the following formula.

$V = Ci \times Pi \times A$

Where, V ; Run-off volume

Ci ; Run-off coefficient (refer to Figure 3.4-3)

Pi ; Rainfall

A ; Watershed

In addition to the run-off water by rainfall, base water flows can be considered if existent.

2) Water losses in reservoir

Evaporation;

Open water evaporation from reservoir is estimated with 70% of pan evaporation value.

Seepage;

Although less than 0.05% of total storage water per day is normally taken for seepage, considering the characteristic of soil in the project area, appproximately 0.1% is adopted.

3) Irrigable area

Exact irrigable area can be estimated through a water balance study (reservoir operation study). According to the results of the study for pilot areas, the irrigable area can be roughly calculated by the following formula.

Type of Pattern

A – Steep mountainous area, no paddy field

B – Rather steep area, openforest

C – Rolling area, open forest, corns paddy fields

D – Gentle slope area, many paddy fields

E – Flat area, many paddy feild

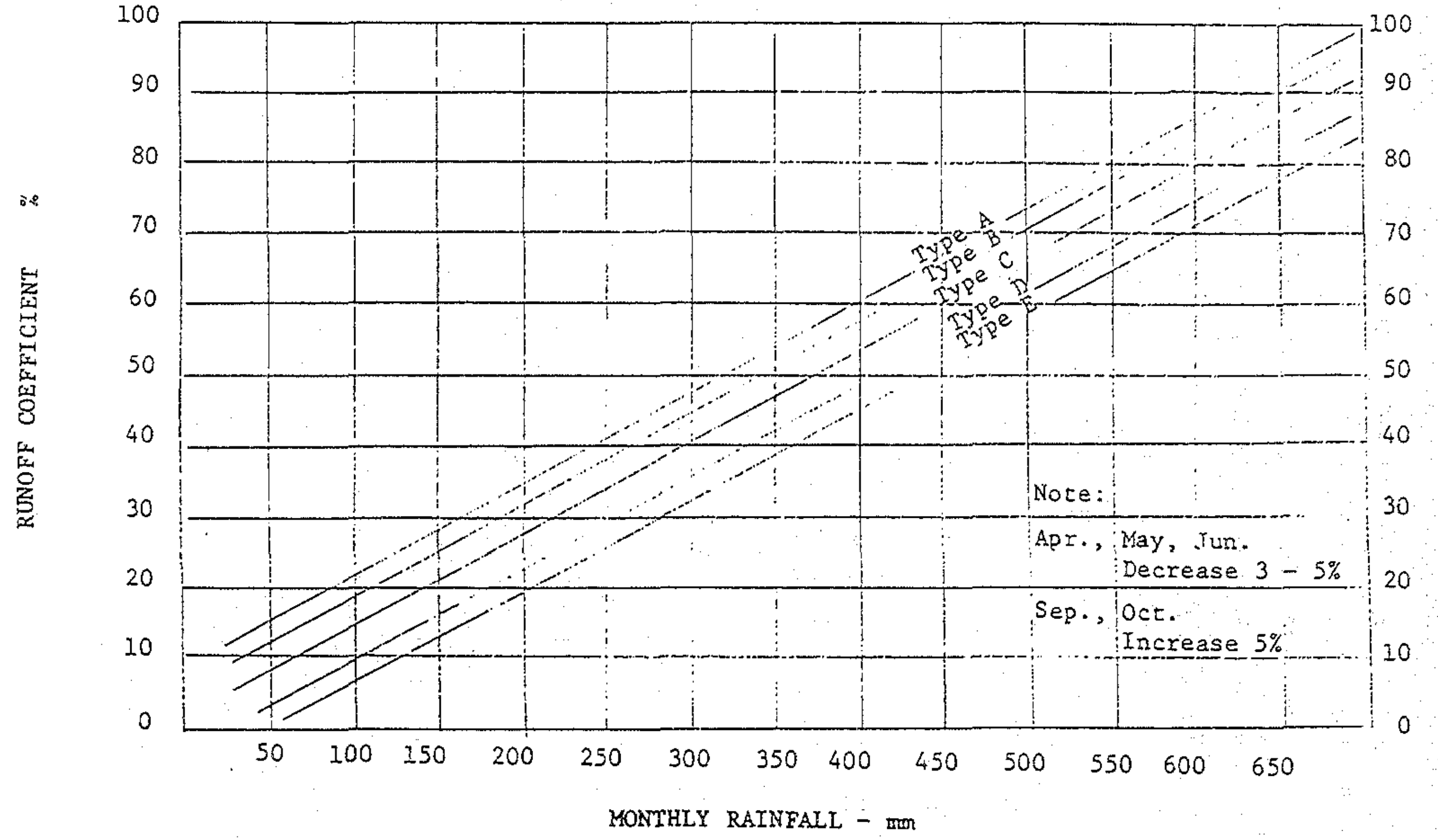


Figure 3.4-3 Estimate of Run-off Coefficient

(Developed by RID)

$IA \doteqdot (V_1+V_2) / Q$ (ha)

where,

IA ; Irrigable area (ha)

V_1 ; Effective storage capacity of reservoir (m^3)

V2 ; Water volume by base flow in the dry season (m^3)

Q ; Diversion water requirement (m^3/ha)

Sample water balanced study is shown in Table 3.4-8 and Figure 3.4-4.

3-3-4 Structural Design

(1) Design flood

1) Frequency of design flood

Frequency of design flood for facilities shall be determined by the importance of facilities and economic aspects.

Judging from other similar projects in Thailand (refer to Table 3.4-9) and the results of the field investigation, the following criteria shall be adopted as the design flood for facilities.

Frequency	Application
1/50 year	Spillway for reservoir and weir
1/10 year	Main drainage, crossing structure of road
1/5 year	Lateral drainage (Grass water-way, terrace, ditch)

2) Estimation of design flood

Design flood is estimated by applying the Rational Formula

$$Q = 0.2778 \cdot C \cdot I \cdot A$$

where,

Q ; Flood discharge (cu·m/sec)

C ; Run-off coefficient (ARDO method)

Figure 3.4-4 Reservoir Operation of Farm Pond NO.1

(RY-NO2/PLAN I)

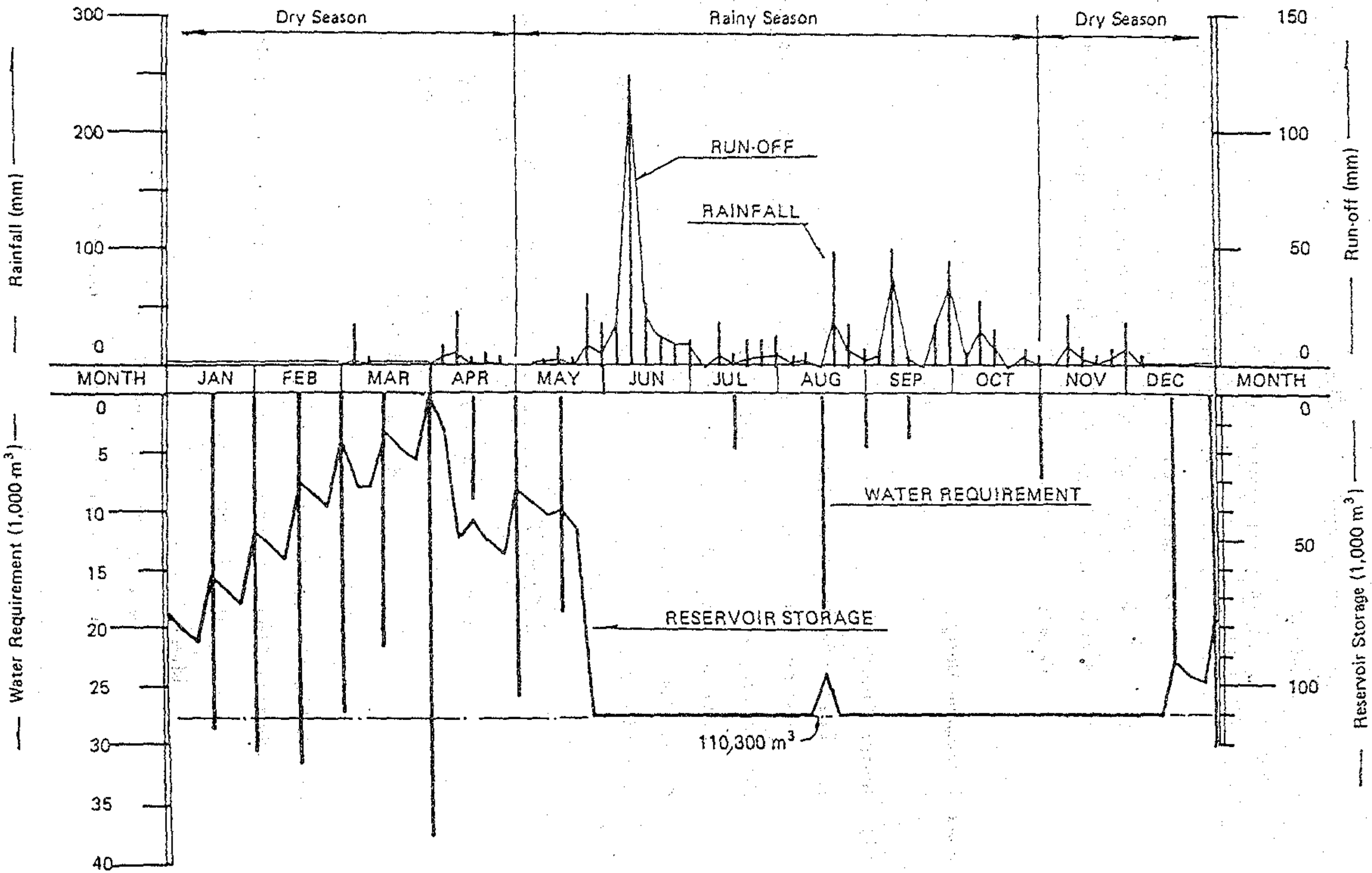


Table 3.4-8 Water Balance Study

WATER BALANCE STUDY

FARM POND :RY2-1.1

E-STORAGE :110300.(M3

NWS-AREA :8.3(HA)

WATERSHED :810.(HA)

G-STATION :RY48022

IRRI-AREA :45.(HA)

BASE FLOW :14.2(L/S)

MON	5DAY	RAINF	RUNOF	W-DEM	INTAK	EW-STO	SPILL
		(MM)	(MM)	10M3	10M3	10M3	100M3
1	1	0.0	0.0	0	0	8138	0
1	2	0.0	0.0	0	0	8606	0
1	3	0.0	0.0	2844	2844	6230	0
1	4	0.0	0.0	0	0	6698	0
1	5	0.0	0.0	0	0	7166	0
1	6	0.0	0.0	3029	3029	4702	0
SUB-T		0.0	0.0	5873	5873		0
2	1	0.0	0.0	0	0	5170	0
2	2	0.0	0.0	0	0	5639	0
2	3	0.0	0.0	3150	3150	2957	0
2	4	0.0	0.0	0	0	3425	0
2	5	0.0	0.0	0	0	3894	0
2	6	0.0	0.0	2732	2732	1439	0
SUB-T		0.0	0.0	5882	5882		0
3	1	31.8	1.9	0	0	3071	0
3	2	3.1	0.2	0	0	3087	0
3	3	0.0	0.0	2165	2165	1364	0
3	4	0.0	0.0	0	0	1806	0
3	5	0.0	0.0	0	0	2248	0
3	6	0.0	0.0	3762	2984	0	0
SUB-T		34.9	2.1	5927	5149		0
4	1	17.1	1.6	0	0	1268	0
4	2	45.4	4.3	0	0	4959	0
4	3	5.1	0.5	896	896	4341	0
4	4	9.8	0.9	0	0	4975	0
4	5	7.8	0.7	0	0	5437	0
4	6	0.0	0.0	2592	2592	3289	0
SUB-T		84.4	8.0	3488	3488		0
5	1	0.0	0.0	0	0	3740	0
5	2	4.4	0.6	0	0	4101	0
5	3	15.8	2.3	1886	1886	4047	0
5	4	6.0	0.9	0	0	4663	0
5	5	60.0	8.6	0	0	11030	93
5	6	35.8	5.1	0	0	11030	424
SUB-T		122.0	17.5	1886	1886		517
6	1	35.9	18.0	0	0	11030	1472
6	2	247.9	124.0	0	0	11030	10234
6	3	46.6	23.3	0	0	11030	1910
6	4	24.6	12.3	0	0	11030	1001
6	5	19.2	9.6	0	0	11030	778
6	6	19.9	10.0	0	0	11030	811
SUB-T		394.1	197.2	0	0		16206

MON	5DAY	RAINF	RUNOF	W-DEM	INTAK	EW-STO	SPILL
		(MM)	(MM)	10M3	10M3	10M3	100M3
7	1	0.0	0.0	0	0	11030	45
7	2	36.8	5.9	0	0	11030	492
7	3	8.1	1.3	482	482	11030	48
7	4	20.6	3.3	0	0	11030	268
7	5	20.7	3.3	0	0	11030	268
7	6	26.1	4.2	0	0	11030	343
SUB-T		112.3	18.0	482	482		1464
8	1	7.1	1.5	0	0	11030	113
8	2	8.1	1.8	0	0	11030	138
8	3	0.0	0.0	1931	1931	9567	0
8	4	96.2	20.9	0	0	11030	1612
8	5	32.6	7.1	0	0	11030	588
8	6	11.3	2.5	455	455	11030	149
SUB-T		155.3	33.8	2386	2386		2600
9	1	11.5	4.5	0	0	11030	359
9	2	100.4	39.5	0	0	11030	3268
9	3	6.3	2.5	401	401	11030	153
9	4	0.0	0.0	0	0	11030	47
9	5	44.9	17.7	0	0	11030	1456
9	6	88.3	34.7	0	0	11030	2869
SUB-T		251.4	98.9	401	401		8152
10	1	11.8	2.9	0	0	11030	238
10	2	64.2	15.6	0	0	11030	1303
10	3	32.3	7.8	0	0	11030	644
10	4	0.0	0.0	0	0	11030	47
10	5	17.1	4.1	0	0	11030	332
10	6	10.9	2.6	738	738	11030	129
SUB-T		136.3	33.0	738	738		2685
11	1	0.0	0.0	0	0	11030	48
11	2	42.0	7.3	0	0	11030	612
11	3	15.9	2.7	0	0	11030	218
11	4	8.2	1.4	0	0	11030	106
11	5	17.9	3.1	0	0	11030	252
11	6	37.1	6.4	0	0	11030	535
SUB-T		121.1	20.9	0	0		1771
12	1	9.5	0.3	0	0	11030	17
12	2	0.0	0.0	0	0	11030	46
12	3	0.0	0.0	2273	2273	9219	0
12	4	0.0	0.0	0	0	9680	0
12	5	0.0	0.0	0	0	10141	0
12	6	0.0	0.0	3029	3029	7670	0
SUB-T		9.5	0.3	5302	5302		63
TOTAL		1421.3	429.7	32365	31587		33458

Table 3.4-9 Frequency of Peak Flood for the Design

Frequency	Type of work
10 yrs	For the Design of Coffer Dam of Medium Project
20 yrs	(a) Design of Coffer Dam for Large Project
	(b) Design of box culvert
30 yrs	For the design of temporary weir
50 yrs	For the design of permanent weir
100 yrs	(a) Regulator
	(b) Service Spillway for Medium & Large Project
	Emergency Spillway of Regulator and Medium Dam Project
1,000 yrs	Emergency Spillway of Large Dam

(Data source : RID Planning Div. 1982)

Table 3.4-10 Coefficient of Run-off (C)

Type of Vegetation	Type of Soil Cover		
	Silty Sand	Silty clay	Clay
Woodland			
– Flat (0-5%)	0.10	0.30	0.40
– Undulation (5-10%)	0.25	0.35	0.50
– Hill (10-30)	0.30	0.50	0.60
Pasture			
– Flat	0.10	0.30	0.40
– Undulation	0.16	0.36	0.55
– Hill	0.22	0.42	0.60
Cultivated land			
– Flat	0.30	0.50	0.60
– Undulation	0.40	0.60	0.70
– Hill	0.52	0.72	0.82

(Data source : Office of Accelerated Rural Development,
Ministry of Interior, 1987)

I ; Rainfall intensity for duration of time of concentration (Tc) (mm/hr)

The rainfall intensity of the project area is estimated by applying the "Talbot Equation" which is well suited to the area.

A ; Watershed (Km^2)

i) Run-off coefficient

Run-off coefficient is dependent upon such conditions as vegetation, slope and soil in the area. In this study the coefficient was determined utilizing the ARDO method which is one of the prevailing methods in Thailand. (refer to Table 3.4-10)

C=0.35

(silty sand/undulation/woodland 0.25 ~ cultivated land 0.40)

ii) Rainfall intensity

According to the analysis data for rainfall intensity by Chulalongkorn University, the Meteorological Department (MD) and the Accelerated Rural Development Office (ARDO), the Talbot equation is said to be well suited for the rainfall intensity in the area. The equation is as follows;

$$I = \frac{A}{Tc + B} \cdot R_N \quad \text{- - - - - - -} \quad (a)$$

where,

I ; Rainfall intensity (mm/hr)

A,B ; Coefficient (refer to Table 3.3-11)

Tc ; Time of concentration (min)

R_N ; Probable rainfall (mm/day)

While, time of concentration, is estimated by applying the Kadoya and Fukusima equation 1/, which take the land use condition of watershed into account.

$$TC = K \cdot A^{0.22} \cdot Rt^{-0.35} \quad \text{- - - - - -} \quad (b)$$

Where, Tc ; Time of concentration (min)

A ; Watershed (Km^2)

Rt ; Effective rainfall intensity (mm/hr)

$R_t = C \cdot I$

K ; Coefficient (based on the land-use conditions of watershed)

Type of land-use	K
- Woodland	250~350 (Av.290)
- Pasture	190~210 (Av.200)
- Grass land	130~150 (Av.140)
- Cultivated land	90~110 (Av.100)
- Town	60~ 90 (Av. 75)

1/ ; Research for preventing disasters of Kyoto University, Japan

Therefore, Tc and I are calculated by solving both equations, (a) and (b).

Specific flood discharge for each province is as shown in Table 3.4-12.

3) Design discharge

Design discharge from the spillway can be reduced from flood discharge taking into account effect of storage above normal water surface in case of large water surface area of reservoir compared with the watershed.

i) Inflow hydrograph

The inflow hydrograph for a reservoir shall normally be computed based on the data observed.

However, effective data are not available, so that the inflow hydrograph will be assumed by the Kadoya (Professor of Kyoto University, Japan) equation.

Upper side curve from peak in flow;

$$\frac{tu}{tp} = \left(\frac{Q}{Qp}\right)^{0.6}$$

Table 3.4-11 Talbot Equation

Province	Coefficient	Return Period (Year) 1/5	1/10	1/50	Equation
Chachoengsao /Chonburi/Rayong	A	69.119	71.209	77.918	$I = \frac{A}{Tc + B} \times R_N$ (mm/hr)
	B	39.358	42.247	44.348	
Chanthaburi	A	61.430	63.660	71.497	
	B	56.401	54.103	67.519	

Table 3.4-12 Specific Flood Discharge (cu.m/sec/km2)

Province	Gaging Station	Return Period (Year) 1/5	1/10	1/50	Application of Pilot Area
Chachoengsao	03052	7.7	9.0	12.9	CS-NO3, CS-NO4, CS-NO5, CS-NO8
Chonburi	09042	8.6	9.9	13.4	CN-NO1, CN-NO2, CN-NO8, CN-NO9
"	09073	8.7	10.7	17.0	CN-NO4
Rayong	48022	9.1	10.9	16.3	RY-NO1, RY-NO2, RY-NO7
"	48032	9.4	10.9	15.3	RY-NO3, RY-NO5
Chanthaburi	06081	7.2	9.5	14.8	CT-NO2, CT-NO3

Note; C = 0.35 (silty sand, cultivated land ~ wood land, undulation)
Tc = 60 min, A = 1.00 km^2
R_N = Probable rainfall (mm/day)

Lower side curve from peak inflow;

$$\frac{tu}{tp} = \frac{1-(Q / Qp)}{(Q / Qp)^{0.40}}$$

where,

tu ; passing time from start of rise to any time (min)

tp ; time of concentration (min)

Q ; inflow at any time (m^3/sec)

Qp ; peak inflow (m^3/sec)

td ; passing time from time of peak to anytime

p ; coefficient 1.0 is normally applied

ii) Flood routing

The accumulation of storage in the reservoir above normal water surface depends on the difference between the rates of inflow and outflow. For an interval of time T, this relationship can be expressed by the following equation;

$$Vtn = Vtn-1 + \frac{Qtn + Qtn-1}{2} - \overline{Qdtn} \times \Delta T$$

where,

Vtn	; storage accumulated at tn time	(m^3)
Vtn-1	; storage accumulated at tn-1 time	(m^3)
Qtn	; inflow at tn time	(m^3/sec)
Qtn-1	; inflow at tn-1 time	(m^3/sec)
Qdtn	; average outflow during ΔT (tn−tn-1)	(m^3/sec)
ΔT	; interval of time from tn to tn-1	(sec)

Based on the method mentioned above, the inflow and outflow of RY-NO2 are as shown in Figure 3.4-5 as a sample study.

Max. inflow = 81.1 m^3/sec

Max. outflow = 70.7 m^3/sec

Figure 3.4-5 In-Flow ~ Out-Flow Hydrograph

(RY-NO.2/PLAN I Farm Pond NO.1)

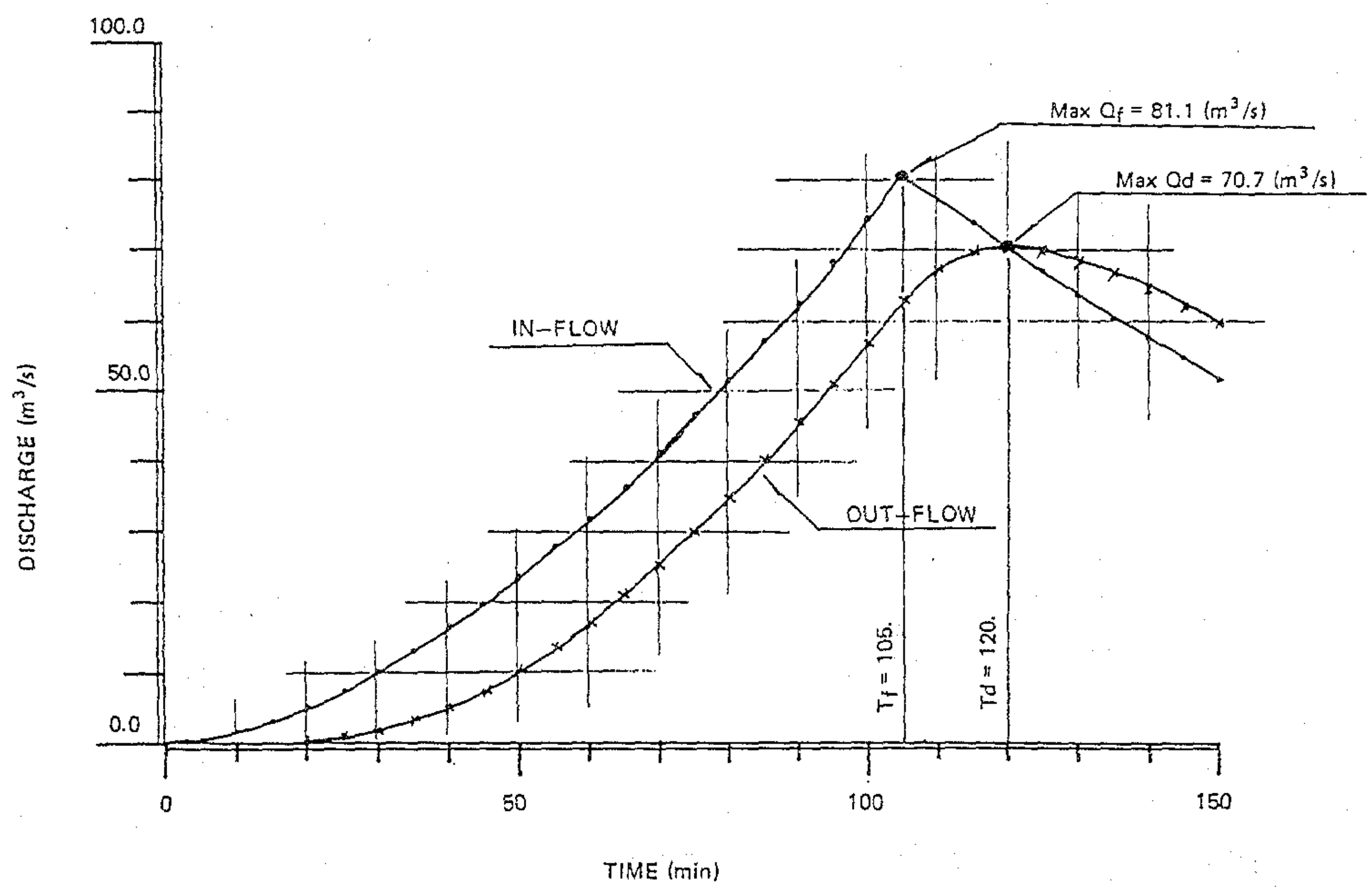
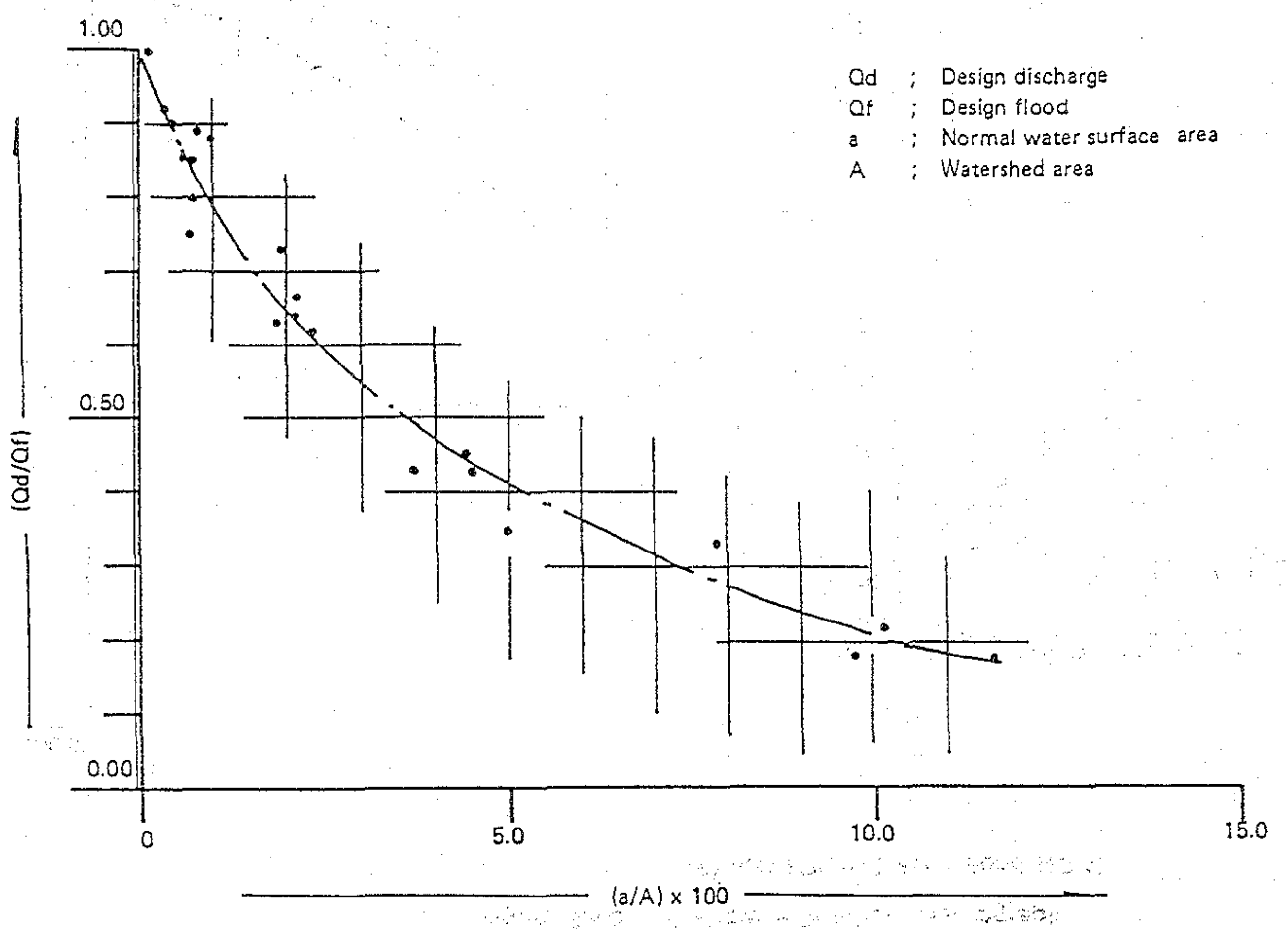


Figure 3.4-6 Relationship between Design Discharge and Design Flood



Therefore, about 10 m^3/sec of discharge can be reduced by reservoir storage and the actual design of the spillway shall be made with the maximum outflow.

From the results of the feasibility study, the relationship between design flood and discharge was found to be as shown in Figure 3.4-6.

4) Design sedimentation

Since almost all of the coarse sand will be stored in the sediment trap and/or pond to be provided upstream of each farm pond, sedimentation for the farm pound will be estimated by the suspended load of the stream. Judging from the study report for the East Coast Water Resources Development project conducted by JICA, the specific yield of sedimentation in the project area is presumed to be 300 m^3/km^2/year. On the assumption that maintenance for ponds will be conducted once every five years, the design sediment volume for the pond is as follows;

$V=300\ m^3/km^2/year \times 5\ year \times A = 1{,}500 \times A\ (m^3)$

where, A ; Watershed (km^2)

(2) Facilities design

1) Farm pond

i) Location

Location of the farm pond shall be selected in un-utilized areas as much as possible in order to minimize the loss of cultivated area.

ii) Suitable reservoir capacity

The reservoir capacity will be determined taking into account the following factors.

- Run-off volume
- Water demand
- Land area loss

Land area loss

In case that the reservoir capacity is determined with the water demand for crop and/or run-off volume from the watershed, the land area loss for the reservoir will be large in some areas, although agricultural production will increase.

The rate of land area loss shall depend on the intention of the land owner. Judging from the previous projects in Thailand, the land area loss for pond construction is about 5 to 10% of total project area.

Example

Project : RY-No. 2 (Rayong Province)

Watershed : 8.1 km^2 (810 ha)

Project area : 194 ha. (Net Cultivation area)

Maximum land loss : 5%

- Run-off volume

  $V1=810\ ha \times 4,300\ cu.m/ha=3,483,000\ m^3$

- Water demand

  $V2=194\ ha \times 7,200\ cu.m/ha=1,396,800\ m^3$

- Land loss

  $A=194\ ha \times 5\%=9.7\ ha$

  $V3=9.7\ ha \times 2.0\ m=194,000\ m^3$

  (Where, 2.0 m; average water depth)

  $V1>V2>V3 \quad =194,000\ m^3$

Therefore, the suitable reservoir capacity for the pilot project will be 194,000 m^3 approximately.

iii) Dam-body

Taking into account existing ponds and reservoirs constructed by RID, ARD, DLD, etc. in the four provinces, soil and geological conditions and DLD's act on reservoir construction, the dam-body will be designed with the following ideas.

a) Dam type:

Dam zoning shall be dependent on quality and quantity of embankment material being obtained inside and/or surrounding the pilot area.

If sufficient volume of impervious and/or semi-pervious material can be obtained, homogeneous earth-fill shall be selected because of easy operation of construction. But if not, zoning type of earth fill shall be selected.

In case of the Eastern Region, obtaining of materials especially impervious material is rather difficult and foundations of ponds are formulated with a high permeability zone due to sandy soil, so that an inclined earth type dam is applicable. (refer to Figure 3.4-7)

b) Dam dimension:

- Maximum height of dam : 6.0 m (from lowest original ground surface to dam crest)
- Width of dam crest : 5.0 m
- Free board : 1.0 m from high water level
- Dam slope : Upstream 1 : 3.0, Downstream 1 : 2.5

c) Foundation treatment:

- Stripping: 0.3 m - 0.5 m thickness
- A cut off trench is provided at the upstream toe of the dam with a depth of 1.5 m at least but deposit materials with N value of less than 15 and permeability value of more than 1 x 103 cm/sec shall be excavated. The width of the cut-off trench is 5.0 m in case of 4.01 to 6.00 m of dam height and is 4.0 m in case of less than 4.00 m of dam height.

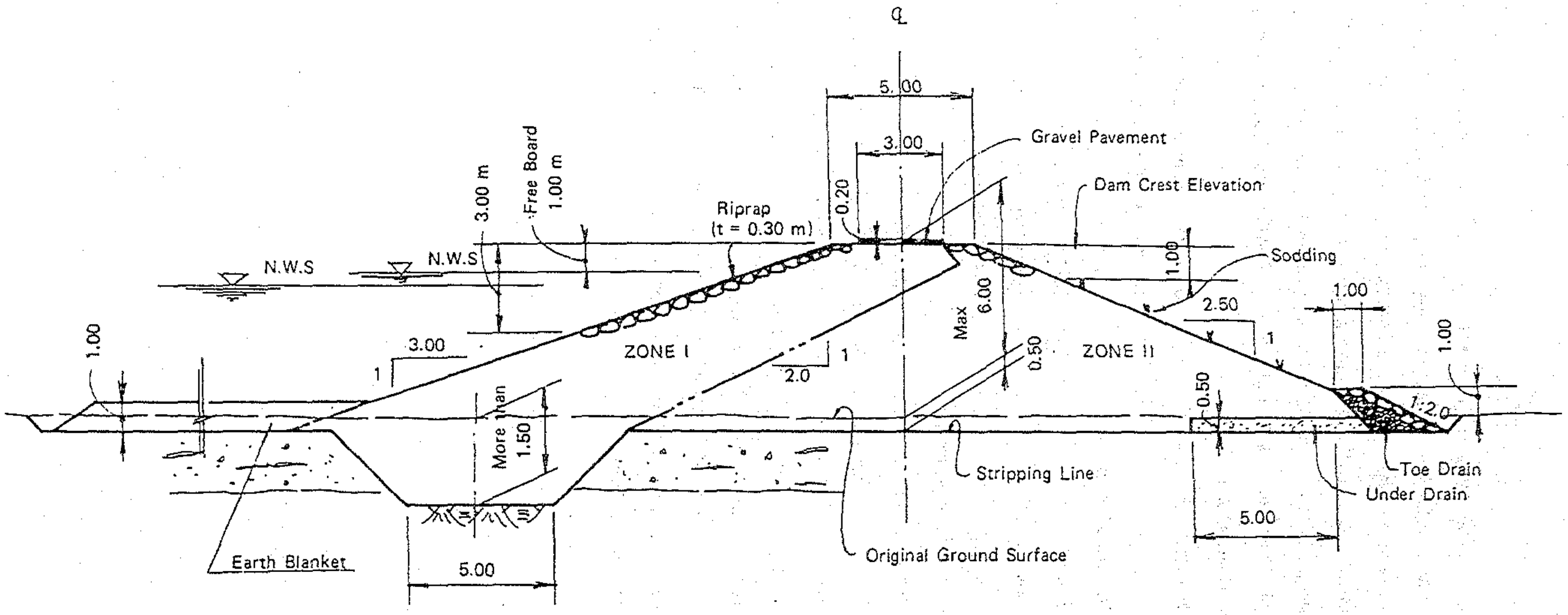


Figure 3.4-7 Dam Typical Section

d) Embankment materials:

Embankment materials except riprap and drain materials shall be obtained from the inside of and/or nearby the pilot project area. Materials available for embankment are as follows:

Embankment	Unified Soil Classification	Material
① Earth Zone		
Zone I : (impervious)	GC, SC ML, CL, CH, MH,	From inside of area or nearby
Zone II : (semi-pervious)	GM, SW, SM,	
② Drain	GW, GP, SP,	Crushed stone (sand & gravel)
③ Riprap	—	Crushed stone or concrete block

iv) Spillway

a) Design discharge:

Actual discharge from spillway can be reduced with water storage above normal water level in the reservoir. (refer to Figure 3.4-6)

b) Water depth:

Discharge volume is calculated applying the following formula.

$$Q = C \cdot B \cdot H^{3/2}$$

where

C = Coefficient of overflow 1.55~2.1

B = Width of crest (m)

H = Water depth (m) 0.30~1.00 m.

c) Structure:

In principal, the spillway shall be designed as follows.

- Crest : Selection of crest type shall be made taking into account geological and topographical conditions at the site, and economical aspect. The crest shall be placed on the original ground with concrete lining.

- Stilling basin : Stilling basin is basically placed on original ground with protection such as concrete and riprap lining.

v) Intake facilities

Intake facilities are divided into two irrigation types, pump irrigation and gravity irrigation.

a) Gravity irrigation:

- Design discharge

Design discharge will be determined according to the scale of the downstream command area.

Crop	Design discharge	Remarks
Paddy	App.120 ℓ/min/ha	10 mm water consumption 24 hr. opearation
Vegetable and Tree crop	App. 80 ℓ/min/ha	10 hr. operation

- Structure

The conduit pipe is designed with circular section and steel pipe enclosed with concrete, and embedded in the dam foundation. The gate for water control and energy dissipation is designed at the end of the conduit pipe.

b) Pump irrigation:

- In case of more than 100,000 m^3 of reservoir capacity, a fixed pump station shall be planned and in other cases, portable pumps shall be procured for easy operation.
- To minimize the pump capacity, rotation block method for irrigation shall be employed.

Pump	Operation Hour	Max Block Size
	(hr/day)	(ha)
φ150 mm	8.0	10.0
φ100 mm	"	5.0

c) Water tank:

Water pumped up from a pond is stored in a water tank for distribution to the irrigable area by gravity. Storage capacity of water tank is planned to meet one day water demand.

2) Irrigation system

In this text, such representative irrigation methods as spray and pipe laying methods are presented as follows;

i) Spray irrigation

- Spray intensity:

Spray intensity is dependent on soil texture and topographic conditions in the field as shown below.

Maximum Alowable Spray Intensity (mm/hr)

Soil	Flat	Incline
Sand	30	20
Loam	15	10
Clay	10	7

(Note) Source : criteria of irrigation planning for upland crop/Ministry of Agriculture, Forestry and Fishery of Japan.

Spray intensity can be estimated by the following formula.

$$I = \frac{60 \cdot Q}{\alpha \cdot \beta} \quad (mm/hr)$$

Where, Q ; Discharge of sprinkler (ℓ/min)

α ; Sprinkler interval (m)

β ; Pipeline interval (m)

- Pipeline and sprinkler distance:

  The following formula is the adaptable distance of pipeline and sprinkler.

  Sprinkler interval, $\alpha = (0.5 \sim 0.7) \cdot D$ (m)

  Pipeline interval, $\beta = (0.55 \sim 0.65) \cdot D$ (m)

  Where, D = spray diameter

Nozzle / Pressure	4.0×2.4 m/m		4.4×2.4 m/m		4.0×3.2 m/m		4.8×2.4 m/m		4.8×3.2 m/m		5.2×3.2 m/m	
	Dia-meter	Amount of Water	Dia-meter	Amount of Water	Dia-meter	Amount of Water	Dia-meter	Amount of Water	Dia-meter	Amount of Water	Dia-meter	Amount of Water
1.5	24.0	16.2	24.4	20.8								
2.0	25.2	19.0	26.4	23.8	26.4	28.4	27.5	27.7	27.5	29.0	27.8	36.4
2.5	26.1	21.4	27.5	26.4	27.5	29.2	28.5	28.4	28.5	33.0	29.4	40.7
3.0	27.0	24.1	28.3	28.6	28.3	32.2	29.5	31.5	29.5	37.0	30.5	44.6
3.5							30.2	33.4	30.2	40.5	31.2	47.7
4.0							30.8	35.3	30.8	42.6	31.8	51.0

Note : Pressure; kg/cm^2 ;

Diameter; Amount of water; ℓ/min

ii) Pipe laying irrigation

- Perforated pipe;

  Irrigataon intensity about 10~50 mm/hr/Irrigation area, 6~15 m under pressure of 0.25~2 kg/cm^2

- Drip irrigation;

  Water head loss for perforated pipe which will be utilized to drip irrigation is about 30% of normal plastic tube. Table 3.4-13 shows irrigation area by discharge from emmitter.

3) Farm road

- Effective width ; Main road 5.0 m

  Lateral road 3.0 m

- Pavement ; at least laterite pavement (t=0.20 m)

- Longitudinal slope ; Maximum 5% (1/20)

Table 3.4-13 Saturated Surface Area by Discharge Water from Emitter

Discharge (l/hr)	Intake Rate (cm/hr)					
	0.25	0.50	0.75	1.00	1.25	1.50
1	0.4	0.2	0.13	0.1	0.08	0.07
2	0.8	0.4	0.27	0.2	0.16	0.13
3	1.2	0.6	0.40	0.3	0.24	0.20
4	1.6	0.8	0.53	0.4	0.32	0.27
5	2.0	1.0	0.67	0.5	0.40	0.33
6	2.4	1.2	0.80	0.6	0.48	0.40
7	2.8	1.4	0.93	0.7	0.50	0.47
8	3.2	1.6	1.07	0.8	0.64	0.53

Chapter 4.

CONSTRUCTION OF PROJECTS

CHAPTER 4 CONSTRUCTION

4-1 Implementation Mode

The implementation of project construction is divided into two modes, force-account basis and contract basis.

Force-account Basis:
The project construction is directly carried out and supervised by the owner, mobilizing staff and using own construction equipment.

Contract Basis:
The project construction will be carried out by entrusting the work to a private company under contract.
As for the contract, two modes can be considered;

- Local competitive tender
- International competitive tender

Moreover, there is the case where the government lends its construction equipment to the contractor.

The selection of implementation mode is made taking into account; employer's policy, project character, project scale and other factors.

Contract basis, however, will be adopted for the Project for taking the following matters into consideration.

a) The project cost on the force account basis may be estimated lower than that on the contract basis due to excluding overhead costs of contractors. However, if the force account basis were taken for the project construction, many type of construction equipment, many engineers, labourers, and materials, in particular, experts and special equipment would be provided by DLD according to the characteristic features of the project. After completion of the project, it would be difficult to use such equipment and personnel for another project effectively. DLD will have to provide expenses and equipment maintenance fees during the period between projects (idling period). Therefore, the force account basis is not economical from the viewpoint of the total cost of Project.

Although the force account basis for project construction had been utilized in the initial stage of economic development even in advanced countries with the purpose of promoting employment, the government budget has become oppressed financially due to the annual increase in maintenance costs. Therefore, most projects have recently come to be constructed on a contractor basis in Thailand except in special cases.

Construction under the contract basis applying lending of construction equipment to the contractor from the government has almost a similar characteristic to that as mentioned above. Namely, the government will have to maintain a lot of construction equipment and to employ personnel during the idling period.

b) The increased capability of private firms will be very useful for the further development of the Thai economy in the future. The technology level of private Thai firms for public works will be increased by executing the works on the contract basis.

4-2 Selection of Construction Method and Schedule

(1) Construction method

1) Workable days

Such earth works as land conservation are mostly affected by rainfall. Therefore, estimation of monthly mean workable days in the construction period is required. It can be done using the daily rainfall records for recent ten years.

In principal, the construction works will be implemented in the dry season due to good working conditions such as number of workable days and easy mobilization of labour.

The workable days are estimated on the basis of the following criteria.

Daily Rainfall Intensity (mm/day)	Suspension of work (day)
0 - 10	Workable day
10.1 - 30	1 day
30.1 - 50	2 day
50.1 - 100	3 day
100.1 and over	4 day

The case of suspension of less than 10 days month;

workable days per month

= 30 – [5+suspension days /2]

The case of suspension of more than 10 days per month;

= 30 – [suspension days]

According to the results of analysis based on the criteria, the workable days for each province are as follows;

Workable days per month

Province	Wet season (May to Oct)	Dry season (Nov. to Apr.)
Chachoengsao	22	25
Chonburi/Rayong	11	24
Chanthaburi	18	24

(Note)

Rainfall data; 1976-1985

2) Selection of equipment

Selection of equipment is very important for construction works particularly earth moving works in order the construction cost. Selection of construction equipment shall be made taking into account the following factors.

- Operation type
- Hauling distance and gradient of hauling road
- Trafficability and ripability
- Work volume, etc.

3) Construction method and equipment

i) Farm pond (Tameike)

The order of dam construction is as follows;

① Setting and measuring the construction area

② Construction of temporary diversion channel outside of natural stream

③ Construction of outlet facilities

④ Stripping and excavation of surface soil

⑤ Preparation of embankment soil

⑥ Embankment of dam-body

⑦ Construction of spillway

⑧ Lining and protection of dam slope

⑨ Construction of intake facilities

⑩ Finishing and clearing

Prior to starting dam construction, preparation for road construction should be made.

The major equipment for construction of dam-body will be as follows;

Equipment		Application
Bulldozer	21 ton	Excavation, Spreading, Compaction
Front loader	1.4 m^3	Loading
Dump truck	8 t	Hauling
Back hoe	0.7 m^3	Excavation, Loading
Water tank truck	6,000 ℓ	Adjustment of moisture ratio
Drainage pump	φ100 mm	Drainage of water
Concrete mixer	0.6 m	Concrete mixing
Water tank truck	6,000 ℓ	Concrete mixing

ii) Sub-Soiling

The major equipment of sub-soiling work will be as follows;

- 70 ps farm tractor with plow
- Bulldozer 11 ton with ripper

iii) Contour terrace and graded terrace

The major equipment of contour terrace work will be as follows;

Equipment		Application
Farm tractor	70 PS	Excavation
Soil compactor	90 kg class	Compaction

iv) Bench terrace

The major equipment of bench terrace work will be as follows;

Equipment		Application
Bulldozer	11~21 m^3	Excavation, hauling, spreading

v) Collecting and draining ditches

The major equipment of canal work will be as follows;

Equipment		Application
Back hoe	0.3~0.7 m^3	Excavation
Soil compactor	90 kg	Compaction

vi) Farm road

Roads will be constructed from the balance of cut and bank earth volume in principle.

The major equipment for road work will be as follows;

Equipment		Application
Bulldozer	11~21 m^3	Excavation, hauling, spreading
Motor grader	3.1 m	Compaction
		Road grading

vii) Check dam and fish pond

The major equipment for these works will be the same type of equipment as for farm pond construction.

viii) Pump station and pipeline

The major equipment for pipe work will be as follows;

Equipment		Application
Back hoe	0.3~0.7 m^3	Excavation, hauling, spreading
Truck crane	2 t	Pipe laying

4) Sample output of construction equipment

Sample outputs of construction equipment on earth works are shown in Table 4.3-2.

(2) Construction schedule

The construction schedule will be shown by bar chart and/or include diagram method.

The former method shows the schedule of each work item clearly. While the latter method shows the procedure of construction works.

Recently the latter is often utilized by applying a computer programme.

Judging from the results of the feasibility study, approximate construction period for each plan is as follows;

Plan I ; 24 ha/month

Plan II ; 31 ha/month

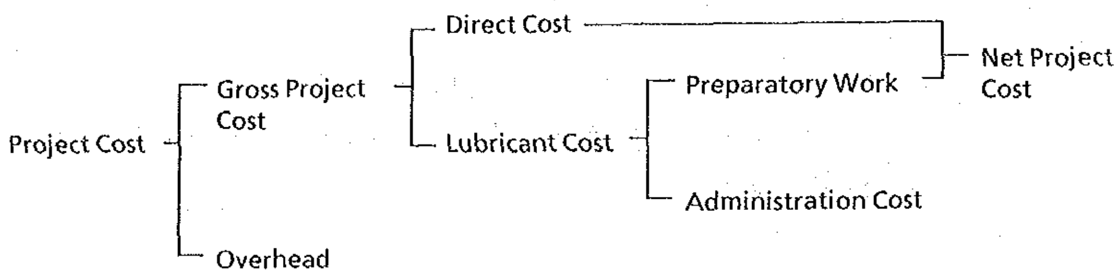
Plan III ; 44 ha/month

4-3 Cost Estimation

For successful implementation of Projects, cost estimation shall be carried out in a right way and with reasonable cost.

4-3-1 Components of Project Cost

The components of project cost for land and water conservation consists of the following items.



(1) Direct cost for construction

1) Material cost

2) Labor cost

3) Machinery cost

4) Power fuel, water, etc.

(2) Lubricant Cost

1) Preparatory Work

- Temporary work
- Safety facilities
- Mobilization of machinery
- Transportation of labor, materials
- Control and check of engineering quality
- Others

2) Administration cost for the site

- Salary and retirement allowance
- Public welfare
- Stationary

- Communication
- Land cost
- Compensation
- Insurance
- Tax
- Power, fuel, water
- Others

(3) Overhead cost for contractor or firm

1) Overhead cost

- Allowance for management staff
- Salary of employee
- Retirement allowance
- Welfare
- O & M cost
- Stationary
- Communication
- Power, fuel, water
- Institutional cost
- PR
- Land and Office rental
- Depreciation
- Research and development cost
- Tax
- Insurance
- Others

2) Benefit

- Tax
- Pay a dividend on the stocks
- Deposit
- Interest

15%~50% of gross project cost shall be estimated considering project size and type of firm.

In addition to the above, the following items shall be considered for Total Project Cost.

① Engineering Services

- Review of feasibility study
- Detailed design
- Tender document
- Assistance of tendering and awarding
- Supervision

5%~8% of project cost shall be estimated.

② Physical contingency

There shall be some difference between the planning stage and construction stage due to increase in the acreage of the project area and some modification of structure.

To adopt such a case, the cost shall be estimated, normally at 10% of the Project Cost.

③ Price contingency

Price escalation rates of materials and civil works shall be estimated at 6.5% for local currency portion and 7.5% for foreign currency portion due to the long period of the construction schedule. This rate, however, shall be considered flexible.

4-3-2 Unit Price

(1) Unit price of materials

The cost of construction work is estimated based on the data collected on prices from DLD and RID as of February 1988.

The unit prices used for estimation of the project cost are as follows;

1) Labour unit price

Item	Rate (Baht/day)
Foreman	160
Equipment Operator	150
Operator Assistant	80
Driver	120
Steel Worker	200
Concrete Worker	80
Carpenter	150
Mechanic	190
Electrician	170
Mason	135
Common Labour	75

2) Unit price of materials

Item	Unit	Rate (Baht)
Sand	cu.m	160
Gravel	cu.m	250
Rip Rap	cu.m	240
Laterite	cu.m	100
Reinforcement Bar	ton	12,000
Cement	ton	1,700
Diesel Oil	litre	6.7
Electrical Charge	KWH	3.5
Timber (Soft)	cu.m	6,500
Timber (Hard)	cu.m	8,500

(2) Rate of foreign and local currentcy

Rate of foreign and local currency portion is normally applied as follows.

Description	Rate of Foreign Currency	Rate of Local Currency
Cement	60%	40%
Steel bar	70%	30%
Timber	20%	80%
Fuel & Oil	80%	20%
Labour	–	100%
Spare parts	90%	10%
Gravel	–	100%
Sand	–	100%
Laterite	–	100%
Concrete block	40%	60%
Reinforced concrete pipe	50%	50%

(3) Unit cost of works

Unit cost of works is shown in Table 4.3-1.

(4) Estimation method of cost price

Some samples, how to estimate unit cost of work are shown in the following.

1) Earth work for excavation and moving

Machinery : Bulldozer, (Swamp Bulldozer)

i) Output (m^3/hr)

Output per hour shall be calculated in the following formula.

$$Q = \frac{60 \times q \times f \times E}{Cm}$$

where Q : Output per one hour (m^3/hr)

q : Output per one cycle (m^3)

Table 4.3-1 Unit Cost of Works (1/3)

F.C. ; Foreign Currency
L.C. ; Local Currency

Description	Unit	Equipment Depreciation	Labour, Material & Repair Cost		Total Cost	Remarks
			F.C.	L.C.		
1. Earth Works						
Stripping (A)	Baht/m3	3.7	5.0	2.9	11.6	Farm Pond
Stripping (B)	Baht/m3	2.2	3.0	1.8	7.0	Check Dam
Common Excavation	Baht/m3	9.3	14.9	9.5	33.7	Farm Pond & Fish Pond
Embankment (A)	Baht/m3	13.4	19.9	12.4	45.7	Farm Pond (Zone II)
Embankment (B)	Baht/m3	14.1	20.3	12.6	47.0	Check Dam & Fish Pond
Embankment (C)	Baht/m3	17.0	25.7	16.1	58.8	Farm Pond (Zone I)
2. Mechanical Measures						
Sub Soiling	Bath/ha	656	889	518	2,063	
Contour Terrace	Baht/m	3	3	23	29	
Collecting Ditch & Draining Ditch						
Grass Waterway	Baht/m	3	3	28	34	
Masonry	Baht/m	7	32	131	170	
Drop Structure	Baht/place	–	117	405	522	Concrete block
Road Crossing Concrete Pavement	Baht/m	25	201	611	837	
Slope Protection	Baht/m2	0.3	0.4	6.4	7.1	
Sediment Trap	Baht/place	–	117	405	552	Sodding Concrete block
Main Farm Road	Baht/m	19	28	123	170	Trunk Road
Lateral Farm Road	Baht/m	13	18	73	104	
Check Dam	Baht/place	17,000	25,000	52,000	94,000	Sediment Pond

Table 4.3-1 Unit Cost of Works (2/3)

Description	Unit	Equipment Depreciation	Labour, Material & Repair Cost		Total Cost	Remarks
			F.C.	L.C.		
3. Irrigation Facilities						
PVC Pipe Laying ø 75 mm	Baht/m	–	44	26	70	Man power
PCV Pipe Laying ø100 mm	Baht/m	–	69	33	102	Man power
Portable Pump ø 80 mm	Baht/unit	–	12,000	12,000	24,000	
4. Supporting Measures						
Fish Pond	Baht/place	49,000	75,000	61,000	185,000	
Well	Baht/place	–	34,500	34,500	69,000	
Meeting Hall	Baht/m	–	1,500	1,500	3,000	
Ware house	Baht/m^2	–	750	750	1,500	

Table 4.3-1 Unit Cost of Works (3/3)

Description	Unit	Equipment Depreciation	Labour, Material & Repair Cost		Total Cost	Remarks
			F.C.	L.C.		
5. Miscellaneous Works						
Concrete Rough	Baht/m^3	23	289	663	975	Stone Concrete
Concrete Plain	Baht/m^3	27	348	1,059	1,434	
Concrete Reinforced	Baht/m^3	23	1,383	1,905	3,311	
Concrete canal lining	Baht/m^3	22	422	1,069	1,513	
Rip rap	Baht/m^3	18	33	313	364	
RC Pipe Laying ø 300m/m	Baht/m	–	105	130	235	Man power
RC Pipe Laying ø 600m/m	Baht/m	9	213	237	459	
Steel Pipe Laying ø 150m/m	Baht/m	9	243	150	402	
Gate Valve Setting ø 75m/m	Place	–	1,029	629	1,658	
Gate Valve Setting ø 100m/m	Place	–	1,323	763	2,086	
Gate Valve Setting ø 150m/m	Place	–	2,168	1,126	3,294	
Drain (Sand & Gravel)	Baht/m	15	29	298	342	Farm Pond
Gravel Pavement	Baht/m	20	36	285	341	Farm Pond

f : Bulk factor of soil
(refer to Table 4.3-5)

E : Working efficiency of machinery
(refer to Table 4.3-4)

Cm : Needed time for one cycle

In case of excavation and moving, Q shall be given in the following procedures.

Machinery	:	Bulldozer 21 ton class
Slope	:	3 ~ 5% up-down
Soil	:	Sandy soil
Moving distance	:	L = 30 m

In the above conditions, each factor was given from the tables as follows;

$q = 2.99\ m^3$ (Table 4.3-2)

$f = 1.00$ (Table 4.3-5)

· due to natural soil excavation

$E = 0.60$ (Table 4.3-4)

· due to common condition

$Cm = 1.27$ (Table 4.3-3)

· due to moving distance (L = 30 m)

Therefore,

$$Q = \frac{60 \cdot q \cdot f \cdot E}{Cm} = \frac{60 \times 2.99 \times 1.00 \times 0.60}{1.27}$$

$$= 34.8\ m^3/hr$$

So, a bulldozer (21 ton class) can excavate and move $84.8\ m^3$ per hour.

From the above calculation, number of machinery, working hour of machinery and period of construction can be estimated depending on working volume.

Note : All data and Tables were quoted from "Cost Estimation Criteria for Land Improvement" Japanese Ministry of Agriculture, Fishery and Forestry, 1987.

Table 4.3-2 Output per one cycle (q) (excavation and moving)

Machinery	Class	Work value (q)
		(m^3)
Bulldozer	3 t	0.368
	6	0.653
	8	0.783
	11	1.34
	15	1.83
	21	2.99
	32	5.01
	44	7.33
Bulldozer for swamp	3.5	0.369
	7	0.801
	9	1.10
	13	1.59
	16	2.09

Table 4.3-3 Needed time for one cycle due to moving distance (L)

L (m)	10	20	30	40	50	60	70
Cm (min)	0.59	0.93	1.27	1.61	1.95	2.29	2.63

where; formula is shown below

$$Cm = 0.034\ L + 0.25$$

In general, maximum moving distance is assumed to be 7.0 m by bulldozer.

Table 4.3-4 Working efficiency (E) for common earth work

Soil \ Condition	Good	Fair	Poor
Sand	0.85 ~ 0.75	0.75 ~ 0.65	0.65 ~ 0.55
Sandy soil	0.75 ~ 0.65	0.65 ~ 0.55	0.55 ~ 0.45
Clayey soil	0.65 ~ 0.55	0.55 ~ 0.45	0.45 ~ 0.35
Grabel	0.65 ~ 0.55	0.55 ~ 0.45	0.45 ~ 0.35

where Good condition

Working space is wide enough and down-slope

Fair condition

Between good and poor condition

Poor condition

Narrow space and up-slope

Table 4.3-5 Bulk factor of soil (f)

Soil	Natural	Excavated	Compacted
Sand	1.00	1.20	0.95
Sandy soil	1.00	1.25	0.90
Clayey soil	1.00	1.35	0.90
Gravel	1.00	1.20	1.00
Crushered rock	1.00	1.50	1.20

Table 4.3-6 Operation Cost of Major Equipment

Unit : Baht/hr

Description			Purchase Price (1) (×10³ B)	Life Time (2) (×10³ B)	Depreciation Cost (3)	Repair Cost			Fuel & Lubricant			Operator & Labour (10)	Administrative Cost			Total Foreign Currency (14)	Total Local Currency (15)
						Rate (4)	Parts (5) F.C	Labour (6) L.C	Fuel (7) (1/hr)	(8) F.C	(9) L.C		Rate (11)	(12) F.C	(13) L.C		
BULLDOZER	11TON	108PS	2350	10000	211.5	0.65	122.2	30.5	11.4	61.1	15.3	50.0	0.07	82.2	82.2	265.6	178.1
BULLDOZER	21TON	211PS	3500	10000	315.0	0.65	182.0	45.5	22.8	122.2	30.6	50.0	0.07	122.5	122.5	426.7	248.6
BACKHOE	0.7M3	140PS	2300	10000	207.0	0.55	101.2	25.3	15.0	80.4	20.1	50.0	0.07	64.4	64.4	246.0	159.8
FLONT LOADER	1.4M3	110PS	1800	10000	162.0	0.70	100.8	25.2	13.0	69.7	17.4	50.0	0.07	63.0	63.0	233.5	155.6
DUMP TRUCK	8TON	240PS	920	10000	82.8	0.60	44.2	11.0	13.3	71.3	17.8	35.0	0.10	36.8	36.8	152.2	100.7
PORTABLE CONCRETE MIXER		0.6M3	330	10000	29.7	0.70	18.5	4.6	0.0	0.0	0.0	0.0	0.05	8.2	8.2	26.7	12.9
TRUCK CRANE	2TON	86PS	430	10000	38.7	0.45	15.5	3.9	3.1	16.6	4.2	35.0	0.10	17.2	17.2	49.3	60.2
MOTOR GRADER	3.1M	113PS	2400	10000	216.0	0.50	96.0	24.0	7.6	40.7	10.2	50.0	0.07	84.0	84.0	220.7	168.2
GRASS SPREADER	1300L	10PS	530	10000	47.7	0.85	36.0	9.0	3.1	16.6	4.2	35.0	0.07	18.5	18.5	71.2	66.7
SOIL COMPACTOR	90KG	4PS	40	4500	8.0	0.45	3.2	0.8	0.8	4.3	1.1	50.0	0.05	1.3	1.3	8.8	53.2
WATER TANK TRUCK		6000L	880	10000	79.2	0.50	35.2	8.8	5.2	27.9	7.0	35.0	0.07	30.8	30.8	93.9	81.6
FARM TRACTOR	6TON	67PS	980	10000	88.2	0.60	47.0	11.8	7.0	37.5	9.4	50.0	0.07	34.3	34.3	118.9	105.4
DRAINAGE PUMP		D100M/M	30	10000	2.7	1.10	2.6	0.7	0.0	0.0	0.0	0.0	0.05	0.7	0.7	3.4	1.4

(3) = (1) / (2) × (1 − 0.1) (5) = (1) / (2) × (4) × 0.8 (6) = (1) / (2) × (4) × 0.2 (8) = 6.70 × (7) × 0.8 (9) = 6.70 × (7) × 0.2

(12) = (1) / (2) × (11) × T × 0.5 (13) = (1) / (2) × (11) × T × 0.5 (14) = (5) + (8) + (12) (15) = (6) + (9) + (10) + (13)

Diesel Oil ; 6.70 B/ℓ T ; Life Year

Note: B = Baht

Data : (1) Marketing price in Bangkok, Mar. 1988
(2) Thailand standard (RID, 1987)
(3) Thailand standard (RID, 1987)
(4) Japanese standard (MAFF 1987)
(7) Japanese standard (MAFF 1987)
(11) Japanese standard (MAFF 1987)

ii) Operation cost

For unit cost calculation of earth work as to excavation and moving, unit cost of operation of equipment is needed.

Machinery : Bulldozer 21 ton

Operation cost : 990.3 Baht/hr

(from Table 4.3-6)

iii) Unit work cost (Baht/m^3) for excavation and moving by bulldozer

$$\text{Unit work cost} = \frac{\text{Operation cost (Baht/hr)}}{\text{Work value} \quad (m^3/hr)}$$

$$= \frac{990.3}{84.8}$$

$$= 11.6 \text{ Baht}/m^3$$

where FC = 8.7 Baht/m^3

LC = 2.9 Baht/m^3

This figure is obtained based on contract basis. In case of force account basis, depreciation cost shall be deducted and procurement cost of machinery shall be added.

2) Embankment work

i) Output of construction equipment per hour

a) Excavation backhoe 0.7 m^3 class [at borrow-pit]

$$Q = \frac{3,600 \times q \times f \times E}{Cm} = \frac{3,600 \times 0.63 \times 1.0 \times 0.70}{33} = 48.1 \ m^3/hr$$

Q ; Output per hour (m^3/hr)

q ; Output per one cycle (m^3)

f ; Bulk factor of soil

E ; Working efficiency

Cm ; Net time per one cycle (sec.)

- Output per one cycle (q)

$q = qo \times K$

$= 0.7 \times 0.9 = 0.63$

qo : Nominal carrying capacity = 0.7 m^3

K : Coefficient of carry = 0.90

- Net time per one cycle (Cm)

$Cm = 0.054 \times \phi + 23$

$= 0.054 \times 180 + 23 = 33$ sec.

ϕ : Circular angle (degree) = 180

Working Efficiency (E)

Soil	Good	Fair	Poor
Sandy soil	0.85~0.75	0.75~0.65	0.65~0.55
Clayey soil	0.75~0.65	0.65~0.55	0.55~0.45

note ; 1. The upper value of good working condition can be adopted when continuous working is expected on such conditions as optimum excavation depth, easy excavation and no working barriers.

2. The lower value of poor working conditions can be adopted when continuous working is hindered by such conditions as inadequate excavation depth and hard soil.

3. The middle value of the above working conditions can be adopted when working

3. The middle value of the above working conditions can be adopted when working condition is categorized in between the above two limnits.

b) Hauling

Dump Truck 8 ton

Hauling distance L = 300 m

$$Q = \frac{60 \times q \times f}{Cm} = \frac{60 \times 5 \times 1.0}{13.7} = 21.9 \text{ m}^3/\text{hr}$$

Q ; Output per hour (m^3/hr)

q ; Output per one cycle (m^3)

f ; Bulk factor of soil

E ; Working efficiency

Cm ; Net time per one cycle (sec.)

- Output per one cycle (q)

$$Q = \frac{T}{W} = \frac{8}{1.6} = 5 \ (m^3)$$

T ; Nominal carrying capacity = 8 ton

W ; Unit weight of soil on the natural condition (ton/m^3)

Soil	Sand	Sandy soil	Clayey soil	Gravel	Rock
W	1.7	1.6	1.8	1.9	2.4

- Net time per one cycle (Cm)

$Cm = 0.0054 \times L \times \alpha + Cms + 4.0$

$= 0.0054 \times 300.0 \times 2.2 + 6.2 + 4.0 = 13.7$ min.

L ; Hauling distance = 300 m

α ; Coefficient of adjustment

Cms ; Net time per one cycle for loading (min)

Qs ; Output per hour of equipment, Backhoe $0.7m^3$ = 48.1 m^3/hr

Coefficient of Adjustment (α)

Pavement Road	Gravel Road (2 lane)	Temporary Road in construction site
0.90	1.30	2.20

c) Spreading and Compaction

Bulldozer 21 ton

- Spreading [D = 20cm]

Q_1 ; Output per hour (m^3/hr)

D ; Thickness after compaction = 0.20 m

$0.15 \leqq D \leqq 0.35$

E ; Working efficiency = 0.65 (quoted below)

Good	Fair	Poor
1.00~0.75	0.75~0.55	0.55~0.35

A, B ; Coefficient of spreading

specification	A	B
6 ton	7	5
11 ton	11	8
15 ton	12	8
21 ton	18	13

note ; The working efficiency is determined in the following way;

1. The upper value can be adopted when there is a favorable balance of supplying embankment materials and working ability, slight undulation and no hindrance.
2. The lower value can be adopted for unfavorable balance of supplying and working ability, poor soil and undulation.
3. The middle value can be adopted when working condition is categorized in between the above two limits.

- Compaction [N = 4 times]

$$Q_2 = \frac{V \times W \times D \times E}{N} = \frac{3500 \times 0.9 \times 0.2 \times 0.6}{4} = 102.4 \ m^3/hr$$

Q_2 ; Output per hour (m^3/hr)

V ; Velocity of compaction work = 3500 (m/hr)

W ; Effective compaction per one time (m)

Bulldozer	W
11 ton	0.7 m
15 ton	0.8
21 ton	0.9

D ; Thickness after compaction = 0.20 m

N ; Number of times of compaction = 4 times

E ; Working efficiency = 0.65

where E = 0.45~0.85

note ; The value of working efficiency can be adopted considering the following conditions. The upper value can be adopted for better working conditions, the lower value can be adopted for poor working conditions.

1. Balance of supplying ability of embankment materials and compacting work ability (working efficiency is good when the supplying capacity exceeds the compacting work ability).
2. Adoptability of embankment materials (soil characteristics, moisture content and grading combination).
3. Degree of hindrance.
4. Topographical feature such as undulation or curve.

- Spreading & Compaction

$$Q = \frac{Q_1 \times Q_2}{Q_1 + Q_2} = \frac{107.9 \times 102.4}{107.9 + 102.4} = 52.5 \ m^3/hr$$

Q ; Output per hour of spreading and compaction (m^3/hr)

Q_1 ; Output per hour of spreading (m^3/hr)

Q_2 ; Output per hour of compaction (m^3/hr)

3) Operation cost of construction equipment per hour

Equipment		Equipment Depreciation	Foreign Currency	Local Currency
Backhoe	0.7 m^3	207.0 Baht/hr	246.0 Baht/h	159.8 Baht/h
Dump Truck	8 ton	82.8	152.2	100.7
Bulldozer	21 ton	315.0	426.7	248.6

Refer to Table 4.3-6.

4) Combination of construction equipment

The required hours of each construction equipment per working volume 100 m^3 are calculated from their output per hour.

Equipment			Required hours
Backhoe (0.7 m^3)	100 m^3	/ 48.1 m^3/hr	= 2.08 hr/unit
Dump truck (8 ton)	100	/ 21.9	= 4.56
Bulldozer (21 ton)	100	/ 52.5	= 1.90

From the above the most effective combination of number of equipment can be given as follows;

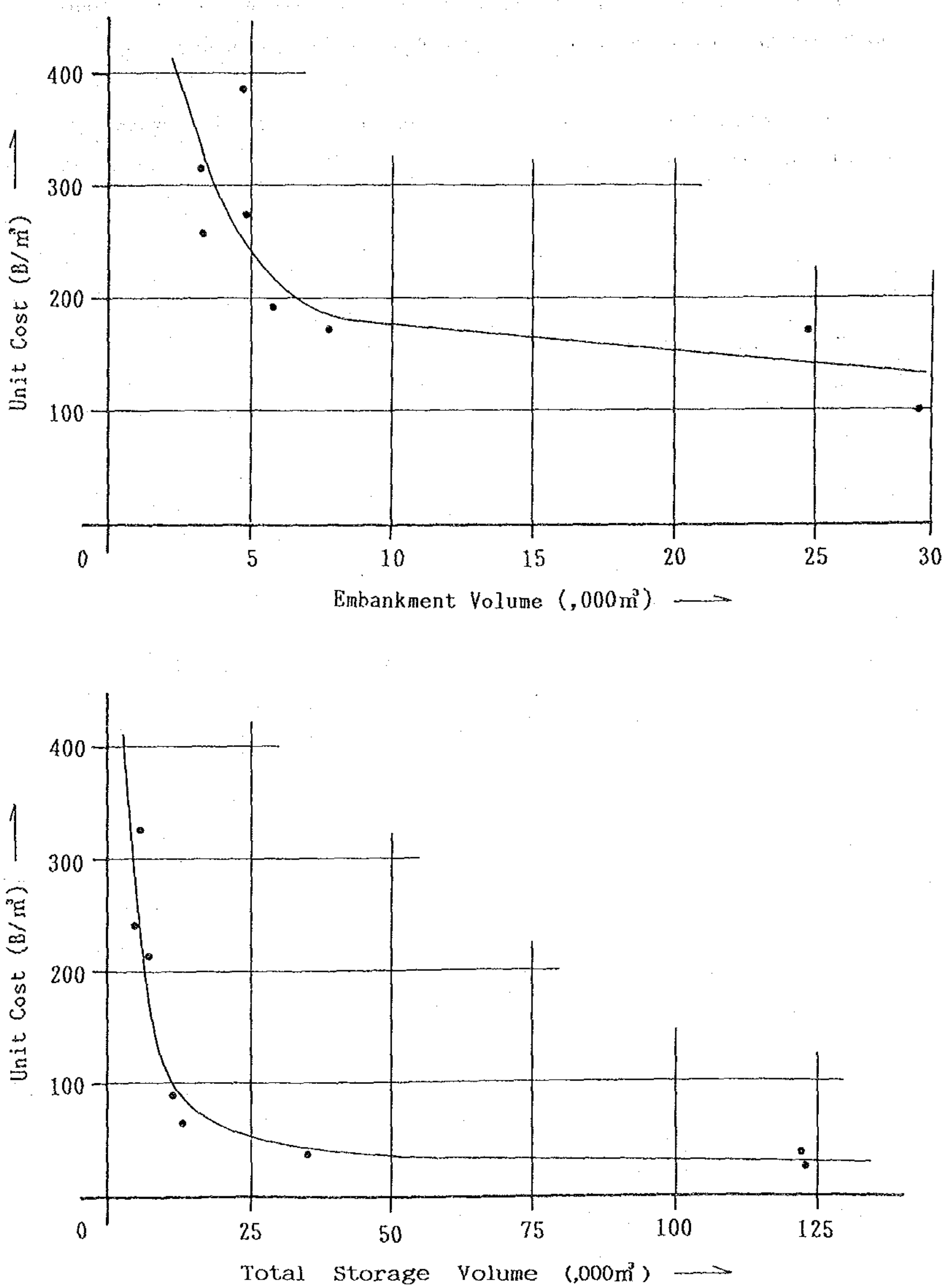
Backhoe	1 unit
Dump truck	2 units
Bulldozer	1 unit

ii) Unit cost of embankment work

Equipment	Unit	Quantity	Operation Cost			Unit Cost		
			Dep.	FC	LC	Dep.	FC	LC
Backhoe 0.7 m3	ha	2.08	207	246	160	431	512	332
Dump Truck 8t	ha	4.56	83	152	101	378	708	459
Bulldozer 21t	ha	1.90	315	427	249	599	811	472
Total	Baht/100m^3					1,408	2,031	1,263
	Baht/m^3					14	20	13

In case of contract basis, unit cost of embankment is 47 Baht per m^3.

Figure 4.3-1 Unit Cost of Farm Pond Construction



4-4 Tendering and Awarding

In case that the construction works will be carried out on a contract basis, the procedure as shown in Figure 4.4-1 will be taken.

It is essential to establish tendering and its awarding system in DLD considering Thai law and regulations.

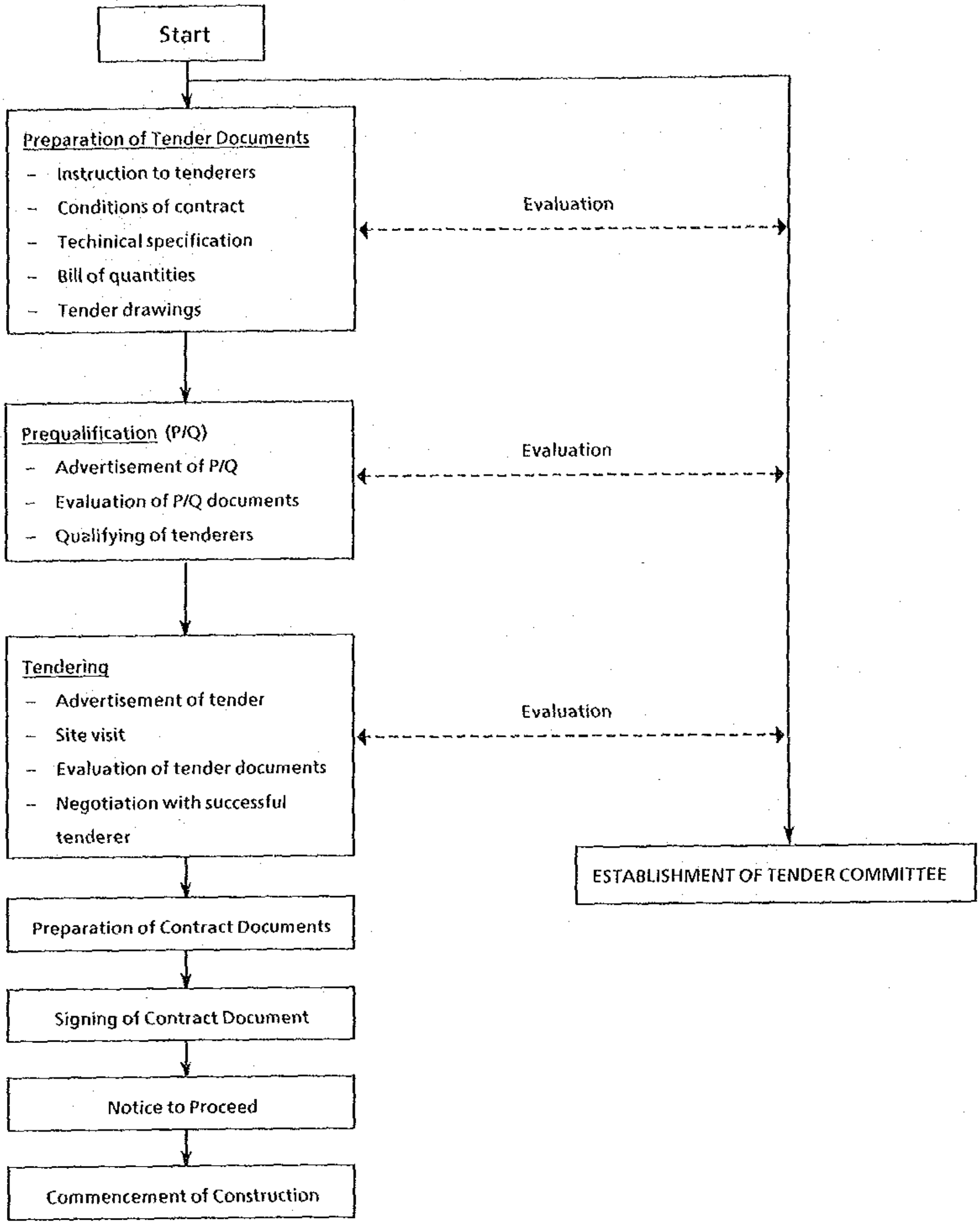


Figure 4.4-1 **TENDERING PROCEDURE**