THE GOVERNMENT OF MALAYSIA
MINISTRY OF AGRICULTURE
DEPARTMENT OF IRRIGATION
AND DRAINAGE (DID)

JAPAN INTERNATIONAL
COOPERATION AGENCY
(JICA)

THE FEASIBILITY STUDY ON SMALL RESERVOIR DEVELOPMENT IN PENINSULAR MALAYSIA

VOLUME III

GUIDELINES

March 1995

NIPPON KOEI CO., LTD.

PACIFIC CONSULTANTS INTERNATIONAL

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX

Definition of Terms

Organisations

DID	Department of Irrigation and Drainage, MOA
DOA	Department of Agriculture
DOE	Department of Environment, MST & E
FAMA	Federal Agricultural Marketing Authority, MOA
FAO	Food and Agricultural Organisation
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
FOA	Farmer Organisation Authority
IADP	Integrated Agricultural Development Project
JICA	Japan International Cooperation Agency
JPS	Jabatan Pengairan dan Saliran (DID)
LPP	Farmers Organisation Authority
MADA	Muda Agricultural Development Authority
MARDI	Malaysian Agricultural Research and Development Institute
MMS	Malaysian Meteorological Service
MOA	Ministry of Agriculture
PPK	Area Farmers Organisation (AFO)
PPN	State Farmers Organisation (SFO)

Others

Bkt.	Bukit (Hill)
EIRR	Economic Internal Rate of Return
cusec	Cubic feet per second
cumec	Cubic meter per second
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
ft	Feet
ha	Hectare
Jl., J.	Jalan (street)
kg	Kilogram
Kg.	Kanpung (village)
Kp.	Kelompok (group)
km	Kilometer
Ldg.	Ladang (town)
m	Meter
MCM	Million Cubic Meter
M/P	Master Plan
O & M	Operation and Maintenance
Sg. S.	Sungai (river)

Environment

Assessor

The assessor is the person who conducts or co-ordinates an environmental impact assessment.

Detailed Assessment

Detailed assessment is the second phase of the environmental impact assessment procedure. Detailed assessment are those for which impacts of unknown significance or significant residual impacts have been identified during the preliminary assessment.

Environmental Characteristics

Environmental characteristics are broad environmental categories such as surface water, atmosphere, species and populations, health and safety etc. as listed in the preliminary assessment matrix.

Environmental Impact Assessment (EIA)

This is an evaluation process designed to identify and predict the impact (good or bad) of the development projects on the well-being of the society.

Environmental Monitoring

Environmental monitoring is a surveillance program to measure the actual impact of the project and will be used as the data-base for future impact prediction.

Mitigating and Abatement Measures

These are the measures adopted in the project plan which either lessen or completely forestall a potential adverse environmental impact.

Preliminary Assessment

Preliminary assessment is the first phase of the environmental impact assessment procedure. Selected projects are subjected only to a preliminary assessment.

Residual Environmental Impact

A residual environmental impact is the potential impact remaining after mitigating measures have been adopted in a project plan.

Significant Environmental Impact

A significant environmental impact is one which will have an appreciable effect on the community or on the ecosystem on which the community depends.

Reference Document / Report

HP 1	Hydrological Procedure No. 1 prepared by DID
HP 4	Hydrological Procedure No. 4 prepared by DID
HP 5	Hydrological Procedure No. 5 prepared by DID
HP11	Hydrological Procedure No.11 prepared by DID
HP17	Hydrological Procedure No.17 prepared by DID

I. GENERAL

1.1 Purpose of the Guidelines

The purpose of the guidelines is to assist Government and Non Government agencies concerned with small reservoir development in Malaysia. These guidelines are prepared to serve technical knowledge and guidance for surveys and investigations, planing, design and operation & maintenance work based on the experience of the Feasibility study on small reservoir development, and these guidelines cover the following major technical fields.

- Meteorology and hydrology
- Irrigation and Drainage
- Geology and Geo-technic
- Agriculture
- Agro-economy
- Environment

1.2 Basic Concepts for Small Reservoir Development

1.2.1 Objectives of Small Reservoir Development

The National Agricultural Policy 1992-2010 aims at the maximisation of income through the optimal utilisation of resources in the agriculture sector. Small reservoir development will provide opportunities to incorporate a number of the goals and strategies of NAP (1992-2010). The small reservoir development project will be a "water-based agricultural development approach" or an "integrated mini agricultural development model". It will be formulated within the framework of NAP (1992-2010) to achieve the following goals and targets.

(1) Expanded Food Production

Small reservoirs provide irrigation water for vegetables, fruits and other high value crops whose production is encouraged to expand by NAP (1992-2010);

(2) Water Resources Development

Sustainable development of water resources through appropriate investments in the engineering infrastructure for irrigation, drainage and farm access should be promoted. Small reservoirs have many advantages including low investment cost, simplified design, construction and O & M, reduced environmental impacts and is quick yielding. As far as possible, it does not involve resettlement of people and land to be acquired is not great. Priority is given to irrigation for diversified crops, but agro-tourism, aqua culture, and domestic and industrial water supply are also taken into consideration.

(3) Reorganisation of the Production System and Structure

Uneconomic farm sizes, labour shortages, irrigation and drainage limitations, and the ageing farm population are problems faced by the agriculture sector in Malaysia. Solutions have been sought in the expansion of mini-estates, group farming and other forms of centralised management systems and encouraging involvement in the development programmes by farmers, women, farmers' organisations as well as the private sector.

(4) Optimising Resource Use

Following the in-situ development policy, the effective and systematic utilisation of abandoned land and idle land is accelerated and the realisation of productivity and other efficiency gains in both crop and non-crop sub sectors are promoted.

(5) Agro-based Industries Development

Agricultural surpluses are used to complement and support the agro-based industries.

1.2.2 Type of Small Reservoirs

The definition of small reservoirs are as follows;

Type A : Low dam built on a small river having a dam height of less than 15 m, a storage capacity of less than 1 million m3 (100 ha-m) and a catchment area of less than 50 km ^{2};

Type B : Pond built by excavation, or dyking, or installation of regulating structures, in swamp, or low-lying land, or abandoned paddy field;

Type C : Pond formed utilising an oxbow along an abolished river course:

Type D : Reservoir created by widening river width, excavating riverbed or heightening of river banks at upstream of an existing weir ; and

Type E : Reservoir utilising a tin mine pond or a natural lake.

1.3 Scope of the Guidelines

The Guidelines consist of the following 4 chapters.

- Guidelines for Survey and Investigation
- Guidelines for Project Planning
- Guidelines for Design
- Guidelines for Operation and Maintenance (O & M)

(1) Guidelines for Survey and Investigation

The guidelines present basic data and information to be collected for the identification of the projects, and survey and investigation methods to be applied for feasibility study of the projects.

(2) Guidelines for Project Planning

The guidelines present basic methods and procedures for project planning on a feasibility study level in the following fields:

- Land use plan
- Water resources plan
- Irrigation and drainage plan
- Water management plan
- Farming and cropping plan
- Farmers' organisation plan
- Extension and support services plan
- Environment conservation plan
- Outline design of main facilities
- Project implementation plan
- Estimates of project costs and benefits
- Project evaluation

(3) Guidelines for Design

The guidelines present basic design concepts to be applied for the design of a fill type dam and its appurtenant structures such as diversion works, outlet works, and spillway.

(4) Guidelines for Operation and Maintenance (O & M)

The guidelines indicate basic concepts for O & M of the fill type dam and its appurtenant structures, which will be applied to study O & M of dams in the feasibility study stage and be used as basic guidelines for the preparation of an O & M manual for individual projects.

Furthermore, the Department of Environment (DOE) under the Ministry of Science, Technology and Environment is responsible for formulating and implementing the environmental policies of the Government of Malaysia. 'A Handbook of Environmental Impact Assessment Guidelines' prepared by DOE provides the environmental guidelines for the project initiator to follow before implementation.

Environmental Guidelines described in this report mainly focus on the guidelines to be followed for small reservoir development projects and are provided for environment conservation plans for small reservoir development.

1.4 Project Implementation Model

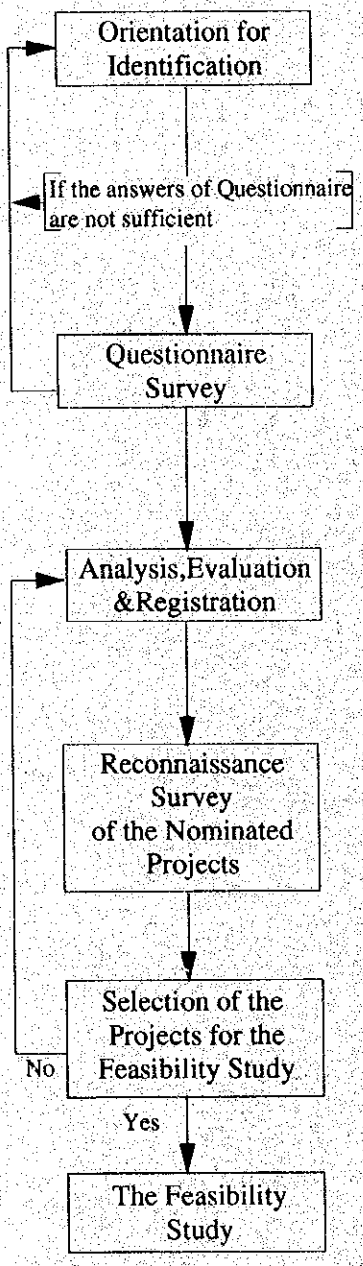
One of the most important issues of small reservoir development is the establishment of a project implementation model comprised of the relevant agencies concerned with small reservoir development projects.

The implementation model shall be one of the following three categories:

(i) Government constructs and government operates
(ii) Government constructs and user operates
(iii) User constructs and user operates

These guidelines shall be used by all the agencies concerned with the project implementation model as a technical guide for the implementation of small reservoir development projects.

Fig.2.1 Identification of the Project



Work Flow	Agencies' Actions	Operation	Reference Sections of Guidelines
Orientation for Identification	DID→Project Owners (Government & Non Government)	(1)Preparation of Questionnaire Form (2)Orientation to Project Owners (3)Information of Questionnaire Survey to Project Owners.	2.2
Questionnaire Survey	Joint operation by DID & Project Owners	(4)Distribution of Questionnaire Form (5)Questionnaire survey by Project Owners and DID	2.3
Analysis,Evaluation &Registration	DID	(6)Analysis of the answers of Questionnaire (7)Categorization of the Project types. (8)Evaluation of the development potential (9)Registration of the Projects (10)Nomination of the Projects	2.4
Reconnaissance Survey of the Nominated Projects	Joint operation by DID&Project Owners	(11)Field Reconnaissance survey (12)Discussion/meeting among DID. Project Owners and Farmers' groups	2.5
Selection of the Projects for the Feasibility Study	Joint operation by DID&Project Owners	(13)Priority ranking (14)Preparation of preliminary development plan (15)Discussion/Meeting among DID& Project Owners	2.6

II. IDENTIFICATION

2.1 General

Figure 2.1 shows the proposed methods and procedure for an identification of the projects. The detailed points of the procedure could be explained from the view points of water resources development, irrigation and drainage, agriculture, and environment fields as follows.

2.2 Orientation for Identification

DID holds the orientation for the identification of the projects together with the project owners who have the candidate sites for the small reservoir development. The project owners will be comprised the Government agencies and/or non Government agencies.

DID shall provide questionnaire forms for survey before the orientation, and explain the procedure and method questionnaire survey to the project owners.

The most important purposes of the questionnaire survey on the identification for small reservoir development are to clarify the necessity of the projects and to confirm the technical soundness of the project. The following main items shall be involved in the questionnaire form.

- General information in villages (Numbers of households, average incomes etc.)
- Present agriculture conditions(cropping pattern, crop intensity)acreage of farm land, unit yield, farmers' organisation, etc.)
- Soils
- Farmers' intention for the development
- Land use
- Conditions of water shortages and flood
- Conditions of existing irrigation & drainage facilities
- Conditions of neighbouring irrigation projects
- The needs of the irrigation development
- Soil erosion or sedimentation
- Water quality
- Health and safety of village peoples
- Socio economic condition
- Communal problems

2.3 Questionnaire Survey

The survey shall be carried out by the joint operation among DID and project owners. If the answers of the questionnaire are not sufficient or much discrepancy and ambiguity are found out among the answers, the questionnaire form shall be returned to the project owners for re-filling the answers.

2.4 Analysis and Evaluation

Though the analysis of the answers of the questionnaire, the categorisation of the projects shall be made, based on the typical categorisation described in the Section 1.2.2. The Evaluation of the development potential shall be made from viewpoints of agriculture development, land use development, water resources development and environmental impact assessment as described below.

Agriculture

- Purpose of the project (poverty alleviation, labour saving, advanced farming, agro-tourism, etc.)
- Will of the farmers (full-time farmers, second generation farmers, etc.)
- Power of the farmers organisation (group power for marketability and financing)
- Farmers' experience for farming of upland crops.
- Soil conditions for crops (Suitable soils for upland crops)
- Scale of the farm land (50-200ha of the total area will be desirable for the main production area of vegetables and fruit crops.)
- Possibility of crop-wise land use
- Agriculture supporting system(agriculture extension work, credit)

Water resources and irrigation

- Reliability of water resources to be developed
- Possibility of further development and extension of neighbouring irrigation projects
- Topographical suitability of the selected sites for the water resources development
- Geological suitability for dam construction
- Necessity and possibility of irrigation

Environment

The selection of the projects for small reservoir development shall be made considering the following factors :

(i) The projects which do not cause environmental problems, or cause problems which can be solved by suitable remedial measures shall be selected.

(ii) The project areas which do not include environmentally sensitive areas shall be selected. The environmentally sensitive areas are as follows ;

- Historic, religious, cultural or archaeological sites
- Existing reserves and parks
- Any area gazetted as a forest reserve or protective forest reserve (including mangrove areas)
- Existing hydro-projects and irrigation schemes
- Water supply intakes
- Coral reefs and major fishing grounds
- Any area with a tourism potential

(iii) Areas which include the prescribed activities mentioned in the Questionnaire (Part-2 of the Environment) shall be avoided. However if necessary, some highly potential areas which also include the prescribed activities shall be selected. If development needs to be carried out in these areas, a detailed Environmental Impact Assessment (EIA) is necessary. The EIA report should be submitted to DOE, and approval from the Department of Environment will be necessary which may take a considerable amount of time.

All information and the results of surveys shall be compiled in a Data Base program with a location maps, following the system prepared by the JICA Feasibility Study on the Small Reservoir Development Projects.

2.5 Reconnaissance Survey

With regard to the nominated projects after the evaluation, the field reconnaissance survey shall be carried out under the joint operation between DID and the project owners. The discussion and meeting on the development shall be held between both agencies. The reconnaissance surveys aims to confirm the answers of questionnaire and review the field conditions, and the following activities are mainly required.

(i) Confirmation of the background of the projects

Through discussion with the project owners and farmers, the background of the projects shall be confirmed.

(ii) Collection of available data for agriculture and agro economy

The data of agriculture and agro economy in and around the project areas shall be collected from the Government or non Government offices concerned.

(iii) Interview survey for agriculture conditions in the project areas.

(iv) Survey on water resources and water shortages

The survey on water resources should include a convenient and temporary survey on the cross section survey of rivers/streams, river discharge and existing irrigation, and drainage facilities.

Furthermore, an interview survey on conditions of the river flow shall be carried out with the local people.

With regard to the survey on water shortage, a field interview will be carried out with the local people. If agriculture data such as crop intensity, production, and unit yield are available in the regional agriculture offices and relevant offices, the agriculture data for every season shall be reviewed. If the indexes mentioned above are lower than the national average, except for crop types and soils, irrigation water shortages will be substantially confirmed.

As for further water resources development in and around the project areas, the extension of neighbouring irrigation facilities such as link canals, recycling use of the return flow, etc. and new developments using other water resources, shall be taken into account.

(v) Survey on existing irrigation areas and related facilities

Delineation of possible irrigation areas shall be made using cad astral maps and topographical maps on a scale of (1 : 25,000), and conditions of agriculture and urbanisation shall be investigated.

If irrigation & drainage facilities and social infrastructures are constructed in the project areas, an inventory survey shall be carried out by using topographical maps (1 : 25,000) and other available maps issued local offices concerned. The location of existing canals, drains, and major related structures shall be plotted on the maps.

(vi) Collection of available data documents of the Project

The following data and documents shall be collected before and during the reconnaissance survey in order to conform the field conditions.

Maps	Topographical maps (1 : 50,000 or 1 : 25,000) Soil maps

	Cad astral maps
	Location and layout maps of existing canals & drains in and around the project areas, if available
Hydrological data	Rainfall & River Discharge
Agriculture	Planted crop, planted areas and yield of respective crops for the past 3 years
Documents	Tender documents on similar works of other projects in and around the project areas
	Study papers/documents of the same projects, if available

2.6 Selection of the Projects

After the discussion with both agencies and priority ranking of the projects for the feasibility study, the following preliminary development plans shall be tentatively examined based on the results of reconnaissance survey.

- Land use development
- Agriculture development plan
- Agro economic development plan
- Agro social development plan
- Water resources development plan
- Irrigation development plan
- Farm road and social infrastructure development plan
- Flood alleviation plan
- Water supply plan of domestic and industrial use
- Agro-tourism facilities development plan

In regard to the water resources and irrigation & drainage development, the following sub works shall be studied.

(i) The reliability of water resources to be developed

- to review and study the watershed area including acreage, vegetation, land use, and soils
- to roughly estimate annual runoff based on hydrological data if available in and around the project areas
- to study seasonal frequency and damage of water shortages and floods

(ii) The possibility of further development and/or extension of neighbouring irrigation projects.

- to find out other irrigation projects and/or similar water resource development projects located near the project areas
- to review the relevant reports and documents of these projects
- to study the possibility of further water resources development by using current water resources.

(iii) The topographical suitability of the selected sites for the water resources development

- to study and investigate river courses and the location of the proposed dam sites such as gradient of the river, soils, field evidence of land sliding and topographical conditions of the valley around the proposed dam sites
- to study and investigate land use, soils and the topographical gradient of the proposed pond

(iv) The necessity and possibility of irrigation

- to study and investigate topographical conditions, land use and soils of the proposed irrigation areas
- to study and investigate the existing irrigation and drainage system, if existing canal and drainage systems are constructed
- to study the background of local requests for irrigation development such as water shortage problems for agriculture production, operation, water management constraints and rehabilitation of the existing irrigation and drainage canal systems

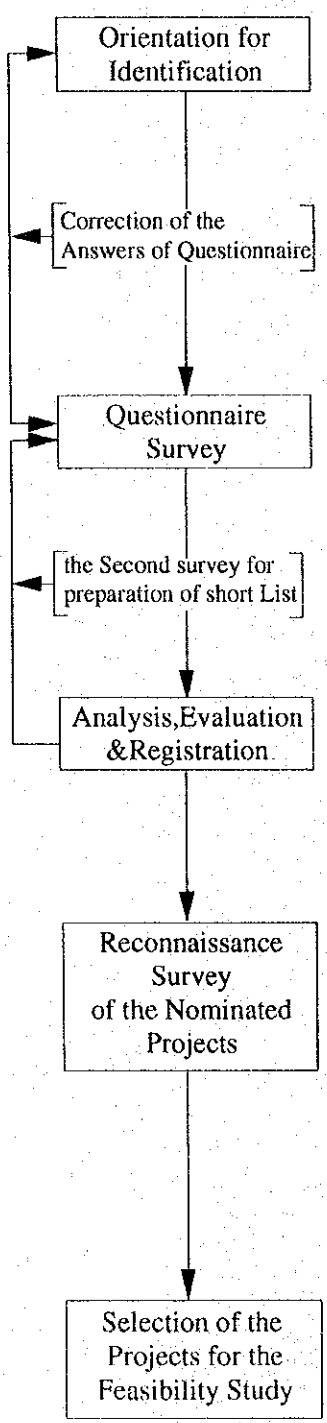
The general layouts of the respective plans will be roughly established by using topographical maps with a scale of (1 : 25,000 or 1 : 50,000) and cad astral maps. The following basic layouts for the plans shall be transposed on the maps.

- dam & reservoir or ponds to be developed
- main off-taking facilities of irrigation
- irrigation & drainage canals or pipe line network
- other major infrastructures to be developed
- irrigation areas and/or other beneficiary areas of the project

2.7 Examples of Identification

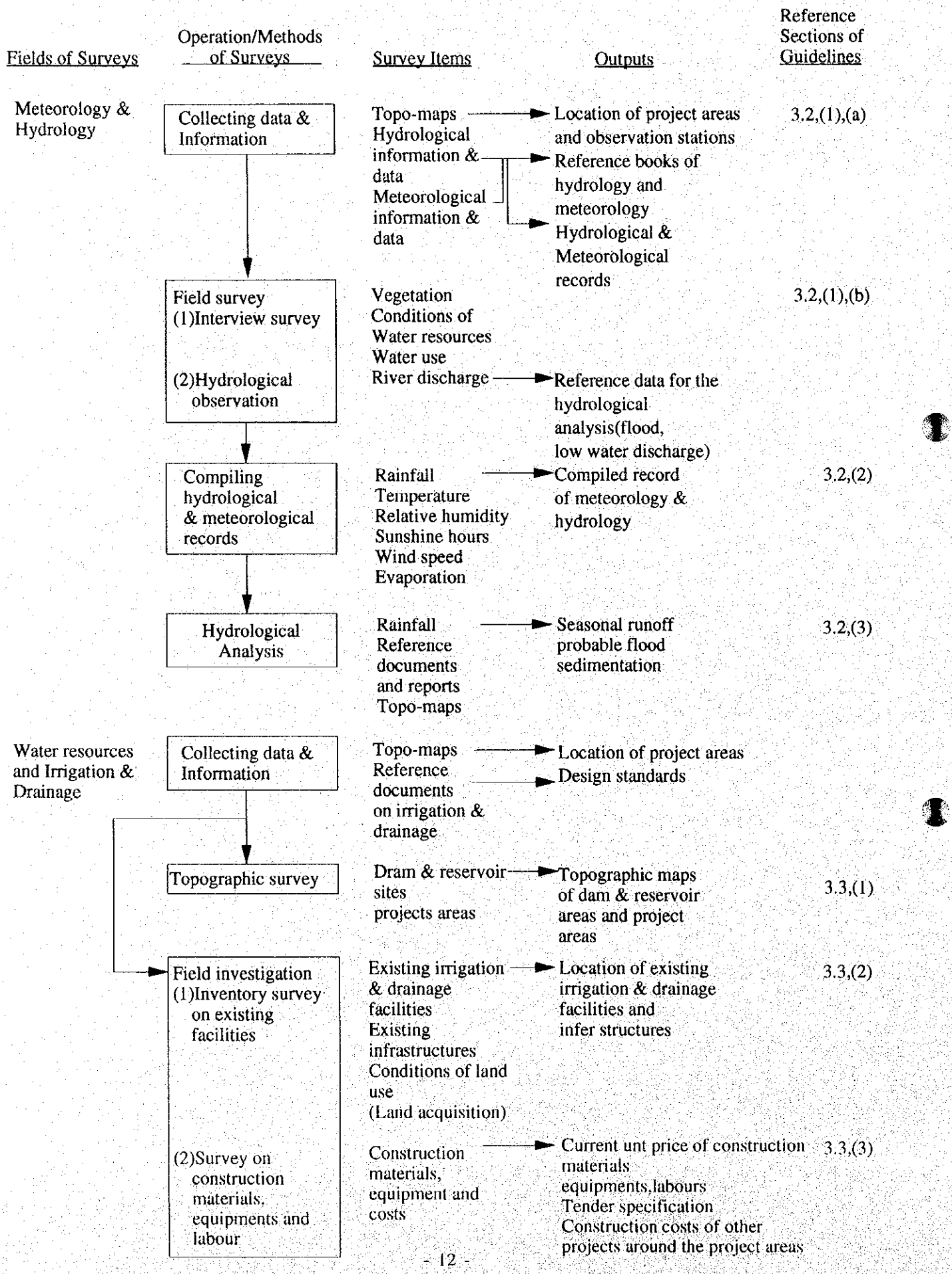
Figure 2.2 shows the examples of the identification for the small reservoir development made by the JICA Study Team. The procedure, survey period, method, survey forms, survey results are described in Annex-1 "Identification" of Volume II of the Feasibility Study Report on the Small Reservoir Development in Peninsular Malaysia by JICA. The detailed points of the Identification shall be referred to the Annex-1 of Volume II, the Feasibility Study Report.

Fig.2.2 Examples of Identification Work



Agencies' Actions	Operation	Reference Report
DID → State DID JICA DOA Study Team IADP State DOA	(1)Orientation through Technical Committee (2)Preparation of Questionnaire Form (3)Explanation of Questionnaire Form (items,survey method,schedule)	Procedure, survey period, survey method, survey forms, survey results, are described in Annex-1 of Volume II,the Feasibility Study Report on small Reservoir Development by JICA.
DID → Local JICA Consultant Study Team State DID	(4)Field survey by Local consultant together with state DID (5)Field investigation by JICA Study Team & DID (6)Data compilation by Local Consultant	
JICA Study Team DID State DID	(7)Analysis by JICA Study Team (8)Categorization by JICA Study Team (9)Registration by JICA Study Team & DID Long List of Projects 266 nos. Short List of Projects 114 nos. (10)Nomination of the Projects by JICA Study Team 18 nos.	
Joint Operation JICA Study Team DID State DID	(11)Field Reconnaissance survey by JICA Study Team,state DID and state DOA (12)Discussion/meeting among JICA Study Team,DID,state DID, DOA,state DOA,IADP,MARDI, FELCRA,FELDA,FOA & Farmers Groups	
Joint Operation DID JICA Study Team State DID DOA State DOA MARDI FELCRA MIADP	(13)The Projects proposed by JICA Study Team 10 nos. (14)The selected projects by DID 8 nos. (15)Preparation of preliminary development plan by JICA Study Team & DID (16)Discussion/Meeting among DID, JICA Study Team,state DID,DOA, state DOA,MARDI,FELCRA, MIADP	

Fig.3.1 Field Surveys and Investigations



Fields of Surveys	Operation/Methods of Surveys	Survey Items	Outputs	Reference Sections of Guidelines
Geology & Geotechnics	Collecting data & Information	Topo-maps Aerial photographs Geological maps	→ Land form classification	3.4,(1) 3.4,(2),(a)
	Field Investigation (1)Drilling and in-situ geotechnical tests at dam sites	Subsurface geological conditions	→ Geological profiles for the dam sites Mechanical properties of the layers	3.4,(2)-(b),(e),(f)&(g)
	(2)Survey in the surrounding area of the reservoir	Land form of the reservoir		3.4,(2),(c)
	(3)Material Investigation	Location and quantity of the proposed materials for dam construction	→ Location maps of the borrows areas	3.4,(3)
	(4)Laboratory tests	Mechanical properties of soils	→ Mechanical test results	3.4,(2),(e)& 3.4,(3)
Agriculture	Collecting data & information	Regional policy of agriculture development Present conditions of agriculture, land use , soils Statistic data of agriculture	→ Summarized data	
	Farmers Interview Survey	Local conditions of agriculture,agro society Farmers' intention for the project	→ Summarized data	3.5,(1),(d)
	Soil survey	Soil profile, Soil properties, Crop suitability	→ Soil maps	3.5,(2)
Agro economy	Collecting data & information	Statistic data of agro economy and agriculture	→ Summarized data	
	Field Investigation & Farm Budget Analysis	Local conditions of agro economy, agriculture,land use,agro society and off-farm income	→ Farm budget	3.6

Fields of Surveys	Operation/Methods of Surveys	Survey Items	Outputs	Reference Sections of Guidelines
Environment	Field Surveys (1)Preliminary Assessment ↓ (2)Detailed Assessment	Major environmental components	Assessment matrix Significance of environmental impacts	3.7,(1)
		Significance of environmental impacts	Suitable mitigation and abatement measures for the projects	3.7,(2)
Agro tourism	Collecting data & information	Data & information of local tourists activities Conditions of transportation		3.8
	↓ Field survey	Conditions of agriculture, infrastructure facilities Accessibility to the project areas Present tourist areas	Potemtcals of agro tourism	3.8

III FIELD SURVEY AND INVESTIGATION

3.1 General

In the feasibility study on small reservoir developments, the field surveys shall be carried out to produce the basic output for making the development plans of water resources, agriculture, irrigation, agro tourism, etc. Figure 3.1 shows the survey methods, the items to be surveyed, the outputs of the surveys. of each the fields.

3.2 Meteorology and Hydrology

(1) Field work

(a) Preparatory work

The following information should be confirmed;

- Catchment area of the proposed intake or dam site on a map of 1 inch to 1 mile or a larger scale.
- River basin number in which the project area is located
- Mean monthly and annual rainfall for the basin
- Estimated mean annual minimum flow (MAM) for the basin
- Estimated available runoff for the basin

(b) Field Survey

The following items are to be confirmed by field and /or interview surveys;

- Locations in the available topographic maps
- Soil cover, development rate and vegetation in the catchment
- Floods (water level of the maximum floods in the past, water level of annual floods, inundated areas, cross-section of the rivers)
- Low flow (annual low water level)
- Sedimentation rate (high, normal, low)
- Water use on the upstream and downstream

(c) Hydrological observations

Intensive discharge measurements (preferably once a week) should be done for a few dry periods in case that;

- actual low flow confirmed at the site is less than the estimated MAM for the basin,
- water source rivers originate from springs or swamps, and/or the actual low flow confirmed at site is much higher than the estimated MAM for the basin, and
- major water use on the upstream is confirmed.

(2) Data required for Hydrological Investigations

(a) Meteorological data

Item

Meteorological data are mainly used for calculating the potential evapo transpiration (ETo) which is required for the estimation of irrigation water requirements. The items of the meteorological data are;

- mean, maximum, and minimum temperature
- mean, maximum, and minimum relative humidity
- sunshine hours
- wind speed

- evaporation

Stations

The above-listed observation items are covered by the principal meteorological stations of the Malaysian Meteorological Services (MMS). The stations are listed below.

Station No.	Station Name
48679	Johor Bahru International Airport (Senai)
48672	Kluang
48674	Mersing
48603	Alor Setar Airport (Kepala Batas)
48600	Pulau Langkawi International Airport
48615	Kota Bharu Airport (Pengkalan Chepa)
48616	Kuala Krai
48665	Melaka Airport (Batu Berendam)
48642	Batu Embun
48631 &32	Cameron Highlands (Tanah Rata)
48657	Kuantan Airport
48649	Muazam Shah
48653	Temerloh
48602	Butterworth Airport
48601	Penang International Airport (Bayan Lepas)
48625	Ipoh Airport
48620	Sitiawan
48604	Chuping
48647	Kuala Lumpur International Airport (Subang)
48648	Petaling Jaya
48619	Kuala Terengganu Airport

Since these are the only stations that cover the required items with a high reliability and long-term availability, it is recommended to use the meteorological data from the nearest MMS principal stations to the proposed project area.

Compilation of data

Meteorological data are to be compiled on a monthly basis. The averaged monthly data for long term (preferably more than ten years) will be applied depending on the calculation period. Compiled meteorological data for the 21 principal stations are given in Table 3.1 as the reference data.

Table 3.1 SUMMARY OF METEOROLOGICAL FEATURES (1/6)

48679 Johor Bahru International Airport (Senai)

Period : 1975-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.3	25.8	26.1	26.3	26.4	26.4	25.8	25.9	25.7	25.9	25.6	25.3	25.9
	Maximum	30.8	32.1	32.5	32.7	32.3	32.0	31.3	31.4	31.4	31.7	31.0	30.3	31.6
	Minimum	21.7	21.8	22.2	22.8	23.0	22.8	22.3	22.3	22.3	22.5	22.6	22.3	22.4
Relative humidity (%)	Mean	84.5	83.1	85.0	87.1	87.6	86.1	86.8	86.8	86.9	86.9	88.1	87.4	86.4
	Maximum	98.2	98.3	98.6	98.6	98.6	98.4	98.7	98.6	98.7	98.3	98.4	98.3	98.5
	Minimum	63.2	57.7	59.4	61.7	64.2	63.1	64.2	64.0	63.3	62.8	66.1	68.2	63.2
Sunhine hours (hours)	Mean	6.1	6.9	6.2	6.0	5.7	5.9	5.7	5.4	4.7	4.8	4.5	5.1	5.6
Wind speed (m/sec)	Mean	2.4	2.0	1.5	1.0	1.1	1.2	1.3	1.4	1.2	1.2	1.5	2.2	1.5
Evaporation (mm)	Mean	3.6	4.0	3.8	3.6	3.3	3.4	3.3	3.3	3.2	3.2	2.9	3.1	3.4

48672 Kluang

Period : 1974-88

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.2	26.0	26.3	26.4	26.5	26.4	25.8	25.9	25.7	25.8	25.5	25.2	25.9
	Maximum	29.8	31.4	32.3	32.5	32.3	31.8	31.1	31.3	31.3	31.6	30.7	29.7	31.3
	Minimum	22.3	22.6	22.9	23.0	23.2	23.0	22.5	22.6	22.4	22.6	22.6	22.5	22.7
Relative humidity (%)	Mean	83.5	82.3	83.3	85.9	86.5	85.8	86.3	86.1	86.6	86.2	87.9	86.6	85.6
	Maximum	95.9	96.4	97.0	98.1	98.1	98.0	98.1	97.9	98.1	98.0	98.4	97.3	97.6
	Minimum	65.3	60.3	59.6	62.5	64.1	64.5	65.3	64.3	64.0	63.5	67.1	69.1	64.1
Sunhine hours (hours)	Mean	6.4	7.1	6.7	6.3	6.4	6.4	6.0	5.8	5.0	5.3	4.9	5.6	6.0
Wind speed (m/sec)	Mean	3.7	3.2	2.2	1.3	1.3	1.5	1.7	1.9	1.5	1.3	1.7	3.0	2.0
Evaporation (mm)	Mean	3.5	3.9	3.7	3.4	3.0	2.9	2.8	2.9	3.0	3.0	2.8	2.9	3.1

48674 Mersing

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.9	26.4	26.8	26.8	26.6	26.4	25.8	25.9	25.7	25.9	25.6	25.7	26.1
	Maximum	28.2	29.2	30.4	31.6	31.9	31.4	30.9	31.0	30.9	31.0	29.6	28.2	30.4
	Minimum	23.6	23.7	23.3	23.0	23.1	22.9	22.4	22.4	22.4	22.6	22.7	23.2	22.9
Relative humidity (%)	Mean	81.8	81.2	81.8	84.2	85.6	85.8	86.2	86.2	86.3	86.1	87.2	85.7	84.9
	Maximum	90.6	90.9	93.4	96.4	96.6	96.5	96.8	96.8	96.9	97.0	96.8	94.3	95.2
	Minimum	73.5	71.4	69.2	67.8	67.5	67.5	67.6	67.3	67.0	67.5	72.7	76.3	69.6
Sunhine hours (hours)	Mean	6.1	7.4	7.4	6.9	6.8	6.3	6.1	5.8	5.6	5.6	4.7	4.8	6.1
Wind speed (m/sec)	Mean	5.1	4.6	3.6	2.5	2.5	2.6	2.7	2.7	2.6	2.4	2.7	4.2	3.2
Evaporation (mm)	Mean	4.1	4.8	4.7	4.2	3.8	3.7	3.6	3.8	3.8	3.7	3.1	3.7	3.9

48603 Alor Setar Airport (Kepala Batas)

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.8	27.6	27.9	28.0	27.6	27.4	26.8	26.9	26.5	26.5	26.4	26.4	27.1
	Maximum	32.8	34.4	34.5	33.8	32.5	31.9	31.6	31.6	31.1	31.3	31.4	31.4	32.4
	Minimum	21.8	22.3	23.0	23.9	24.3	24.1	23.6	23.6	23.5	23.5	23.2	22.7	23.3
Relative humidity (%)	Mean	72.7	71.4	74.7	79.8	83.9	84.2	84.8	84.5	85.5	86.0	84.3	78.7	80.9
	Maximum	93.3	93.2	94.3	95.5	96.2	96.2	96.6	96.6	96.7	96.7	96.4	94.4	95.5
	Minimum	48.7	43.9	47.4	56.4	65.2	66.4	66.0	65.2	67.1	66.8	64.4	58.7	59.7
Sunhine hours (hours)	Mean	8.6	8.8	8.6	8.4	7.2	6.7	6.8	6.5	5.8	5.8	6.1	7.0	7.2
Wind speed (m/sec)	Mean	1.8	1.6	1.3	1.1	1.0	0.9	1.0	1.1	1.1	1.0	1.0	1.5	1.2
Evaporation (mm)	Mean	5.4	5.9	5.7	5.0	3.9	3.6	3.6	3.7	3.5	3.5	3.4	4.3	4.3

Table 3.1 SUMMARY OF METEOROLOGICAL FEATURES (2/6)

48600 Pulau Langkawi International Airport
Period : 1988-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	27.8	27.9	28.0	27.9	27.5	27.5	27.0	27.2	26.6	26.6	27.0	27.2	27.4
	Maximum	32.8	33.1	32.8	31.9	30.9	30.9	30.3	30.4	29.9	30.1	30.8	31.4	31.3
	Minimum	24.0	24.0	24.3	24.6	24.8	24.6	24.2	24.6	24.1	24.0	24.2	24.0	24.3
Relative humidity (%)	Mean	72.8	74.4	76.6	82.2	85.0	82.8	81.8	81.4	84.0	84.8	80.2	74.8	80.1
	Maximum	88.8	90.2	92.0	94.0	94.8	93.8	95.8	95.4	96.4	96.2	94.0	89.8	93.4
	Minimum	54.4	54.0	57.0	65.2	70.8	68.4	66.6	67.0	68.6	70.0	64.8	58.6	63.8
Sunhine hours (hours)	Mean	8.9	9.3	9.1	8.4	6.6	6.8	6.3	6.4	5.2	5.8	6.9	8.1	7.3
Wind speed (m/sec)	Mean	3.4	2.7	2.2	1.9	1.6	1.7	1.7	2.3	1.9	1.9	2.4	3.5	2.3
Evaporation (mm)	Mean	7.1	6.6	6.2	5.2	3.6	4.0	3.7	3.9	3.5	3.4	4.5	6.4	4.8

48615 Kota Bharu Airport (Pengkalan Chepa)
Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.7	26.2	27.0	27.9	28.0	27.6	27.1	27.0	26.8	26.6	26.0	25.8	26.8
	Maximum	29.1	30.2	31.3	32.5	32.8	32.4	32.0	31.9	31.6	31.0	29.5	28.8	31.1
	Minimum	22.5	22.6	23.2	23.9	24.3	23.9	23.5	23.5	23.4	23.4	23.3	23.2	23.4
Relative humidity (%)	Mean	80.2	79.4	79.2	79.3	79.7	80.2	80.9	81.6	82.2	83.4	85.6	82.9	81.2
	Maximum	93.5	94.0	94.6	95.0	94.5	94.7	95.2	95.4	95.5	95.9	96.1	94.0	94.9
	Minimum	66.8	63.8	61.9	60.2	60.5	60.9	61.0	61.8	62.5	65.9	71.9	71.6	64.1
Sunhine hours (hours)	Mean	7.3	8.3	8.6	8.9	8.0	7.1	7.3	7.1	6.8	6.3	5.4	5.5	7.2
Wind speed (m/sec)	Mean	2.6	2.5	2.3	1.9	1.7	1.5	1.5	1.5	1.6	1.7	1.8	2.7	1.9
Evaporation (mm)	Mean	4.5	5.0	5.2	5.5	4.9	4.4	4.6	4.4	4.4	4.2	3.6	3.8	4.5

48616 Kuala Krai
Period : 1985-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	24.6	25.7	26.6	27.2	27.0	26.9	26.3	26.2	25.9	25.7	25.1	24.4	26.0
	Maximum	30.2	32.5	33.6	34.8	34.1	33.6	33.1	32.9	32.7	32.3	30.5	29.3	32.4
	Minimum	21.4	21.5	22.4	23.0	23.3	22.9	22.5	22.5	22.4	22.6	22.5	21.8	22.4
Relative humidity (%)	Mean	87.8	83.5	83.1	83.5	85.3	85.5	85.5	86.6	87.3	88.8	90.4	89.9	86.4
	Maximum	99.5	99.4	99.1	99.5	98.9	99.1	99.4	99.0	99.3	99.4	99.6	99.4	99.3
	Minimum	66.0	55.5	54.6	53.9	58.5	59.0	59.6	61.3	61.6	63.1	70.3	71.8	61.3
Sunhine hours (hours)	Mean	4.9	7.1	6.6	7.2	6.2	6.6	6.5	6.0	5.5	4.9	4.2	4.0	5.8
Wind speed (m/sec)	Mean	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.7	0.8	0.6	0.6	0.6	0.6
Evaporation (mm)	Mean	2.7	3.9	4.2	4.4	4.0	3.9	4.0	3.7	3.7	3.2	2.5	2.3	3.5

48665 Melaka Airport (Batu Berendam)
Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.4	27.0	27.2	27.2	27.2	27.0	26.6	26.6	26.5	26.6	26.2	26.1	26.7
	Maximum	31.7	33.0	33.0	32.5	32.0	31.6	31.1	31.1	31.1	31.5	31.1	31.0	31.7
	Minimum	22.5	23.0	23.2	23.4	23.5	23.1	22.8	22.7	22.8	23.0	22.9	22.7	23.0
Relative humidity (%)	Mean	78.4	77.4	80.5	84.0	84.7	84.7	84.6	84.8	84.8	84.5	85.7	82.8	83.1
	Maximum	93.9	94.0	95.7	97.6	97.8	98.1	98.1	98.1	98.1	98.0	97.8	96.0	96.9
	Minimum	55.9	52.2	55.6	61.3	64.0	64.0	64.1	64.2	64.0	62.9	64.4	62.1	61.2
Sunhine hours (hours)	Mean	6.7	7.6	7.1	7.0	6.9	6.6	6.7	6.3	5.8	5.9	5.3	5.7	6.4
Wind speed (m/sec)	Mean	2.8	2.7	2.0	1.4	1.2	1.2	1.2	1.2	1.3	1.4	1.6	2.3	1.7
Evaporation (mm)	Mean	5.0	5.5	5.2	4.5	4.1	4.0	3.9	4.0	4.2	4.2	3.8	4.3	4.4

Table 3.1 SUMMARY OF METEOROLOGICAL FEATURES (3/6)

48642 Batu Embun

Period : 1983-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.3	26.2	26.9	27.4	27.2	26.9	26.4	26.5	26.1	26.2	25.8	25.0	26.3
	Maximum	30.8	32.7	33.5	34.1	33.5	33.2	32.7	32.9	32.5	32.4	31.3	30.0	32.5
	Minimum	21.7	21.9	22.6	23.2	23.3	22.9	22.4	22.5	22.5	22.7	22.7	22.0	22.5
Relative humidity (%)	Mean	86.3	83.0	83.0	83.6	85.1	84.9	85.1	84.7	84.7	84.9	86.7	87.8	85.0
	Maximum	97.9	97.6	97.4	97.6	97.9	97.8	98.0	98.1	98.2	98.2	98.2	98.4	97.9
	Minimum	63.4	56.3	56.4	56.8	60.3	59.7	60.4	58.7	58.7	59.2	64.3	66.3	60.0
Sunhine hours (hours)	Mean	5.7	7.1	7.0	7.2	6.6	6.6	6.5	6.0	5.5	5.4	5.0	4.8	6.1
Wind speed (m/sec)	Mean	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.6	0.5	0.5	0.6	0.5
Evaporation (mm)	Mean	2.6	3.4	3.8	3.9	3.5	3.3	3.3	3.3	3.4	3.1	2.7	2.1	3.2

48632 Cameron Highlands (Tanah Rata)

Period : 1984-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	17.1	17.7	18.3	18.7	18.7	18.5	17.9	17.9	17.6	17.6	17.6	17.1	17.9
	Maximum	20.9	22.1	22.7	22.9	22.7	22.4	22.0	21.7	21.5	21.5	21.2	20.7	21.9
	Minimum	14.4	14.5	15.1	15.8	15.9	15.5	15.1	15.1	15.1	15.2	15.1	14.8	15.1
Relative humidity (%)	Mean	86.0	86.0	86.4	89.9	90.9	87.6	88.6	89.2	91.0	91.2	91.3	89.6	89.0
	Maximum	96.2	96.8	96.9	97.9	98.1	97.1	97.7	97.8	98.3	98.2	98.1	97.4	97.5
	Minimum	69.9	68.3	68.7	73.7	75.9	72.2	72.9	74.9	77.0	77.6	78.2	75.6	73.7
Sunhine hours (hours)	Mean	5.0	5.8	5.6	5.5	4.6	5.5	5.5	4.7	4.0	3.8	3.7	4.4	4.8
Wind speed (m/sec)	Mean	3.1	2.4	2.3	1.7	1.4	1.6	1.7	1.7	1.9	1.8	2.0	2.9	2.0
Evaporation (mm)	Mean	2.1	2.3	2.5	2.2	2.0	2.2	2.0	2.0	1.8	1.7	1.5	1.8	2.0

48657 Kuantan Airport

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	24.8	25.5	26.2	26.9	27.1	27.0	26.5	26.7	26.3	26.2	25.3	24.7	26.1
	Maximum	29.5	30.8	31.7	32.7	33.0	32.7	32.4	32.5	32.3	31.9	30.2	28.8	31.5
	Minimum	21.6	21.8	22.4	23.0	23.3	23.2	22.7	22.8	22.7	22.8	22.6	22.2	22.6
Relative humidity (%)	Mean	85.1	83.4	83.6	83.8	84.4	83.7	83.6	83.2	84.2	85.6	88.6	88.4	84.8
	Maximum	97.0	97.1	97.6	97.8	97.9	97.8	97.8	97.7	98.0	98.2	98.3	97.7	97.7
	Minimum	65.8	61.6	61.4	60.6	60.6	59.8	59.1	58.2	59.3	61.6	69.0	72.1	62.4
Sunhine hours (hours)	Mean	5.7	6.8	6.9	6.9	6.6	6.4	6.6	6.2	5.8	5.2	4.2	4.3	6.0
Wind speed (m/sec)	Mean	2.8	2.6	2.1	1.6	1.4	1.6	1.8	1.8	1.7	1.4	1.5	2.5	1.9
Evaporation (mm)	Mean	3.2	3.8	4.2	4.1	4.1	3.9	4.0	4.1	4.1	3.7	2.9	2.9	3.8

48649 Muazam Shah

Period : 1984-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.4	26.0	26.3	27.0	26.9	26.9	26.3	26.4	26.2	26.2	25.7	25.4	26.2
	Maximum	29.6	31.3	31.9	33.1	33.1	32.9	32.5	32.8	32.6	32.3	30.7	29.4	31.9
	Minimum	22.3	22.1	22.5	23.0	23.2	22.8	22.3	22.3	22.4	22.6	22.7	22.6	22.6
Relative humidity (%)	Mean	83.6	82.2	84.1	84.4	85.6	84.3	84.4	84.0	84.7	85.4	87.1	85.4	84.6
	Maximum	95.9	96.3	97.0	97.2	97.2	97.4	97.7	97.8	97.7	97.7	97.6	96.4	97.2
	Minimum	65.2	59.2	61.6	59.6	62.3	61.2	59.9	58.6	59.1	60.9	67.1	69.1	62.0
Sunhine hours (hours)	Mean	5.8	7.2	6.6	6.8	6.8	7.0	6.9	6.5	6.0	5.5	4.7	4.8	6.2
Wind speed (m/sec)	Mean	2.4	1.9	1.3	0.7	0.7	0.7	0.7	0.8	0.9	0.8	1.0	2.0	1.2
Evaporation (mm)	Mean	3.4	4.1	3.8	3.8	3.5	3.5	3.5	3.7	3.6	3.5	2.8	2.9	3.5

Table 3.1 SUMMARY OF METEOROLOGICAL FEATURES (4/6)

48653 Temerloh
Period : 1984-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.5	26.5	27.1	27.4	27.4	27.2	26.7	26.7	26.4	26.5	26.0	25.4	26.6
	Maximum	30.9	32.8	33.6	34.0	33.7	33.4	33.1	33.3	32.9	32.7	31.6	30.2	32.7
	Minimum	21.9	22.2	22.8	23.5	23.6	23.2	22.7	22.6	22.7	22.9	22.9	22.3	22.8
Relative humidity (%)	Mean	85.0	81.5	81.7	83.7	85.0	84.5	84.4	83.7	85.6	86.0	87.7	87.7	84.7
	Maximum	100.0	99.7	99.9	100.0	100.0	99.9	100.0	99.9	100.0	100.0	99.9	99.9	99.9
	Minimum	48.5	44.1	43.1	46.9	49.7	48.5	47.4	47.1	48.3	49.9	53.2	52.1	48.3
Sunhine hours (hours)	Mean	5.8	6.8	6.6	6.6	6.4	6.3	6.2	6.1	5.4	5.1	4.8	4.8	5.9
Wind speed (m/sec)	Mean	0.6	0.7	0.6	0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.7	0.5
Evaporation (mm)	Mean	3.1	3.8	4.0	3.8	3.6	3.4	3.4	3.5	3.5	3.3	2.9	2.6	3.4

48602 Butterworth Airport
Period : 1985-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	27.3	27.7	27.7	28.0	27.8	28.0	27.4	27.3	26.7	26.6	26.6	26.9	27.3
	Maximum	32.3	32.4	32.4	32.3	32.0	32.2	31.7	31.4	30.7	30.7	31.0	31.8	31.7
	Minimum	23.0	23.3	23.6	24.3	24.4	24.2	23.6	23.6	23.5	23.5	23.4	23.1	23.6
Relative humidity (%)	Mean	73.6	75.1	78.8	81.6	82.8	80.4	81.1	81.6	84.4	84.9	82.8	75.9	80.2
	Maximum	90.5	92.1	95.0	95.9	96.0	95.6	95.9	96.1	96.9	97.1	96.0	91.1	94.9
	Minimum	53.3	55.6	59.5	63.8	64.8	62.5	62.3	63.9	67.0	67.5	64.6	56.5	61.8
Sunhine hours (hours)	Mean	data not available												
Wind speed (m/sec)	Mean	1.6	1.7	1.6	1.4	1.3	1.4	1.5	1.5	1.4	1.4	1.4	1.8	1.5
Evaporation (mm)	Mean	data not available												

49601 Penang International Airport (Bayan Lepas)
Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	27.2	27.5	27.7	27.8	27.6	27.5	27.0	26.9	26.5	26.5	26.7	27.0	27.2
	Maximum	31.8	32.2	32.2	32.0	31.6	31.5	31.1	31.0	30.5	30.5	30.7	31.2	31.3
	Minimum	23.3	23.6	23.8	24.2	24.2	24.0	23.5	23.5	23.3	23.3	23.4	23.6	23.6
Relative humidity (%)	Mean	73.7	76.1	79.2	82.8	84.2	83.2	83.0	83.9	85.3	85.6	83.1	77.3	81.4
	Maximum	91.4	94.2	96.0	96.9	97.2	97.1	96.9	97.1	97.5	97.4	96.0	92.0	95.8
	Minimum	55.5	56.3	59.6	65.1	66.9	65.4	64.9	65.8	67.9	68.2	65.8	60.4	63.5
Sunhine hours (hours)	Mean	8.2	8.3	8.0	7.5	6.7	6.9	6.7	6.3	5.5	5.6	6.2	7.0	6.9
Wind speed (m/sec)	Mean	2.2	2.0	1.8	1.5	1.4	1.4	1.5	1.5	1.4	1.4	1.7	2.3	1.7
Evaporation (mm)	Mean	5.0	5.0	4.7	4.3	3.8	3.9	3.8	3.7	3.5	3.4	3.6	4.4	4.1

48625 Ipoh Airport
Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.7	27.1	27.4	27.5	27.5	27.5	27.0	27.1	26.6	26.5	26.2	26.3	27.0
	Maximum	32.9	33.8	33.9	33.6	33.3	33.3	33.0	33.0	32.4	32.3	32.0	32.0	32.9
	Minimum	22.3	22.7	23.2	23.7	23.8	23.4	22.9	23.0	22.9	22.9	22.9	22.6	23.0
Relative humidity (%)	Mean	77.7	77.3	78.4	81.5	81.5	79.0	78.7	79.1	81.5	82.9	83.8	81.9	80.3
	Maximum	94.7	94.6	94.8	95.6	95.7	94.7	94.7	94.9	95.7	96.2	96.5	96.0	95.3
	Minimum	51.4	49.2	51.4	56.4	57.2	54.5	53.7	53.9	56.3	58.0	59.7	57.7	55.0
Sunhine hours (hours)	Mean	7.1	7.5	7.3	7.0	6.6	6.7	6.7	6.1	5.5	5.5	5.5	5.9	6.5
Wind speed (m/sec)	Mean	1.7	1.8	1.7	1.6	1.6	1.6	1.8	1.7	1.7	1.6	1.6	1.6	1.7
Evaporation (mm)	Mean	4.2	4.5	4.6	4.5	4.0	4.1	4.0	4.1	3.8	3.9	3.4	3.7	4.1

Table 3.1 SUMMARY OF METEOROLOGICAL FEATURES (5/6)

48620 Sitiawan

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.3	26.7	27.1	27.4	27.4	27.3	26.9	26.9	26.5	26.4	26.2	26.1	26.8
	Maximum	31.5	32.2	32.6	32.6	32.5	32.6	32.2	32.2	31.7	31.4	31.1	31.2	32.0
	Minimum	22.3	22.7	23.1	23.6	23.7	23.3	22.8	22.9	22.9	23.0	22.9	22.6	23.0
Relative humidity (%)	Mean	84.1	82.8	83.1	84.3	84.3	83.2	82.7	82.8	84.5	85.6	86.6	85.9	84.2
	Maximum	97.9	97.8	97.8	97.9	97.9	97.6	97.6	97.6	98.0	98.1	98.2	98.1	97.9
	Minimum	61.7	59.8	60.9	63.5	63.3	61.4	60.1	60.4	62.5	64.8	66.3	64.7	62.5
Sunhine hours (hours)	Mean	6.9	7.3	7.1	7.1	6.9	6.9	6.8	6.3	5.7	5.7	5.5	5.9	6.5
Wind speed (m/sec)	Mean	1.2	1.4	1.5	1.4	1.4	1.3	1.4	1.5	1.5	1.5	1.3	1.2	1.4
Evaporation (mm)	Mean	2.6	3.0	3.1	3.0	2.9	2.8	2.9	2.8	2.8	2.7	2.4	2.5	2.8

48604 Chuping

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.8	27.6	28.0	27.9	27.4	27.2	26.7	26.7	26.4	26.2	26.1	26.1	26.9
	Maximum	32.9	34.8	34.9	34.2	32.7	32.3	31.8	31.7	31.4	31.5	31.4	31.1	32.6
	Minimum	23.1	23.3	23.8	24.1	24.1	23.9	23.3	23.4	23.4	23.3	23.3	23.1	23.5
Relative humidity (%)	Mean	75.6	73.5	76.7	81.9	86.5	86.3	86.5	86.7	87.8	88.4	86.8	82.0	83.2
	Maximum	97.4	98.5	99.8	99.8	99.9	100.0	99.9	99.9	100.0	100.0	99.9	98.8	99.5
	Minimum	41.1	35.3	35.4	41.6	52.6	52.9	54.1	54.9	56.4	55.2	55.4	51.8	48.9
Sunhine hours (hours)	Mean	8.5	8.7	8.2	7.8	6.8	6.5	6.8	6.6	5.7	5.7	6.0	7.0	7.0
Wind speed (m/sec)	Mean	2.3	2.4	1.6	1.0	0.7	0.7	0.9	0.9	0.9	0.8	1.4	2.1	1.3
Evaporation (mm)	Mean	4.8	5.5	5.1	4.6	3.7	3.2	3.2	3.2	3.1	2.8	2.9	3.4	3.8

48647 Kuala Lumpur International Airport (Subang)

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.3	26.7	27.0	27.1	27.3	27.2	26.8	26.8	26.6	26.5	26.2	26.2	26.7
	Maximum	32.0	32.9	33.1	33.0	32.7	32.5	32.1	32.3	31.9	31.9	31.4	31.4	32.3
	Minimum	22.1	22.4	22.9	23.4	23.6	23.2	22.8	22.8	22.8	23.0	23.0	22.6	22.9
Relative humidity (%)	Mean	81.1	80.2	81.2	83.6	83.0	81.5	81.4	80.9	82.9	83.7	85.2	83.9	82.4
	Maximum	97.0	96.6	96.8	97.1	96.5	96.2	96.2	95.9	96.5	96.8	97.2	97.1	96.7
	Minimum	54.0	52.0	53.8	58.4	59.7	58.0	58.1	56.7	58.9	59.6	62.0	59.5	57.6
Sunhine hours (hours)	Mean	6.2	7.0	6.8	6.6	6.6	6.5	6.5	6.2	5.4	5.5	5.1	5.4	6.1
Wind speed (m/sec)	Mean	0.9	1.1	1.1	1.1	1.2	1.2	1.4	1.3	1.3	1.2	1.1	0.9	1.1
Evaporation (mm)	Mean	4.0	4.7	4.9	4.5	4.3	4.2	4.1	4.3	4.1	4.1	3.8	3.7	4.2

48648 Petaling Jaya

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.8	27.2	27.5	27.5	27.8	27.8	27.3	27.4	27.0	27.0	26.6	26.6	27.2
	Maximum	32.6	33.3	33.6	33.5	33.2	33.1	32.6	32.8	32.5	32.6	32.0	32.1	32.8
	Minimum	23.0	23.3	23.8	24.1	24.3	24.0	23.6	23.7	23.6	23.6	23.5	23.2	23.6
Relative humidity (%)	Mean	77.7	77.4	78.6	80.8	80.3	77.6	78.2	77.0	80.1	80.9	83.1	80.6	79.3
	Maximum	94.5	94.3	94.7	95.3	94.6	93.4	93.7	92.9	94.4	94.7	95.7	95.1	94.4
	Minimum	52.1	50.8	52.8	56.4	57.9	55.9	56.6	55.2	57.7	58.3	60.6	57.1	55.9
Sunhine hours (hours)	Mean	5.9	6.7	6.4	6.2	6.2	6.1	6.1	6.0	5.3	5.4	4.7	5.2	5.8
Wind speed (m/sec)	Mean	1.0	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.1	1.2	1.0	0.9	1.1
Evaporation (mm)	Mean	3.3	3.7	3.8	3.6	3.3	3.3	3.1	3.4	3.1	3.2	2.8	2.8	3.3

Table 3.1 SUMMARY OF METEOROLOGICAL FEATURES (6/6)

48619 Kuala Terengganu Airport

Period : 1968-92

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	25.3	25.8	26.6	27.2	27.4	27.1	26.6	26.5	26.3	26.2	25.6	25.4	26.3
	Maximum	28.3	29.3	30.5	31.6	32.1	31.8	31.3	31.3	30.9	30.5	29.0	28.1	30.4
	Minimum	22.4	22.5	22.9	23.5	23.7	23.6	23.1	23.1	23.0	23.1	23.0	23.0	23.1
Relative humidity (%)	Mean	83.1	82.7	82.6	83.1	83.6	84.1	84.0	84.6	85.0	86.3	88.2	85.4	84.4
	Maximum	95.4	96.1	96.2	96.7	96.7	96.6	96.5	96.7	97.0	97.4	97.4	95.4	96.5
	Minimum	71.2	69.0	67.3	66.1	65.4	66.1	66.0	66.3	66.8	68.8	74.6	75.0	68.5
Sunhine hours (hours)	Mean	6.6	7.9	8.2	8.6	7.9	7.1	7.2	6.8	6.5	6.1	5.4	4.9	6.9
Wind speed (m/sec)	Mean	3.2	2.9	2.7	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.5	3.5	2.5
Evaporation (mm)	Mean	3.7	4.2	4.7	4.7	4.4	4.0	4.0	4.0	3.9	3.5	3.1	3.3	4.0

(b) Rainfall data

Daily rainfall records are used for estimating (i) water availability (runoff), (ii) floods, (iii) effective rainfall for irrigation planning, etc.

Selection of stations

In selecting rainfall stations, the following priorities are to be considered:

Priority 1:	Stations which do not have "missing or incomplete" data
Priority 2:	Long-term availability of data (preferably more than 10 years)
Priority 3:	The nearest station to the project
Others:	Type of station (1st: data logger, 2nd: automatic, 3rd: manual)
	Adequate location and maintenance of the stations, etc.

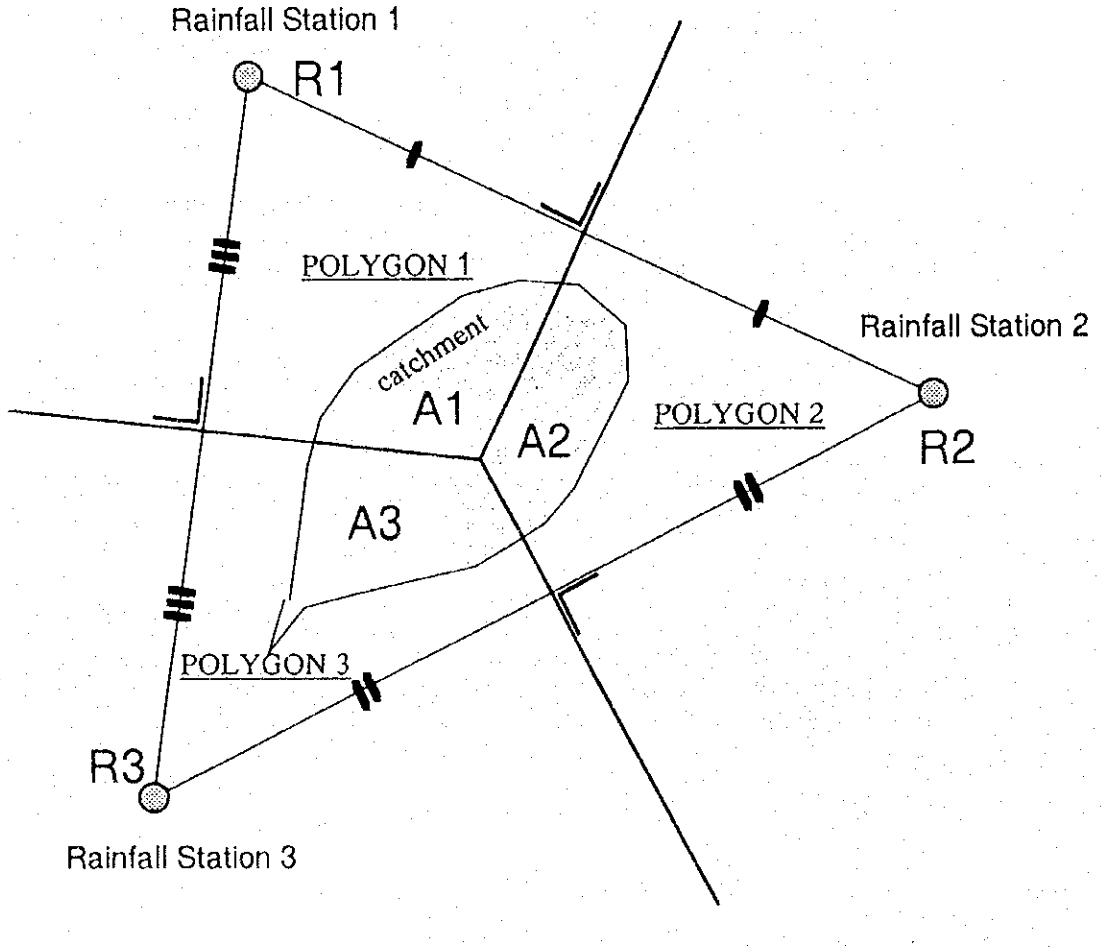
According to these priorities, rainfall stations are to be nominated and selected. More than one of stations may be selected. If the proposed catchment is included in several Thiessen polygons, all the stations forming these polygons are to be selected as follows:

Step 1:	Locate all the stations in the vicinity of the proposed project on a map (1 inch to 1 mile or larger) of the catchment areas of the proposed intake or dam sites.
Step 2:	Draw the Thiessen polygons on the map.
Step 3:	Select all the stations that are included in the catchment area. See Figure 3.2

Compilation of data

Daily rainfall records are available in the DID publication, "Hydrological Data (Rainfall and Evaporation Records for Malaysia)". They are also available on computer disks, on request, with a text format. It is recommendable to compile the data by personal computer applications.

Fig. 3.2 **Areal Rainfall**



Catchment Rainfall = (R1 x A1 + R2 x A2 + R3 x A3) / (A1 + A2 + A3)

where,

R1, R2, R3 : Rainfall at station, 1, 2, 3, respectively

A1, A2, A3 : Area (km^2)

(c) Stream flow and sediment

A record of stream flow and sediment will be used to check the estimated runoff and sedimentation rate. These data are available in the DID publication "Hydrological Data (Stream Flow and River Suspended Sediment Records)". They are also provided on computer disks.

(3) Hydrological Analyses

(a) Runoff

It could be recommended that available water at the proposed intake or dam site is to be evaluated in an approach shown in Figure 3.3 and is described below.

STEP 1: Locate the project area in Figure 3.4 and identify the basin number.

STEP 2: Identify the catchment area at the proposed intake or dam site.

STEP 3: Find the mean rainfall for the basin. Reference data are shown in Table 3.2

STEP 4: Check the actual low flow investigated at the site and the estimated low flow by HP12. Reference data are shown in Table 3.3. If the estimated low flow is considered reasonable, proceed to STEP 5.
If the actual low flow is less than the estimated low flow or much bigger, then go to STEP 4A ; otherwise STEP 5.

STEP 4A: Estimate the mean annual low flow (cumec) by field measurements or observations (by not only surveyors/engineers but also farmers or residents in the vicinity).

STEP 5, 5A: Check the direct runoff rate. If the actual rainfall at a near-by station is much different from the listed rainfall pattern in Table 3.2, and the actual annual rainfall belongs to another category shown below, reset the direct runoff rate.

Category	Annual rainfall (mm)	Direct runoff rate
High	over 2,500 mm	0.100
Intermediate	2,000 - 2,500 mm	0.050
Low	less than 2,000 mm	0.010

STEP 6, 6A :If;

i) the base flow was changed in STEP 4A ,or
ii) the direct runoff rate was changed in STEP 5A ,or
iii) the estimated runoff other than monthly is required, then the daily-base calculation is to be done by the spread sheet programme prepared in the feasibility study.

STEP 7: Compile the estimated daily runoff for the required unit of period. The estimated monthly runoff using the given parameters is given in Table 3.4 as reference data.

Fig. 3.3 Estimation of Available Water

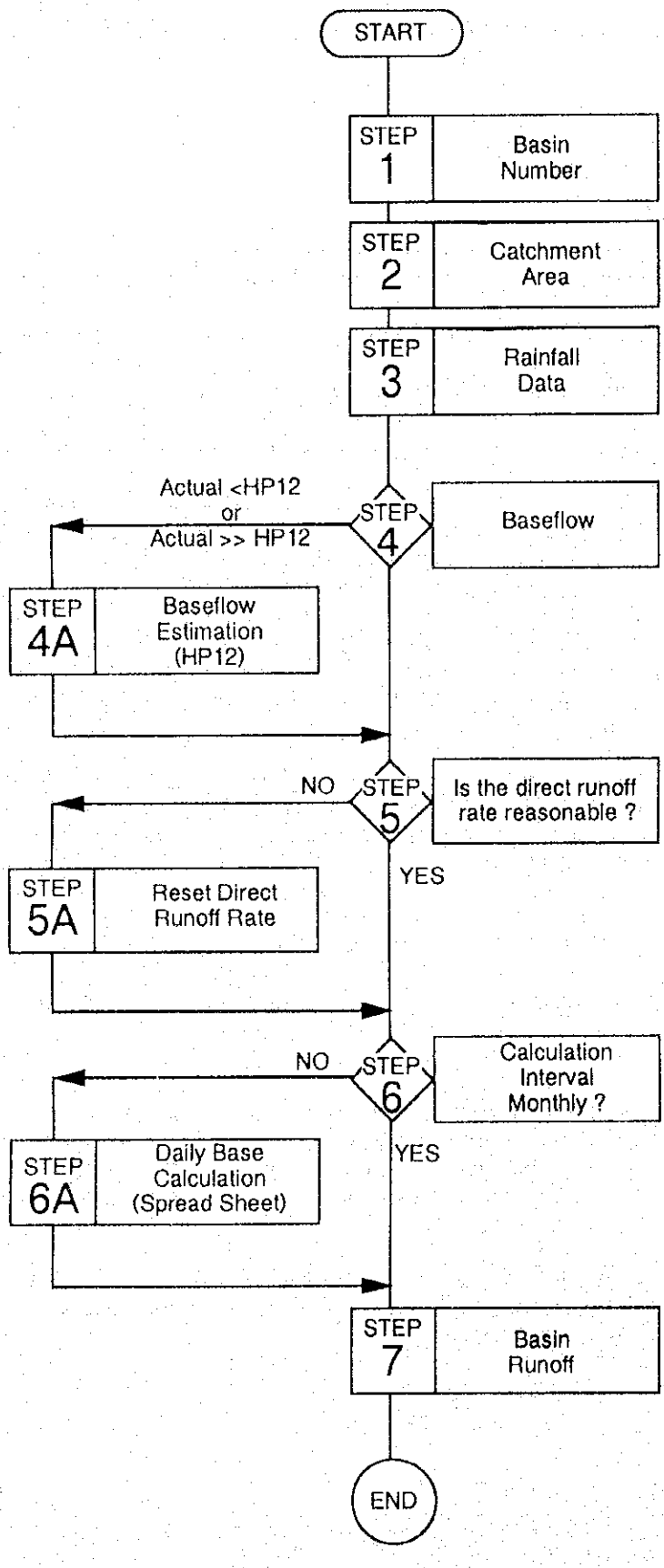


Fig. 3.4 River Basins

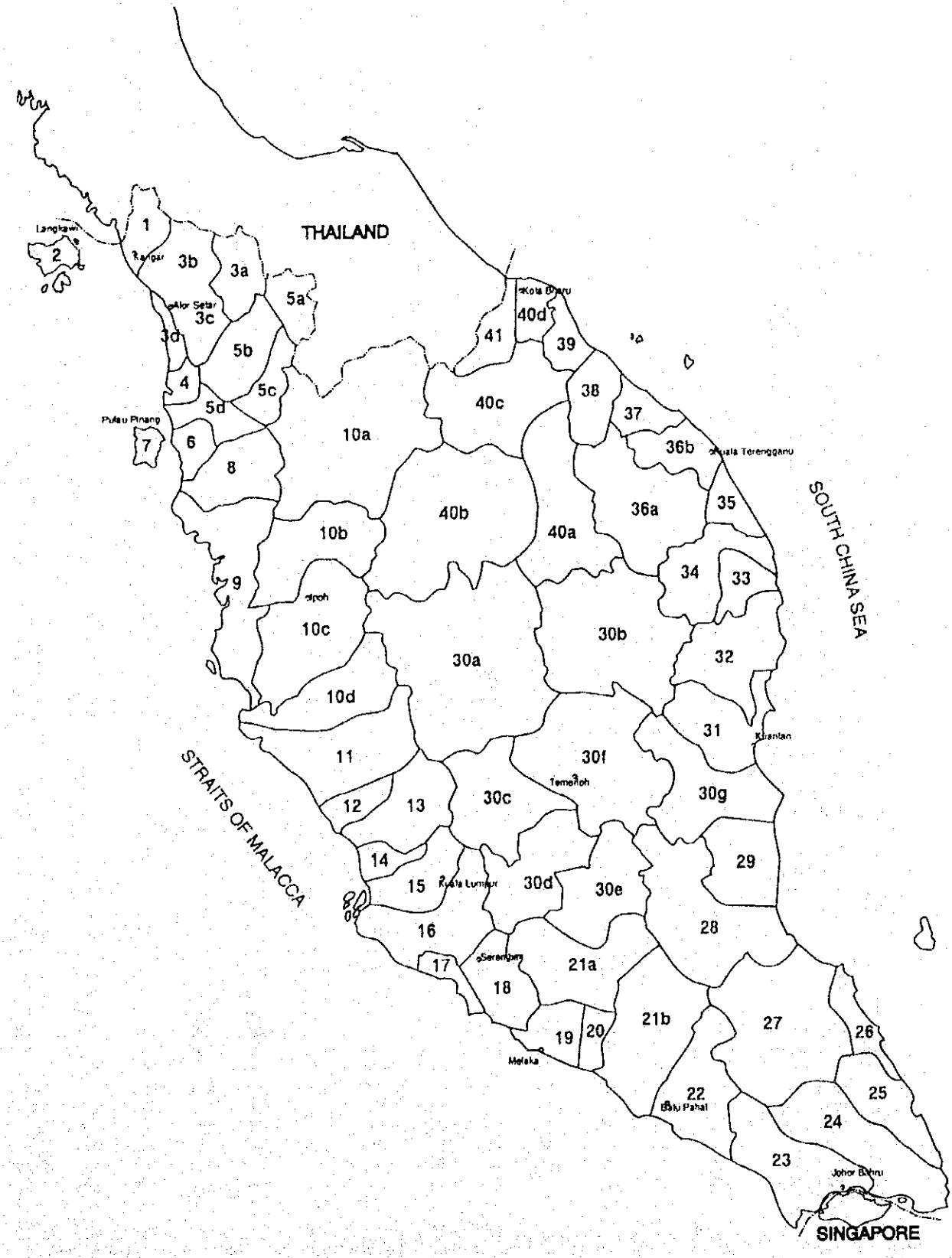


Table 3.2 MEAN MONTHLY RAINFALL BY RIVER BASIN

unit : mm

Basin	Period	Month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	1983-1992	19	47	111	138	177	129	180	182	257	247	169	76	1733
2	1983-1992	12	51	102	212	288	225	359	316	459	409	218	35	2686
3a	1983-1992	18	35	102	172	221	138	270	294	327	258	168	64	2066
3b	1983-1992	18	39	105	162	207	135	243	260	306	255	169	67	1966
3c	1983-1992	18	53	121	187	237	141	263	289	332	289	202	73	2203
3d	1983-1992	18	52	121	186	236	141	263	289	331	287	201	72	2198
4	1983-1992	51	116	175	253	273	156	214	232	324	351	283	121	2549
5a	1983-1992	18	89	161	217	270	147	248	278	340	350	269	91	2478
5b	1983-1992	18	99	172	226	279	149	244	275	342	368	288	97	2557
5c	1983-1992	18	99	172	226	279	149	244	275	342	368	288	97	2557
5d	1983-1992	95	138	180	289	266	166	174	176	299	329	276	153	2540
6	1983-1992	95	138	180	289	266	166	174	176	300	329	276	153	2540
7	1983-1992	58	63	138	221	262	189	256	240	385	365	236	96	2508
8	1983-1992	97	128	167	255	235	148	156	157	272	294	252	144	2305
9	1983-1992	130	102	143	148	123	81	81	85	155	152	181	149	1530
10a	1983-1992	79	123	153	186	242	132	184	190	278	273	280	227	2348
10b	1983-1992	84	143	150	153	207	104	129	138	206	190	188	127	1820
10c	1983-1992	169	210	240	280	244	151	175	160	243	260	296	235	2663
10d	1983-1992	180	211	249	298	253	162	175	160	247	276	329	256	2794
11	1983-1992	147	144	198	239	219	130	115	145	207	232	290	226	2292
12	1983-1992	169	115	141	158	149	74	116	139	180	187	184	221	1833
13	1983-1992	143	123	155	183	179	88	119	141	200	206	206	207	1950
14	1983-1992	169	115	141	158	149	74	116	139	180	187	184	221	1833
15	1983-1992	113	132	205	201	210	86	173	157	263	265	298	214	2317
16	1983-1992	89	97	162	166	216	106	167	142	256	244	263	168	2075
17	1983-1992	83	86	142	153	198	99	150	121	218	205	229	138	1822
18	1983-1992	72	102	164	186	191	90	142	114	183	178	230	128	1779
19	1983-1992	72	102	164	186	191	90	142	114	183	178	230	128	1779
20	1983-1992	78	104	176	236	193	146	153	152	205	186	233	142	2003
21a	1983-1992	122	108	184	141	197	84	129	128	187	163	218	197	1856
21b	1983-1992	152	78	221	173	170	96	125	120	160	172	249	244	1962
22	1983-1992	174	108	240	192	176	102	131	122	168	186	263	231	2094
23	1983-1992	186	115	195	194	207	124	138	123	182	149	186	252	2051
24	1983-1992	233	107	197	205	233	146	153	154	221	178	225	340	2392
25	1983-1992	300	100	196	206	250	167	169	189	259	210	295	474	2815
26	1983-1992	349	110	135	119	146	119	151	159	187	157	409	656	2698
27	1983-1992	244	72	192	152	149	117	133	130	168	161	303	431	2254
28	1983-1992	222	99	172	133	150	86	115	120	148	154	273	386	2058
29	1983-1992	307	112	198	154	121	122	123	114	174	199	472	577	2675
30a	1983-1992	152	115	162	187	224	165	174	155	261	283	306	284	2467
30b	1977-1986	92	90	131	213	228	153	178	140	201	256	238	337	2258
30c	1983-1992	119	119	173	188	205	95	123	138	225	227	240	196	2048
30d	1983-1992	102	99	162	139	196	116	149	118	200	192	221	196	1888
30e	1983-1992	129	102	172	149	192	87	115	124	184	171	214	212	1852
30f	1977-1986	104	91	144	197	203	118	138	99	171	225	209	171	1868
30g	1983-1992	262	106	197	143	119	113	105	108	172	220	499	566	2610
31	1983-1992	180	76	151	106	130	105	100	115	168	151	298	420	1999
32	1983-1992	153	73	125	98	128	105	101	123	190	167	421	487	2172
33	1983-1992	120	69	93	89	124	105	102	134	218	188	573	569	2385
34	1983-1992	120	69	93	89	124	105	102	134	218	188	573	569	2385
35	1983-1992	114	57	108	89	109	109	93	131	206	202	655	534	2408
36a	1977-1986	64	78	96	112	142	115	133	148	193	237	463	471	2252
36b	1983-1992	110	50	117	89	99	111	88	130	199	211	706	512	2421
37	1983-1992	110	50	117	89	99	111	88	130	199	211	706	512	2421
38	1983-1992	155	71	102	135	169	141	212	178	300	271	425	599	2757
39	1983-1992	97	51	98	82	169	177	200	213	271	235	486	608	2687
40a	1977-1986	78	85	108	165	233	158	184	180	256	295	294	333	2368
40b	1983-1992	119	100	139	158	243	156	164	171	287	274	308	309	2429
40c	1983-1992	155	71	102	135	169	141	212	178	300	271	425	599	2757
40d	1983-1992	97	51	98	82	169	177	200	213	271	235	486	608	2687
41	1983-1992	97	51	98	82	169	177	200	213	271	235	486	608	2687

Note : River basin : 41 basins with 27 sub-basins which originate from "National Water Resources Study, Malaysia (JICA 1982)"

Table 3.3 BASINWISE MEAN ANNUAL MINIMUM FLOW ESTIMATED BY HP12

Basin No.	RC	RE	Low Flow CA=1 sq.km		CA=2 sq.km		CA=5 sq.km		CA=10 sq.km		CA=20 sq.km		Mean	
			cumec	mm	cumec	mm	cumec	mm	cumec	mm	cumec	mm	cumec	mm
1	1	1	0.0027	0.2307	0.0057	0.2459	0.0155	0.2675	0.0330	0.2851	0.0703	0.3039	0.0254	0.2666
2	1	1	0.0055	0.4780	0.0118	0.5094	0.0321	0.5542	0.0684	0.5907	0.1457	0.6296	0.0527	0.5524
3 a	1	1	0.0036	0.3089	0.0076	0.3292	0.0207	0.3581	0.0442	0.3817	0.0942	0.4069	0.0341	0.3570
b	1	1	0.0033	0.2844	0.0070	0.3032	0.0191	0.3298	0.0407	0.3516	0.0867	0.3747	0.0314	0.3287
c	1	1	0.0040	0.3438	0.0085	0.3664	0.0231	0.3986	0.0492	0.4249	0.1048	0.4529	0.0379	0.3973
d	1	1	0.0040	0.3425	0.0085	0.3650	0.0230	0.3972	0.0490	0.4233	0.1044	0.4512	0.0378	0.3958
4	1	1	0.0051	0.4382	0.0108	0.4670	0.0294	0.5081	0.0627	0.5416	0.1336	0.5772	0.0483	0.5064
5 a	1	1	0.0048	0.4180	0.0103	0.4455	0.0280	0.4847	0.0598	0.5166	0.1275	0.5506	0.0461	0.4831
b	1	1	0.0051	0.4402	0.0109	0.4692	0.0295	0.5105	0.0630	0.5441	0.1342	0.5799	0.0485	0.5088
c	1	1	0.0051	0.4402	0.0109	0.4692	0.0295	0.5105	0.0630	0.5441	0.1342	0.5799	0.0485	0.5088
d	1	1	0.0050	0.4354	0.0107	0.4641	0.0292	0.5049	0.0623	0.5382	0.1328	0.5736	0.0480	0.5032
6	1	1	0.0050	0.4354	0.0107	0.4641	0.0292	0.5049	0.0623	0.5382	0.1328	0.5736	0.0480	0.5032
7	1	1	0.0049	0.4264	0.0105	0.4545	0.0286	0.4945	0.0610	0.5270	0.1300	0.5617	0.0470	0.4928
8	1	1	0.0043	0.3705	0.0091	0.3949	0.0249	0.4296	0.0530	0.4579	0.1130	0.4881	0.0409	0.4282
9	1	1	0.0022	0.1874	0.0046	0.1998	0.0126	0.2174	0.0268	0.2317	0.0572	0.2469	0.0207	0.2166
10 a	1	1	0.0044	0.3821	0.0094	0.4072	0.0256	0.4431	0.0547	0.4772	0.1165	0.5033	0.0421	0.4426
b	1	1	0.0029	0.2502	0.0062	0.2666	0.0168	0.2901	0.0358	0.3092	0.0763	0.3295	0.0276	0.2891
c	2	2	0.0251	2.1729	0.0476	2.0557	0.1106	1.9104	0.2092	1.8073	0.3958	1.7099	0.1577	1.9312
d	2	2	0.0282	2.4365	0.0534	2.3051	0.1240	2.1421	0.2346	2.0266	0.4438	1.9173	0.1768	2.1655
11	2	2	0.0176	1.5183	0.0333	1.4364	0.0773	1.3349	0.1462	1.2629	0.2766	1.1948	0.1102	1.3495
12	2	2	0.0103	0.8907	0.0195	0.8426	0.0453	0.7831	0.0857	0.7408	0.1622	0.7009	0.0646	0.7916
13	2	2	0.0120	1.0328	0.0226	0.9771	0.0525	0.9080	0.0994	0.8590	0.1881	0.8127	0.0749	0.9179
14	2	2	0.0103	0.8907	0.0195	0.8426	0.0453	0.7831	0.0857	0.7408	0.1622	0.7009	0.0646	0.7916
15	3	2	0.0180	1.5575	0.0341	1.4735	0.0792	1.3694	0.1499	1.2955	0.2837	1.2256	0.1130	1.3843
16	3	3	0.0010	0.0894	0.0024	0.1025	0.0071	0.1227	0.0163	0.1407	0.0373	0.1613	0.0128	0.1233
17	3	3	0.0006	0.0541	0.0014	0.0620	0.0043	0.0743	0.0099	0.0852	0.0226	0.0977	0.0078	0.0747
18	3	3	0.0006	0.0493	0.0013	0.0565	0.0039	0.0677	0.0090	0.0776	0.0206	0.0890	0.0071	0.0680
19	3	3	0.0009	0.0780	0.0021	0.0894	0.0062	0.1007	0.0142	0.1227	0.0326	0.1407	0.0112	0.1063
20	3	3	0.0009	0.0780	0.0021	0.0894	0.0062	0.1007	0.0142	0.1227	0.0326	0.1407	0.0112	0.1063
21 a	3	3	0.0007	0.0582	0.0015	0.0667	0.0046	0.0799	0.0106	0.0915	0.0243	0.1049	0.0083	0.0802
b	3	3	0.0008	0.0720	0.0019	0.0826	0.0057	0.0989	0.0131	0.1134	0.0301	0.1300	0.0103	0.0994
22	3	3	0.0011	0.0925	0.0025	0.1060	0.0073	0.1270	0.0168	0.1456	0.0386	0.1669	0.0133	0.1276
23	1	3	0.0010	0.0855	0.0023	0.0980	0.0068	0.1173	0.0156	0.1345	0.0357	0.1542	0.0123	0.1179
24	1	3	0.0018	0.1545	0.0041	0.1771	0.0123	0.2121	0.0281	0.2432	0.0645	0.2787	0.0222	0.2131
25	1	3	0.0034	0.2897	0.0077	0.3321	0.0230	0.3978	0.0528	0.4560	0.1210	0.5227	0.0416	0.3997
26	3	3	0.0028	0.2458	0.0065	0.2818	0.0195	0.3376	0.0448	0.3870	0.1027	0.4436	0.0353	0.3392
27	3	3	0.0014	0.1228	0.0033	0.1408	0.0098	0.1687	0.0224	0.1933	0.0513	0.2216	0.0176	0.1694
28	3	3	0.0010	0.0865	0.0023	0.0992	0.0069	0.1188	0.0158	0.1362	0.0361	0.1561	0.0124	0.1194
29	3	3	0.0028	0.2380	0.0063	0.2728	0.0189	0.3268	0.0434	0.3746	0.0994	0.4294	0.0342	0.3283
30 a	3	3	0.0020	0.1741	0.0046	0.1996	0.0138	0.2391	0.0317	0.2741	0.0727	0.3141	0.0250	0.2402
b	3	3	0.0014	0.1236	0.0033	0.1417	0.0098	0.1698	0.0225	0.1946	0.0516	0.2231	0.0177	0.1706
c	3	3	0.0010	0.0849	0.0023	0.0973	0.0067	0.1165	0.0155	0.1336	0.0354	0.1531	0.0122	0.1171
d	3	3	0.0007	0.0620	0.0016	0.0711	0.0049	0.0852	0.0113	0.0977	0.0259	0.1119	0.0089	0.0856
e	3	3	0.0007	0.0576	0.0015	0.0660	0.0046	0.0792	0.0105	0.0907	0.0241	0.1040	0.0083	0.0795
f	3	3	0.0007	0.0595	0.0016	0.0683	0.0047	0.0818	0.0108	0.0937	0.0249	0.1074	0.0085	0.0821
g	3	3	0.0025	0.2164	0.0057	0.2481	0.0172	0.2972	0.0394	0.3407	0.0904	0.3905	0.0310	0.2986
31	1	1	0.0034	0.2923	0.0072	0.3115	0.0196	0.3389	0.0418	0.3612	0.0891	0.3850	0.0322	0.3378
32	1	1	0.0039	0.3358	0.0083	0.3579	0.0225	0.3894	0.0480	0.4150	0.1024	0.4423	0.0370	0.3881
33	1	1	0.0045	0.3922	0.0097	0.4180	0.0263	0.4548	0.0561	0.4847	0.1196	0.5166	0.0432	0.4533
34	1	1	0.0045	0.3922	0.0097	0.4180	0.0263	0.4548	0.0561	0.4847	0.1196	0.5166	0.0432	0.4533
35	1	1	0.0046	0.3984	0.0098	0.4246	0.0267	0.4620	0.0570	0.4924	0.1215	0.5248	0.0439	0.4604
36 a	1	1	0.0041	0.3564	0.0088	0.3798	0.0239	0.4132	0.0510	0.4404	0.1087	0.4694	0.0393	0.4118
b	1	1	0.0047	0.4022	0.0099	0.4287	0.0270	0.4664	0.0575	0.4971	0.1226	0.5298	0.0443	0.4648
37	1	1	0.0047	0.4022	0.0099	0.4287	0.0270	0.4664	0.0575	0.4971	0.1226	0.5298	0.0443	0.4648
38	1	1	0.0058	0.4991	0.0123	0.5320	0.0335	0.5788	0.0714	0.6169	0.1522	0.6575	0.0550	0.5769
39	1	1	0.0055	0.4781	0.0118	0.5096	0.0321	0.5544	0.0684	0.5909	0.1458	0.6298	0.0527	0.5526
40 a	1	1	0.0045	0.3876	0.0096	0.4131	0.0260	0.4494	0.0554	0.4790	0.1182	0.5106	0.0427	0.4479
b	1	1	0.0047	0.4043	0.0100	0.4309	0.0271	0.4688	0.0578	0.4997	0.1233	0.5326	0.0446	0.4673
c	1	1	0.0058	0.4991	0.0123	0.5320	0.0335	0.5788	0.0714	0.6169	0.1522	0.6575	0.0550	0.5769
d	1	1	0.0055	0.4781	0.0118	0.5096	0.0321	0.5544	0.0684	0.5909	0.1458	0.6298	0.0527	0.5526
41	1	1	0.0055	0.4781	0.0118	0.5096	0.0321	0.5544	0.0684	0.5909	0.1458	0.6298	0.0527	0.5526

Remarks: RC; Low flow frequency regions (1 to 4) as illustrated in Map A of HP12.
RE; Mean annual minimum flow regions (1 to 3) as illustrated in Map B of HP12.
CA; Catchment area

Table 3.4 ESTIMATED RUNOFF BY RIVER BASIN

unit : mm

Basin	Period	Month												A	B	A/B
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Rainfall	%
1	1983-1992	15	12	9	17	37	33	27	48	82	119	132	55	586	1733	34%
2	1983-1992	18	19	24	34	65	105	192	203	272	322	193	56	1504	2686	56%
3a	1983-1992	13	11	14	21	44	45	73	136	163	175	117	53	864	2066	42%
3b	1983-1992	11	9	10	13	31	35	59	107	137	158	117	47	735	1966	37%
3c	1983-1992	15	12	15	20	51	48	73	125	166	193	148	69	936	2203	42%
3d	1983-1992	15	12	15	20	51	48	72	126	166	192	147	69	933	2198	42%
4	1983-1992	31	28	38	70	109	89	63	72	144	216	232	104	1195	2549	47%
5a	1983-1992	19	16	24	44	82	83	73	105	173	236	214	102	1171	2478	47%
5b	1983-1992	25	23	35	57	94	92	80	103	171	241	232	116	1269	2557	50%
5c	1983-1992	25	23	35	57	94	92	80	103	171	241	232	116	1269	2557	50%
5d	1983-1992	56	56	44	101	127	103	60	60	120	187	228	93	1236	2540	49%
6	1983-1992	56	56	44	101	127	103	60	60	120	187	228	93	1236	2540	49%
7	1983-1992	31	19	29	64	95	84	108	108	182	250	196	96	1263	2492	51%
8	1983-1992	46	47	31	79	98	77	41	39	97	156	197	77	985	2305	43%
9	1983-1992	38	37	33	36	18	13	11	7	36	29	44	50	352	1530	23%
10a	1983-1992	52	36	40	60	112	79	63	71	138	177	189	199	1216	2360	52%
10b	1983-1992	22	27	21	36	64	40	18	22	62	69	99	66	544	1818	30%
10c	1983-1992	99	88	92	120	142	99	80	73	106	108	151	131	1289	2654	49%
10d	1983-1992	114	99	104	150	165	115	88	84	114	120	176	151	1481	2794	53%
11	1983-1992	77	68	84	102	103	69	51	51	60	76	135	137	1013	2292	44%
12	1983-1992	85	46	47	55	39	40	31	40	57	53	77	100	670	1833	37%
13	1983-1992	69	46	48	60	58	50	29	34	61	62	94	112	724	1950	37%
14	1983-1992	85	46	47	55	39	40	31	40	57	53	77	100	670	1833	37%
15	1983-1992	58	49	76	99	101	69	54	46	67	141	203	162	1125	2320	49%
16	1983-1992	34	17	25	48	77	62	32	22	75	143	170	128	834	2090	40%
17	1983-1992	24	16	15	39	60	52	37	35	58	91	128	83	638	1822	35%
18	1983-1992	24	18	22	61	78	50	44	45	39	72	127	78	658	1777	37%
19	1983-1992	28	26	54	62	84	77	57	64	64	83	118	81	798	2000	40%
20	1983-1992	28	26	54	62	84	77	57	64	64	83	118	81	798	2000	40%
21a	1983-1992	57	34	49	31	49	34	21	28	36	58	104	111	613	1851	33%
21b	1983-1992	83	21	73	38	56	25	19	23	25	56	117	161	698	1965	35%
22	1983-1992	96	44	86	60	75	35	28	33	34	73	142	149	856	2099	41%
23	1983-1992	115	60	58	53	97	53	35	37	46	52	95	144	844	2051	41%
24	1983-1992	172	69	64	67	115	62	52	53	87	86	125	227	1176	2392	49%
25	1983-1992	254	88	65	70	109	66	68	67	118	117	164	351	1539	2815	55%
26	1983-1992	350	121	60	24	35	31	26	43	54	60	187	534	1527	2698	57%
27	1983-1992	201	45	62	33	39	27	23	33	38	58	140	321	1020	2260	45%
28	1983-1992	174	78	69	40	33	14	13	27	24	42	109	291	915	2058	44%
29	1983-1992	275	111	109	59	33	23	31	25	41	57	242	524	1531	2675	57%
30a	1983-1992	97	49	52	50	99	87	69	59	102	177	198	225	1264	2467	51%
30b	1977-1986	62	26	42	62	114	79	50	55	75	126	146	156	994	2124	47%
30c	1983-1992	54	44	51	57	89	50	18	23	55	120	145	121	829	2069	40%
30d	1983-1992	46	29	42	37	50	47	39	20	57	86	128	109	690	1921	36%
30e	1983-1992	68	42	48	27	48	30	15	25	35	64	104	134	642	1845	35%
30f	1977-1986	48	29	36	56	94	44	23	25	36	86	105	110	691	1876	37%
30g	1983-1992	223	93	110	54	31	27	24	21	30	66	268	551	1496	2610	57%
31	1983-1992	119	48	73	23	24	29	16	26	23	43	125	348	896	1999	45%
32	1983-1992	121	42	60	21	19	20	18	18	29	50	197	465	1062	2172	49%
33	1983-1992	131	46	41	20	19	17	19	21	31	53	281	592	1271	2385	53%
34	1983-1992	131	46	41	20	19	17	19	21	31	53	281	592	1271	2385	53%
35	1983-1992	113	31	42	24	17	16	16	17	19	35	334	596	1259	2408	52%
36a	1977-1986	85	21	38	16	14	14	21	22	22	54	225	529	1062	2270	47%
36b	1983-1992	111	25	44	33	18	17	17	18	19	41	360	600	1302	2421	54%
37	1983-1992	111	25	44	33	18	17	17	18	19	41	360	600	1302	2421	54%
38	1983-1992	175	50	49	34	43	40	53	55	107	153	228	529	1517	2759	55%
39	1983-1992	163	39	54	27	35	38	52	80	114	129	257	556	1544	2696	57%
40a	1977-1986	78	34	48	35	78	59	47	63	119	172	202	311	1246	2371	53%
40b	1983-1992	99	39	54	37	81	74	51	60	136	184	198	275	1287	2411	53%
40c	1983-1992	184	57	56	39	50	43	73	73	140	171	249	559	1693	2759	61%
40d	1983-1992	163	39	54	27	35	38	52	80	114	129	257	556	1544	2696	57%
41	1983-1992	163	39	54	27	35	38	52	80	114	129	257	556	1544	2696	57%

Note : River basin : 41 basins with 27 sub-basins which originate from "National Water Resources Study, Malaysia (JICA 1982)"

(b) Flood

The design of the water control structures depends largely on the expected flood discharge. If a stream flow is gauged and the duration and quality of the records are adequate, a frequency analysis could be done. Since the catchment and water sources for small reservoirs are generally small, long-term measurements of rainfall and stream flow have seldom been taken. If such data are not available, the designer will have to use other techniques.

A flood analysis shall be carried out using several procedures introduced in the Hydrological Procedures (HP) provided by DID. The peak discharge at the proposed dam site can be estimated by the methods given in HP4, HP5, and HP11. Rainstorms within the time of concentration can be calculated according to the procedures given in HP1.

Design flood discharge can be estimated following the procedure as described below and in Figure 3.5.

STEP 1: The data required are the daily rainfall at near-by stations. For the flood estimation purpose, long-term records are necessary. It should be noted that only the flood with a return period up to a few times the observation period can be estimated with a high reliability for the frequency analysis. It means that rainfall stations which have more than 30 years' records are to be selected for estimating a 100-year flood.
Topographic maps with contours for obtaining catchment parameters are required.
A field reconnaissance survey is to be done to check the topography, and other catchment parameters.

STEP 2: Determine the catchment parameters which are necessary for the HPs. Results of the field survey should be taken into consideration.

STEP 3: Return periods for the calculation are to be determined according to the criteria on the structure design.

STEP 4: HP4 was developed for catchments larger than 20 km^2. If the proposed catchment area is smaller than 20 km^2, HP4 should not be used.

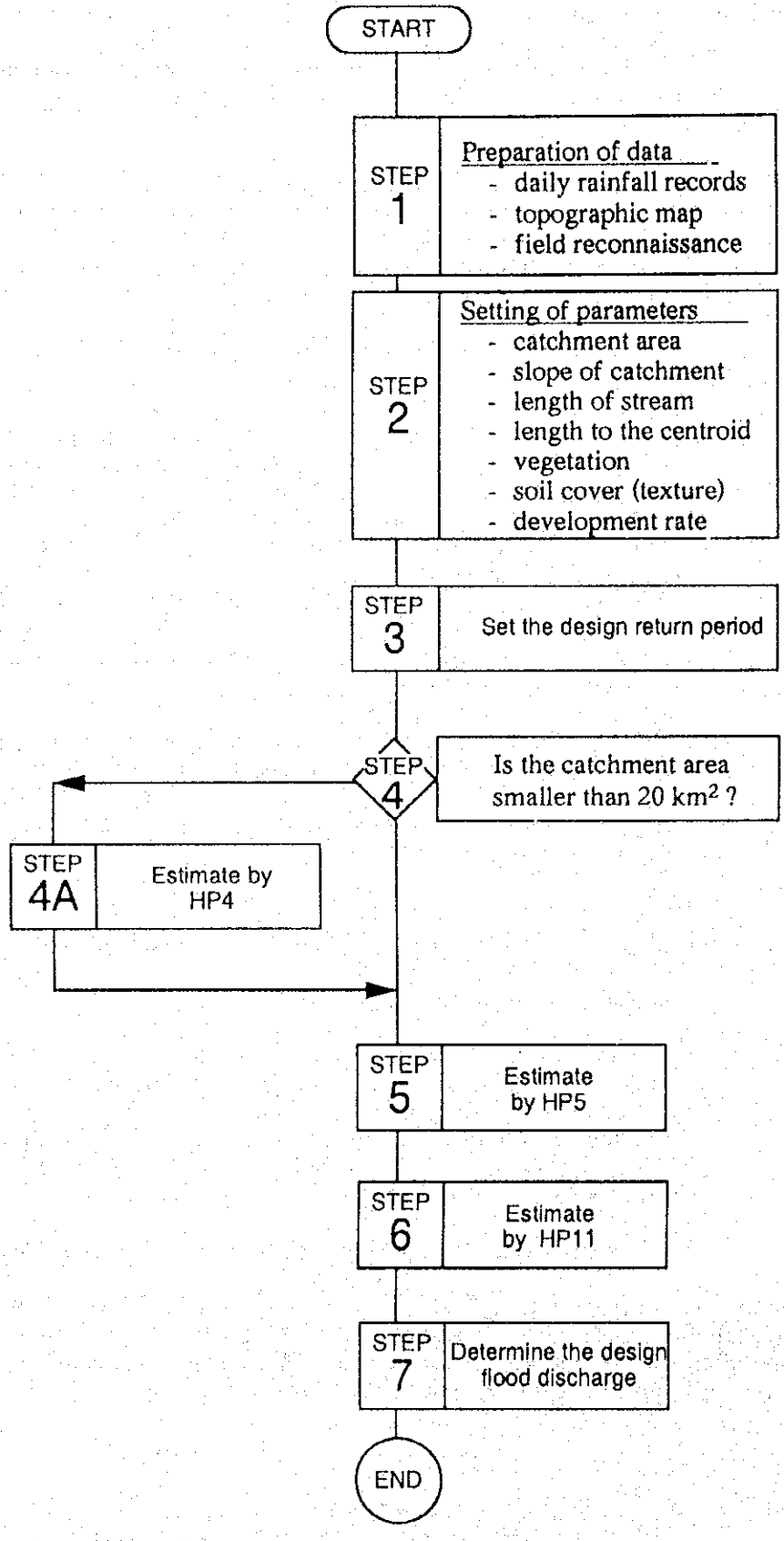
STEP 5: Calculation by the rational method (HP5).

STEP 6: Estimation by the triangular flood hydrograph. This is a procedure to estimate flood volume. However it also gives the peak discharges. For the flood estimation in dry regions, where the flood discharges tend to be estimated lower by HP5, HP11 is to be used for comparison. The catchment group is to be determined by weighted average according to the catchment characteristics.

STEP 7: The largest estimated floods should be basically taken as the design floods.

Regarding the "Type A (small dam)" reservoir, the Probable Maximum Flood (PMF), which is generally used for determining the design flood, is recommended to be evaluated in case the scale of dam is comparatively big in terms of dam height (nearly or higher than 10 meter), or the influence on the downstream is assumed to be great.

Fig. 3.5 Estimation of Flood Discharge



(c) Sediment

The sediment load consists of two parts ; (i)bed load, and (ii)suspended load. The bed load is the material in the bottom layers of the flow and moves by rolling, sliding and hopping, i.e., saltation, depending on the velocity of flow.

With a further increase of velocity, smaller-size particles in saltation are thrown in suspension by the transport of the upward component of the turbulent velocity of flow. Thus transport by suspension is an advanced stage of bed load movement, intensified by eddies with vertical axes. The weight of the particles is supported by the surrounding fluid. The term wash load is often used to designate very minute particles approaching colloidal sizes which always remain in suspension. Annual sediment production is generally expressed in the following formula:

$$q_S = KA^n \quad \text{----------} \quad (1)$$

where, q_S : mean annual sediment production ($m^3/km^2/year$)
A : catchment area (km^2)
K, n : constant

The constant "n" is normally a negative value which means that the sediment production decreases as the catchment area increases. This is because of the larger sediment storage function and the higher percentage of plains in the bigger catchments.

In Japan, -0.7 is used as the constant "n", whereas in India, -0.2 to -0.5 is applied(Engineering Hydrology. R.S. Varsheny, 1986). The arithmetic average of sediment production rates obtained from 1,000 existing measurements in the U.S., gave a rate of 1,800 $m^3/km^2/year$ for the catchments of less than 25 km^2.

In Malaysia, long-term sampling of bed loads has not been done, and only suspended load records at 53 DID hydrological stations are available. The rate of bed load was assumed at 10 to 20 % of the total sediment load (11% to 25% of the suspended load) in the "National Water Resources Study Malaysia, Perlis-Kedah-Pulau Pinang Regional Water Resources Study", and the rate of 20 % was finally adopted for the bed load.

The relationship between the mean annual sediment transport and catchment area is shown in Figure 3.6. The sediment transport was estimated by converting the suspended load transported in tonnes to the total sediment volume in m^3 assuming that; i) the bed load is 20 % of the total sediment load, and ii) the specific weight of the deposit is 1.0 ton/m^3.

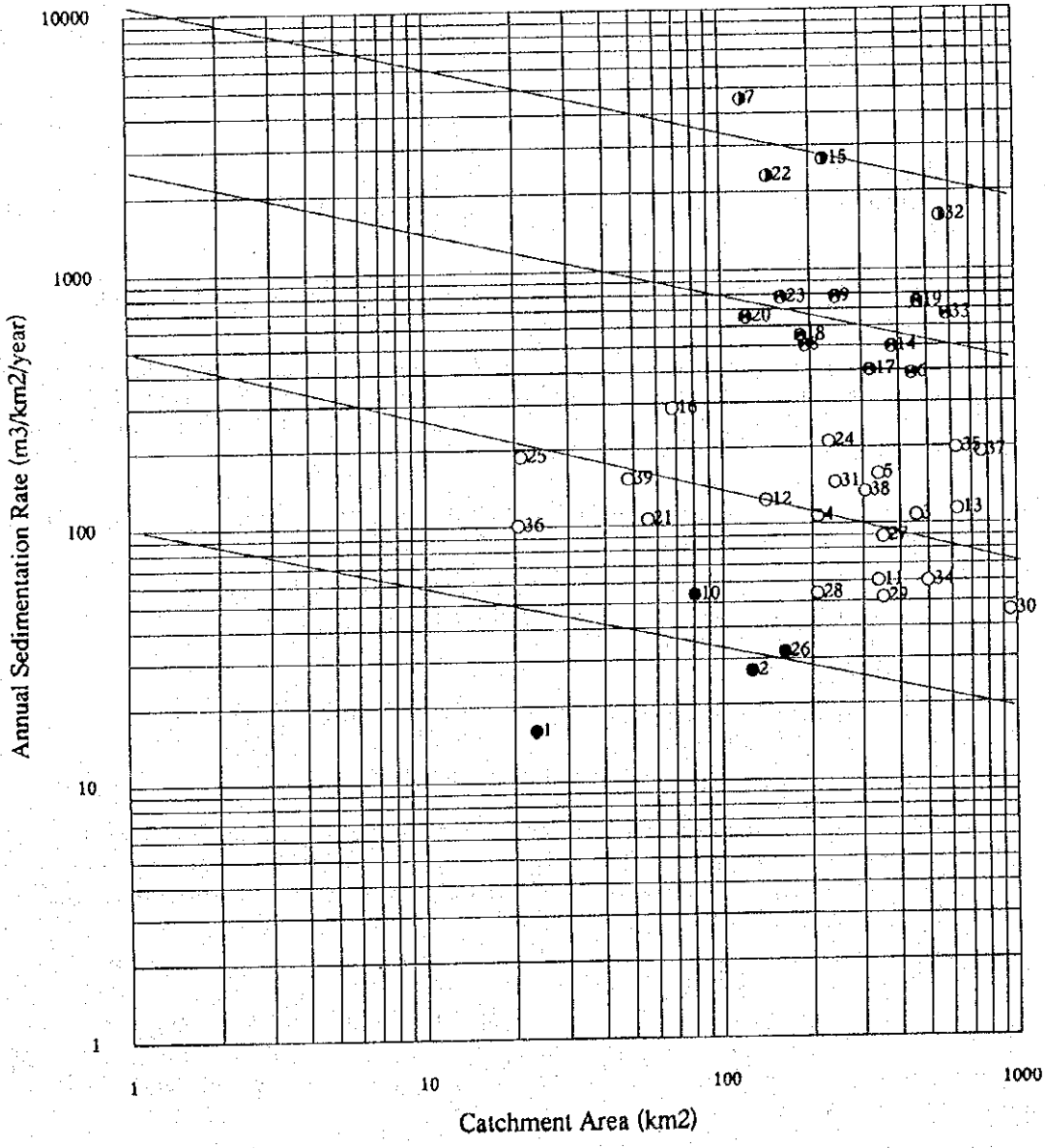
Four groups can be found according to the sedimentation rates as follows.

Sedimentation rate	Area
Very high	Part of Selangor (Sg. Batu, Sg. Semenyih), Perak (Sg. Cenderiang), Pahang (Sg. Lepar)
High	Selangor, Lower Pahang river basin Central Perak (Ipoh, Kampar, Tapah)
Low	Perlis, Melaka
Intermediate	Others

According to the location of the proposed project, the group is to be selected, and the sedimentation rate can be determined. If the following situations are confirmed in the proposed catchments, the upper limit of each group should be properly taken as the design sedimentation rate:

- Soil cover in the catchment is sandy-textured
- Catchment slope is very steep
- Development rate is more than 50 %
- Vegetation cover is less than 50 %
- High sedimentation was confirmed at near-by catchments

Fig. 3.6 Sedimentation Rates



Legend

◑	Group 1	Very High (part of Selangor, Perak)
⊗	Group 2	High (Selangor, Lower Sg. Pahang basin)
○	Group 3	Intermediate
●	Group 4	Low (Perlis, Melaka)

3.3 Topography and Irrigation & Drainage

(1) A topographical Survey of Dams & Reservoirs and Irrigation Areas

Based on the preliminary development plan, a topographical survey shall be carried out to specify the following.

-Dam & reservoir	Scale :	1 : 1,000 with a contour interval of 0.5m or 1.0m
- Longitudinal & cross sections of the dam axis including the alternative dam axis	Scale :	Longitudinal section 1 : 1,000, Cross section 1 : 500
- Interval of cross section :		20m to 30m
- Irrigation area	Scale :	1 : 5,000 with a contour interval of 0.5m to 1.0m
- Canal and/or pipe line route	Scale :	1 : 1,000

(2) Inventory Survey on Existing Irrigation & Drainage Facilities and Social Infrastructures

If existing irrigation and drainage canals are present in and around the project areas, an inventory survey of existing canals & drains and major structures shall be carried out to obtain the hydraulic conditions of them. The inventory survey shall be carried out as mentioned below.

Major structures such as intake weirs, gates, diversification structures, pump stations siphons, culverts, drops, etc.

- dimensions of structures related to the water flow
- main materials and corrosion of the structures

Canals & Drains

- typical cross sections of the respective canals & drains
- lined conditions of the canals
- rough longitudinal sections of the canals & drains

The location of respective infrastructures to be related to the development plan including roads and related structures, electric distribution lines, etc, shall be transposed on topographical maps with a scale of 1 : 1,000 and/or 1 : 5,000 and typical sections and construction materials of these structures shall be surveyed.

(3) Survey on Construction Materials and Cost

Survey methods on costs of basic construction materials, labor and equipment can be divided into two (2) systems, (i) a field survey on the costs of basic construction materials, labor and equipment and (ii) a review works on bidding prices which were made for other projects in the same regional areas.

Survey results on costs of basic construction materials, labor and equipment shall be examined and reviewed to compare with the scheduled price recently issued by the Quantity Survey Section of DID and/or the Ministry of Public Works.

The bidding prices of other projects shall be reviewed considering the working conditions such as contract system, field conditions, and quantity of works.

3.4 Geology and Geo-technics

Geological investigations are classified into the following three (3) works.

- Investigation on land form classification

- Geological investigation, and
- Material investigation

(1) Investigation on Land Form Classification

Topographic features are classified using a topographic map with a scale of about 1 : 1,000, field observation of actual topography, and aerophotographical measurements in order to forecast the problems associated with the dam construction at the proposed site.

(a) Items and procedures for investigation on the land form's classification

Topographic features are the comprehensive results of past geo dynamic activities such as ground movements, volcanic activity, and geomorphologic activities such as weathering and erosion.
Therefore, topography reflects the geological features, geologic hardness and structures as well as weathering and fractures that can be interpreted to some degree through aerial photographs, contour maps and topographic field observation.

Since topographic patterns show only indirect geologic features, the knowledge to identify the geologic relationship with the topographic features is indispensable. Intensive investigations should be carried out at the early stages of the dam study, i.e. during the formulation stage of the tentative development plan for selecting a suitable dam-site and dam type. Essential factors such as faults, landslides, depressions in the reservoir basins, and leakage should be clarified in order to avoid any drastic changes to the construction plan due to geologic problems encountered only after the commencement of the construction stage.

Land form classification shall be carried out to determine the topographical characteristics which may be analysed geomorphometrically using accurate contour maps, aerial photo interpretations using a stereoscope, and geological field reconnaissance.

(b) Problematic features of topography and geology for dam construction

Attention should be given to the following topographical and geological conditions at dam-sites because treatment and remedial measures will be considerably expensive.

- The dam foundation or reservoir basin is thick and leaky (fissured and hollow limestone or vesicular limestone, fissured and hollow volcanic rock, pyroclastic flow deposit or vesicular volcanic rock, and permeable sand and gavel.
- The dam-site area and reservoir basin are formed with a dissolutive foundation (carbonate rock such as calcium carbonate, iron sulphide and material with rich iron bacteria).
- Large-scale landslides which have occurred in natural ground in the area where the dam foundation or the reservoir is to be located, or the said foundation is susceptible to sliding.
- Large-scale faults or foldings exist in the reservoir basin.
- Existence of a source of large amounts of harmful materials such as volcanic ash or heavy metal in the river basin and surroundings (an active volcano, mining)
- Dam foundation ground consisting of alluvium, mud flow deposits or a loose sand layer that can be liquefied by vibration.

All the geologic features mentioned above are closely related to topographic characteristics and can be identified in advance by means of contour maps and aerial-photo interpretations.

(2) Geological Investigations

Geological conditions in and around the proposed reservoir including the borrow areas are to be clarified through data collection, field survey and necessary tests.

(a) Data collection and study

The first step in the geological investigation for the dam construction is the collection of existing data and the study thereof. Necessary data and items to be studied are presented below.

- Topographic map and aerial photographs:
  For preliminary studies on,
  active storage and dimensions of the dam,
  examination of possible landslide zones and
  prediction of geological distribution and structures.
- Geological map:
  For studies on,
  strength and permeability properties of the dam foundation,
  distribution and properties of the construction materials through the interpretation of rock properties,
  geological structures,
  surface soil thickness and
  characteristics of the earth materials.

(b) Dam-site investigation

(i) Investigation during the Feasibility Study Stage (Planning and Basic Design Stage)

The ultimate objective of the geological investigations at the dam-site during this stage is to ascertain the possibility of construction at the selected location and roughly estimate the construction costs. To achieve these objectives, studies on the following items are required.

- Whether the bearing capacity of the ground is adequate for the construction of the dam at the proposed location with the proposed dimensions.
- A preliminary selection of the foundation cut lines for the dam and spillway.
- Preliminary planning of the foundation treatment work

Efforts should be made to achieve the above objectives with a minimum amount of investigations, as this stage is for examining the feasibility of projects implementation.

Generally, in the case of a small dam with a rock foundation, there is almost no problem except for matters relevant to its permeability. Major investigation items to be conducted at the proposed dam-site during this stage are described as follows.

Drilling

This is the most effective method for carrying out subsurface geological investigations because direct observation of subsurface geological conditions and various tests at boreholes are possible.

In this stage of investigation, two drillings along the dam axis on either sides of the river banks and two to three drillings on the river bed (at 50 m intervals) are required. In addition, drillings at the point of spillway crest and other points should be made, if necessary.

In-situ geotechnical test

The Standard Penetration Test (SPT) at 1.0 m to 1.5 m intervals and the Borehole Permeability Test (Open-end method) at 5.0 m intervals at the boreholes are required.

Location maps of boreholes and geological profiles on a scale of 1 : 200 to 1 : 1,000 are to be prepared on the basis of results of the geological investigations, and will be utilised as basic data during the following stage of investigation.

(ii) Investigation during the detailed design stage

Investigations at the detailed design stage aim to collect geological data necessary for the detailed design and cost estimation of the dam construction. The quality and quantity of geological data shall be up-dated based on the results of the feasibility study stage. Major items for geological investigations at the dam-sites are presented below.

Subsurface geological survey

This survey aims at classifying the foundation ground at the dam-sites on the basis of engineering properties such as geological conditions (soil type, characteristics, etc.), physical, mechanical, and hydraulic properties for the detailed design of the dam and foundation improvement. Geological conditions are generally investigated through core drilling.

Drillings are usually conducted to obtain further geological information based on the geological information in the feasibility study. Nevertheless, final numbers and locations of drilling can not be specified as a general rule because they are dependent on the site conditions. However, even in the case of dams lower than 15 m in height, drillings with an interval of 20 to 30 m and along both side slopes of the river and river bed are recommended.

Hydraulic characteristics are studied from their permeability properties by utilising the boreholes.

On the basis of the results of the above surveys, detailed subsurface geological profiles and a coefficient of the permeability map showing classification of the permeability are to be prepared. Detailed subsurface geological profiles are necessary for the determination of locations and the depth of foundation treatment as well as for stress analysis, etc.. A permeability profile is a prerequisite for the determination of the depth and density of the curtain grouting or to study blanket treatment for sealing and for the selection of injection agents or materials.

Geotechnical tests

In order to understand the mechanical conditions of the natural foundation, in-situ geotechnical tests such as soundings and load tests shall be carried out on the original ground using test pits or boreholes.

Strength parameters generally required for the soil foundation of the dam are divided into two types:

- consolidation characteristics which shows the consolidation settlement characteristics of the foundation under the unconfined compression load and
- shearing strength which expresses the resistivity of the foundation against shearing stress.

Consolidation tests and shearing tests on samples from boreholes or test pits may be adopted to test the consolidation characteristics and shearing strength of the foundation.

On the basis of the evaluation results of various tests on the foundation strength, the mechanical behaviour of the foundation, after the completion of the dam, is forecasted. Design and construction planning of the dam will be conducted after the completion of the necessary studies.

(iii) Supplementary investigation

Observation and description of the geological conditions at the dam-site should continue after the commencement of construction works, as various significant issues may subsequently arise.

(c) Survey in the surrounding area of the reservoir

In dam planning, various geological aspects in the surrounding area should be studied. The possibility of landslides, landslips, etc. after ponding and water leakage through the surrounding natural ground shall be studied.

(d) Investigation for the borrow areas

"Investigation for the Borrow Area" is described in the section (3) of "Material Investigations".

(e) Procedures for subsurface geological investigation

(i) Drilling

Drilling to a high degree is effective as a method of subsurface geological investigation for dam construction as collection of geological samples from deep underground is possible, and various tests can be carried out in the boreholes. A large amount of information on subsurface geology can be obtained through drilling. The following items are particularly important in planning and implementing the drilling at the dam-site.

Items to be carefully considered during planning

- Standard diameter of drilling bit should be larger than 56 mm. If borehole testing is carried out, the diameter should be larger than 66 mm. In addition, if the core recovery rate for the deteriorated and unconsolidated sections of the bedrock is to be increased, the diameter mentioned above should be larger.
- Standard drilling depth at the dam-site is to be from 2/3 to the full height of the dam and drilling should be conducted up to a depth where ground water level is confirmed.

In general, the stress imposed on the surface of the foundation decreases underground roughly in proportion to the square of the depth, according to Boussinesq's equation for elastic half-space. Therefore, theoretically, mechanical properties of the upper layer of the foundation are far significant than those of the lower layer. In addition, the permeability of the upper layer is more important than that of the lower layer because the percolation rate in the vertical direction is far less than in the horizontal direction.

Items to be observed in core sampling

- 100 % core recovery rate should be aimed at.
- Recovery rate should be increased using double core tubes and triple core tubes or by dry drilling when recovery rate is not satisfactory.
- All matters encountered if the drilling operations should be precisely recorded including lost circulation, ground water level, cavities, gas emission, etc.

(ii) Test pits (test shafts)

Test shafts or vertical test pits are adopted for the investigation of the fill dam borrow material, riverbed deposits at the dam base, etc.. Test shafts for the investigation of the fill dam material are excavated mainly to collect earth samples for testing in addition to visual confirmation of the earth strata. However, if there is an existing borrow area in the vicinity of the proposed dam-site, there would be a cut face in the area. In general, the pit is excavated manually, the diameter and depth of which are 1.0 to 1.5 and 1.0 to 5.0 meters, respectively. On the other hand, test shafts for the investigation of riverbed deposits are excavated to identify the thickness of deposits and grain size distribution of the material, and also for conducting the permeability and load tests in the shaft.

(iii) In-situ permeability test

In-situ permeability tests are carried out for various purposes such as the evaluation of the permeability of the dam foundation, planning, implementation and the evaluation of results of the cut off work (mainly grouting work), etc. Among the various test methods, the permeability test applying to Darcy's Law is adopted for the evaluation of the permeability of homogeneous ground, judged as a porous media, such as unconsolidated deposits, heavily weathered granite, etc. in which the proportional relationship between pressure difference and seepage is considered.

The open-end test is a typical method for performing a field permeability test on a small dam with a loose soil foundation.

(f) In-situ geotechnical test

(i) Soundings

Soundings is the general term used for the investigation methods of soil characteristics which are measured with penetration, revolution, pull resistance, etc.. Soundings include the Standard Penetration Test (SPT), Penetration Tests with various Cone Penetrometers, Swedish Weight Sounding, Vane Test, etc..

(ii) Load test

The jacking test (or plate loading test) in a test pit, the borehole load test, etc. are familiar testing methods to obtain properties of deformation, i.e., a modulus of ground deformation. Each method utilises the application of an elastic solution for homogeneous and isotropic ground. Accordingly, it shall be considered that the results obtained are comprehensive, and do not always represent the characteristics of a limited part of the ground.

(iii) Laboratory test

If there are any problems associated with the stability or consolidation settlement of the foundation, laboratory tests on the undisturbed samples are required.

(g) Processing of investigation results

(i) Engineering classification of the dam foundation

The ground shall be classified and assessed based on its engineering properties in order to evaluate its suitability for a dam foundation and to estimate the mechanical behavior of the ground after the completion of the dam. The following characteristics of the ground can be considered as major factors in the engineering classification of the ground:

- Soil characteristics
  origin, era, grain size distribution, etc.
- Mechanical properties of the layers
  bearing capacity, shear strength, elastic modulus, etc.

- Other factors
  permeability, etc.

(ii) Preservation of the investigation results

The results of the geological investigations are expressed principally on the investigation location map and geological profile, with employing various geological symbols and coloring. Symbols and coloring for the geological characteristics are determined in accordance with common practice.

Location map

The map for the project area is prepared as follows:

- Area covers the dam-site, reservoir basin and surroundings.
- Scale of the map is 1 : 500 to 1 : 1,000.
- Outline of the dam and its appurtenant structures, and the full supply level are indicated on the map.
- Symbols for the investigated locations and the proposed borrow areas are indicated, if they are located in the area covered by the map.
- The results of the land form classification survey, such as classification of topography, landslide, landslip, etc. are indicated.

Geological profile for the dam-site

Geological profile for the dam-site shall be prepared as follows:

- Geological profile and cross sections are prepared. The profile is a section along the dam axis as viewed from upstream.
- Scale of these maps is 1 : 200 to 1 : 1,000 and the vertical and horizontal scales are identical.
- Area to be indicated in the profile covers at least up to where the cut line intersects with the ground surface at the dam abutment (including the spillway in the case of a fill dam) and covers the diversion tunnel, intake tunnel and the proposed depths of grouting.
- Based on the results of borings, the soil type and permeability are classified and indicated on the maps, and the ground water table is shown.
- The proposed foundation excavation line, which is determined from the comprehensive study of the results of geological survey, dam type, etc., is indicated.

Boring log

A boring log is prepared with due consideration to the following:

- "boring location", the location such as on the right or left bank, or on the riverbed, at the dam centre, toe, etc. and the station number with the distance interval of the survey, etc. are indicated.
- "layer and age", the type of soil layer and geologic age are indicated.
- "boring log", etc., the obvious boundary of the layer is indicated with a solid line and the transitional boundary with a dotted line.
- "water level before the work", the depth to the water table from the original ground surface before commencement of the daily work, is recorded at the line indicating the elevation of the hole bottom.
- "others", the results of other tests conducted in the hole is indicated appropriately.

(3) Material Investigations

The location, quantity of the proposed materials and other necessary data concerning materials required for dam construction, are to be obtained through investigation, testing, etc.

(a) Investigation items and plan for the materials

In order to design and construct the dam economically and safely, the selection of the fill dam material should be carefully investigated, as the design and construction will be influenced by the selected materials. Investigation should not be carried out through a standardised approach but rather conducted with careful consideration to the dam design and construction and based on a rational and economical investigation plan.

The material investigation aims to mainly define the following:

- Technical possibility of using soils around the dam site as the fill dam material
- Distributed condition and available volume, engineering classification, and physical and mechanical properties of the proposed material
- Conditions regarding the collection and transportation of the material, and the design and construction of the dam

The fill dam material is affected by such factors as the necessity of large quantities of natural material, the generally complex geology of the distributed site, and the wide variation of quality compared with artificial material. Therefore, the characteristics of this material is a controlling factor in the dam design and construction work. Accordingly, an investigation plan must take the factors described above into consideration, and should avoid a standardised approach. The plan should include consideration of social and economical constraints.

Generally, the fill dam material is investigated in the order of (i) feasibility study(planning and basic design), (ii) detailed design and (iii) supplemental investigation. Investigation results at each stage may be reflected in the design and construction planning, or conversely, requirements for the design and construction may be the basis for the subsequent survey. Thus, an investigation that tightly correlates with the design and construction plan would be conducted.

The selection of necessary investigation items and methodology shall be based on the following fundamental approach:

- from general area to specific area
- from rough to high accuracy
- from an investigation to know the overall tendencies to the understanding of specific conditions.

Items and methodology that would be appropriate for the required objectives and accuracy of the investigation at the respective stages, topographical and geological conditions, and the quality and quantity of materials, shall be decided. Especially for earth materials, the miss-selection of investigation methodology may result in not only less accurate or unnecessary results but may also cause serious errors in the subsequent investigations and design. Engineers in charge of the investigation would be expected to have through fundamental and practical knowledge on geology, soils, testing methodology, etc.

(b) Investigation of the fill dam materials

(i) Area to be investigated

An area within a circle of 500 meters to 1 km radius around the proposed dam site shall be investigated during the first stage. If the quantity or quality of the required materials, might be insufficient, the investigated area will be gradually increased in order to secure two to three times the proposed quantity of material, depending on the accuracy of the investigation. Generally speaking, 2 to 5 km would be the economical limit, depending

on the specifics of the topographic conditions and local situation. The fundamental feature of fill dam should be the economical use of the existing natural material around the dam-site; therefore, it is essential to obtain a large quantity of material occupying a high ratio of dams at locations where the cost of transportation is minimum.

(ii) Method of investigation for the fill dam material

Reconnaissance survey

A reconnaissance survey for the fill dam material is carried out based upon the results obtained from the previous investigation of surface geology, using a topographic map with the required accuracy for the investigation. In the investigation for the feasibility study, field conditions and features such as soil type, topography of surroundings, existing structure, and land use, etc. shall be surveyed. Furthermore, the distributed conditions of material and their availability shall be studied, and the location for underground exploration shall be determined. Observations are required on natural outcrops at rivers, valleys and cut slopes of roads, railroads, etc. Where outcrops are rare, the material quality is observed from samples of auger boring. Particularly, for earth materials, it is necessary to obtain grain size distribution and natural moisture content.

The reconnaissance survey mainly aims to select the locations for underground exploration and material sampling.

Drilling

A hole is drilled into the ground and direct soil and rock samples obtained from the drilling are used for the observation and material tests. Therefore, the drilling method should be chosen to avoid fracturing and altering the sample by water. The soil auger method and the rotary drilling method are commonly utilised.

Test pit (shaft)

Test pits are the most reliable method for underground investigation. The geological structure and variation of the layer can be thoroughly surveyed, and large amounts of samples can be easily obtained. In the case of a square or circular shaft, the minimum size may be 1.2 meters for the side width or diameter. Mechanical excavation must be carried out carefully in order to obtain precise geological information and representative samples. The depth of the pit differs depending on the distributed conditions of the material. One meter below ground water table is the limit for the depth. For safety and protecting the pit wall from rupture, appropriate supports, depending on the geological conditions, are to be installed, and ventilation is required in deep pits. Sufficient measures such as fencing, should be taken to prevent people or animals from falling in during and after the excavation, etc., The test pit (shaft) method is omitted for small borrow areas favoured with good out crops, like a cut face, in their vicinities.

(c) Material test

Various tests presented in Table 3.5 and other tests if needed are recommended to be carried out on the collected samples. However, the samples to be judged by the specialist should be representative samples and the test should be allowed only for the samples that are within the objectives of the investigation, the cost and term of tests, and the magnitude of the project.

The tests shown in Table 3.5 are standardised in major countries and testing is carried out based on these standards.

The results of the tests shall be summarised in the table of the summary for the fill dam material tests.

Table 3.5 Test items on fill dam material

Material/Stage of study		Impervious		Semi-pervious		Pervious		Reference	Remarks
Test items		F/S	D/D	F/S	D/D	F/S	D/D	(BS 1377:1975 or)	
Physical test	Specific gravity	○	○	○	○	○	○	JIS A 1202	Grain size of less than 4.76mm /1
	Natural water content	○	○	○	○	○	○	-do- 1203	
	Grain size analysis	○	○	○	○	△	○	-do- 1204	
	Liuid limit	○	○	△	○	△	△	-do- 1205	For pervious material, soft, fine grained rock which is liable to fracture and slaking should be used for sample /1
	Plastic limit	○	○	△	△	△	△	-do- 1206	
	Organic matter content	△	△	-	△	-	-	JSF T 8	
	Field density	△	△	△	△	-	-	JIS A 1214,etc.	
	Others	△	△	△	△	△	△		
Mechanical test	Compaction	○	○	○	○	△	○	JIS A 1210,etc.	When non-standarized mold is used, allowable max.grain size should be less than 1/5 of inner mold diameter. Inner diameter of mold for compaction shoul be more than 10 cm
	Cone index	△	△	-	-	-	-	Portable cone	
	Permeability	○	○	○	○	△	△	JIS A 1218	
	Consolidaion	○	○	△	△	△	△	-do-	Compression index should be determined When Md 10, dmax Md/10 When Md 10, dmax Md/10-5 /3
	Triaxial compression	○	○	○	○	○	○	JSSMFE /2	
	Fine grained	△	△	△	△	△	○		
	Others	△	△	△	△	△	△		

Note:
In case of small dam, impervious and/or semi-imprevious material is used
○ : to be implemented
△ : to be implemented, if necessary
/1;Sample includes fine grained soil and is arranged in non-dry condition for testing
/2;Japanese Society of Soil Mechanics and Foundation Engineering
/3;Md=mold diameter, dmax=allowable max. grain size

3.5 Agriculture

In the agricultural sector, two types of surveys such as a farmers interview survey and a soil survey will be necessary:

(1) Farmers Interview Survey

(a) Farmers meeting

The farmers should be informed about the project and the survey prior to the implementation of farmers interview survey. Meetings should be held for that purpose, with the attendance of all farmers. In most cases when farmers interview survey is carried out, the farmers are not well informed of the project. Therefore, DID and other agencies engaged in the project should hold farmers meetings to provide explanation about the farmers interview survey questionnaires. This type of meeting is a good opportunity to hear the farmers thoughts on the project.

(b) Sample number for the farmers interview survey

In a small project, all the farmers should be interviewed. For large projects, the number of samples and sampling method will be decided by the interviewer. The sampling method can be decided on the conditions of the village and the purpose of the project.

(c) Interviewers for the farmers interview survey

The interview will include some specific questions on farming in the project area. Therefore the interviewers should be persons acquainted with the farmers and with enough knowledge on farming in the project area. It is recommended that the interviewer should be chosen from the agricultural extension workers, local school teachers, and University or College students from the village within the project area.

(d) Items of the survey

The survey shall include all items necessary for the project formulation. The investigation should be rational and efficient. Typical items to be investigated are:

- Family characteristics :	age, education, labor availability, status
- Land ownership:	average area per household
- Paddy cultivation:	assessing the cropping area, cost of nursery, cost of seeds, fertiliser, chemicals, cost of machinery, hired labor, family labor, crop yield, marketing amounts, marketing price.
- Fruit trees:	name of species, number of trees, age of trees, management cost, number of fruit bearing trees, yield, marketing amounts, marketing price.
- Livestock:	number of cattle, goats, hogs, chickens, cost of breeding, income from livestock.
- Farmers' intention:	farmers' support for the development plan, desire for group farming, request for agricultural credit, existence of farmers' successor.

(2) Soil Survey

The soil survey should investigate the following items required for project formulation and crop selection.

- Soil profile: Colour matrix, texture, drainage class, slop
- Soil properties: series, composition, pH, water holding capacity, permeability, organic carbon content, Cation Exchange Capacity (CEC)

- Crop suitability: Suitable crops for each soil series

3.6 Agro-economy

(a) Field survey

Surveys on the following items shall be carried out to make the farm budget analysis.

- investment,
- annual labor requirement per hectare by crop and operation,
- labor distribution by crop and month per hectare,
- land use,
- yield and carrying capacity,
- farm-gate price,
- off-farm income,

(b) Farm budget analysis

These correspond to the seven meshed frames on the column at the left end of the flow chart given in Figure 3.7. This shows the basic information on which any farm investment analysis relies.

Fig. 3.7 Flowchart of Farm Budget Analysis