CHAPTER 1 INTRODUCTION

1.1 General

This guideline titled "Planning Guideline for Rehabilitation and Reconstruction of Irrigation Systems in the Kingdom of Cambodia" was prepared in accordance with the Scope of Work (S/W) for "the Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin, the Kingdom of Cambodia" (the Study) agreed upon between the Ministry of Water Resources and Meteorology (MOWRAM), the Royal Government of Cambodia (RGC), and the Japan International Cooperation Agency (JICA) on October 09, 2000.

One of the main themes of the Study was to recover the function of existing irrigation systems in Cambodia that were mostly constructed during the Pol Pot Regime but have now fallen into disrepair.

The Study was carried out in a selected irrigation system in Takeo Province whose command area was about 30,000 ha.

The Study consisted of two phases, namely Phase-I: Master Plan and Phase-II: Feasibility Study. In Phase-I, a master plan was formulated for the whole Study Area mainly focusing on the rehabilitation and reconstruction of the existing irrigation systems. For this, three types of irrigation systems were proposed. The Upper Slakou River Irrigation Reconstruction Plan (USP) has an irrigation area of 3,500 ha with three reservoirs and two main canals. The Small Reservoir Rehabilitation Plan (SRP) was composed of independent small reservoir irrigation systems distributed in the Study Area with each irrigation area of about 20 ha. The Small Pond Development Plan (PDP) was proposed to cover the areas that could not be commanded either by USP or SRP.

Supporting programs for the above three plans were also proposed to optimize the benefit of the plans. They were; Agricultural Production Program, Rural Road Improvement Program, Agriculture Support Program, Institutional Development Program, and Environment Conservation Program.

These plans and programs were developed and presented as a model package for sustainable development of irrigation systems in Cambodia. This guideline compiles and introduces the planning method of the rehabilitation and reconstruction of the irrigation systems in Cambodia, practically, on the basis of the limited experience and outcome of the Study conducted within the Study Area. In general, different projects have different natural and socio-economic conditions. Therefore, it is requested to users that application of the guideline to individual project needs user's authorized engineer's permission and/or responsibility.

1.2 Objectives of the Guideline

The guideline was prepared according to one of the objectives of the Study that; i) the formulated plan should be a model for the rehabilitation and reconstruction of many agricultural production systems existing in Cambodia, and ii) the formulated plan should be sustainable, the guideline was prepared.

The guideline is aiming at all personnel and organizations involved in the reconstruction and rehabilitation of existing irrigation systems in Cambodia, namely, public services, NGOs, Farmer Water User Community (FWUC) and other communities and groups.

The objectives of the guideline are; i) to formulate and compile the planning approach, method and procedure systematically, ii) to provide and transfer the know-how of the planning to the Cambodian personnel and experts concerned, and iii) to support expansion of the proper reconstruction and rehabilitation plans of the irrigation systems in Cambodia.

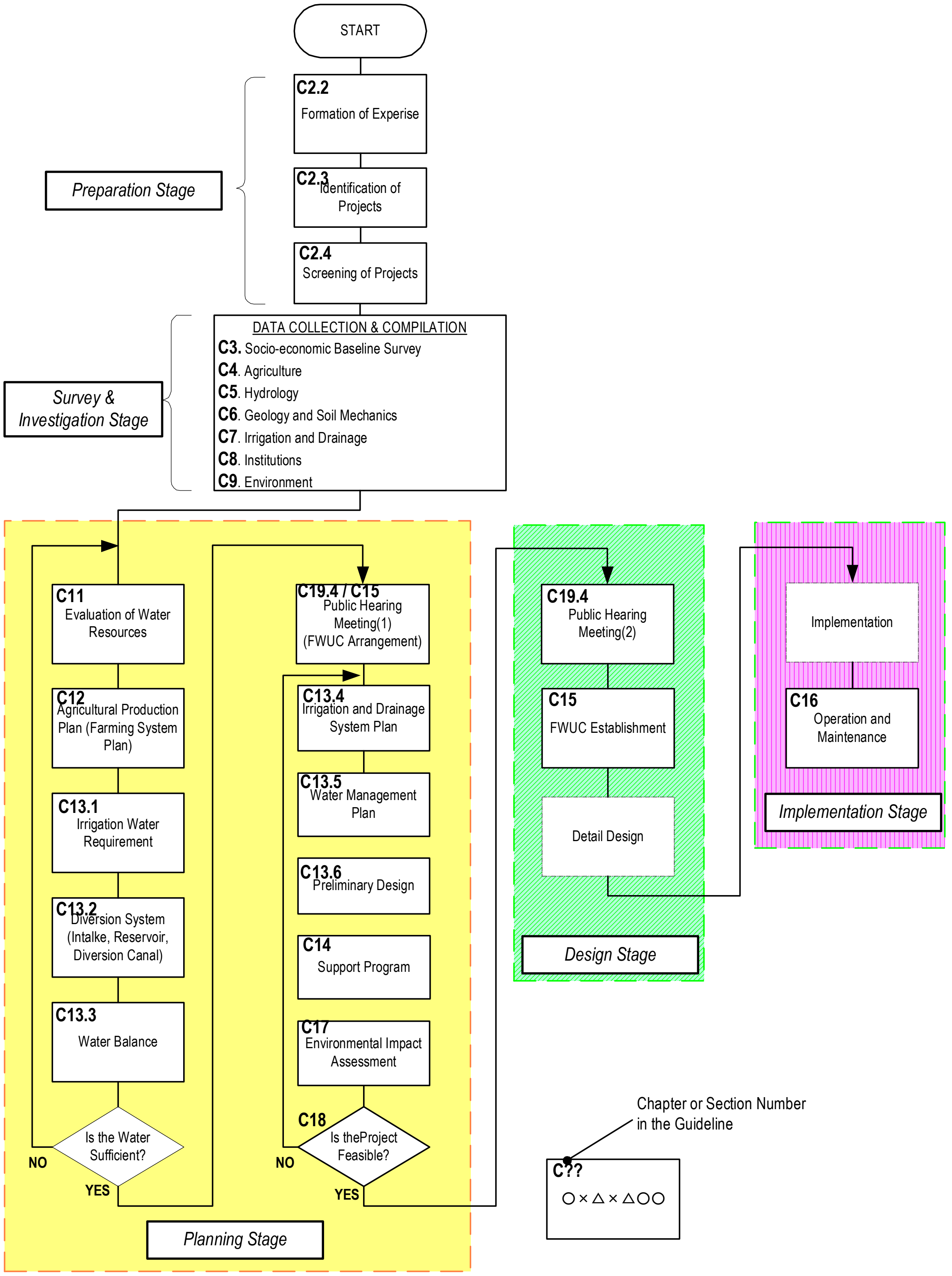
1.3 Composition of the Guideline

The guideline consists of two (2) parts, namely;

- PART-I Preparation, Survey and Investigation
- PART-II Planning and Design

"Preparation, Survey and Investigation" covers; i) how to identify the project, ii) necessary expertise and work period, and iii) necessary data and information to conduct the expert planning and design and how to compile them. "Planning and Design" shows; i) the procedures of analysis of the compiled data, ii) determination of development scale, iii) design concept and criteria to be adopted, iv) procedures for formulating supporting programs, v) environmental consideration to be taken, vi) project evaluation and vii) institutional development particularly on FWUC.

Special attention is paid to explaining the use of "participatory planning approach", which is one of the most important concepts that must be applied to realize the sustainable development in Cambodia.



The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin, The Kingdom of Cambodia	Fig.1.1 Flow Diagram of Project of Rehabilitation and Reconstruction of Irrigation System
Japan International Cooperation Agency	

PART 1

PREPARATION, SURVEY AND INVESTIGATION

CHAPTER 2 APPROACH OF PROJECT

2.1 Flow of Planning and Design

2.1.1 Preparation Stage

Responsible Organization / Personnel

- MOWRAM / DWRAM

Work Item

- Identification of Potential Projects
- Screening of Projects
- Assignment of Experts / Staff

Before the planning and design can commence, the responsible organization should identify and screen projects and then assign the necessary resources such as manpower, budget, etc. For the planning of irrigation rehabilitation and reconstruction, MOWRAM and DWRAM should be the responsible organization.

2.1.2 Survey and Investigation Stage

According to the results of the identification and screening of the projects, survey and investigations will be conducted for the following purposes.

Purpose of Survey and Investigation

- To clarify existing problems and development constraints in the proposed project area
- To provide data for planning and design

For these purposes, the following items will be surveyed and investigated:

Items for Survey and Investigation

- Socio-economy
- Agriculture
- Hydrology and water use
- Geology and soil mechanics
- Irrigation and drainage
- Institutions
- Environment

2.1.3 Planning and Design Stage

One of the most important aspects of the planning an irrigation project is water resources evaluation and water balance study. In Cambodia, water resources evaluation has not been well-conducted, mainly due to the lack of proper observation and compilation of hydrological data (rainfall, river gauge and discharge, water quality, sediment, etc). Thus, the development scale of irrigation schemes is generally very large compared with available water. Poor maintenance and deterioration of the facilities were caused by a lack of a sense of "beneficiaries' participation" mainly due to the low reliability of the irrigation water. In order to achieve a sustainable irrigation project, a water resources evaluation and water balance study to identify a known dependability and adoption of a participatory approach are essential, particularly at the initial planning stage.

A public hearing meeting should be held after determination of the development potential in order to delineate the command area of the project. According to the command area determined, concrete alternative plans and supporting programs should be formulated, then the preliminary design would be carried out to estimate the project cost. Environmental impact assessment would also be conducted in the planning stage. The project should be evaluated mainly by focusing on the financial aspects of target farm households.

Another public hearing meeting should be held at the beginning of the design stage so that the involvement, participation and contribution of beneficiaries and details of the project can be confirmed. FWUC would also be organized and established at this stage. Training and guidance to FWUC and other farmers' groups should be implemented at this stage or further.

Operation and maintenance, which is the most important part of the irrigation project, would be formulated and transferred to related officials of DWRAM and FWUC, not only in the planning and design stage but also in the implementation stage as "on the job training" (OJT).

A Flow diagram of the project of rehabilitation and reconstruction of irrigation system is given in Fig. 2.1.

2.2 Expertise and Period Required

2.2.1 Expertise and Formation

In order to conduct planning and design works for irrigation reconstruction projects, various fields of expertise are required. It is recommended to organize a task force for a project consisting of experts as shown below:

Table Expertise and Staff Required for Irrigation Planning and Design

Expertise	Expert / Staff	Related Organization
Irrigation	Hydrologist Water resources engineer River engineer Geo-technical engineer Survey and mapping specialist Irrigation and drainage engineer Design engineer O&M specialist FWUC organizer	MOWRAM, DWRAM
Agriculture, Agro-economy	Agriculturist Soil scientist Agro-economist Marketing specialist Extensionist	MOA, DOA, CARDI
Community Development	Sociologist Local facilitator Community and Group leader	Local administration (District, Commune, Village), NGO
Others	Environmental specialist Legal adviser	MOE, DOE Lawyer, etc.

Note: Underlined experts/staffs are essential.

2.2.2 Period Required

It is necessary to allocate a sufficient period for the planning and design. Particularly for a larger development plan of more than 2,000 ha, the hydrological investigation and study are required for at least one hydrological year (one rainy season and one dry season), unless the hydrological data are available from existing hydrological stations in the subject area. The work items and schedule required for a basin-wide irrigation reconstruction study are shown in the following table.

Table Typical Work Item and Schedule for a Basin-Wide Study

Expertise	Work Item	Period Required
Hydrology	Collection and compilation of existing data	0.5 months
	Field measurement (river discharge, rainfall, water level)	1 hydrological year (one rainy season, one dry season)
	Estimation of runoff	1 month
	Water quality evaluation	1 month (including laboratory test)
	Sedimentation analysis	0.5 months
	Water balance study	1 month
Survey and Mapping	Survey of reservoir area	0.5 months
	Survey of canals (profile and cross-section)	0.5~2 months
	Mapping (based on the existing digital map)	1~2 months (scale 1:5,000~10,000)
Geo-technical Survey	Geological boring and tests	1~2 months
Agriculture, Agro-economy	Present farming practices	0.5 months
	Cropping system plan	0.5 months

Expertise	Work Item	Period Required
	Supporting services plan (agricultural input, extension, etc.)	0.5 months
	Farmers group arrangement	3 months
	Farm budget	0.5 months
	Marketing	0.5 months
	Project evaluation	0.5 months
Irrigation and drainage	Existing irrigation system	1.0 month
	Irrigation water requirement	0.2 months
	Irrigation system plan	0.5 months
	Drainage system plan	0.5 months
	Water management plan	0.5 months
	Operation and management plan	0.5 months
Design	Reservoir	2.0 months
	Intake facilities (weir, headworks)	2.0 months
	Main irrigation system	2.0 months
	Tertiary system	1.0 month
	Road improvement	1.0 month
	Cost estimate	1.0 month
	Drawings	3.0 months
FWUC Arrangement	Explanation to beneficiaries	3.0 months
	Establishment of FWUC	3.0 months
	Training and guidance (before operation)	3.0 months
	Training and guidance (OJT)	12.0 months
Participatory Planning	Socio-economic baseline survey	0.5 months
	Farm-household survey	0.5 months
	Public hearing meeting (planning)	0.5 months
	Public hearing meeting (design)	0.5 months

2.3 Identification of Project

In order to promote the rehabilitation and reconstruction of an irrigation scheme, it is necessary to prepare an inventory of existing irrigation schemes in Cambodia. The inventory should include the following information.

- Location (province, district, commune)
- Name of scheme
- Irrigation area (ha)
- Water source (river name, catchment area, nearest rainfall station)
- Irrigation system (reservoir number and volume, canal, pump, etc.)
- Farmer Water User Community
- Crops (main crops, other crops)
- Access road (distance from district center to the beginning point of the main canal, road condition)
- Completion year
- Project fund
- Current status

The above information would be compiled in the following format[1] by DWRAM, and the data would be input in a worksheet of a computer program.

Table Inventory of Existing Irrigation Scheme (FORM-1)

No.	Province	District	Commune	Name of Scheme	Irrigation area (ha)	Water Source			Irrigation System					FWUC	Crops		Access Road		Year	Fund	Status
						River	Catchment Area (km^2)	Rainfall Station	Reservoir No.	Reservoir Volume	Canal	Pump	Others		Main	Other	Distance to District Center (km)	Condition			

2.4 Screening and Prioritization

From the inventory of existing irrigation schemes, candidate irrigation schemes would be nominated through a screening process so that the limited funds and resources can be optimized. The schemes should also be categorized according to their size (large, medium, small) and current status (for rehabilitation, for reconstruction). The screening and categorizing processes are illustrated in Fig. 2.2.

2.4.1 Categorization by Irrigation Area

According to the MOWRAM's definition, the irrigation schemes are categorized by their command area as follows:

<u>Scale of Irrigation Scheme</u>

- Large scale : Irrigation are over a 5,000 ha
- Medium scale : Irrigation area between 200 ha and 5,000 ha
- Small scale : Irrigation area less than 200 ha

The resources and costs required for conducting the planning and design works depend on the scale of the target scheme.

2.4.2 Current Status

If the functions of a certain irrigation scheme are maintained well, needless to say, neither rehabilitation nor reconstruction is required.

If the scheme is being operated below capacity with deteriorated facilities, or has

[1] This format is listed in Attachment-1 "Forms for Survey and Investigation" as "FORM-1" with instruction how to fill up the form.

not been operated temporarily (for a few years) due to deterioration of the facilities, rehabilitation works should be considered.

Abandoned schemes which have not functioned for more than five (5) years would require reconstruction, assuming that there has been serious deterioration and no maintenance works for a long period.

According to the above definition, the candidate projects would be categorized.

2.4.3 Site Confirmation

The candidate schemes should be examined at the field level. Check points to be examined are as follows:

Check Point at Field Level

- Confirmation of information in the inventory (dimension, number, etc.)
- Current land use in the irrigation area (Cultivated or not. What percentage? Land use in the reservoir, cultivated or not?)
- Existence of land-use conflict (submerged, occupied by facilities, etc.)
- Other negative impacts
- Water resources (rough estimation of discharge. seasonal ? perennial?)
- Need of beneficiaries (strong request or not)
- Work volume (big, small)
- Other problems and constraints

2.4.4 Prioritization at Provincial Level

The candidate schemes should be prioritized with respect to the available development budget of each project. The Provincial Development Committee (PRDC) would organize a meeting for this purpose. Participants in the meeting would be:

Participants to the Meeting for Prioritization at Provincial Level

- Chairman: Governor
- Secretariat: DWRAM
- Representative from the governor's office (provincial office)
- Representative from related districts
- Provincial directions of public services (MAFF, MRD, etc.)

Representatives of the beneficiaries such as chiefs of communes and villages, FWUC, etc. could be invited to the meeting. After prioritization, the sequence or classification of the priority would be given to each scheme (Refer to **FORM-2**).

Reasons of the high priority should be written on the form.

2.4.5 Selection at Central Level

The result of prioritization at the provincial level would be forwarded to the Department of Planning, MOWRAM. The Department of Planning will organize a meeting at central level to select the schemes according to the national development policy. Then, after making a cost estimate for the planning and design works, MOWRAM would make a necessary budgetary arrangements for either domestic or international funding.

2.5 Data and Information Required

The data and information required to carry out the planning and design are summarized in the following.

Table Data and Information Required for the Planning and Design

Category	Data / Information	Sources
Topographic condition	Map (1:100,000) Map (1: 5,000~10,000) Map (1:100, structure) Aero-photograph	MPWT Cartography from aero-photo Plain survey MPWT
Socio-economy	Statistical Year Book General Population Census Development plan of province Statistics compiled in District Statistics compiled in Commune Census village level 1998 Village registration book	Min. Planning -do- Provincial office District office Commune office Min. Planning (CD-ROM) Village chief
Agriculture Agro-economy Project evaluation	Soil map of rice growing area Agricultural Development Plan Commodity price (input) Farm gate product price Present cropping pattern Farm household economy Soil and land suitability Supporting services	Geography Dept, IRIC MAFF To be surveyed in the Study -do- -do- -do- (sample survey) -do- -do-(MAFF, NGO, etc.)
Hydrology and water use	Hydro-geological map Rainfall, river water level, discharge data Water quality Sedimentation Empirical formula for runoff and flood	Geography Dept., IRIC MOWRAM, DWRAM and field measurement MOWRAM, MRD, MOE And field measurement MOWRAM, field measurement Study, design report of previous work
Geology and soil mechanics	Engineering soil map Engineering boring Material test and volume estimation	Geography Dept., IRIC To be surveyed in the study -do-
Irrigation and drainage	Inventory of irrigation canal Inventory of structures Inventory of road and dikes	To be collected through field survey -do- -do-

Category	Data / Information	Sources
Design	Design standard Cost of materials, equipment, labor, etc.	MOWRAM, MPWT, MRD -do-, To be surveyed in the study
Institution	FWUC and activities Farmers' group VDC and activity	To be surveyed in the Study (DWRAM, village) -do- (MAFF, VDC, village) -do- (DRD, district, village)
Environment	Laws and sub-decree on EIA Initial environmental examinations Environmental Impact Asessment	MOE To be conducted in the Study -do- (if required)
Participatory Planning	Farm household sampling survey Rapid Rural Appraisal Public hearing meeting at planning stage Village meeting Public hearing meeting at design stage	To be conducted in the Study -do- -do- -do- -do-

CHAPTER 3 SOCIO-ECONOMY

3.1 General

In order to grasp the existing socio-economic conditions, problems, and constraints to development in the target area, any existing socio-economic data should be obtained and analyzed, then followed by supplemental survey in the project area.

Some of the existing socio-economic data at national and provincial levels are compiled in publications of the Ministry of Planning, whilst local data are mostly compiled at provincial and district offices.

National and provincial level statistics would be used to categorize, prioritize and select provinces in terms of poverty level, low production, etc.

The local level socio-economic data would also be used as indices of target setting and project evaluation.

3.2 Regional Economy and Social Condition

3.2.1 National and Provincial Level

Major socio-economic statistics and reports available at the national and provincial level are listed in the following table.

Table Major Socio-economic Statistics at National Level

Name of Publication	Contents	Related Organization
Cambodia Statistical Year Book	Population and demography, labor and wages, prices and exchange rate, income and expenditure, agriculture, fishery and forestry, etc.	Ministry of Planning
Consumer Price Index	Monthly publication on consumer price of major commodities	-do-
National Accounts of Cambodia, 1996-1999	National income and expenditure, trade of Cambodia.	Ministry of Economy and Finance
Identifying Poor Areas in Cambodia	Poverty maps of Cambodia, Results and analysis of The National Population Census (1998) and The Cambodia Socio-Economic Survey 1999, Poverty lines, etc.	WFP, Ministry of Planning, UNDP
A Poverty Profile of Cambodia	Results of socio-economic survey of Cambodia 1993-94, Setting a poverty line for Cambodia, Characteristics of poor	World Bank Discussion Paper No.373
Five Year Development Plan 2001-2005 Takeo Province	Development targets and plans of each sector in Takeo Province	Provincial Government of Takeo, Ministry of Planning

3.2.2 District and Commune Level

A district office consists of administrative officers and technical officers appointed by relevant line agencies. For instance, MOWRAM (DWRAM) has a few officers in each district office. They collect basic data and information, identify the requests and needs of residents, and propose development plans of the district to DWRAM (MOWRAM).

The commune is the lowest level of official administration under the district. Districts generally consist of 4 to 15 communes. The commune office collects and compiles socio-economic data from villages and send them to the district office. For small irrigation schemes located within one commune, it is quicker and more appropriate to collect the socio-economic data at the commune level. However, some commune offices do not always keep data systematically or consistently, therefore supplemental or additional survey by questionnaire and interview (to the commune staff) is required on most occasions.

In many provinces, districts and communes, projects conducted by international organizations (IOs) and NGOs exist, and field offices for the projects are set up. Those projects also collect the socio-economic data at district level or lower. It will be also useful to collect such information from those organizations.

3.2.3 Village Level

Most of the development works are implemented in close contact with the villages. The starting point of the development should be at the villages considering the need for a participatory approach to promise sustainable development.

At the village level, basic socio-economic information is compiled in the "Villagers Registration Book", which is kept by the village chief. The information compiled in the book varies by village, but the following information is generally included.

- Name of villagers by household,
- Head of each household, and
- Age, sex, educational background, religion, occupation, etc.

From these information, a demographic profile of the village can be obtained, but other information such as land tenure, economic status, are to be collected by applying questionnaire and interview to target households. In general, each village consists of several residential groups called "Krom". An efficient survey would be achieved by contacting the village chief and group leaders.

The socio-economic data collection by administration level is summarized in Fig. 3.1.

3.3 Detailed Survey

3.3.1 Commune Profile Survey

In order to determine the general socio-economic conditions in the target area, a commune profile survey is one of the most effective procedures. As mentioned above, the socio-economic data at the commune level are not always compiled systematically, and additional or supplemental survey (interview with questionnaire) is often required. Items to be colleted through the commune profile survey are listed below:

Items for Commune Profile Survey

- General information (area, administration, population, household number, etc.)
- Living condition (access, drinking water, health center and services, number of school and teachers, literacy rate, electricity, etc)
- Land use and land tenure
- Agriculture (production and yield, extension services, livestock and fishery, etc.)
- Agro-economy (production cost, farm input cost, farm-gate prices and marketing of products, agricultural / rural credit services

Sample questionnaire for the commune profile survey is shown as **FORM-3** in the Attachment-1.

3.3.2 Farm Household Survey

(1) Type of Survey

In order to grasp the detailed and specific socio-economic conditions of the target area, a farm household survey is conducted. The survey consists of both a sample survey and a survey of all households.

The sample survey is conducted for large projects whose area expands over several villages in a commune or larger administrative area. For small scale irrigation developments with a command area within one village, the survey of all households is preferable, not only for data collection and compilation, but also to assist participatory planning. The number of samples also depends on the time and resources to be allocated, but at least one sample (household) per village should be taken.

(2) Survey Team

Considering the large number of target households, the survey would be conducted by a team. The team would consist of one coordinator cum supervisor and enumerators. The coordinator cum supervisor should have an educational background of sociology, economy or community development, and experience training staff to assist with the farm household survey or the participatory planning approach.

The survey would be conducted by a few teams. In advance of the survey, the coordinator cum supervisor should hold an orientation and training for the enumerators including on-the-job training.

An enumerator would cover about 50 respondents and would interview five (5) respondents per day. The formation of a team and roles of the coordinator cum supervisor and the enumerators are given in the Fig. 3.2.

(3) Selection of Respondent

Considering the number of the respondents (a few samples in a village[2]), the sampling should be conducted carefully not to be biased. It is appropriate to select the sample households in accordance with the results of the commune profile survey, but certain indices should be selected, such as rich farm household, poor farm household, widow-headed household, etc.

3.4 Data Compilation

The results of the socio-economic survey would be checked and compiled in a format so that the different information sources, namely statistic of publications and the results of the household survey should represent the socio-economic conditions of the target area.

A sample form for the data compilation of the farm household survey is given in **FORM-4** in Attachment-1.

[2] One village has 1 to 3,767 households.

CHAPTER 4 AGRICULTURE

4.1 Data and Information Required

An irrigation and drainage plan is formulated on the basis as an agricultural development plan as shown below:

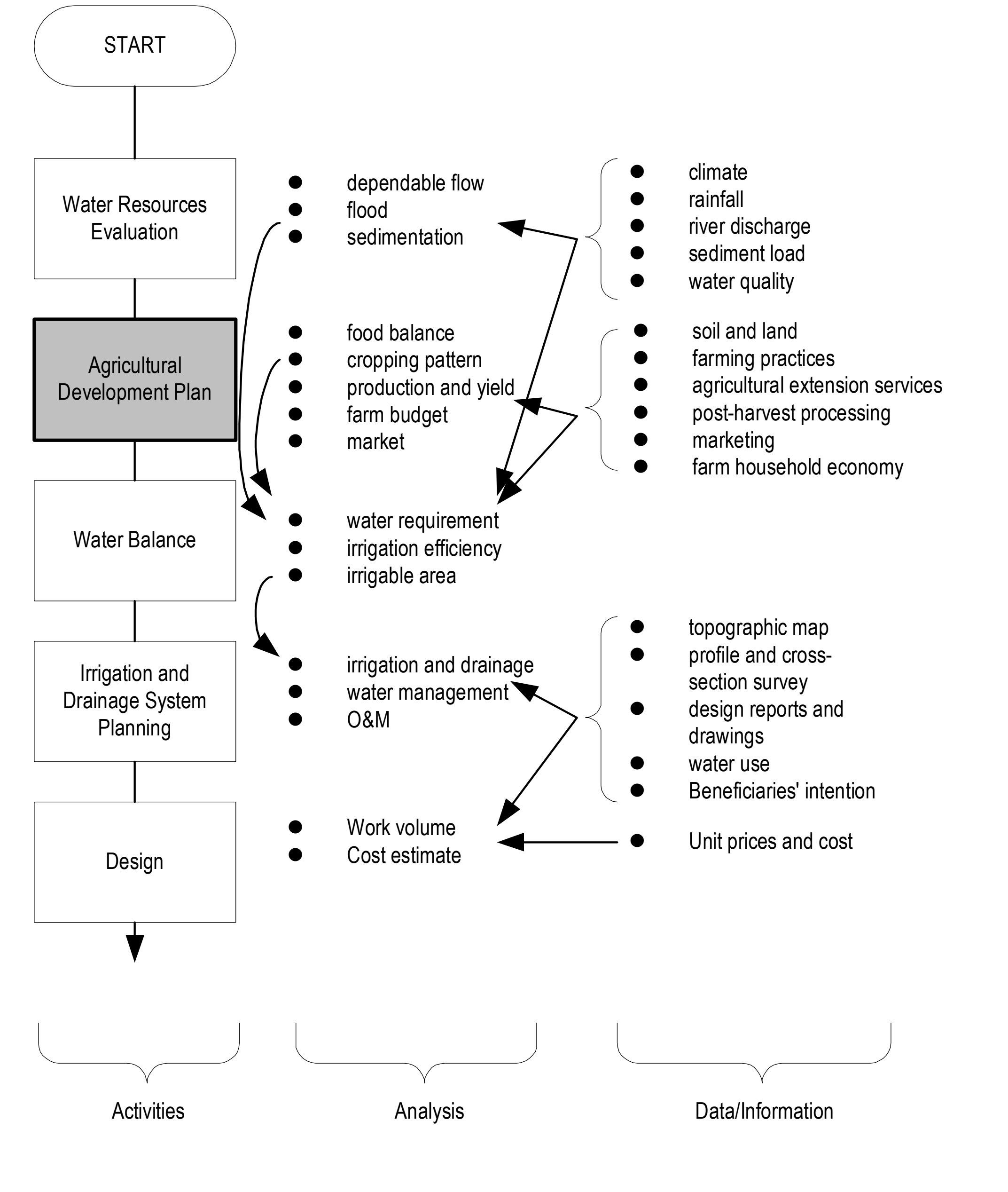


Figure Data/Information Required for Irrigation Development

For large irrigation schemes, it is necessary to consider the food balance in/around the project area. For instance, large-scale irrigation development of rice deficit areas would greatly improve their self-sufficiency rate and people's living standard, while in rice surplus areas, irrigation development will increase the farmers' cash income. In this case, marketing aspect and impact to the surrounding area should duly be considered.

For small and medium irrigation developments, especially for rehabilitation and reconstruction projects, the present cropping pattern and farmers' intention, in other words, favorite crops should be respected in the proposed cropping pattern. However, for the introduction of high value crops, which are not very familiar to the farmers but might improve their income, soil and land suitability, the farming skills of farmers, availability of present supporting services and agricultural inputs such as improved seeds, fertilizers, etc. should also be considered.

Most of the information and data on agriculture and farming practice should be collected in the target area, either by interview survey or through hearing meetings. **FORM-5** in Attachment-1 is a sample of the survey sheet which could be used as the questionnaire.

4.2 Soils and Land

4.2.1 Land Unit and Soils

Soils in the rice growing area are classified into 10 groups by "Soil of the "Cambodian Agronomic Soil Classification" (CASC), which was produced by Cambodia-IRRI-Australia Project in 1999. The project provided a soil map for the whole country (1:900,000) and for some provinces (1:50,000). These are available from MAFF. Details of the soil groups are introduced in "The Soils Used for Rice Production in Cambodia ~ A Manual for Their Identification and Management" and summarized in Table 4.1.

A soil survey should be conducted for detailed study or new irrigation development. The number of sampling locations depends on the distribution of soil series mentioned above. It is recommended to take samples from a few test pits per soil group. The size of a test pit should be 1 m x 1 m x 1 m, and samples should be taken from each layer. Photographs and sketches of the profile should be taken at each test pit. After the sampling, it can be determined whether some samples belong to the same soil group. The selected samples should be sent to a laboratory for checking of the following items:

- Soil bulk density
- Particle size analysis
- pH

- Electric conductivity (EC)
- Total nitrogen (T-N)
- Total carbon (T-C)
- Ammonium-nitrogen (NH_4-N)
- Nitrate-nitrogen (NO_3-N)
- Total phosphate (T-P)
- Available phosphate (Av.-P)
- Exchangeable cations (Ca, Mg, K, Na)
- Cation exchangeable capacity (CEC)
- Moisture content

4.2.2 Land Suitability

Land suitability for agricultural use is judged on the basis of the properties of the surface soils. The soils and suitable crops are summarized below:

Table Soils and Suitable Crops

Soil Group		Crops		Productivity
General	CASC	Rainy season	Dry season	
Alluvial / Colluvial soils	*Prey Khmer* soils	Paddy, secondary crops, vegetables	Paddy, secondary crops, vegetables	Low
	Prateah Lang soils	Paddy, secondary crops, vegetables	Paddy, secondary crops, vegetables	Low - Medium
	Bakan soils	Paddy	Paddy, secondary crops, vegetables	Medium
	Koktrap soils	Paddy	Paddy, secondary crops, vegetables	Medium
	Toul Samroung soils	Paddy, secondary crops, vegetables	Paddy, secondary crops, vegetables	High
Recent alluvial soils	*Kein Svay soils*	Paddy or flooded	Paddy, secondary crops, vegetables	Medium - high
	Kbal Po soils	Flooded	Paddy	High
	Krakor soils	Flooded	Paddy	High
Residual weathered soils	*Labansiek* soils	Paddy, secondary crops, vegetables	Paddy, secondary crops, vegetables	Medium - High
	Kompong Siem soils	Paddy, secondary crops, vegetables	Paddy, secondary crops, vegetables	Medium - High

Note: CASC; “Cambodia Agronomic Soil Classification”.

4.2.3 Land Use

Land use is the essential information for agricultural planning. The land use (area) should be specified for the following categories;

1. Cultivated land (net area)
   1.1 paddy field
   1.2 other crop field

2. Bush, shrub, forestry, mountain
3. Residential and building area
4. Others (road, pond, canal, reservoir, etc.)

4.2.4 Land Tenure and Land Holding Size

According to the Land Law promulgated in 1992, the land basically belongs to the National Government and farmers have the right to use the land.

In formulating an agricultural plan or irrigation plan, it is important to grasp the land tenure. The structure and institutions of the local society often affect the land tenure and vice versa. The number, area and percentage of following categories should be confirmed:

- Owner operator (farm household that cultivates on his/her own land)
- Tenant farmer (farm household that cultivates on rented land)
- Owner cum tenant farmer (farm household that cultivates both on his/her own land and rented land, and
- Farm laborer (farming household that does not have any land but householders works as farm laborers.

The land holding size is also an important factor in agricultural planning. According to the land holding size, introduction of farm machinery and labor balance should be duly considered. The following information should be collected and compiled on the land holding size:

- Average or typical land holding size (ha/household),
- Maximum farm size (ha/household), and
- Minimum farm size (ha/household).

In case the land holding size varies considerably by location (village, commune, etc.) the land holding size may be shown as a range (ex. xx~yy ha/household).

4.3 Farming Practices

4.3.1 Cropping Pattern and Production

(1) Present Cropping Pattern

The description of the cropping pattern should include the following information illustrated as a figure:

- names of crops planted,
- planted area of each crop,
- growth season and cultivation events,

It should be noted that the total area should coincide with the cultivated area in the land use. A sample cropping pattern is shown in Fig. 4.1.

The basic information used to describe the present cropping pattern can be obtained from the statistics, DAFF and interview survey. For small irrigation schemes (200 ha or less), only a few villages are included, and the interview survey to the village chiefs would be the best way to know the land use. Then, several farmers should be selected at each sub-village (residential group) to get the information on the cropping pattern.

The paddy rice is generally divided into three types, namely, i) early maturing paddy (high yield variety), ii) medium maturing paddy (local variety) and, iii) late maturing paddy (local variety).

As for the "other crops" in the land use, the planted area and period of; i) secondary crops (non-paddy crops planted in the paddy field in the dry season), ii) upland crops (crops planted in non-paddy field), iii) perennial crops, and iv) tree crops are to be specified

Farmers' crop preferences should be confirmed in the course of the interview survey. In Cambodia, farmers are fond of planting medium and long paddy rice (local variety) because of its "taste", even though the yield is lower than other varieties. Such farmers' choice should also be adopted in the proposed cropping pattern.

(2) Production and Yield

Production and yield of each crop presently planted should be confirmed. If some farmers are not familiar with units of volume (m^3) and weight (kg), it is better to ask them, "How many baskets (or bags) do you harvest from your farm field?"

The production and yield should be specified by season according to the cropping pattern.

4.3.2 Agricultural Input

Agricultural input consists of; i) seed, ii) fertilizer, iii) agro-chemicals such as pesticides. Application of the seed by crop variety (kg/ha), dosage of the fertilizers and agro-chemicals by type (kg/ha) should be confirmed. The cost of those inputs should also be confirmed at the nearest market (private sector) and at government supported suppliers, if any.

4.3.3 Farming Practices

The following items should be confirmed on the farming practices:

- labor ; land preparation, transplanting and harvesting by type of labor (hired or family),

- number of draft animal,
- agricultural machine, equipment for crop management, farming tools,
- procedure of land preparation, transplanting and harvesting,
- application of fertilizer and agro-chemicals (quantity and timing),
- weed control,
- pest control, and
- irrigation, watering

4.3.4 Livestock

Livestock raising is the biggest cash income source for many farm households. The number of the livestock animals often gives an index of income level of the farm household. Most poor households cannot produce sufficient rice for self-consumption, but still have to sell the harvested rice to obtain cash for routine necessities such as clothes, medicine, education, fuel wood, etc.

The following information should be collected on the livestock:

- number of livestock animal by kind (head/household),
- period of raising by kind (months),
- price of purchase by kind (Riel/head),
- price of selling by kind (Riel/head),
- how to get feeds,
- consumption of feed by kind (kg/head/month)
- cost of feed per month (Riel/month)

4.4 Agricultural Extension Services

Agricultural support services play a significant role in agricultural development. The availability of services should be clarified prior to the formulation of the development plan in order to propose the required supporting services.

The extension services consist of; i) guidance on crop and farm management (technical support on the farming), and ii) credit services. The following information should be confirmed at the proposed area:

- organization and functions of Provincial MAFF (DAFF) on the extension services,
- number of extension workers and their specialties in charge of the area (to be confirmed at DAFF),
- activities and frequency or schedule of field visit by the extension workers (to be confirmed at DAFF),

- activities and frequency of visit by the extension workers (to be confirmed in the project area),
- available credit services by both private, public and other sectors (such as NGO) and their conditions (period, interest rate, etc.),
- expected extension by the farmers (to be confirmed in the project area), and
- other project and/or program on the extension by NGO and IOs.

4.5 Post Harvest and Marketing

4.5.1 Post Harvest

Post harvest processing is conducted in two stages, namely, the producer' stages and distribution stage. Harvesting and threshing, drying and storage are done by the producers, and milling is generally done by middlemen, wholesalers and/or retailers. The costs of processing and handling directly affect farm-gate prices of the products, and the present post-harvest processing system should be grasped for increasing the profit to farmers. The following items are to be confirmed on the post-harvesting:

- methods of harvesting and threshing,
- cost of threshing,
- losses in harvesting and threshing,
- method of drying,
- availability of storage,
- loss in storage,
- milling charge, and
- problems on the post-harvest processing

4.5.2 Marketing

The marketing channel for each crop should be confirmed, particularly for newly proposed crops and vegetables. The following items are to be confirmed on the market:

- farm-gate price of each product,
- nearest market by product including livestock, and
- transport cost to the nearest market

4.6 Farm Economy

4.6.1 Crop Budget

A typical crop budget in the target area should be known so that the targets of the agricultural plan can be properly set.

The crop budget consists of; i) gross income (value of product), ii) production cost (seed, fertilizer, other input, labor, draft animal, machine, etc.), and iii) profit.

The production cost can be estimated according to the data on agricultural inputs (Sub-section 4.3.2) and farming practices (Sub-section 4.3.3).

The gross income can be estimated from the average production and the farm gate prices (Sub-section 4.3.2).

The crop budget should be summarized in a balance sheet whose sample is given in Table 4.2. Conditions and assumptions of the estimation should be clearly mentioned in the balance sheet.

4.6.2 Household Economy

The living standard of households can be analyzed by income and expenditure. The cash income and expenditure on the basic commodities of life is low for poor households. On the other hand, as the living standard is improved, the living expenses would increase. Thus, the household economy is used as an index to evaluate the outcome of the project.

For such evaluation, the survey of changes to the household economy after the project should be carried out. Rapid Rural Appraisal (RRA. Refer to Chapter 19 "Participatory Planning Approach".) is a suitable method for the survey. For the income and expenditure, products for self-consumption should be converted into cash value both for income and expenditure. The income and expenditure would consist of the following factors:

Table Factors of Income and Expenditure

Factors		Item
Gross Income	Agricultural income	Paddy rice (cash / in kind) Livestock (-do-) Vegetable (-do-) Fruit (-do-)
	Off farm income	On-farm labor (including exchange labor, temporary) Off-farm labor (-do-, temporary) Sales of non-product forest resources (firewood, timber, etc) Private business Salary (permanent, contract, etc.) Others
	Debt and loan	Cash In kind (rice, pig, etc.)

<table>
<tr><th colspan="2">Factors</th><th>Item</th></tr>
<tr><td rowspan="3">Gross Outgoing</td><td>Production cost</td><td>Seed,
Fertilizer,
Agro-chemicals,
Labor (family, hired),
Draft animal (family, hired),
Machine,
Water charge (ISF),
Fuel,
Others</td></tr>
<tr><td>Living expenses</td><td>Health care,
Clothes,
Education,
Transportation,
Food (essential food)
Other food (nonessential; tea, tobacco, etc)
Fuel,
Tax,
Others</td></tr>
<tr><td>Investment</td><td>Cash
In kind (rice, pig, etc.)</td></tr>
<tr><td colspan="2">Saving</td><td>Cash
In kind (rice, pig, etc.)</td></tr>
</table>

CHAPTER 5 HYDROLOGY

5.1 Data and Information Required

As shown below, hydrological data and analysis are an essential and fundamental part of irrigation planning.

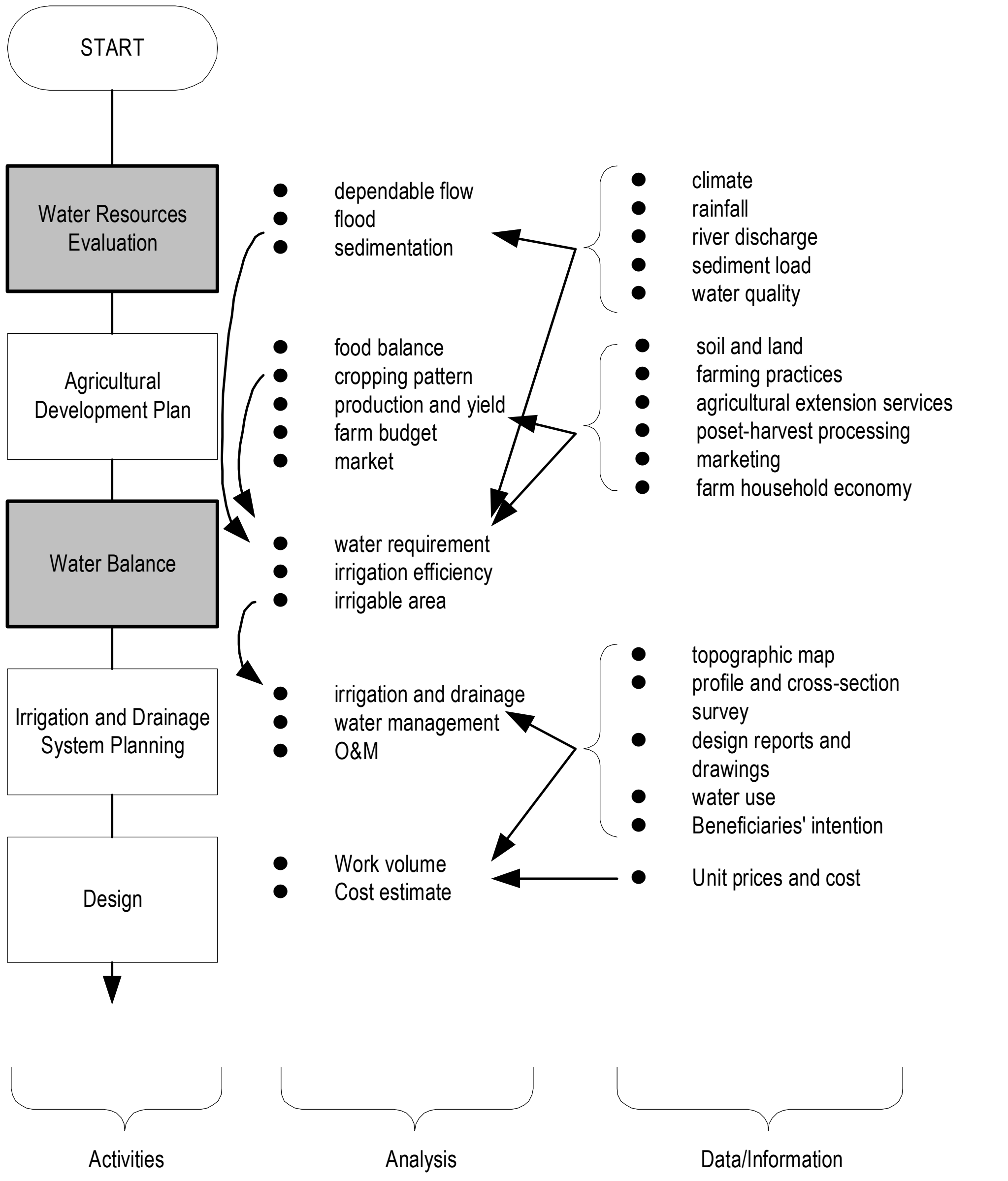


Figure Data/Information Required for Irrigation Development

Meteorological data including rainfall are required for estimating water requirements, while hydrological data (river discharge, sediment load, water quality) are used for estimating water availability and dead capacity of reservoirs.

The river discharge and rainfall being natural phenomena, the hydrological analysis is conducted with probability analysis. For the probability analysis, certain period of continuous data observed on the daily basis are required. Necessary data and observation period by analysis are explained in the following.

5.2 Collection and Compilation of Existing Data

5.2.1 Rainfall

(1) Preparation of Rainfall Data Inventory

Prior to collection of the rainfall data, it is necessary to arrange an inventory of rainfall data. The inventory should include the following information.

- number or code of rainfall station,
- location of the station (location map of the stations to be collected, if available),
- type of observation (manual or automatic, daily, monthly, etc.)
- observation period
- owner of the station (MOWRAM, MAFF, etc.)

The above information is available in the Hydrological Year Book published by the Mekong River Commission.

(2) Selection of stations

Several rainfall stations in the proposed project area (including catchment area) or its surrounding area should be used. The stations with longer observation periods and less missing data are more preferable. In case that there exist few rainfall stations in/around the project area, the rainfall stations with surrounding natural conditions (geography, annual rainfall, climate, etc.) most similar to those of the project area, should be primarily selected.

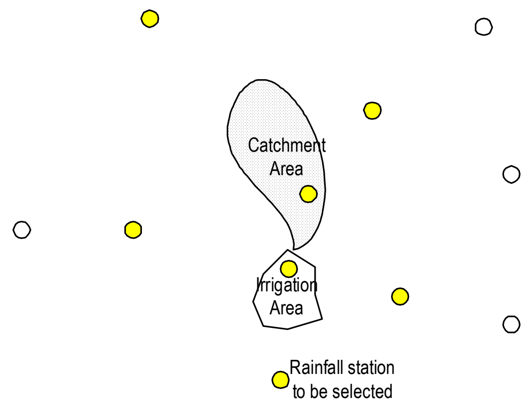


Figure Rainfall station to be colleted

(3) Checking the Rainfall Data

It is important to check the reliability of the collected data prior to the analysis.

Firstly, abnormal values should be checked. For most stations, daily rainfall values over 100 mm are rarely observed. If such “big” daily rainfall records are found, the season (dry or rainy) and rainfall before and after the day should also be checked. Similarly, the maximum monthly rainfall is normally less than 500 mm, and annual rainfall generally ranges from 500 to 3000 mm in Cambodia. Such "normal" values should always be considered in dealing with the rainfall data.

Secondly, the difference between "0 mm", "no rainfall" and "not available" should carefully be checked. The difference is;

"0 mm":	It rained but not measurable,
"no rainfall" or "-":	No rainfall was observed,
"not available" or "NA":	Rainfall was not measured

In case the above difference can not be specified, the data should be regarded as "not available", namely, "missing data".

(4) Data Compilation

(a) Daily rainfall

On the basis of the daily rainfall data, the following values should be calculated and compiled in the monthly record.

- total of half month,
- total of month,
- maximum and minimum daily rainfall in the month, and
- rain days in the month.

A sample of monthly rainfall record is given in Table 5.1.

(b) Monthly Rainfall and 80 % Dependable Monthly Rainfall

In irrigation planning, a probability of 80 % is generally adopted. Therefore, the monthly rainfall records should be compiled for the 80 % dependable monthly rainfall (R80). R80 is calculated in a simplified procedure as follows:

R80 = {(n / 5) + 1}th smallest monthly rainfall.

Where, n: years of records.

A sample monthly rainfall records is given in Table 5.2 with R80.

5.2.2 River Discharge and River Gauge Data

In Cambodia, there are few discharge and river gauging stations apart from in the Mekong River. It is considered quite necessary to establish a network of river gauging stations so that the surface water resources of the country can be optimized.

River gauge reading is generally kept at least once a day manually (by human eyes) or continuously with automatic water level recorders. The procedure for checking the data is similar to that of rainfall data.

In general, the river gauge data are converted to discharge by using a "rating curve" (refer to sub-section 5.3.3 (4)). When the discharge data are used for hydrological analysis, the following points should be carefully considered.

(1) Difference from Actual Runoff

For the manual river gauge stations, at which the river gauge is read once a day, flood runoff is not always presented as shown below. The estimated runoff volume derived from such river gauge or discharge data is often lower than actual one for small catchments because the flood period is short.

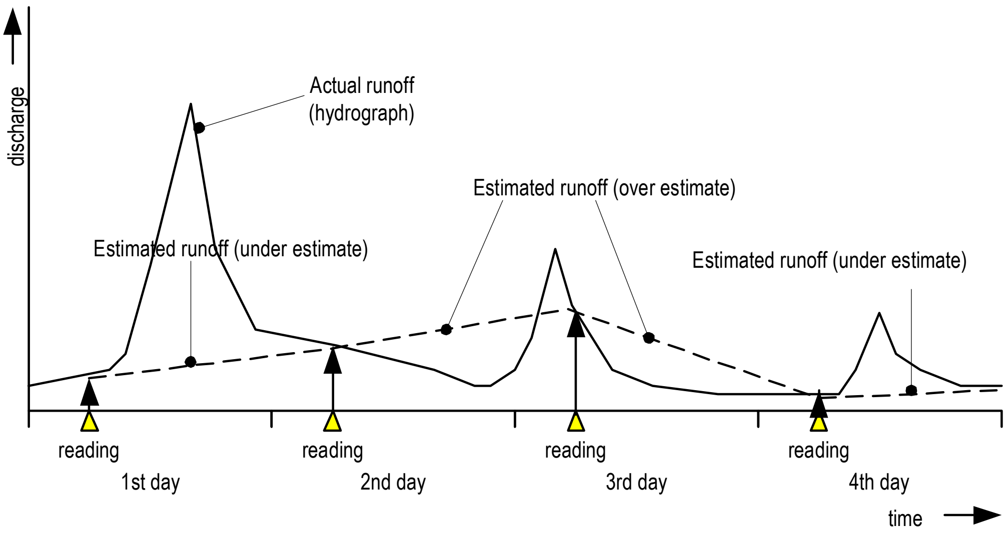


Figure Difference between Actual and Estimated Runoff

(2) Extrapolated Discharge

As mentioned above, the discharge is converted from the water level by using a rating curve. However, during flooding time, it is difficult to measure the discharge with a current meter. Thus, flood discharges are often derived by extrapolating part of the rating curve. In this case, the reliability of the discharge is not high enough.

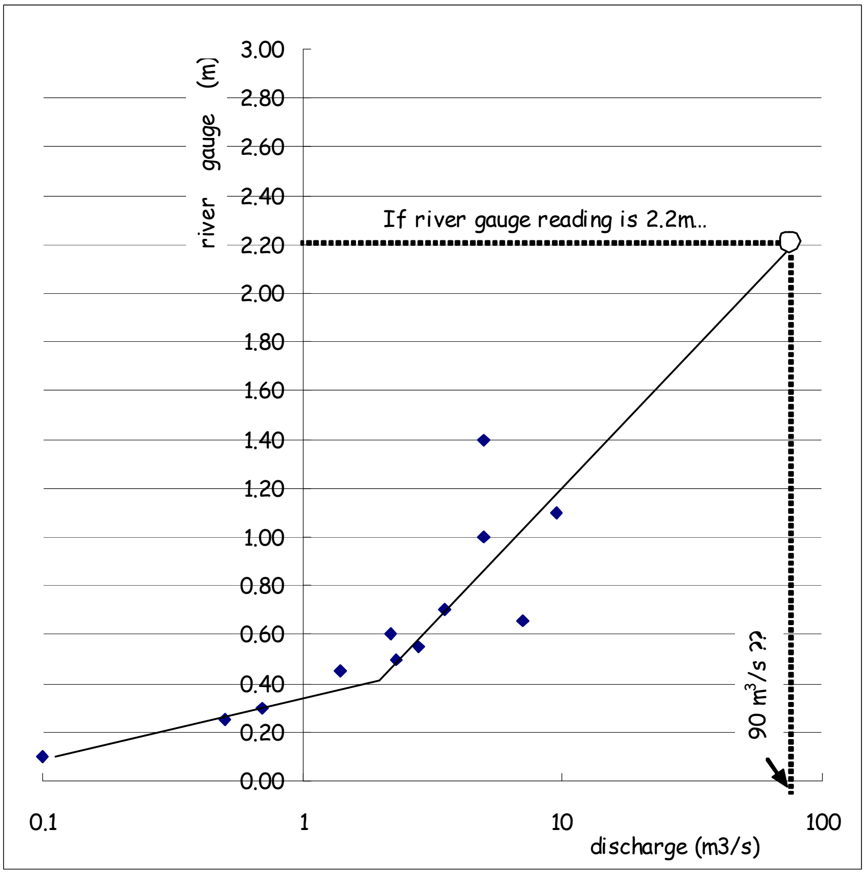


Figure Reliability of Extrapolated Discharge

5.2.3 Meteorological Data

Meteorological data are required for calculating potential evapotranspiration (ETo), which is the basic parameter used to estimate the irrigation water requirement.

One of the most popular procedures for calculating the irrigation water requirement is the Modified Penman Method, which is introduced in the Irrigation and Drainage Paper No.24 “Crop Water Requirement” published by FAO.

For the Modified Penman Method, the following monthly average meteorological data are required:

- air temperature,
- relative humidity (or wet bulb and dry bulb temperature),
- wind speed, and
- sunshine hours.

In Cambodia, the above data have been observed at Phnom Penh (Pochengtong Airport) for a comparatively long term of 10 years or more. Since the dependability of the irrigation plan is generally set at 80 % or four years out of five, the meteorological data are required for five years or more.

The most influential factor irrigation water requirements is rainfall, so rainfall data should be selected carefully in terms of location and rainfall pattern. However, for other meteorological factors, differences between the data of several stations is not as much as rainfall. Thus, the meteorological data of Phnom Penh can be adopted to represent most of the paddy rice area in Cambodia, except some mountainous areas where the average air temperature is much lower.

The compilation of the meteorological data is done similarly to that of the rainfall data.

5.2.4 Sedimentation

There are no periodical or continuous records of sediment load in rivers or reservoirs in Cambodia. Some measurements have been made on a project basis and the results compiled in reports. It is recommended to collect such study or project reports in/around the target area, if any, and confirm the sedimentation rate adopted.

For example, a sedimentation rate of 0.1 mm/km^2/year was adopted for design of Tnot Teh Irrigation Project in Takeo Province. Making reference to this value and difference in catchment characteristics and field observation, the sedimentation rate was estimated at 0.1 mm/km^2/year for the Upper Slakou River Irrigation Reconstruction Plan (USP).

It is also important to observe the actual sedimentation in reservoirs or dams which were constructed in the past.

5.3 Field Measurement and Observation

5.3.1 Rainfall

(1) Type of Rain gauge

A manual-type rain gauge consists of an outer cylinder and an inner cylinder (mess cylinder) whose section areas differ by ten times. For example, one millimeter of actual rainfall is measured at 10 millimeter in the mess cylinder. Thus the rainfall can be measured at 0.1 mm accuracy.

An automatic rain gauge consists of; i) a rain gauge with pulse-emitter which generates one pulse per one or half millimeter of rainfall and send it to the recorder, and ii) recorder (role paper recorder or data logger). In general, the recorder is installed in a stand box apart from the rain gauge. The recorder is driven by battery. For the role paper recorder, the paper should be replaced once a month at the beginning of the month.

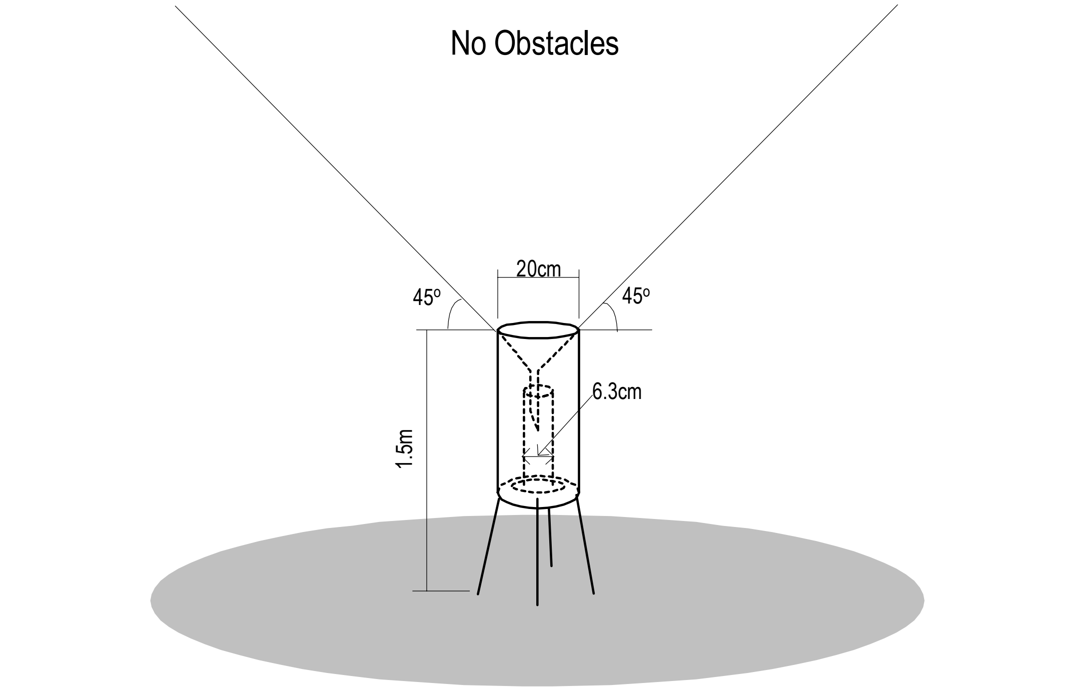


Figure Installation of Rain gauge

The advantage or main purpose of the rain gauge is to observe the rainfall continuouslyso that hourly rainfall data, or rainfall intensity, can be measured. Even for the automatic rain gauge, it is preferable to install a manual rain gauge in the same location for compensation of missing data.

(2) Installation

The rain gauge should be installed in an open space about 1.5 m from the ground, and no obstacles located above an imaginary 45-degree line drawn from the rine of the raingauge. The rain gauge should be surrounded by a fence with a locked gate to avoid any intentional disturbance. Preferably, a gauge keeper should be hired in the neighborhood.

date	rainfall
1	25.1
2	-
3	-
4	NA
5	NA
6	**31.5**
7	0.0
8	2.5

Figure Missing Data

(3) Observation

For the manual rain gauge, it is important to measure the depth of the rainwater in the inner cylinder every day at the same time. In many cases, the rainfall is measured in the early morning. If the gauge keeper forgets measuring for two days, he should measure the rainfall and write the value on the data book "NA" (not available), "NA" (not available), and rainfall for three days as shown in the figure above.

For the automatic rain gauge, the records should be collected at the beginning of each month. In collecting the records it is important to check the clock of the recorder, ink of the recording pen, remaining memory of the data logger, etc.

5.3.2 River Gauge

(1) Type of Gauge

Plate-type gauges which are read by the human eye should be made with clear divisions of scale and letters.

Popular water level sensors used with an automatic recorder or data logger are of "float type". A standing well is constructed on the river bank vertically, and the automatic recorder is installed on the well. The float is dropped into the well and moves according to the water level in the well. A recorder with role paper or data logger records the water level transferred either mechanically (analog) or with converted digital signals. The float type river gauges are available at comparatively low prices. However, it should be noted that the cost of civil works for constructing the wells, recorder housing, and an access bridge to the housing will be very high.

The automatic gauge station should also have a plate-type gauge for reading.

(2) Installation

The river gauge should be installed at locations where:

- The water course is stable and does not move by flood,
- The safety of the gauge keeper (reader) is secured even during the flood period,
- The river cross-section is clear, and the water does not stagnate, and
- The gauge can be easily read from the front.

It is more preferable to install the gauge on a permanent structure such as a retaining wall or abutment of bridge. It is not recommended to install the gauge on a bridge pier because the water level changes near piers and obstacles caught around the pier often disturb the reading.

A gauge keeper should be hired in the neighborhood for maintaining the gauge and keeping the records. It is preferable to install the rain gauge in the catchment to know the relation between rainfall and runoff.

(3) Gauge Reading

The river gauge should be read and recorded every day at the same time. It will be very useful to record short-term changes of water level during flood periods so that flood characteristics can be grasped. If an automatic chart-type recorder is installed, the reading of the plate-type gauge should be written on the chart for calibration.

In the "Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin, The Kingdom of Cambodia" in which this guideline was prepared, two water level gauges of "pressure bulb type" were installed in the Slakou River. The water level gauges consist of a pressure bulb sensor and data logger.

5.3.3 Discharge Measurement

(1) Measuring Point

Discharge measurement is conducted to generate the rating curve. For this, it is necessary to measure the discharge near the gauge. It is important to select the measuring point as follows:

- Water flow is stable and does not stagnate,
- the water flow is not divided at the section,
- no inflow or outflow exists between the point and the gauge, and
- the point is easily accessible.

(2) Measurement with a Current Meter

(a) Current Meter and Measuring Method

Current meters are divided into two types. One is for measuring large discharges of the river including floods, and the other is for measuring small discharge in the canal or low flow of the river. For the irrigation planning, the low flow is the main concern in order to estimate the dependable flow of the river.

For the flood discharge measurement, other facilities and tools such as a boat, life jacket, float, and ropes are required. For large rivers such as the Mekong River, it is more appropriate to construct towers on both river banks with connecting wires between the towers to drag and drop the current meter across the river.

(b) Measuring Point

Prior to measurement, a cross-section level survey of the measuring point should be carried out. Then the cross-section should be divided into segments equally. The minimum width of the segment can be set at half (0.5) meter. For example, a water flow of three (3) meters width should be divided into six (6) segments of half meter.

For each segment, one or two measurements would be made according to the water depth (D) at the segment as follows:

- If D>0.5 m, measure at two depth, 0.2D and 0.8D (average velocity would be the velocity of segment)
- If D<= 0.5 m, measure at one depth, 0.6D from the surface.

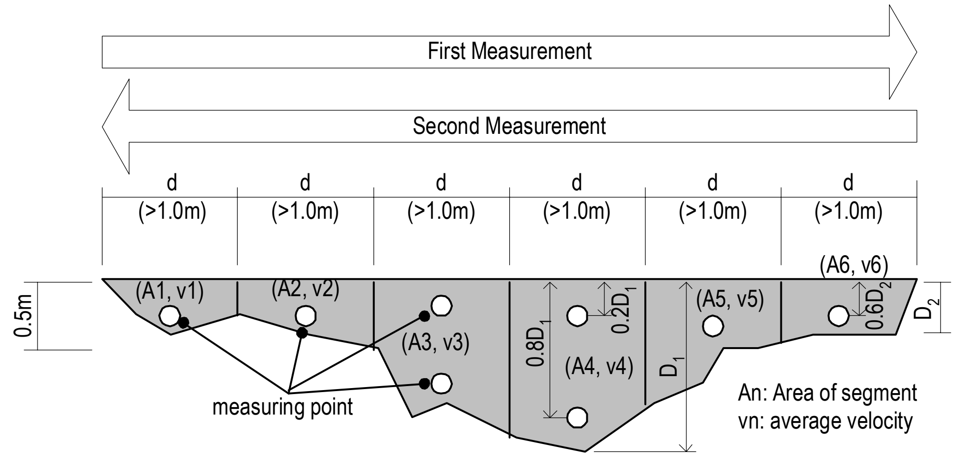


Figure Measuring Point

(c) Measurement and calculation

The measurement should be conducted by each the segment. The average velocity of the segment should be multiplied by the area of segment, then the discharge of the segment is calculated. The total discharge would be the discharge of the flow.

<u>The measurement should be done at least twice</u>, and the average total discharge would be adopted. The discharge should be calculated immediately after the measurement so that any error in the measuring could be found and re-measured.

The recording and calculation of the discharge measurement are done with a calculation sheet, **FORM-6** in Attachment-1 with detailed explanation of usage of the current meter and calculation of the discharge.

(3) Other Measuring Method

It is very difficult and dangerous to measure the flood discharge with the current meter. Particularly for small catchments, the flood occurs in a short period with rapid and high peak discharge, which makes the measurement more difficult.

In this case, pipe floats can be used for rough estimation of the flood discharge.

A pipe float, with some weight inside to keep the float at a certain depth in the current, would be thrown into the current and the time to pass a certain distance would be measured by a stopwatch. The length of the float should be changed according to the depth of the current.

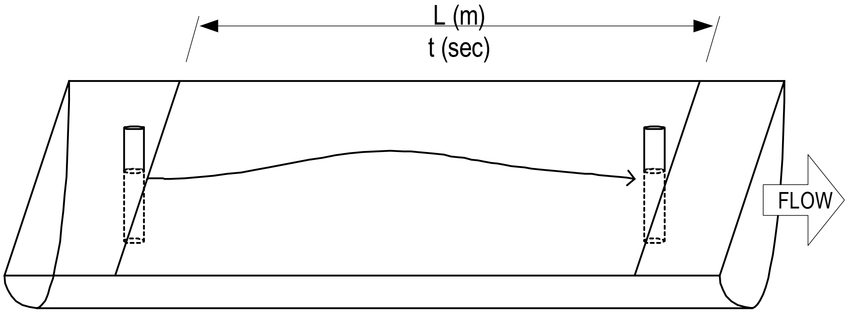


Figure Measurement by Float

(4) Generation of Rating Curve

A rating curve is prepared to obtain the discharge from the water level. The results of discharge measurement would be plotted on a graph whose X-axis is for the discharge and Y-axis is for the water level. Logarithmic axes may be adopted according to the data. The following things are to be noted on the rating curve:

- Extrapolation should basically not be done particularly on the high water side to avoid over or underestimation.
- The rating curve should be checked or revised a few times a year, because the river cross-section often changes by the floods.

A sample of the rating curve is given in Fig. 5.1.

5.3.4 Water Quality

(1) Water Quality to be Checked

Water quality of the irrigation water is generally checked for pH and salinity. The latter is measured as electric conductivity (EC). These two factors are considered to affect crop growth and production.

However, in most developing countries, the water for irrigation is not always used only for irrigation but also for domestic and drinking purposes. Thus, the water quality should not be polluted by agricultural inputs such as fertilizers and agro-chemicals. In this sense, the following water quality parameters should be checked:

- pH
- Electric conductivity (EC)
- Color
- Total dissolved solid (TDS)
- Bacteria
- Coliform Group
- Nitrate Nitrogen (NO_3-N)
- Nitrite Nitrogen (NO_2-N)
- Ammonia Nitrogen (NH_4-N)
- Total Nitrogen (T-N)
- Total Phosphorus (T-P)
- Managanese (Mn)
- Zinc (Zn)
- Copper (Cu)
- Sodium (Na)
- Calcium (Ca)
- Chlorine (Cl)
- Iron (Fe)
- Potassium (K)
- Arsenic (As)
- Fluorine (F)

The water quality should be checked both in the rainy season and the dry season. The water quality test is generally carried out in laboratories, but some field measurement such as temperature of the ambient air and water, discharge of the flow, etc., should be done at the sampling location.

(2) Sampling

Samples for the water quality test are taken and put in plastic sample bottle at the sampling locations, then sent to the laboratory. The capacity and number of the container depend on the test to be conducted. For samples for bacteria and coliform group, some chemicals and special containers are used to keep the samples, then the samples have to be sent quickly to the laboratory in cold storage.

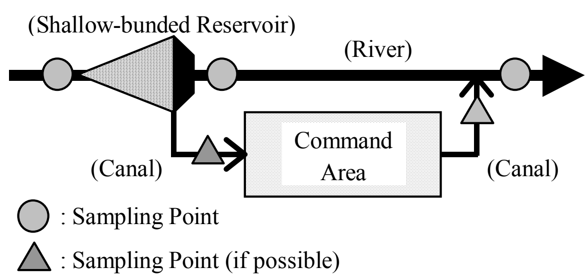


Figure Sampling Points for Water Quality Test

The date, time, temperature, location, discharge, and photographs should be taken and recorded.

5.3.5 Sediment Load

(1) Type of Sediment Load

Sediment load is divided into two categories. One is suspended load, and the other is bed load. The suspended load is the particles which are conveyed floating in the water, while the bed load is conveyed rolling on the river bed.

(2) Sampling

The suspended load is taken by a cylinder type sampler at several depths of the current. The sample volume depends on the sediment load. For clear water, at least 10 to 20 liter samples should be taken. In order to analyze the sediment load, river discharge should also be measured, because the sediment load has certain correlation with the water discharge. Longitudinal profile survey of the river at the sampling location should also be conducted to obtain the river bed gradient which is used for estimating the total sediment volume.

The bed load is collected by a special sampler which is put on the river bed to collect the bed load for a certain period of time. Since the bed load sampler is very heavy (60 kg to 80 kg), a truck crane is required for sampling. Thus, the sampling should properly be done at the road bridge across the target river.

The sediment samples from the river bed are also analyzed. The sampling is done at the river bed where the river is flowing at a normal discharge. The sediment samples at a typical river bed (particle size of the sediments, stones, rocks) should be taken. For rocks or stones which can not be conveyed to the laboratory, the particle size (diameter) should be measured and recorded at the site. In general 20 to 30 kg of samples should be taken and brought to the laboratory.

(3) Analysis

The particle size analysis is conducted in the laboratory for the samples of the suspended load, bed load and river bed materials. The particle size analysis is done by sieve test and hydrometer test. The specific gravity and sedimentation rate should be measured.

CHAPTER 6 GEOLOGY AND SOIL MECHANICS

6.1 Data and Information Required

6.1.1 Maps

In order to grasp the general geological condition of the project area, the geological maps should be assembled. In Cambodia, "Engineering Soil Map of Cambodia" (scale: about 1: 2,000,000) and "Hydro-geological Map of Cambodia" are published by the Integrated Resource Information Center (IRIC). These maps provide general features of geology and soils in the project area.

6.1.2 Reports

There exists a number of tubewells in Cambodia. They were constructed by the government project (mostly MRD), NGO and privately. In general, boring logs (geological profile) are made for determining the location and length of strainers. Such data can be obtained at the Provincial Department of Rural Development (DRD). National or regional study on the groundwater development is also conducted by MRD. The study reports of such study would also provide geological information of the project area.

Ministry of Public Works and Transport (MPWT) and MRD are conducting a number of road projects. The road projects use laterite, gravels and other construction materials. The location of quarries can be obtained from regional offices of MRD or MPWT.

6.1.3 Reconnaissance Survey

On the basis of the above mentioned data and information, a reconnaissance survey should be conducted so that the geological condition of major structures, canal lines, quarry sites, etc. can be confirmed. Necessity and volume of geological investigations and tests should be identified in the reconnaissance survey.

6.1.4 Soil Mechanical Investigation

Geological and soil mechanical investigation for the design of structures are mainly done by boring and test (in situ, laboratory). The purposes of the investigation are to grasp; i) the geological profile and ii) characteristics on the soil mechanics. The investigation consists of; i) boring, ii) sounding test, iii) sampling, iv) in situ permeability test, and v) soil mechanical test.

Procedures of the soil mechanical investigation for the dikes are summarized in Table 6.1.

6.2 Geological Boring and Sampling

6.2.1 Objectives and Procedures

(1) Objectives

The objectives of the boring are; i) to investigate the condition of strata, particularly their hardness and softness, ii) to take samples for the laboratory test, and iii) to conduct in situ tests such as standard penetration test, bore hole test, etc. and iv) to install equipment such as pressure bulb sensors.

Location of the boring should be selected at; i) center line (axis) of dikes, ii) proposed site of major facilities such as gate, concrete weir, etc.

(2) Procedures of Boring

A rotary boring machine is generally used for the boring, but auger boring is also adopted for shallow strata less than 5 m or for strata above the groundwater table. Manual boring by manpower is also possible for shallow strata less than 5 m.

The boring should be conducted paying due attention to the following points:

Important Point of the Boring

- The boring should not use water for the strata above the groundwater table,
- Rotary boring should be adopted with mud water circulation for the strata below the groundwater table,
- In situ percolation test and observation of the groundwater table should be done at the bore hole dug with the rotary machine with clear water or cleaned bore hole,
- A casing should be pushed into the bore hole by rotating the casing itself down to the point of 10 to 20 cm above the proposed sampling point,
- For in situ test using the undisturbed materials, attention should be paid not to smear the bottom and wall of the bore hole with slime.

A geologic profile should be prepared after the sampling. Conditions of the strata, hardness, color, location of the in situ test and results, location of the sampling, and groundwater table should be recorded accurately. Photographs of the boring should also be taken.

6.2.2 Sampling

Sampling should be conducted separately for disturbed material and undisturbed material. The disturbed samples are used for preparation of a soil profile map, confirmation of soils, and the tests for disturbed materials. The undisturbed materials are used for the test which examines the characteristic of the soil in the laboratory under the natural condition.

For construction of new dikes and reconstruction of existing dikes, it is necessary to take undisturbed sample of soft clay for examining the stability and susceptibility to subsidence of the proposed dikes. For examination of leakage through sandy soils, undisturbed soils are not always required, but particle size analysis would provide the necessary parameters to estimate the permeability of the material.

Sampling should be carried out paying due attention as described below:

<u>Important Point of the Sampling</u>

- Inserting of the sampler should be done in a short time but smoothly in constant speed,
- The sampler should be pulled up slowly without rotating the sampler,
- Locations of the sampling depend on the objectives of the test, but in general;

  for disturbed soil; one sample per strata or every two (2) meters for continuous strata

  for undisturbed soil; one sample per strata or every five (5) meters for continuous strata

6.2.3 Data Compilation

The disturbed soil samples should be kept in sample bags, then necessary site information such as date, weather, location, depth, color of the sampling should be recorded in the field book.

The undisturbed samples kept in sampling tubes should be cut on the both edges which are disturbed, then the edges should be fixed with paraffin and sent to the laboratory. The samples should be kept from direct sunshine, shocks and other conditions which might change the physical condition of the samples.

6.2.4 Soil Mechanical Test

(1) Test for Soft Ground

The following soil mechanical tests would be conducted in accordance with the soil characteristics and foundation conditions of the site:

Soil Mechanical Test	
Clayey Soil;	particle size analysis / natural water content test / specific gravity test / soil density / consistency test / unconfined compaction test / consolidation test / triaxial compaction test / others
Peat soil;	natural water content test / specific gravity test / consolidation test / ignition loss test / others
Sandy soil;	particle size analysis / specific gravity test / natural water content test / others

(2) Test for Permeable Soil

For permeable soils, the following in situ test and the laboratory test should be conducted.

(a) In Situ Test

A sounding test is conducted to confirm the thickness of the permeable surface layer.

In situ permeability test is conducted for each layer which form the permeable ground. Injection method is adopted for the permeability test with pumping test if required.

Observation of fluctuations in the groundwater table should be conducted at the bore holes if necessary, existing wells, and other observation wells so that contours of groundwater table be obtained.

(b) Laboratory Test

The following tests should be done in the laboratory for the collected samples:

- specific gravity test,
- particle size analysis,
- natural water content test, and
- permeability test.

(3) Test for Embankment Material

Dikes are often damaged by sliding and erosion due to a lack of proper protection and/or poor structure. Preliminary investigation and necessary soil mechanical test should be undertaken for proposed quarry sites in order to determine the dike structure.

Sampling at the quarry site is done by auger boring, mechanical boring and manual boring. For soil materials, static cone penetration test should be conducted as required. The laboratory test should include;

- specific gravity test,
- particle size analysis,
- natural water content test,
- consistency test,
- compaction test,
- permeability test,
- searing test, and
- static cone penetration test.

The results of the above investigations and tests should be compiled in a topographic map which can be used for estimating the volume of the materials.

CHAPTER 7 IRRIGATION AND DRAINAGE

7.1 Data and Information Required

As mentioned in Section 2.5 "Data and Information Required", planning the reconstruction and rehabilitation of an irrigation system requires information from various sectors and such information should be utilized in an integrated manner as shown below:

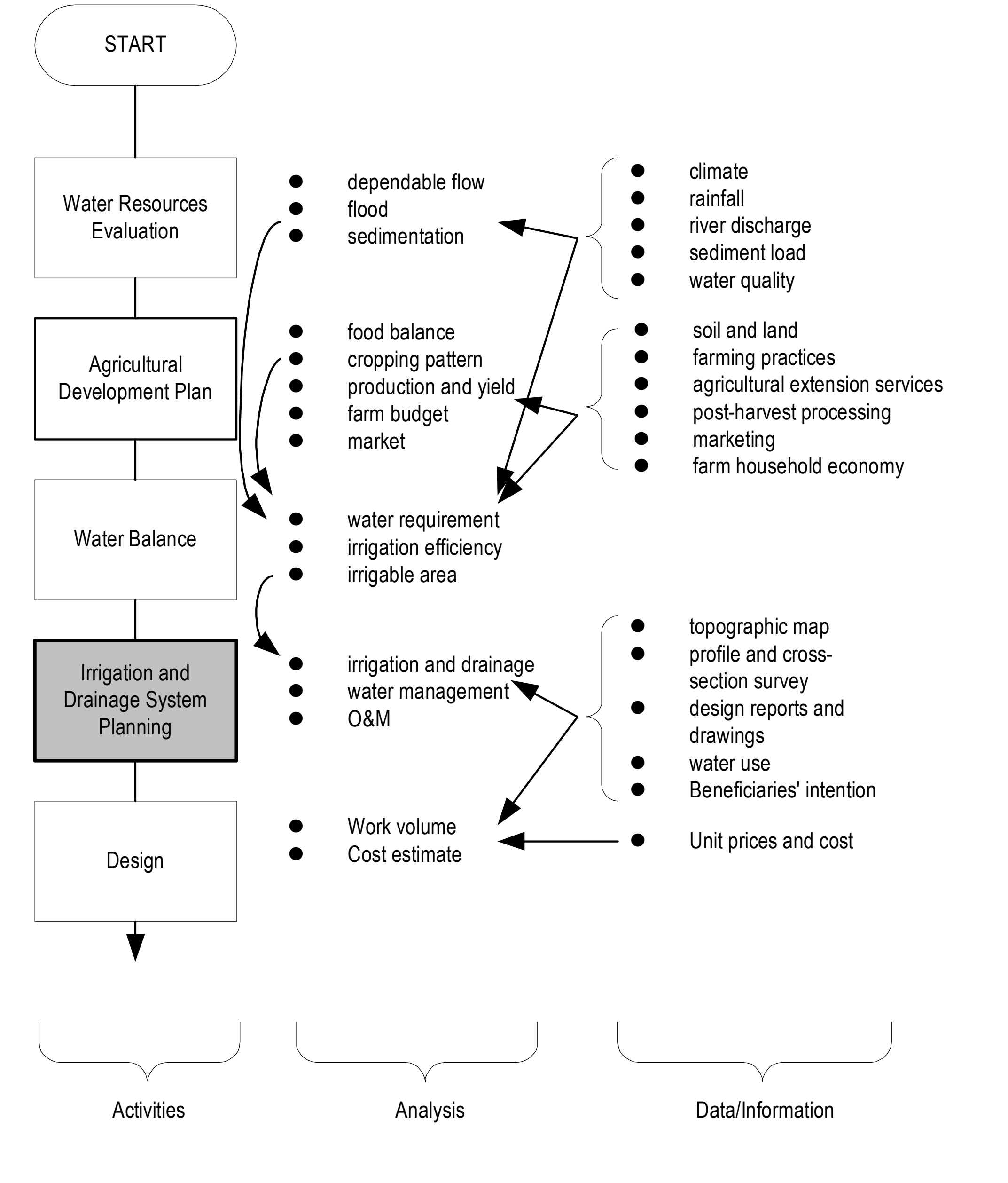


Figure Data/Information Required for Irrigation Development

The data/information on topographic survey and existing irrigation and drainage system are mentioned in this chapter, while those on agriculture, water resources, geology and soil mechanics and related institutions are mentioned in other chapters.

7.2 Survey and Mapping

7.2.1 Maps for Planning and Design

In Cambodia, topographic maps with a scale of 1: 100,000 are published by the Ministry of Public Works and Transport. These maps would be useful for the planning of irrigation developments of medium or large scale.

7.2.2 Cartography for Larger Maps

For the planning and preliminary design of the irrigation system, topographic maps of 1:10,000 or larger scale with contours every one meter or less are necessary. The topographic map up to 1: 5,000 scale can be prepared from aerial photographs of 1: 25,000 that were taken in 1992 for making the 1: 100,000 topographic maps mentioned in 7.2.1 above.

Supplemental field survey on land cover and elevation of control points should be done prior to the cartography.

7.2.3 Survey Works

(1) Rivers

In order to analyze the present river capacity and change in river flow after constructing structures on the river, a river profile and cross-section survey should be conducted. The survey results would be used for non-uniform flow analysis to determine the river water level after the construction of the structures.

Pitch of the cross-section of the river course to be taken should be set between 250 m and 500 m according to the river condition. For the river with little change in the river conditions such as route, width and longitudinal gradient, the pitch can be set at 500 m or more, while the rivers whose conditions change in a short stretch, the survey pitch should be set at 250 m. Additional cross-section should be taken at the change point along the river.

The longitudinal measurement should be taken at least every 200 m with additional measurements at place where the river condition changes.

The width of the cross-section should depend on the river condition. At least 50 m beyond the for of the banks should be measured on both river banks.

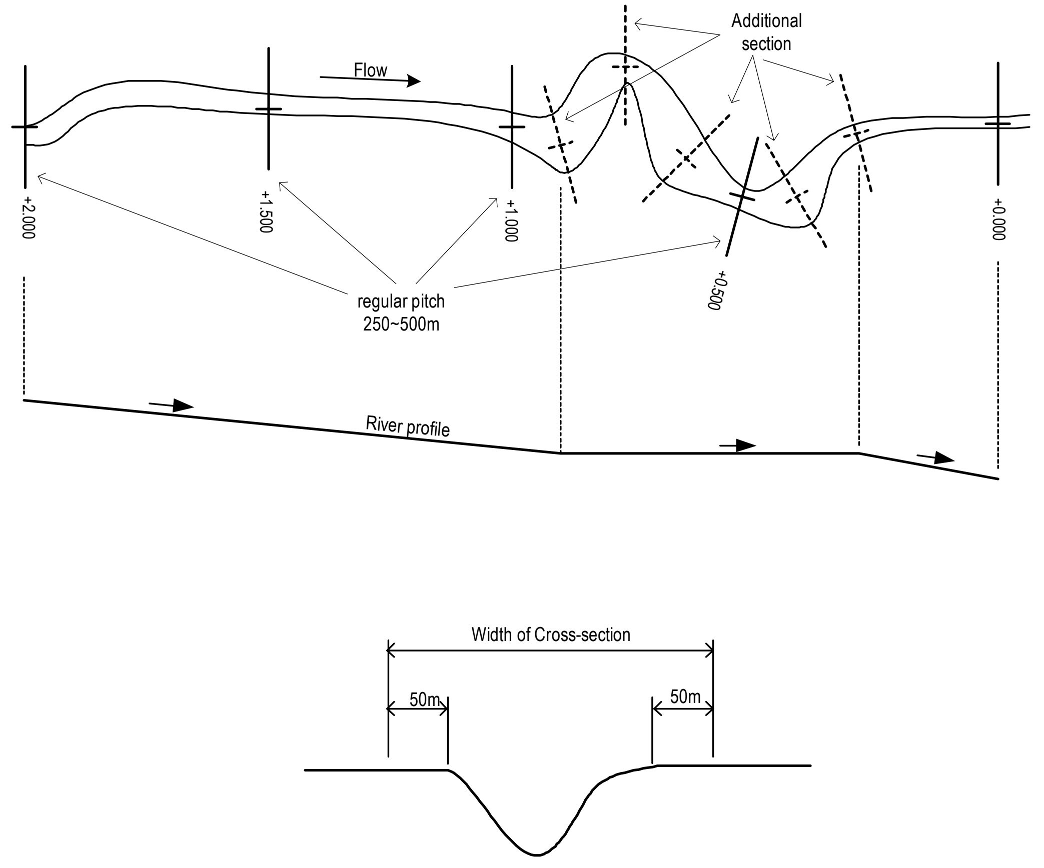


Figure Survey of River

(2) Canal

The profile and cross-section survey of the existing and proposed canals should be conducted in the following specifications:

- Longitudinal profile : 100 m pitch
- Cross-section : 100 m pitch,
- Width of the cross-section : canal width + 20 m on both banks

(3) Reservoir

In order to estimate the storage volume of a reservoir, a leveling survey in the reservoir area should be conducted. Contour lines should be drawn by 0.1 m pitch. A longitudinal survey line is set on the top of dikes and the crossing lines are set every 200 m on the longitudinal line. Elevation should be measured every 100 m on the cross-section lines. The measuring points are shown in the following figure.

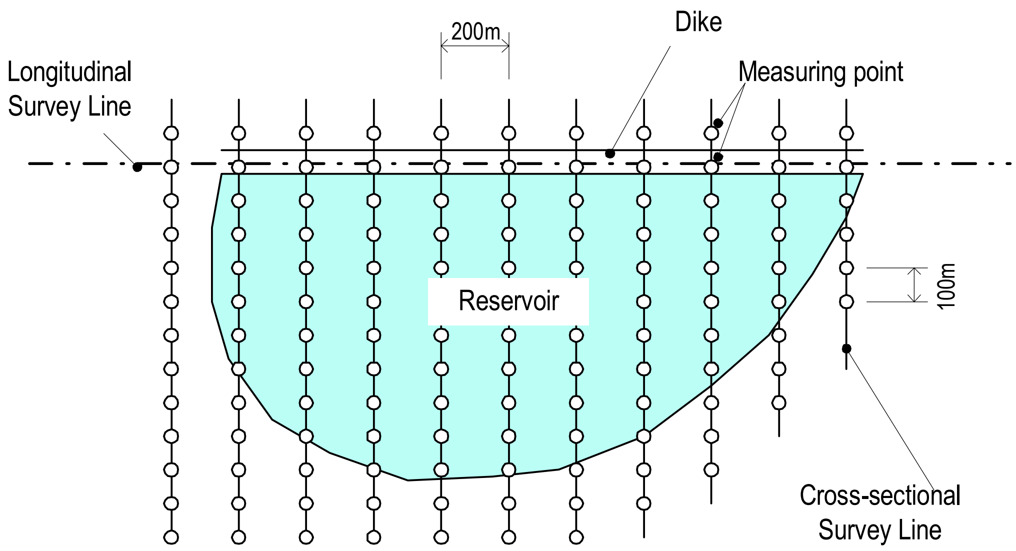


Figure Survey of Reservoir

7.3 Existing Irrigation and Drainage System

7.3.1 Design Reports and Drawings

For existing irrigation systems, it is important to obtain the planning and/or design reports and drawings of the system.The planning and design works can be undertaken on the basis of such information, and lots of time and resources would be saved.

However, in most cases, few design and planning reports and drawings have been kept, and the planning and design should be started similarly to those of a new development project. In such cases, "Inventory Survey on Irrigation Facilities" should be conducted as mentioned in Sub-section 7.6. Getting the results of the inventory survey, i) general layout plan of the existing irrigation system and ii) general plan of structures would be prepared as mentioned in the following.

7.3.2 Schematic Plan of Existing Irrigation and Drainage System

In order to grasp the existing irrigation system at a glance, a schematic plan of the existing irrigation system should be prepared. The plan should include the following information:

- Water source (name, intake point and catchment area)
- Reservoir (name, storage volume, dimension, number of structures, etc.)
- Diversion canal (name, length, etc.)
- Irrigation canal (length of main and secondary canal, command area,

etc.)

A sample of the general layout plan is given in Fig. 7.1.

7.4 Present Water Use

7.4.1 Irrigated Area

For the existing irrigation systems which were constructed more than decades ago, the tertiary irrigation system does not function or exist. In this case, the actual irrigated area is limited to the main and secondary canals. It is necessary to clarify the present water distribution from the canals to farm fields. For this, intensive field survey is required. The survey would be carried out by interview to the village office, the chief of sub-village, or farmers themselves. The exact area (acreage) of irrigated land is not very important, but the extent to which water is conveyed in the command area should be delineated on the General Plan of Existing Irrigation and Drainage System.

7.4.2 Present Water Distribution

On the basis of the General Plan of the Irrigation and Drainage System, the present water flow from the canals should be clarified in order to prepare the tertiary development plan and the water management plan. The present water distribution system has been established reflecting the dynamism of the local society and should be respected in the proposed plan.

The water distribution should be confirmed at random in the field particularly for areas located far from the main or secondary canals.

7.5 Operation and Maintenance

7.5.1 Organization for Operation and Maintenance

In Cambodia, the basic policy of operation and maintenance (O&M) of the irrigation system is that all irrigation systems should be handed over to the water users or FWUCs and they should conduct the O&M works. However, in reality, the medium to large scale irrigation systems require technical guidance and support by the government, namely, MOWRAM or DWRAM.

Prior to the planning and design of the rehabilitation and reconstruction of an irrigation system, it is necessary to grasp the present O&M body and activities so that sustainability of the projects and its benefits can be ensured.

7.5.2 Confirmation of O&M Activities in the Project Area

In most cases, FWUCs do not exist or do not function well for the malfunctioning irrigation systems. However, it is also important to confirm the intentions of the beneficiaries as to whether they would operate and maintain the improved system by themselves. In this sense, the following items should be confirmed in the target area:

- Existence of FWUC or organization for O&M,
- O&M activities being carried out,
- Awareness of government policy on O&M,
- Opinion on the government policy on O&M,
- Prerequisites for the beneficiaries prior to implementation of the project,
- Difficulties for O&M activities by the beneficiaries, and
- Others.

The above items would be confirmed at village level by using of **FORM-7** in Attachment-1. The confirmation work might be carried out at commune offices by inviting village chiefs.

7.5.3 Confirmation of O&M Activities in the Vicinity of the Project Area

In case there is no FWUC in the project area, it is useful to confirm the activities and performance of any FWUCs in the vicinity of the project area. By knowing such information, possible O&M works in the project area can be examined. The same FORM would be used for the field confirmation.

7.6 Inventory Survey on Irrigation Facilities

7.6.1 General

As mentioned above, few design reports and drawings on the existing irrigation systems are available. Therefore, survey and investigation should be conducted similarly to those of new irrigation projects. The concept and basic idea of the existing system can be derived from the detailed inspection of the dimensions, alignment, and distribution of the existing facilities.

Inventory survey on the existing irrigation facilities is thus required to compensate for the lack of design documents and to provide basic information necessary for the planning and design of the rehabilitation and reconstruction works.

7.6.2 Inventory Survey of Canals

(1) Survey

Inventory survey on the canals should be done for all the main and secondary canals drawn on the topographic map of 1: 100,000. Check point should be located at major structures such as intake gates, diversion structures, crossing structures, or the point where the design capacity changes. For a long stretch of the canal without any structures, the check point should be set at about every one kilometer as shown below.

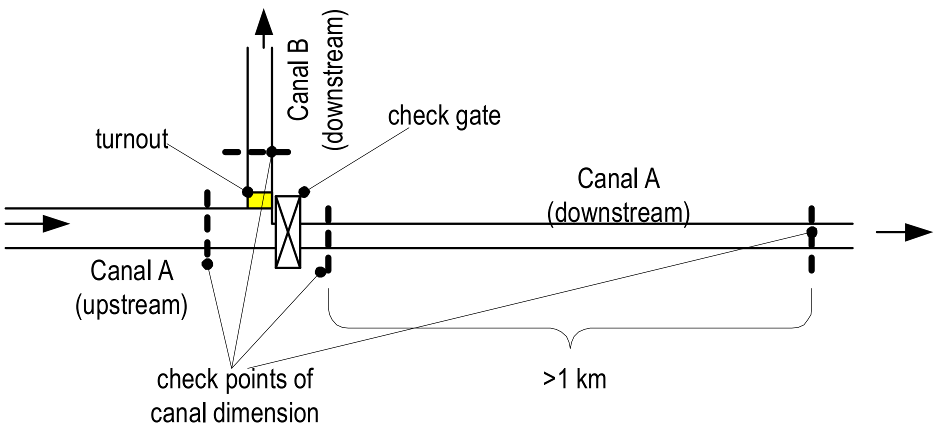


Figure Check Point on the Canals

At each check point, the following items should be confirmed.

<u>General</u>

- Location (UTM Map coordinate measured with GPS)
- Name of canal
- Purpose (irrigation, drainage, others)

<u>Dimension and conditions</u>

- Dimension (bed and top width, depth of canal, depth of water) on both upstream and downstream

<u>Present land use near the canal</u>

- Land use on both side (village, paddy field, etc.)

<u>Problems on the Canal</u>

- Sediments in the canal (none / some / serious)
- Leakage (none / some / serious)
- Inspection road (none / some / serious)
- Others (none / some / serious)

<u>Evaluation</u>

A: Fully functioning

B: Partly deteriorated, but functioning in a satisfactory range

C: Not functioning well and/or affecting the downstream flow

D: Completely not functioning

<u>Photograph and Sketch</u>

Photographs and sketch of the check point with direction of photo shooting.

FORM-8 for the inventory survey of canal is given in Attachment-1.

(2) Database

The results of the survey written in the **FORM-8** should be compiled in a spreadsheet computer program for further analysis of the data. An example of compiled database is given in Table 7.1.

7.6.3 Inventory Survey of Roads / Dikes

(1) Role of Roads/Dikes in the Irrigation Area

Improvement of roads is one of the largest demands of farmers in rural areas along with the improvement of the irrigation system. The dikes of reservoirs are often used as roads, and drains along the roads are used not only for drainage, but also for collecting or distributing irrigation water. Thus, the roads and the dikes play an important role in the irrigation area.

(2) Survey

Inventory survey on the roads/dikes should be done for all the permanent roads that are drawn on the topographic map of 1 in 100,000 with a solid line[3]. Check points should be located at intersection with other roads. For a long stretch road without any intersection, the check points should be set about every one kilometer as shown in the following page.

At each check point, the following items should be confirmed.

<u>General</u>

- Location (UTM Map coordinate measured with GPS)
- Name or code of road (to be put prior to the survey. Ex. "RA", "RB".

<u>Dimension and conditions</u>

- Dimension (total width, effective width) for all the roads crossing at the point.
- Facilities (existence of side drain, surface, access)

<u>Present land use near the canal</u>

- Land use on both side (village, paddy field, etc.)

<u>Problems on the Road/Dike</u>

- Road surface (none / some / serious)
- Sub-surface (none / some / serious)
- Side slope (none / some / serious)

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[3] "Solid line" means "═══" or "───". Other roads are drawn in dotted line as "— — — ".

- Drain (none / some / serious)
- Others (none / some / serious)

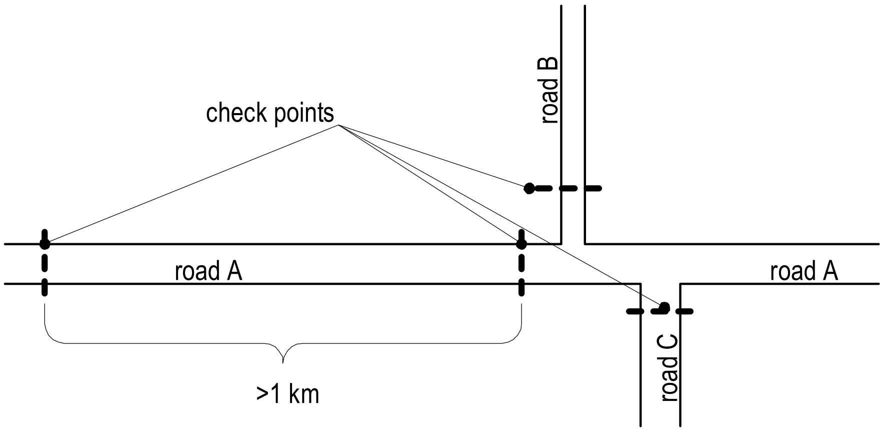

Figure Check Point on the Road / Canal

Evaluation

A: Fully functioning

B: Partly deteriorated, but functioning in a satisfactory range

C: Not functioning well and/or affecting access to the adjacent area

D: Completely not functioning

Photograph and Sketch

Photographs and sketch of the check point with direction of photo shooting.

FORM-9 for the inventory survey of the roads/dikes is given in Attachment-1.

(2) Database

The results of the survey written in the **FORM-9** should be compiled in a spread sheet computer program for further analysis of the data.

7.6.4 Inventory Survey of Structures

(1) Survey

Inventory survey of the structures should be done for major canal and roads structures. The structures are; bridge, box and pipe culvert, check gate, intake gate, diversion structure, drop structure, siphon, etc.

For each structure, the following items should be confirmed.

General

- Location (UTM Map coordinate measured with GPS)
- Type of structure

- Related road number or canal number

Dimension and conditions

- Structure type (concrete / masonry or brick / others)
- Dimension (width, length, height, number)

Problems on the Structure

- Structure (none / some / serious)
- Others (none / some / serious)

Evaluation

A: Fully functioning
B: Partly deteriorated, but functioning in a satisfactory range
C: Not functioning well and/or affecting access/flow to the adjacent area
D: Completely not functioning

Photograph and Sketch

Photographs and sketches of the check points nothing the direction that the photo was shot.

FORM-10 for the inventory survey of the structures is given in Attachment-1.

(2) Database

The results of the survey written in the **FORM-10** should be compiled in a spreadsheet computer program for further analysis of the data.

CHAPTER 8 INSTITUTIONS

8.1 Public Administration

Water resources and rural development program and project in a province are generally conducted according to the protocol as shown below:

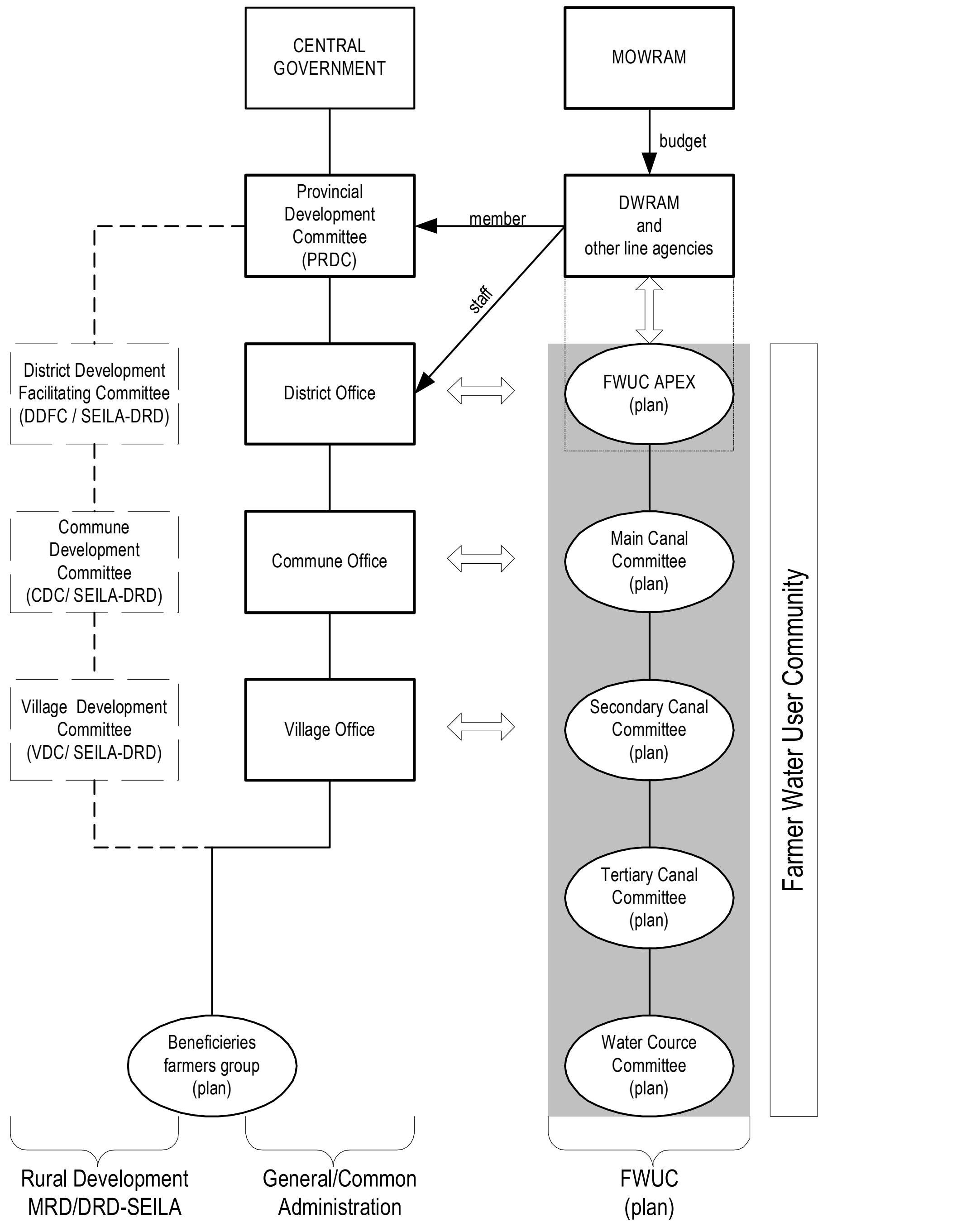

Figure Public Administration Related to the Irrigation Project

The department of Water Resources and Meteorology (DWRAM) is the main agency responsible for water resources, irrigation and drainage development, and the chief of DWRAM is a member of the Provincial Development Committee (PRDC), which is chaired by the governor of the province. PRDC also has members from the line agencies such as Department of Agriculture, Forestry and Fisheries (DAFF), the Department of Rural Department (DRD), etc. Each line agency has its own staff in the district office, who give technical guidance to communes and villages.

Under PRDC, there is no general or common development committee. The SEILA program in association with MRD/DRD proposed and established the development committee at each administration level. They are District Development Facilitating Committee (DDFC) at district level, Commune Development Committee (CDC) at commune level, and Village Development Committee (VDC) at village level. Though DDFC, CDC and VDC were originally established for the rural development, the development of water resources and irrigation, such as formation and guidance for the Farmer Water User Committee (FWUC) could be coordinated by these organizations with the guidance of DWRAM.

The priority of development in the province is determined at PRDC, but most of the budget for the development works are arranged by the central government including foreign aid.

Understanding these development protocols, the following data/information should be collected on public administration:

- Organization, function, number, distribution, name and status (permanent, temporary) of staffs of DWRAM,
- Organization, function, number, distribution, name and status (permanent, temporary) of staffs of DAFF,
- Existence of VDC in the project area, and DDFC and CDC in the related districts and communes,
- Number and name of staff in charge of infrastructure development and agriculture at commune offices related to the project,
- Organization and function of related village development committees (VDC) or villages to the project, with name of the chiefs and persons in charge,

Personnel related to the project should be compiled in a list of key personnel as shown in **FORM-11** in Attachment-1, then the list should be distributed to them.

8.2 Farmer Water User Community

8.2.1 Government Policy

MOWRAM issued the Circular No.1 on the Implementation Policy for Sustainable Irrigation System (1999), which was followed by the Policy for Sustainability of Operation and Maintenance Irrigation System and the Steps in the Formation of a Farmer Water User Community (FWUC) in 2000. In these, the responsibilities and duties of FWUC are defined as follows:

<u>Policy on FWUC</u>

- Irrigation development shall be implemented on the basis of demand of farmers.
- Full participation of FWUC shall be taken place from the very beginning.
- Formation of FWUC shall be the primary task.
- FWUC shall take over operation and maintenance (O&M) of the irrigation system in five years after completion. (Government share of O&M will decrease by 20 % every year and become 0 % in five years)
- FWUC member shall pay for irrigation service fee (ISF) by 20 % of increased production, and O&M cost which is collected in proportion with irrigation area.
- FWUC has duties as follows:
  1. implementing work program of the community,
  2. organizing O&M of irrigation system,
  3. collecting ISF from the members, and
  4. dispute resolution among the community members

It is very important that the beneficiaries of the irrigation project should know, understand and agree with the above mentioned government policy, or at least, such government policy should be discussed with the beneficiaries.

8.2.2 Public Hearing Meeting with the Beneficiaries

In order to confirm the beneficiaries' intentions, public hearing meetings should properly be held at the commune or village level.

The objectives of the meeting are; i) to explain the position (identification, planning, design, or implementation) and policy (target beneficiaries, contribution of beneficiaries, grant or credit, etc.) of the proposed project, ii) to explain the government policy for the irrigation project, iii) to confirm need of the beneficiaries for the project, and iv) to confirm conditions to be fulfilled for implementation of the project.

The following five points would be the main issues concerning the beneficiaries that should be discussed and confirmed until both sides (project and beneficiaries) agree on them:

Points to be Confirmed with the Beneficiaries

1. The beneficiaries would establish FWUC (if they do not have any).
2. The beneficiaries would pay ISF.
3. The beneficiaries would take over the irrigation system and manage O&M.
4. The beneficiaries would abandon cultivated land in the public land (reservoir, canal, etc.) which would be used for the projects, and/or provide some of their land for the irrigation and related facilities.
5. The beneficiaries would solve disputes and problems which might occur on the above by themselves.

Any conditions from the beneficiaries' side and the project side needed to agree on the above issues should be clearly mentioned for each item.

The minutes of the meeting should always be prepared and confirmed with each other. The agreed minutes of meetings should be attached in the reports of study, planning or design. A sample of the minutes is given in Table 8.1.

8.2.3 Activities of Existing FWUC in the Vicinity

It is considered that the existing irrigation schemes which have FWUCs authorized by MOWRAM are not many at present. The government policy on FWUC itself is very new, and details to embody the policy might be properly modified case by case according to the conditions of the project area.

Therefore, activities and performance of the existing FWUC in the vicinity of the target area would give suggestions in the formation of FWUC in the target area. Particularly, actual collection rate of ISF and treatment of defaulters and delinquents would be useful information for organizing of new FWUC.

8.3 Farmers Group and Local Community

The "Phum" ("village" in Khmer) is the basic institution of local society. Solution of problems and disputes, development activities and important issues are discussed and determined at the village level.

On the other hand, there exist several groups and communities for certain purposes at the village level. For the development of infrastructure, a Village Development Committees (VDC) is established on some villages, and farmers groups are organized for joint purchase of agricultural inputs.

"Krom" ("sub-village group" in Khmer) is the minimum unit of local (residential) community, whose leaders are called into the village meeting for decision making on important issues.

It would be convenient to make an organization chart of the target village for a better understanding of the village and easy access to the leaders. A sample village organization chart is given below.

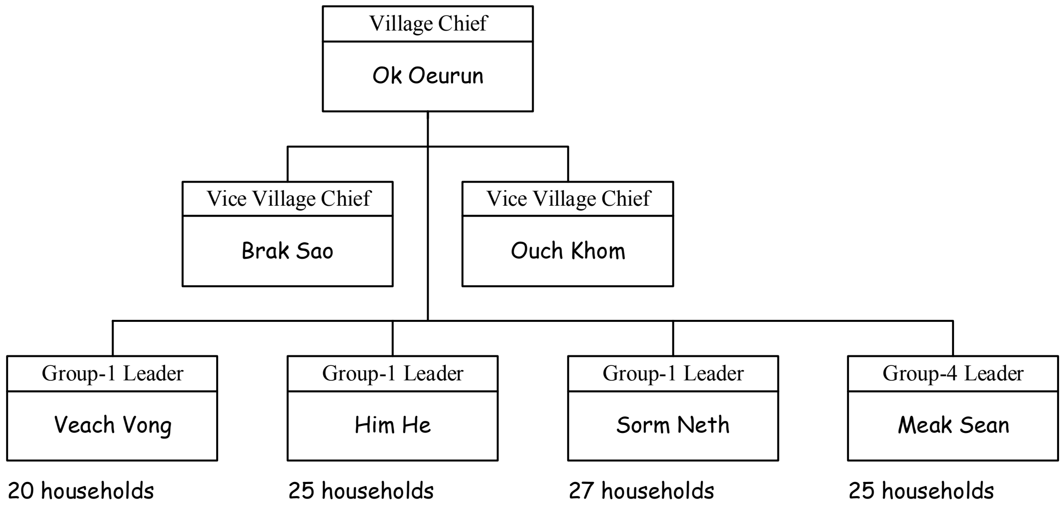

Figure Sample of Village Organization Chart

8.4 Other Development Program and Project

Many of the farmers' groups, local communities, FWUCs, etc. have been organized and supported by programs and projects conducted by the government, international organizations (IOs), and NGOs.

There are a number of local staff that were trained by such projects and programs, and are experienced in the participatory planning approach, organizing of FWUC, community development, extension works, etc. For example, in Takeo Province, there exist more than 50 NGOs, and most of them are working in collaboration with local communities. The experience and know-how of such local human resources would greatly help the project implementation.

Thus, the following information should be collected and utilized in the planning of the projects:

- NGOs working in/around the project area and sectors of their programs, numbers of staff, location of the project, etc.
- IOs working in/around the project area and sectors of their programs, number of staff, location of the project, etc.
- Appraisal, evaluation and monitoring reports on the above programs and activities.

CHAPTER 9 ENVIRONMENTAL PLANNING

9.1 General

The basic principle of environmental consideration is to make proposed projects environmentally sound and sustainable. Although environmental negative impacts caused by a project for rehabilitation and reconstruction of existing irrigation system are relatively low or negligible on the whole, it is essential to foresee any potentially significant impacts and to take necessary measures for achieving the above principle.

Chapters 9 and 17 of this guideline were prepared to assist eliciting the environmental issues to be examined for expediting the appropriate considerations during the investigations and planning of the project for rehabilitation and reconstruction of existing irrigation systems. The official EIA procedure of RGC is also mentioned briefly. The overall work flow on environment are shown in Fig. 9.1.

9.2 Official EIA Procedure of RGC

9.2.1 Law on Environmental Protection and Natural Resources Management

RGC established "Law on Environmental Protection and Natural Resources Management" (1996), which was a fundamental legislation focusing on protection of environmental quality and human health, and on sustainable use of the nation's rich and diverse natural resources. The law stipulates i) development of national and regional environmental plan, ii) environmental impact assessment (EIA), iii) natural resources management, iv) environmental protection, v) monitoring and inspection, and vi) public participation.

In order to ensure the contents of the law, the following sub-decrees were issued or drafted:

- Sub-decree on Environmental Impact Assessment Process
- Sub-decree on Water Pollution Control
- Sub-decree on Solid Waste Management
- Sub-decree on Air and Noise Pollution Control, and
- Sub-decree on Protected Areas

9.2.2 Official EIA Procedure

The law on Environmental Protection and Natural Resource Management stipulates that EIA shall be done for all proposed projects, and be evaluated by MOE prior to issuing a decision on project implementation by RGC. According to the Sub-decree on Environmental Impact Assessment Process (1999), the official EIA procedure are stipulated as shown in Fig. 9.2 and is summarized as follows:

Official EIA Procedure

1. Project owner (PO) conducts Initial Environmental Impact Assessment (IEIA) to identify magnitude and extent of the impacts,
2. PO submit IEIA Report to MOE. MOE notifies PO if EIA is required or not within 30 days after submission.
3. PO prepares EIA Report which includes necessary investigations as pointed out by MOE, then submits to MOE.
4. MOE reviews, gives comment on the report, then after revision or modification of either project component or EIA report, consents implementation of the project.

Article and Annex of EIA Sub-decree stipulate the project types / activities and their size/capacity, on which an IEIA or EIA is required. Conditions of agricultural development projects to required comply with the procedure as per EIA Sub-decree are as follows:

Table List of Project Required for IEIA or EIA

	Type and Activities of Projects	Size / Capacity
1	Agriculture	
	1) Concession forest	≥ 10,000 ha
	2) Logging	≥ 500 ha
	3) Land covered by forest	≥ 500 ha
	4) Agricultural and agro-industrial land	≥ 10,000 ha
	5) Flooded and coastal forests	All sizes
	6) Irrigation systems	≥ 5,000 ha
	7) Drainage systems	≥ 5,000 ha
	8) Fishing ports	All sizes
2	Projects related to agriculture	
	1) Food processing and caned	≥ 500 ton / year
	2) Rice mill and cereal grains	≥ 3,000 ton / year
	3) Chemical fertilizer plants	≥ 10,000 ton / year
	4) Pesticide industry	All sizes
	5) Animals food processing	≥ 10,000 ton / year

Source: Sub-decree on Environmental Impact Assessment Process, 1999

In case that the official EIA procedure is required, the IEIA or EIA report should be prepared including the following contents as per the format issued by the Department of EIA Monitoring and Review of MOE.

Table Format of IEIA or EIA Report

Item	Contents
1. Summary	- Summary of the report
2. Introduction	- Background of the project - Project's target and goal within the national or regional plan
3. Purpose of the Project	- Purpose of the project
4. Project Description	- Location, size, timeframe, material/machinery/manpower requirement, related activities, etc.
5. Description of Environmental Resources	- Physical resources (air, water, soil, geology, etc.) - Ecological resources (fauna, flora, forest, etc.) - Socio-economic resources (population, land use, public health, etc.)
6. Public Participation	- Concerns of local authorities, the public, stakeholders, etc.
7. Environmental Impact Analysis	- Description of significant environmental impacts resulting from the project
8. Assessment of Environmental Impact	- Impacts assessment to define the specific mitigation measures
9. Environmental Management Plan	- Environmental protection measures - Environmental monitoring programs
10. Institutional Capacity	- Institutional frame and budget for implementation of the environmental management plan
11. Conclusion and Suggestion	- Overall assessment and suggestions for the project from the environmental viewpoint
12. References	

Source: Declaration on Guideline for Conducting Environmental Impact Assessment Report, 2000

The outcomes derived through the investigation and planning in accordance with this guideline can be fully utilized for preparation of the official IEIA or EIA report as per Sub-decree.

9.3 Identification of Important Environmental Conditions

Prior to determining the area of the project activities, it is necessary to identify important environmental conditions in/around the project area. The following items are to be considered and the existence of these factors should be confirmed as "yes", "no", or "unknown".

Table Important Environmental Conditions

Important Environmental Conditions	In the Project Area	Around the Project Area
Protected Areas		
- Fauna and flora listed in the Washington Convention	Yes/no/unknown	Yes/no/unknown
- Wetland listed in the Ramsar Convention	Yes/no/unknown	Yes/no/unknown
- National park, wildlife sanctuaries, protected landscape, multiple use management areas	Yes/no/unknown	Yes/no/unknown
Social condition		
- Minority, aborigine, nomads	Yes/no/unknown	Yes/no/unknown
- Historic remains, cultural assets, scenic spot	Yes/no/unknown	Yes/no/unknown
- Economic center to be largely affected by the impact	Yes/no/unknown	Yes/no/unknown
- Others	Yes/no/unknown	Yes/no/unknown
Natural condition		
- Dry / arid zone	Yes/no/unknown	Yes/no/unknown

Important Environmental Conditions	In the Project Area	Around the Project Area
- Tropical rain forest, wild land	Yes/no/unknown	Yes/no/unknown
- Wet land, peat land	Yes/no/unknown	Yes/no/unknown
- Coastal zone (mangrove, coral leaf, etc)	Yes/no/unknown	Yes/no/unknown
- Mountain, steep slope, erosive land, devastated land	Yes/no/unknown	Yes/no/unknown
- Closed water body (lake, pond, reservoir)	Yes/no/unknown	Yes/no/unknown
- Others	Yes/no/unknown	Yes/no/unknown

If the above listed environmental conditions are identified in/around the project area, special attention should be paid to them and detailed investigation and due countermeasure should be taken so that those conditions are not affected by the project implementation (See Section 17.2 and 17.3).

9.4 Investigation of Environmental Aspects

The environmental aspects in/around the project area are to be grasped for examination of the likely impacts of the project. Available data and information on the environment are to be collected to the greatest possible by means of literature review, field reconnaissance or survey, lab-analysis, interview to the local or officials, review of outcomes from other experts, and so on. The aspects to be investigated are as follows:

Table Environmental Aspects to be Investigated

Natural environment	- Atmosphere (meteorology, air pollution, etc.) - Hydrosphere (hydrology, water quality, river bed, etc.) - Geosphere (soil, topography, etc) - Biosphere (flora, fauna, vegetation, forest, etc.)
Social environment	- Living conditions (demography, minorities, life-style, land holding and tenure, etc.) - Health and sanitary (infectious or water-borne diseases, drinking water condition, etc.) - Economic activities (industries, income generation, etc.) - Cultural property (historic remains, cultural heritage, scenic spot, etc.)

PART 2

PLANNING AND DESIGN

CHAPTER 10 BASIC CONCEPT AND APPROACH

10.1 Basic Concept

10.1.1 Model Development

The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin, The Kingdom of Cambodia" was conducted for a selected existing irrigation area (650 km^2 of gross area) in the Slakou River Basin.

Since the Study began, the Study team has analyzed the present conditions, problems and constraints of the Study Area, and formulated a Master Plan for the rehabilitation and reconstruction of the existing agricultural production system in Cambodia. Characteristics of the agricultural production system in the Study Area are; i) paddy rice monoculture under rain-fed condition, and ii) small scale poly-culture system consisting of cash crops, livestock, etc.

The Master Plan proposed three types of agricultural production systems, namely, the Upper Slakou River Irrigation Reconstruction Plan (USP), the Small Reservoir Rehabilitation Plan (SRP), and the Small Pond Development Plan (PDP).

USP is a surface water resources development for a larger area, while SRP and PDP are small-scale water resources development for the paddy rice cultivation and the secondary crops, and development of small-scale poly-culture supporting system at village and/or household level.

These three production systems are thus regarded as "model plans for reconstruction and rehabilitation of the agricultural production system in Cambodia".

Table Model Plans

Models	Plans in the Study	Target Crops and Animals
Surface water resources development for larger irrigation area	Upper Slakou River Irrigation Reconstruction Plan (USP)	Paddy rice and secondary crops
Small reservoir rehabilitation plan	Small Reservoir Rehabilitation Plan (SRP)	Paddy rice and secondary crops
Small Pond development plan	Small Pond Development Plan (PDP)	Nursery of paddy rice, vegetables, cash crops, livestock, etc.

The agricultural areas would be commanded by a model or a few models as shown in the following figure.

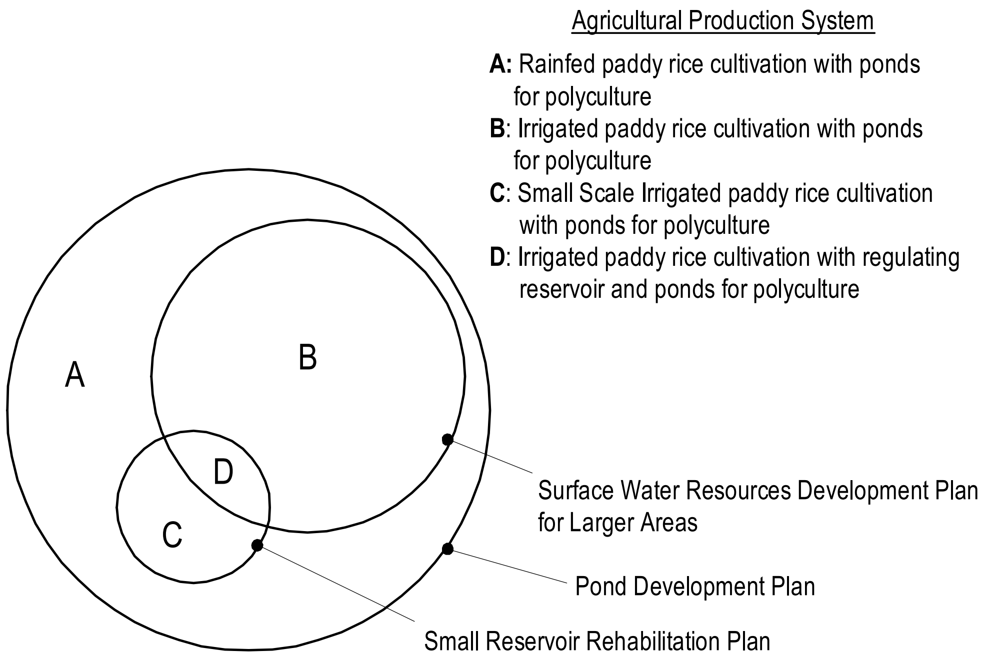

Figure Coverage of the Model Plans and Agricultural Production Systems

In this Study, USP, SRP and PDP were formulated as "independent project", but SRP and PDP could be proposed even within the large irrigation area, for regulation purposes and supporting the poly-culture system of the farm households.

10.1.2 Stage-wise Development

The target level of development greatly affects the project costs and sustainability. The development works should be conducted stage-wise, according to the present conditions of the target areas.

The results of the Study show that there is still a food shortage, epidemic diseases (the biggest cause of death from sickness in Takeo Province is malaria, then tuberculosis and bronchitis follow), lack of access to safe drinking water and sanitation facilities. A number of programs and projects to improve these conditions have been conducted by IOs and NGOs in Takeo Province, too, and certain benefits have been generated through those projects and programs. Local NGOs, whose staff were trained by the projects, have started their own programs even in cooperation with the international NGOs and IOs.

The SEILA Program, which was coordinated by UNDP and MRD, has been implemented in many provinces including Takeo. The program is aiming at improving rural infrastructures such as roads, structures, schools, wells, community ponds for domestic purposes, etc. in a self-supportive procedure by the villages (VDC). Considering these situations, the target development level of the plans would be set as "improvement of agricultural production by water resources development and improvement of irrigation facilities". Needless to say, further development targets should always be considered in the planning. The following table shows the development stage, needs, problems and components of projects to be planned by stage.

Table Development Stage and Target

Target of Development Stage and Needs	Main Problems	Project Component
Level-1: Basic Human Needs ● Primary health care, ● Drinking water, ● Housing, ● Vocational training, etc.	Poverty and food shortage ● Nutrition, ● Drinking water shortage, ● Woman and child labor, ● Housing, ● Little employment, ● Epidemic diseases, etc.	● Health (vaccination, family planning), ● Primary education, ● Emergency food assistance (food for work, etc.)
Level-2: Infrastructure ● Irrigation improvement, ● Farm road, ● Agricultural extension,	Low Production ● Water shortage, ● Low input, ● Poor farming technique, etc.	● Rehabilitation of irrigation facilities, ● Water resources development, ● Pest management, ● Training of farmers, etc.
Level-3: Reduction of Production Cost ● Improve of profits in production activities	Low Efficiency (profit) ● high labor cost, ● high input cost, ● losses in harvesting, ● low bargaining power, ● losses in post-harvest processing, etc.	● farmers' group for procurement, extension, post-harvesting, marketing, ● FWUC, etc.
Level-4: Agro-industry ● Quality control, ● Formation of production area, ● Added value by processing, etc	Low added value ● Lack of processing skills, ● Lack of fund, ● Lack of market channels, etc.	● Training in processing skills, ● Introduction of private sector, ● Micro credit for agro-industry, etc.

The Study Area is considered to be situated at Level-1 or Level-2, and the intensive development of the infrastructures for the agricultural production is necessary.

10.1.3 Target Level of Irrigation System

As for the irrigation systems, there are the following three categories:

(1) Technical Irrigation

A technical irrigation system has check and control structures up to the tertiary system. The irrigation water is distributed to each farm plot through gate structures at the watercourse level. The technical irrigation system enables minute water management with measuring devices up to the tail farm plots.

(2) Semi-Technical Irrigation

A semi-technical irrigation system has the check and control structures on the main and secondary canals. The irrigation water is distributed to the tertiary blocks through gate structures. From the tertiary canals, the water is distributed without permanent structures but temporary control and check with local materials such as soils, woods, etc is employed.

(3) Non-Technical Irrigation

A non-technical irrigation system has few control structures on the main and secondary canals. The structures are used to adjust the water level in the canal so that the water could be distributed to other canals. Systematic water distribution such as rotational irrigation could not be attained by the system.

Considering the present level of irrigation facilities in Cambodia and experience of water management by FWUC and DWRAM, the semi-technical irrigation is considered to be the target level of development at present. Target level of each facility is mentioned in detail in Section 13.2 “Setting of Target Level of Reconstruction and Rehabilitation”.

10.2 Approach

10.2.1 Participatory Approach

It can be said that the participation of beneficiaries does not always gayrantee the sustainability of the development, but that the sustainability could certainly not be attained without the participation.

Parts of the construction of irrigation facilities would be carried out by beneficiaries themselves. Moreover, O&M works of the irrigation facilities would also be conducted by the beneficiaries or FWUC/FWUG. For these, the beneficiaries should be involved from the early stages of the project, such as planning and design.

For the small reservoir rehabilitation projects, a common problem is illegal cultivation in the reservoirs. In general, the illegal cultivators in the reservoirs and the cultivators in the irrigated area belong to a village, and such problems and conflict have to be solved by the beneficiaries themselves getting coordination by MOWRAM and its project office.

10.2.2 Probability and Reliability

Since irrigation projects largely depend on the prevailing rainfall, it is very important to assume a certain probability and reliability in the planning. For irrigation projects, a reliability of 80 % is generally adopted. By “80%”, we mean that the proposed irrigation area can receive the proposed volume of water four years out of five years. The probability level is set to fix the development level of the project so that certain economic viability can be assured.

In Cambodia, the irrigable area has been often estimated on the basis of “average value” and “annual level”. The average values for long term do not often represent critical water shortage for the crops and serious floods. Even for the rainy season, there are dry periods that will affect the growth of crops, and such condition is taken into account by probability analysis.

10.2.3 Maintaining and Restoration of Original Function

Prior to the planning, the original function of the existing system should be examined. If the original function was sufficient for the planned command area, the rehabilitation works should be proposed, while if not sufficient, then reconstruction should be proposed. However, reconstruction does not always mean extension of the irrigation area with development of larger reservoirs and canals. Considering the technical soundness and environmental impact, it may be recommended to maintain the original capacity, and the extent of the command area or irrigation method should be determined accordingly.

CHAPTER 11 WATER RESOURCES

Water resources are one of the most important issues for planning and design of irrigation projects. This chapter deals with methods to estimate the availability of water resources and floods, especially for the lowland lying to the eastern part of the Elephant Mountains in Cambodia. However, due to insufficient data and information, this paper is subject to reinforcement with additional new data and information.

11.1 Water Availability

Water availability is very important information for design of river structures. However, no flow data are available for most small rivers and streams in Cambodia.

A relation between annual runoff (AQ) and annual rainfall (AR) is presented by the following equation[4].

$$AQ(mm) = 0.982AR - 863$$

According to this equation, annual runoff in the lowlands extending from Batambang Province to Takeo Province is 315 mm, where the average annual rainfall is around 1200 mm. The annual runoff rate is 25 %. If annual rainfall is 1500 mm, the annual runoff is 610 mm, about double the annual runoff if the annual rainfall is 1200 mm. When annual rainfall is less than 1200 mm, the above equation can not be applied. Both loss and runoff decrease, as rainfall reduces. Probably, annual runoff expected is around 200 mm of 1000 mm annual rainfall or 150 mm of 900 mm annual rainfall.

In order to estimate monthly runoff of rivers flowing from the Elephant Mountains to the eastern lowland, the following equation[5] is useful.

$$ER = R - L$$

$$L = 1.23 \times ET_0 \times (1 - \exp^{-0.006 \times R})$$

where, ER: effective rainfall, which contributes to runoff (mm),
R: monthly rainfall (mm)
L: loss (mm)
ETo: potential evapotranspiration (mm)

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[4] Annex A – Hydrology, Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, June 1994

[5] The equation was obtained from the correlation analyses between monthly rainfall and monthly runoff of the Prek Thnot River basin.

$$Q = 0.66ER_0 + 0.23ER_1 + 0.08ER_2 0.015ER_3 + 0.01ER_4 + 0.005ER_5$$

Where, Q: monthly runoff (mm)
ER: effective rainfall (mm)
Attached figures 0,1,2,3 and 4 indicate this month, last month, 2 months ago, three months and four months ago, respectively.

Table ETo estimated from climate data obtained Pochentong by modified Penman

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
162	174	216	206	191	167	153	159	140	133	150	156

About 65 % of monthly effective rainfall contributes to runoff within the same month, 25 % to the second month and 8 % to the third month.

In case of small rivers, for example, if you get information that the river has no flow in the dry season from February to May, coefficients of ER3, ER4 and ER5 are reduced or zero and instead, the coefficient of ER0 and ER1 is given a larger value so that the monthly runoff during February to May becomes zero or very small.

Monthly runoff of small rivers originating in hilly area in the zone where annual rainfall is around 1200 mm is shown below.

Table Flow in Small River in the Lowland

Unit : x 1,000m^3/month/km^2

Return Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2 years	Nil	0	0	0	0	7	9	19	59	85	35	9
5 years	Nil	0	0	0	0	0	4	6	39	33	21	5

Small rivers dry up from January and May except during occasional heavy rainfall. Runoff starts in June or July. September and October are the peak of the runoff season. In November and December, runoff reduces remarkably.

If the catchment area of a small stream is mostly a rain-fed paddy field, steady runoff is not expected until the paddy plots are full of water and the starting time of runoff is often July in a normal year and probably August or September in a drought year.

It is noted that the stream flow cannot be totally diverted by a small diversion structure that has no water storage capacity, because a large part of the flow is storm flow that is usually bigger than the diversion capacity of the intake structure.

The monthly amount diverted by an intake is roughly estimated by the following condition[6].

If Qr > Qc/0.7, Qin = Qc

If Qr < Qc/0.7, Qin = 0.7 Qr

on the condition that Qc = CA/(50～150)

Where, Qin: monthly diverted amount
Qr: monthly river discharge
Qc: intake capacity (m^3/sec)
CA: catchment area (km^2)

11.2 Flood

Flood discharge is very important information for the design of river and canal structures. However, no flood data are available for most of the small rivers and streams in Cambodia.

Four methods such as; (1) a method (hereinafter called as the IRS method) recommended in Irrigation Rehabilitation Study in Cambodia, 1994, Mekong Secretariat, based on growth factors for flood frequencies in the Thai catchments with areas less than 15000 km^2 and elevations below 100 m and (2) Rational formula, (3)Unit hydrograph method and (4) Manning formula are explained

(1) Probable Rainfall

The Rational formula and Unit hydrograph method need probable rainfall. Tomas method and Hazen method presented are facile methods to estimate probable values by plotting order statistics on probability paper according to the following plotting position.

Hazen Method: $P = 100(2m-1)/(2N)$

Tomas Method: $P = 100m/(N+1)$

Where, N: number of records
m: rank number of descending values, with largest equal to 1
P: plotting position

The following paper is a sample of the probability paper. This logarithmic normal distribution paper is often utilized for estimating the probability of exceedence of daily rainfall.

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[6] The condition was decided comparing hourly river discharge measured by automatic water level gauge installed at Tumnup Lok Reservoir site on the Slakou River and design diversion capacity. The measured period is still limited to a few months. Thus the condition is subject to review, when discharge data is collected for a few years.

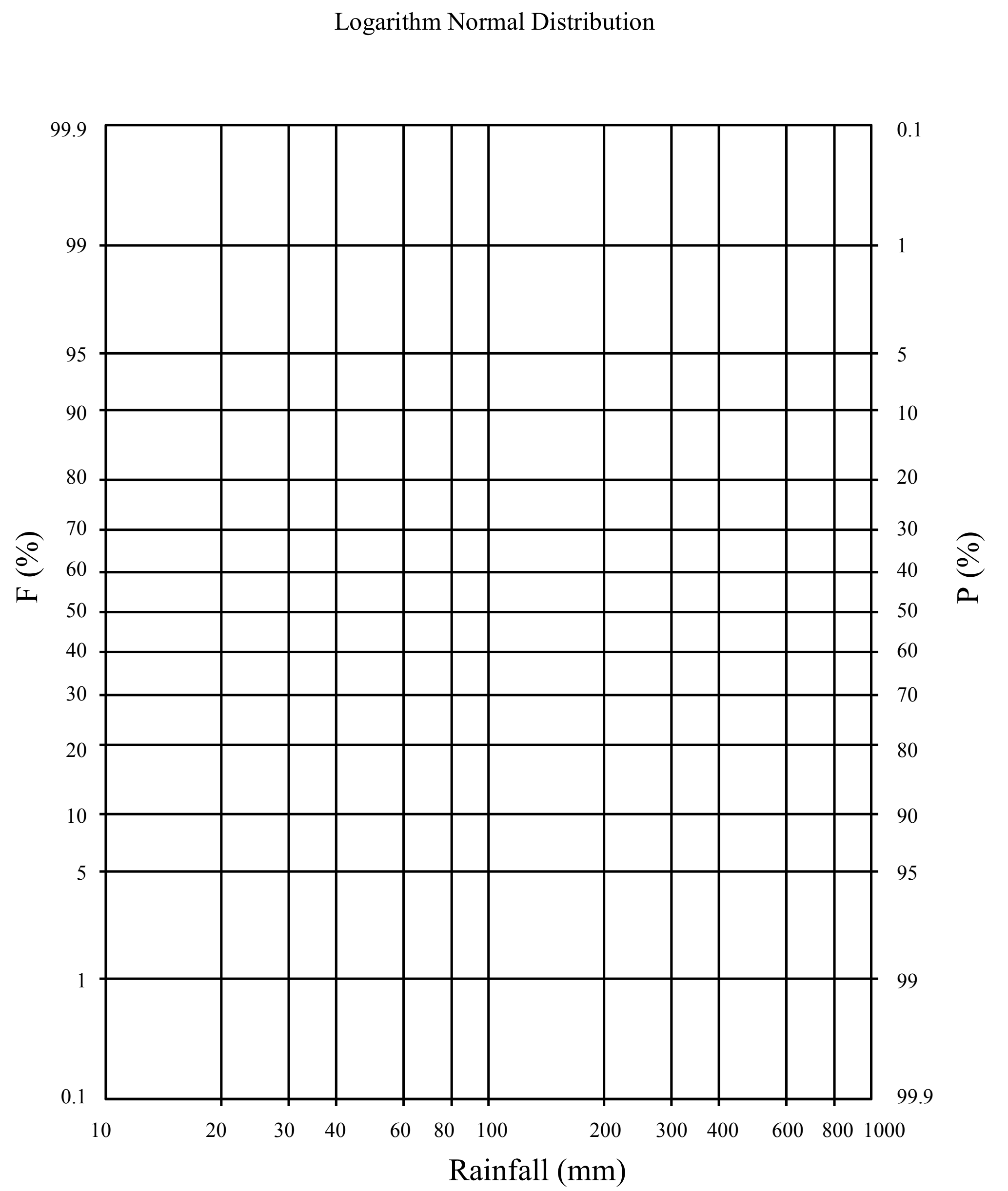

Figure Paper for Log-normal Distribution Analaysis

(2) The IRS method

The method is represented by the following equations.

$MAF = AREA^{0.9}$

$Q_{10} = 1.53\ MAF$

$Q_{20} = 1.77\ MAF$

$Q_{50} = 2.00\ MAF$

$Q_{100} = 2.20$ MAF

where, MAF : mean annual flood (m^3/sec)

Q_n: flood expected to occur not more than once every n years on average,

n : Return period (years).

For example, the catchment area used and flood estimated by this method are as follows:

Table Flood (Q_{10} & Q_{100})

Name of Stream	Name of Reservoir	Catchment Area (km^2)	Flood, Q_{10} (m^3/sec)	Flood, Q_{100} (m^3/sec)
Don Phe	Kpob Trobek	137	128	184
Krouch	O Saray	51	53	76
Tras	Tumnup Lok	332	284	409

(3) Rational Formula

The Rational Formula is employed for small streams with catchment area usually less than 50 km^2. The flood peak is presented by the following equation:

$$Q_{\max} = 1/3.6 \times f \times r_t \times A$$

where: Qmax: flood peak (m^3/sec)

f: runoff coefficient (see the following table)

Table Peak Runoff Coefficient

Steep slope topography	0.75 - 0.9
Hilly area and forest	0.5 - 0.75
Plain agricultural land	0.45 - 0.6
Paddy field under irrigation	0.7 - 0.8
Small river in plain	0.45 - 0.75
Mountain river	0.75 - 0.85

r_t: rainfall intensity (mm/hr)

A: catchment area (km^2)

The flood concentration time has to be known to estimate rainfall intensity during the flood concentration time.

The rainfall intensity is often estimated by the following equation when there is no rainfall intensity data.

$$r_t = R_{24} / 24 \times (24 / T)^n$$

where, r_t: T-hour maximum rainfall intensity (mm/hr)

R_{24} : daily rainfall (mm)

n: 0.5～ 0.667. generally 0.5 is used.

The flood concentration time is calculated by the Rziha equation or Fukushima-Kadoya equation.

Rziha equation

$$T_a = 72 \times (h/l)^{0.6} \quad \text{(km/hr)}$$

where, T_a: flood arrival time

l: length of stream from flood-estimate point to upstream end of valley (km)

h: elevation difference between the l–length (km)

If this equation gives a flood arrival time of less than one hour, one hour flood arrival time is taken.

Fukushima-Kadoya equation

$$t_p = C \times A^{0.22} \times r_e^{-0.35}$$

Where, C : coefficient in accordance with land use as follows:

Natural hilly area = 250 ～ 350 = 290

Grazing area 190 ～ 210 = 200

Here, C =290 was taken.

A : catchment area (km^2)

r_e : average effective rainfall during flood concentration time (mm/hr)

The following table shows the flood calculation for Ang 160 Reservoir applying the Fukushima-Kadoya equation.

Table Flood Calculation of Ang 160 Reservoir, Takeo Province

Ang 160

Return Period (years)	R24 (mm/day)	C	A (km^2)	rt (mm/hr)	re (mm/hr)	tp (min)	d (h)	n	f	Qp (m^3/sec)
100	147	290	2	20.09	14.07	133.90	2.23	0.5	0.7	7.81
20	118	290	2	15.39	10.78	146.99	2.45	0.5	0.7	5.99

(4) Unit Hydrograph Method

The unit hydrograph method based of the ARD Manual 1, which is used and accepted at the Office of Accelerated Rural Development (ARD), Ministry of Interior, Thailand, is employed for estimating flood for small rivers. More information on the theory is given by Design of Small Dams or Hydrology Section 4, SCS. This method is explained here by applying it to the Tras Stream – Tumnup Lok Reservoir as a sample in accordance with "Engineering Training Manual Peace Corps Thailand".

Step1

From the 1 : 100,000 topographic map, the following items are first determined . Catchment area (A) (332 km^2),

The length of stream measured from reservoir site to the watershed divide (L) (25 km),

Centroid of drainage area (coa), length of the stream from the point of intersection of a line drawn from the centroid (Lc) (12 km),

Average slope of the stream in the watershed measured from contour lines (s) which is 0.00433, based on the condition that the elevation at Tumnup Lok Reservoir site is 36.0 m, and that the uppermost elevation is 140 m at a distance of 24,000 m from Tumnup Lok.

The lag time, t_{lag} , which is defined as the time from the midpoint of the storm to the peak flow of that storm is calculated by the following.

$$t_{lag} = 1.90 \left[\frac{LL_c}{\sqrt{s}} \right]^{0.162} = 7.44 \, \text{hrs}$$

Tp = 1.11 x t_{lag}, , usually rounded to the nearest half hour = 8.26 hrs =8.5 hrs

Tp / 5 : plotting interval or the duration of the individual storm = 1.7 hrs

Step 2

Hourly rainfall data are not available. From probable daily rainfall (R_{24}), the hourly distribution is estimated by the following equation.

$$R_t = R_{24} \left(\frac{t}{24} \right)^k$$

where, R_t : maximum rainfall during t hours

k : constant value, 1/2～1/3, 1/2 is often used.

Then the substorm runoff hydrograph is computed from hourly rainfall distribution as follows.

Table Calculation of Effective Rainfall

1	2	3	4	5	6	7	8
hrs	cm		cm	cm	cm	cm	cm
0.0	0.00	0.00	0.00	0.00	0.00	-	0.33
1.7	3.94	0.76	2.99	2.99	0.51	2.48	0.48
3.4	5.57	0.84	4.68	1.69	0.51	1.18	0.68
5.1	6.82	0.86	5.87	1.19	0.51	0.68	2.48
6.8	7.88	0.87	6.85	0.99	0.51	0.48	1.18
8.5	8.81	0.88	7.75	0.90	0.51	0.39	0.39
10.2	9.65	0.89	8.59	0.84	0.51	0.33	
11.9	10.42	0.90	9.38	0.79	0.51	0.28	
13.6	11.14	0.91	10.14	0.76	0.51	0.25	
15.3	11.82	0.92	10.87	0.73	0.51	0.22	
17.0	12.46	0.93	11.58	0.71	0.51	0.20	
18.7	13.06	0.93	12.15	0.57	0.51	0.06	

Column 1: Δt, time in hrs (from Tp/5 determination)

Column 2: pt, rainfall, cumulative, in cm calculated by the equation above.

Column 3: % reduction due to variation in storm intensity over the watershed area (see Fig. 11.1)

Column 4: Column 2 * Column 3

Column 5: incremental rainfall, or rainfall during each Δt period

Column 6: amount of infiltration, ARD assumes 0.3 cm per hour and that the infiltration rate is constant throughout the storm

Column 7: Column 5 - Column 6 = surface runoff. These values represent the runoff from each of sub-storms.

Column 8: The values from Column 7 are rearranged to achieve a median composite of Q_{peak}. The Design of Small Dams recommends ordering them in the following pattern: 6, 4, 3, 1, 2, 5.

<u>Step 3:</u> Determine an unit hydrograph for the watershed from the Dimensionless Unit hydrograph (DUH) coordinates which are given in Fig. 11.1.

Column 1: Δt, time in hrs (from Tp/5 determination)

Column 2: Δt/Tp

Column 3: DUH ordinates from graph

Column 4: DUH ordinate from Column 3 divided by F where

$F = (0.36 * \Delta t * \Sigma DUH) / (\text{Watershed}, km^2) =$ 0.0123

F is merely a conversion factor which converts the DUH into a flow value based on 1 cm of total runoff for a given watershed area and Δt. For accurate results, regardless of the number of sub-storms analyzed, the Σ DUH value should sum the coordinates under the entire curve. By not including the entire curve coordinates in the Σ DUH value, the peak discharge is increased.

Table Unit Hydrograph for Effective Rainfall of 1cm

1	2	3	4
hrs			
0.0	0.0	0.00	0.00
1.7	0.2	0.10	8.14
3.4	0.4	0.31	25.23
5.1	0.6	0.66	53.72
6.8	0.8	0.93	75.70
8.5	1.0	1.00	81.39
10.2	1.2	0.93	75.70
11.9	1.4	0.78	63.49
13.6	1.6	0.56	45.58
15.3	1.8	0.39	31.74
17.0	2.0	0.28	22.79
18.7	2.2	0.21	17.09
20.4	2.4	0.15	12.21
22.1	2.6	0.11	8.95
23.8	2.8	0.08	6.51
25.5	3.0	0.06	4.88
27.2	3.2	0.04	3.26
28.9	3.4	0.03	2.44
30.6	3.6	0.02	1.63
32.3	3.8	0.02	1.22
34.0	4.0	0.01	0.81
Sum of DUH		6.67	

Step 4: Determine inflow hydrograph (unit hydrograph ordinate from step 3 multiplied by the sub-storm runoff from step 2)

Table Sub-storm and Composite Hydrographs

Time hr	Sub-Storm						Total
	0.33	0.48	0.68	2.48	1.18	0.39	
0.0	0	0	0	0	0	0	0.0
1.7	2.66	0	0	0	0	0	2.7
3.4	8.23	3.88	0	0	0	0	12.1
5.1	17.53	12.02	5.52	0	0	0	35.1
6.8	24.70	25.59	17.11	20.21	0	0	87.6
8.5	26.56	36.07	36.43	62.67	9.57	0	171.3
10.2	24.70	38.78	51.33	133.42	29.66	3.15	281.0
11.9	20.71	36.07	55.19	188.00	63.15	9.77	372.9
13.6	14.87	30.25	51.33	202.15	88.99	20.79	408.4
15.3	10.36	21.72	43.05	188.00	95.69	29.30	388.1
17.0	7.44	15.12	30.91	157.68	88.99	31.50	331.6
18.7	5.58	10.86	21.52	113.20	74.64	29.30	255.1
20.4	3.98	8.14	15.45	78.84	53.59	24.57	184.6
22.1	2.92	5.82	11.59	56.60	37.32	17.64	131.9
23.8	2.12	4.27	8.28	42.45	26.79	12.29	96.2

The number above each column represents the excess for the sub-storm flows in cm. The computed numbers in the columns below these numbers represent sub-storm flows in m^3/sec and the following graph represents the resulting inflow hydrograph for the composite storm. Base flow is not considered in this method. Thus the peak flow should be determined by adding the base flow, if necessary.

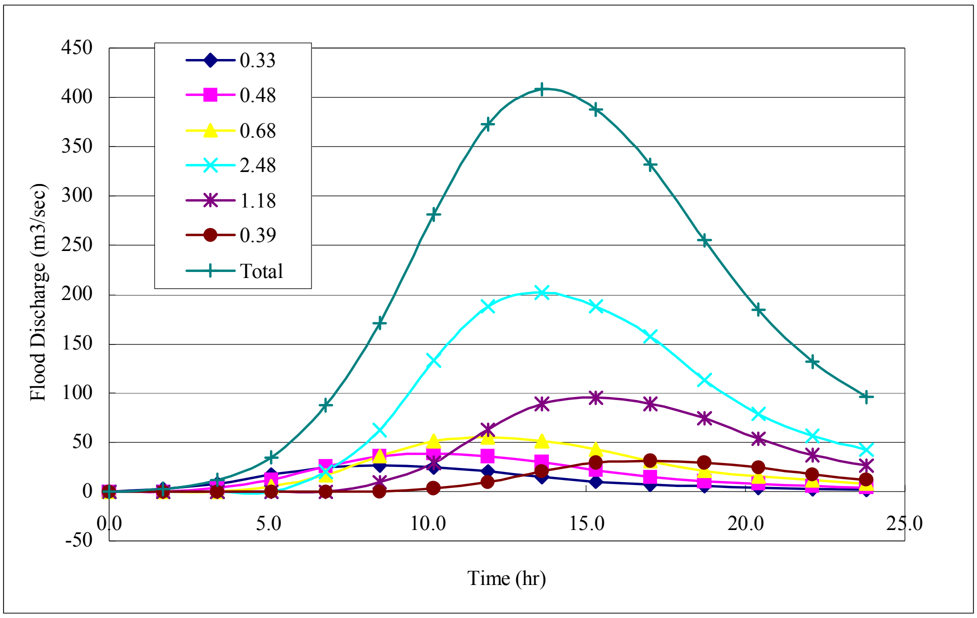

Figure Graph of Sub-storms and Composite Hydrograph

(5) Hydraulic Calculation by Manning Formula

Manning formula expresses mean velocity as a function of the roughness of the channel, the hydraulic radius and the slope of the energy gradient.

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

$$Q = AV$$

where, V: mean velocity (m/sec)

n: roughness coefficient

R: hydraulic radius, = A/S (m)

I: hydraulic energy gradient

Q: discharge

A: cross sectional area (m^2)

S: wetted perimeter (m)

If stream flow area can be clearly defined in such a place as where a river runs through a valley, then we can estimate the past maximum water level from flood trace, vegetation alteration, and interviewing inhabitants along the reaches. The past maximum flood water level pointed out by inhabitants should be measured together with the river cross section by survey equipment. From these investigations, we can know the flow cross sectional area, (A) and hydraulic gradient, (I).

Table Roughness Coefficient, n

Materials and Conditions of Channel		Roughness Coefficient Min.	Mean	Max.
Small river in plain				
1.	no weed, straight, no deep pools at the time of full water lev	0.025	0.030	0.033
2.	ditto, and stone and weed existing	0.030	0.035	0.040
3.	shallows	0.033	0.040	0.045
4.	ditto, and some stones and weed	0.035	0.045	0.050
5.	ditto, and more variation of gradient and cross section	0.040	0.048	0.055
6.	the same as item 4, but many stones	0.045	0.050	0.060
7.	weed and deep pools in calm flow reaches	0.050	0.070	0.080
8.	etc.	0.075	0.100	0.115
Rivers in hilly area having little plants in the river bed and steep gradient in river banks. Trees and shrubs along banks is submerged at storm time.				
1.	cobble stones and gravels in riverbed	0.030	0.040	0.050
2.	large cobble stones	0.040	0.050	0.070
Big river				
1.	regular cross section with no large cobble stones and no trees & shrubs	0.025		0.060
2.	irregular coarse cross section	0.035		0.100

Source: Irrigation and Drainage Handbook, 5th Edition, Japanese Society of Irri. Drain. and Reclamation Engineering

11.3 Water Quality

The pH and salinity are checked for irrigation purposes, and other items are be evaluated for drinking water. The water quality standard by item is given in Table 11.1.

From the viewpoint of the irrigation water quality (refer to FAO standard values in Table 11.1), neither soil nor cropping problems are ordinarily experienced or recognized when water is used that has values less than the FAO standard for “no degree of restriction on use”. With restriction in the slight to moderate range, gradually increasing care in selection of crop and management alternatives is required, if full yield potential is to be achieved. When water exceeds the values shown as severe restriction, soil and cropping problems or reduced yield will be experienced. Therefore, if water quality values are found that indicate restricted irrigation use, it is recommendable that a series of pilot farming studies be conducted to determine the farming and cropping techniques to be adopted before initiating the use of the water in the project.

To cope with the salinity problem observed occasionally in flood irrigation system, several management options for salinity control are available as follows.

- Drainage improvement to control and stabilize the shallow water table
- Leaching to control soluble salts by application of extra water
- Improvement of farming/cropping practice (land leveling or grading, timing of irrigation, seeding, fertilization, deep cultivation, etc.)
- Changing or mixing water supplies
- Examination and application of salt-tolerant crops

From the viewpoint of drinking water, the basic principle is to maintain the existing water quality to the greatest extent possible, since the water is generally used both for irrigation and for drinking or domestic purpose. This means that the plan and practice of the farming/cropping should be considered carefully in order not to cause the serious water pollution, such as:

- Organic pollution mainly caused by the agricultural effluent or solute of fertilizer,
- Bacterial pollution mainly caused by the enhancement of livestock husbandry, and
- Toxic pollution mainly caused by the agro-chemicals.

CHAPTER 12 AGRICULTURE

12.1 Flow of Planning on Irrigated Agricultural Program

The flow of planning of the agricultural program for the irrigation project is shown below:

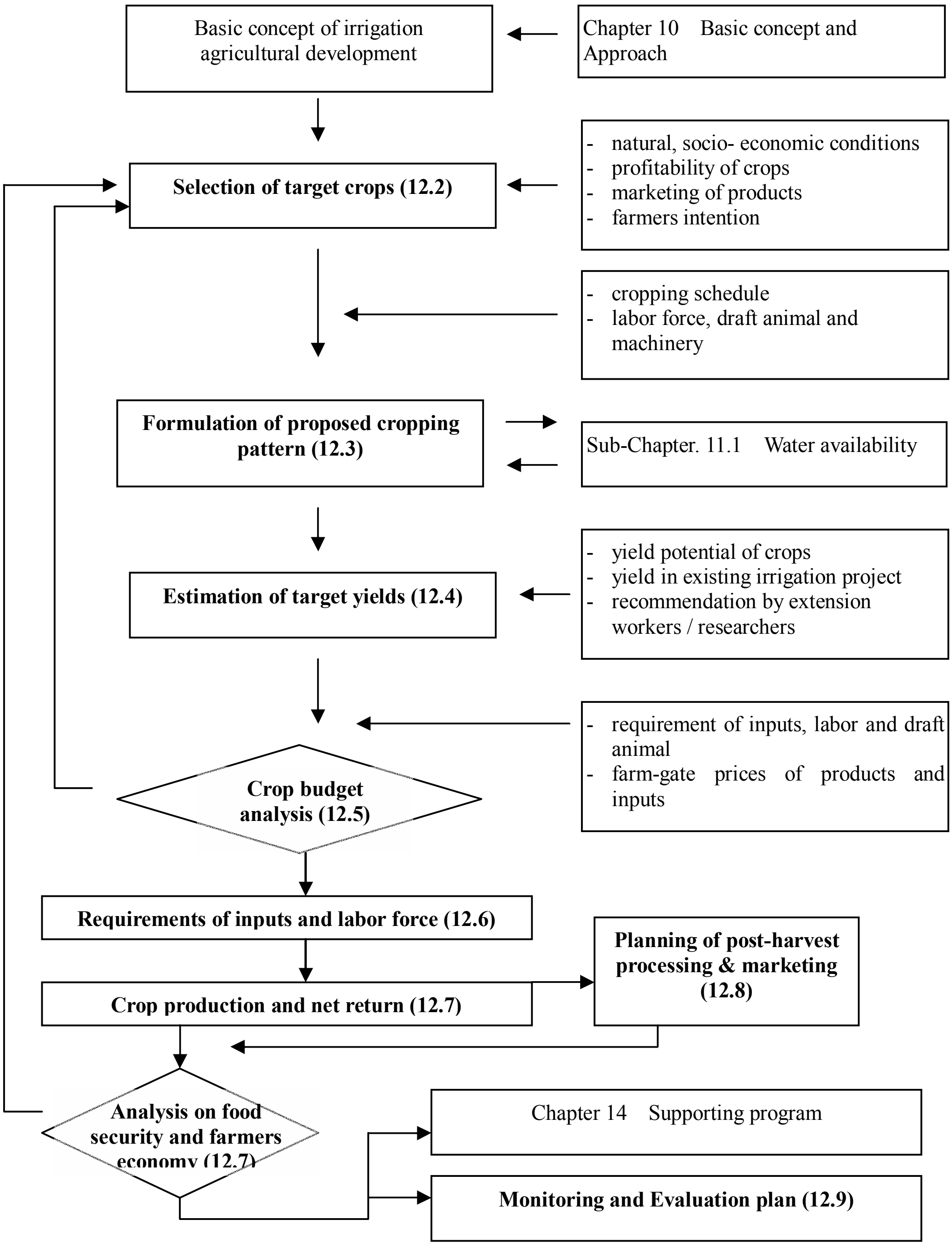

Figure Flow of Planning on Agricultural Program

12.2 Selection of Target Crops

The target crops to be irrigated in the project area should be selected by comprehensive examination of the following items:

i) natural condition: climate and soil in the project area,
ii) availability of irrigation water source,
iii) social and economic conditions: profitability and marketability of crop, food security in and around the project area, availability of labor force, draft animals and inputs required,
iv) situation of beneficiary farmers: awareness and willingness for crop, farming skill level, and financial capacity for investment to the required inputs, and,
v) possibility of introducing support programs such as extension services, input supply, credit, and marketing.

For the above examination, it is necessary to know the ecological and characteristics of farming techniques on the candidate crops, as well as the data and information from the survey on the present conditions on socio-economy and agriculture as mentioned in Part-1 of this guideline. The target crops should be selected in coordination with economists, agronomists and extension officers of MAFF and after obtaining the opinion and recommendations of agricultural researchers.

The main crop to be selected would be paddy in due consideration of the situation of rural areas of Cambodia for attainment of food sufficiency and farmers consciousness at present. Food-sufficiency at the national level has been attained through the increase of rice production. However, it is not quite satisfactory in terms of stable sufficiency. There are also still a lot of rice-deficit areas in the country and the population is still growing at a high rate. Paddy must be the most major crop for the irrigation project. As for varieties of paddy rice, it should be duly examined , local varieties (longer growing period) or high yielding ones (shorter growing period) should be selected, considering the irrigable period, market prices and farmers intention.

On the other hand, the introduction of cash crops, namely, diversified crops including vegetables, will be important to improve farmers economic conditions. Those crops will bring more cash income to the farmers. However, crop diversification should be determined in conformity with market demand, agricultural potential, and the farming practices currently undertaken.

The target crops will be selected the range of candidate crops that are planted around the project area at the time of project planning varieties selected should be desired by the beneficiary farmers and considered suitable in the project area.

Items to be examined for selection of the target crops are shown in Table 12.1 and a sample of the results of an examination for crop selection is given in Table 12.2.

12.3 Formulation of Proposed Cropping Pattern

The cropping schedule of the target crops selected for irrigated agriculture is shown in the form (figure) of the "cropping pattern". The cropping pattern shows information of the cropping plan in a simple format with; i) name of crop, ii) planted area, iii) growing season and period of crop, iv) start and end of planting and harvesting, and v) period of land preparation / nursery.

The cropping pattern has to be examined considering climatic conditions during proposed harvesting and/or drying period as well as the availability of labor force, draft animals and agricultural machinery. The proposed cropping pattern will be finalized after an examination of the balance between water availability and requirement as mentioned in Section 11.1 "Water Availability".

A sample proposed cropping pattern, which was proposed on the basis of the present cropping pattern in the project area, is shown in Fig. 12.1.

12.4 Estimation of Target Yields

The anticipated yields of the target crops under irrigated condition will be estimated on the basis of the following data and information:

- present yield level under irrigation in and around the project area,
- yield in years of good climatic (rainfall) condition in and around the project area,
- opinions of extension workers and agronomists of MAFF (DAFF),
- yield by field level trials by agricultural research stations,
- possibility of extension activity and other support program in the project area and,
- possibility of improvement of farming practices such as applying of good seeds, fertilizers, and plant protection.

It is essential that the anticipated unit yield is a target yield on the average after the completion of the construction of the irrigation facilities by the project. The yield will increase gradually after distribution of water by the project according to the improvement of cultivation skill of farmers and supporting services. It usually takes several years to attain the target yield.

The target yields of irrigated paddy in the near future in Cambodia are roughly estimated on the basis of the present circumstances of paddy production as shown in the following table.

Table Anticipated Paddy Yield in Irrigation Project

Variety	Dry season	Rainy season
HYV	3.0 - 4.0 ton/ha	3.0 - 3.5 ton/ha
Local variety	2.5 - 3.5 ton/ha	2.0 - 3.0 ton/ha

12.5 Crop Budget Analysis

The proposed crop budget shows the values of gross income from products, production cost and net return per unit area (ha) of each crop for the future plan. The crop budget gives basic data for the estimation of irrigation benefit from crop production and the prospective farmers economy. The profitability of crops can be estimated from a comparison of the crop budgets. Table 12.3 shows a sample of proposed crop budgets compared with those under present condition.

The gross income of the proposed crop budget is given on the basis of the anticipated unit yield and farm-gate price of the product.

Direct production cost is given on the basis of the required quantities and the unit prices of inputs, hired labor force, draft animal and others. Cost of the family labor force is usually excluded from the production cost.

Indirect cost includes the tax on farmland and products, irrigation service fee depreciation cost, and land fee.

12.6 Examination of Input and Labor Force Requirements

The availability of the required inputs for the proposed agricultural production program should be examined from the viewpoint of supply market: the quantity, quality, supplying season and prices. If there is a problem in the input supply, the production plan would not be feasible. In this case, it is necessary to change the plan or to provide a supporting program, for example, paddy seed production program for the deficit of good seed, and fertilizer transportation program into the project area for the difficulty of fertilizer transportation. A sample estimation of the input requirement is given in Table 12.4.

The labor force requirement for the agricultural production program would generally increase from that of the present condition. The labor force balance between requirements and availability should be carefully examined for the busiest season, i.e., planting and harvesting periods. The availability of the labor force for on-farm work can be estimated with some assumptions on the average labor force per family, workable labor force for on-farm work, and workable days in the field. Some proportion of the family labor force would work for non-farm work such as housekeeping, childcare, livestock raising, marketing of products, etc. A sample of the examination of the labor force balance by month is given in Table 12.5.

If the labor requirement in the busiest season is not satisfied, mechanization of farming practices or availability of hired labor force from outside the project area should be considered.

12.7 Prospective Crop Production and Net Profit

12.7.1 Prospective Crop Production

The prospective crop production by the project can be estimated from the proposed planted areas and unit yields. The production increase by the project can be given by the differences between conditions of "with-project" (proposed plan) and "without-project[7]". A sample of the prospective crop production is given in Table 12.6.

12.7.2 Food Security Analysis

A supply demand and analysis of the products of the future plan is necessary for the assessment of food security as well as the marketing plan of products. The procedures of examinations are shown below:

(1) Food balance:

It is necessary to analyze the food balance for a paddy production project, especially, for a project which aims to improve food security or to market a large quantity of surplus paddy. Food security in and around the project area will be examined by the following MAFF indicators:

Table Standard Indicators for Food Security Examination

1. Average rice demand per capita	151.2 kg
2. Recovery rate of rice milling	62%
3. Paddy demand per capita (1) / (2)	244 kg
4. Post-harvest loss and reserve for seed	17% of production
5. Required paddy production per capita (3) / (100% - (4))	294 kg

Source: MAFF

In the above estimation, the population in the target area at the target year should

[7] "Without-project condition" is not same as present condition. However, the present condition could be used expediently for without project conditions if it is estimated that both conditions of "without" and

be forecasted by using population growth rate. In these projects, it is important to estimate the percentage improvement in food sufficiency, or what volume of surplus paddy would be marketed.

(2) Supply and Demand Analysis of Cash Crops

As for cash crops, a balance analysis on the supply and demand is necessary for the future marketing plan of the product. An examination of the target marketing area is required: in the project area, rural area in and around the project area, near towns/cities, or in large cities. For the analysis, the marketing including market channel, target market, marketed volume and condition of supply-demand balance in the market, seasonable fluctuation of price by the products would be examined.

12.7.3 Financial Irrigation Benefit

Financial irrigation benefit by the crop production is given by the difference between the total net returns under with-project and without-project conditions, namely “incremental benefit”. Table 12.7 shows a sample of analysis of the incremental benefit.

12.7.4 Household Economy Analysis

The profit produced from cropping under the irrigation project will increase the farmers’ income. A household economy analysis is used to evaluate the contribution of the irrigation project to the household economy. Table 12.7 shows the estimation of gross income, production cost, net return and incremental net return on a household of an average sized farm.

12.8 Planning of Post-harvest Processing and Marketing

The supporting program should be formulated in view of post-harvest processing and marketing in order to ensure the income increase of producers expected in the agricultural production plan.

Under the free market economy, the agricultural products transported from various production areas and also imported from Vietnam and Thailand compete with each other in the markets in Cambodia. Therefore, it is necessary to understand that no product can be guaranteed to be sold at a satisfactory range of prices in the market unless the product is superior to other competitive products and/or meets market needs. Then the support program for marketing is desirable for producers to satisfy the economic effect by the agricultural production plan.

“present” would be similar.

The planning of a support program should be conducted based on the agricultural production plan as shown below:

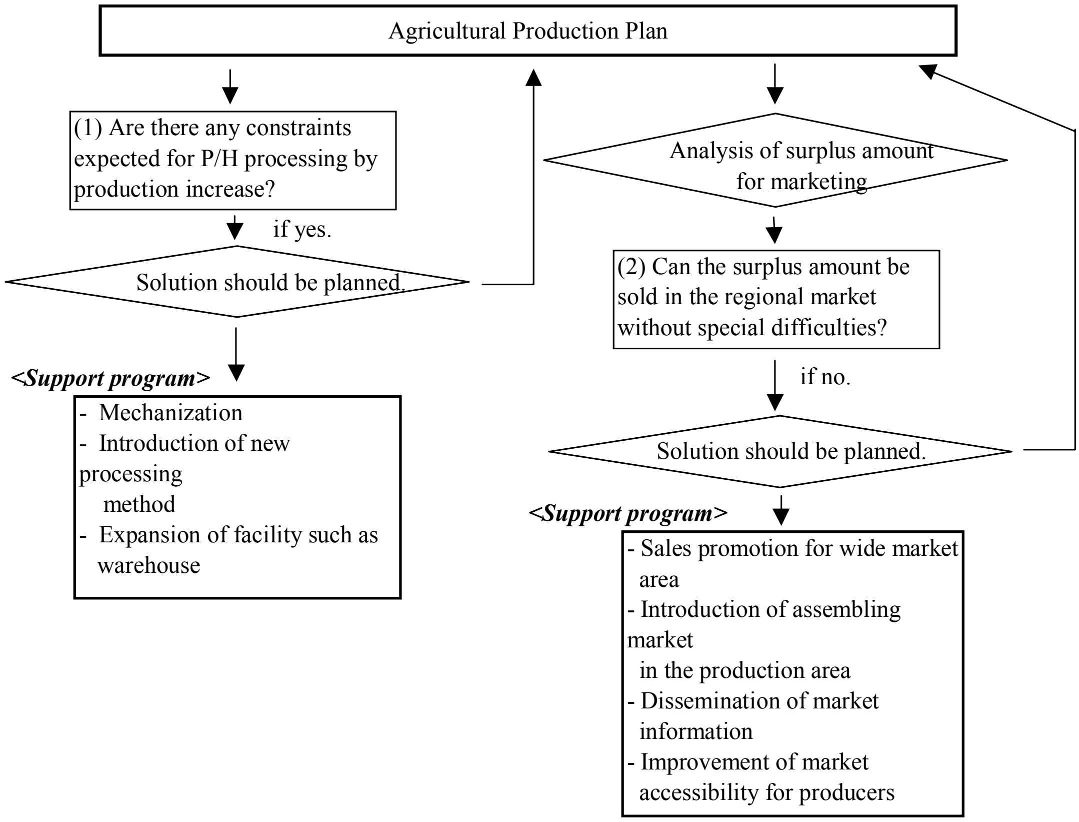

Figure Flow of planning on Post-harvest and Processing

To implement these supporting programs, inputs such as credit, facilities and equipment and training would be necessary. Therefore, collaboration with the official agencies concerned such as MAFF, MRD, MOT and NGOs that are implementing the same or similar programs in the project area would be advisable from the planning stage.

12.9 Monitoring and Evaluation Plan

Monitoring and Evaluation (M&E) of the agricultural production in the project should be conducted after the irrigation system is constructed in order to assess the project impact, to clarify problems of the beneficiaries and identify the reasons, to learn lessons from the project, and to practically use the lessons in subsequent project planning.

The general indicators and procedures for M&E are shown in **FORM 12** consisting of the following parameters.

- Production volume by crops (planted area and average yield)

- Actual input application
- Farm-gate price of products
- Sold volume and value of products
- Food sufficiency
- Inputs supply
- Extension activities
- Activities of farmers groups concerning agriculture

CHAPTER 13 IRRIGATION AND DRAINAGE

13.1 Review of Design Concept of the Existing Facilities

13.1.1 Review of Design Background

For most existing irrigation systems, particularly those constructed during the Pol Pot Regime, few documents and drawings of irrigation planning and design are available at present. Therefore, it is difficult to grasp the concepts of the original plans and designs of the existing facilities. For planning the rehabilitation and reconstruction of existing irrigation systems, it is necessary to grasp the characteristics of the system at the very beginning of the work. An outline of the original plan, design standard, and basic information for the design should be confirmed either by site reconnaissance, survey or interview to the previous users of the facilities.

The following information should be confirmed at the initial stage of the planning:

- Outline of the Original Plan
  - topography, geology, and layout of existing irrigation system,
  - farming practices and cropping pattern of the proposed area,
  - outline of the original irrigation plan (irrigation area, irrigation facilities, etc)
- Geographic and topographic conditions (map, slope, depression, river, drain, upland, etc.)
- Land use and land unit by elevation
- Meteorology and hydrology,
- Capacity and function of existing irrigation facilities
- Design standard

13.1.2 Special Consideration on Existing System

According to the results of the Study, many technical problems with the existing facilities may be found. Some of these problems might not be solved by rehabilitation and reconstruction of the original structures. The following issues should be duly examined on the existing facilities.

(1) Route of Canals

In some cases, the existing canals are located in a disadvantageous position that most of the canal sections were constructed by excavation. In Cambodia, so called “dispersible soil” are dominantly distributed. Earth structures in dispersible soil easily collapse when the soil has a high water content. The canal route should properly be determined so that the balance of cut and embankment be maintained and the cut depth be kept no more than two (2) meters. If the original route does not satisfy such requirements, an alternative route of the canal should be considered.

(2) Embankment Materials

For many reservoirs and dikes, local materials at the construction site are used without proper treatment. As mentioned above, sandy or dispersible soils are not suitable for embankment, and impervious materials such as laterite should be used. Protection of the dike such as rip rap is also necessary. Thus, location and volume of construction materials for the embankment should be carefully investigated.

(3) Spillway of Reservoir

Many reservoirs have lost functions due to damage of dikes. Major reasons of the damage are; i) lack of spillway, ii) poor maneuverability of gates (stop log), iii) poor embankment materials (sand, dispersible soils), iv) inadequate slope of embankment, v) poor protection of embankment and structures, etc.

Thus, overflow-type spillways that require little maintenance and operation should be constructed, and operational spillways should have well-maintained gates to allows prompt operation during floods.

(4) Canal Crossing Structures

In many cases, the capacity of canal crossing structures (bridge, cross-drain, culvert, aqueduct, etc.) is insufficient, and flood water often damages the canal itself. Thus the capacity of the crossing structures should properly be re-examined.

(5) Capacity of Existing Canals

Existing canals are used not only for irrigation but also for drainage. Thus the proposed capacity of canals should be determined taking such conjunctive purposes into account.

13.2 Setting of Target Level of Rehabilitation and Reconstruction

The target level of rehabilitation and reconstruction of irrigation and drainage system is described in the following and summarized in Table 13.1.

13.2.1 Irrigation Plan

(1) Irrigation Method

As for paddy rice irrigation, “Ponding Irrigation Method” or “Water Saving

Irrigation Method" should be used. If the water resources are not sufficient for the ponding irrigation method, the water saving irrigation method should be applied for paddy rice so that the limited water resources be saved. Rotation irrigation is applied for tertiary blocks. The main and secondary canals should be used for 24 hours and diversion water level would be maintained with check structures. The concepts of the irrigation methods are mentioned in Sub-section 13.4.1 "Field Application System", while the procedures for water requirement estimation are mentioned in Sub-section 13.4.2 "Net Irrigation Water Requirements".

(2) Dependability

Eighty percent or 4 in 5 year should be adopted as the dependability level of irrigation. At this probability, the proposed irrigation area can be irrigated with the proposed water volume at Eighty percent dependability.

13.2.2 Irrigation Facilities

(1) Reservoirs

1) Design Flood

Design flood of reservoirs should conform to the following criteria:

Table Design Flood

Conditions on Reservoirs	Target Development Level
Design flood for spillway on the perennial river.	Flood of 100 year recurrence period, or the maximum flood in the past (to be estimated by flood trace and interview to the residents in the vicinity), whichever is larger
Design flood for small reservoirs with a catchment area less than 10 km^2 or total storage capacity less than 50,000 m^3.	Flood of 20 year recurrence period.

The procedures for estimating of the design flood are described in detail in Section 11.2 "Flood".

2) Dike

Reservoirs dikes should be constructed with earth materials. The maximum dike height should basically be limited to 5 m so that stability of the dike is maintained. If the dike height exceeds 5 m, stability analysis should be conducted. Local materials near the proposed location can be used if the materials are not "sandy"[8] or dispersible. The slope on the reservoir side

[8] Here, "sandy" means soils consisting of or more than 75 % sand. If 15 % or more clay is included , the materials could be used for embankment materials of homogeneous type.

should be protected with impervious materials and rip rap. Standard sections of the dike are shown in Fig 13.1. If impervious materials could not be obtained, the embankment slope would have to be changed to be gentler so that the stability of the dike can be secured. As for rehabilitation of the existing dikes, reinforcement works as shown in Fig. 13.2 are recommended.

3) Intake Structure

The intake structure should consist of gates that can be operated manually. Gate size should be determined so that maneuverability is secured. The gate sill level would be set at the estimated dead storage level after 20 years of operation. Water levels of the reservoir are mentioned in Section 13.5.

4) Spillway

An overflow-type spillway should be provided so that rapid floods can be discharged without fail. If the design flood discharge is extraordinarily lrge, due to a large catchment area, an operational spillway and emergency spillway should be proposed separately. Since the cost of the spillway is a large part of the total construction cost, a simple structure type with local materials should be examined and adopted. A gate outlet would be constructed near the overflow-type spillway so that the water level in the reservoir could be controlled, even below the full supply level, and to allow river maintenance flow to be discharged.

5) Freeboard

The freeboard of a reservoir should be basically no less than 0.90 m. For small reservoirs with a catchment area less than 10 km^2, or total storage capacity less than 50,000 m^3, a freeboard of 0.60 m could be adopted.

6) Sedimentation

Sedimentation of the reservoirs should be estimated for determining the required dead storage capacity. A standard unit sedimentation rate of 0.1 $mm/km^2/year$ could be used for estimation of the sediment volume. The sediment level after 20 years that should be adopted is the “low water level”, i.e. the intake level.

(2) Canals

1) Canal Network and Irrigation Block

The canals network usually consists of main canal(s), secondary canals, tertiary canals and water courses. The main and secondary canals would have check gates and diversion gate structures so that discharge could be controlled.

The off-take to tertiary blocks would also have a check structure (gate or stop log) and intake gate to control the water flow. The area of a tertiary block would be about 50 ha, which would be located within a village. Length of a tertiary canal would not exceed 1 km. Diversion from the tertiary canal to the water courses would be controlled without gate structures. The tertiary canal and water courses should have sufficient capacity to enable rotation of irrigation.

2) Lining

The necessity of lining should be basically judged from the soil characteristics of the cut portion and embankment materials. For the lining, earth lining would be the first option with Manning's roughness coefficient of 0.025[9]. In case that design velocity[10] cannot be maintained, lining with soil cement, concrete panel and/or in situ concrete should be examined. Where canals run through areas of sandy soils they should be properly lined with impervious soil materials or other lining materials. A typical canal section is given in Fig. 13.3. It should be noted that the earth-lined canal requires routine maintenance works to remove weeds and sediments, which is to be done by FWUC. From another point of view, lining of the canals would mitigate the burden of routine maintenance on the FWUC. So, the lining will increase initial investment cost, but will reduce the maintenance cost.

3) Utilization of Existing Capacity

The priority for rehabilitation and reconstruction of the canals should be given to secure required water flow in the canal. For this, existing canal sections be utilized as much as possible to minimize the earthwork volume. In this case, a larger roughness number of 0.035 (if the existing section is fully utilized) or 0.030 (if the existing section is partly used) should be adopted. Details are illustrated in Fig. 13.4. If the existing canal is used for the full stretch (BP to EP), the capacity and water level in the canal should

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[9] Adopt of adequate roughness coefficient is mentioned in Sub-section 11.2.5 "Hydraulic Calculation by Manning Formula"

[10] Refer to Section 13.6.7 "Preliminary Design of Canal System"

be checked by non-uniform flow analysis.

4) Freeboard

Taking into account the movement of water surface by backwater, etc., a certain amount of freeboard should be provided. The depth of freeboard is mentioned in Sub-section 13.6.7 “Preliminary Design of Canal System”.

5) Conjunctive Use of Canal

Irrigation canals should primarily be designed with a capacity for the design amount of irrigation water. Drained water from the surrounding farm field might be drained to the irrigation canal through inlet structure or field outlet of the paddy field. Such inflow would be drained using the free board or existing capacity of the canal.

6) Inspection Road

The main canal and secondary canals whose command area exceeds 1,000 ha should have an inspection road of 4 m in total width. The inspection road would be used for vehicles. The canals for the command area of less than 1,000 ha would have smaller dimensions, and maintenance works would not require construction machines. Thus, the total width of the inspection road for the secondary canal for less than 1,000 ha would be 2.0 m, which is accessible by motorcycle. In case a canals runs along an existing road whose dimension satisfies the above-mentioned widths, the inspection road would not be proposed.

7) Crossing Structures

Cross drains and road culverts should be planned with concrete pipes. The minimum diameter of the pipe would be 0.60 m.

8) Measuring Devices

Two water level gauges would be attached at diversion facilities from the main canal to the secondary canal. The gauges would be installed both on the upstream (main canal) and downstream (secondary canal). Rotational irrigation would be applied at the tertiary block, then the water distribution for the tertiary block would be controlled by time. Opening of the gate would be controlled according to the water level in the tertiary canal.

(3) Pond

1) Pond

The depth of excavated pond should be 3 m so that a certain amount of groundwater would be utilized. The side slope of pond should be 1:1.5. Lining of the side slope is not considered necessary. A small dike should be constructed around the pond and should be constructed so as to avoid erosion of the side slope.

2) Related Facilities

A wooden ladder as a step and fence around the dike should be included.

13.2.3 Drainage Facilities

(1) Improvement Policy

In Cambodia, paddy rice cultivation utilizing flooding condition, namely, “receding cultivation” is conducted in many locations.

However, drains should basically be designed to have sufficient capacity up to the tail end, namely, rivers. If the existing capacity of the tail end river is insufficient, the capacity should be enlarged either by excavation or construction of dikes. Considering the large work volume for the construction works, drainage improvement would be considered for the area that has existing drains, streams or rivers with sufficient capacity.

(2) Design Capacity

For irrigation rehabilitation and reconstruction planning, drainage is primarily considered “to drain irrigation water outside the area” for maintaining the existing condition. A tertiary block should have field drains with a capacity equivalent to the tertiary irrigation canals. The tertiary drains should be connected to a larger drains or irrigation canals to allow the areas downstream to reuse the drained water.

If, the capacity of the existing canals and rivers is sufficient, the drainage improvement would be considered with a unit drainage requirement for draining consecutive 3-day rainfall of 1 in 10 year recurrence period within 3 days following inundation. The unit drainage requirement would be reduced by accounting for storage (water holding capacity) on the paddy field. Details are mentioned in Sub-section 13.6.7 “Preliminary Design of Canal Systems” and Section 13.9 “Drainage”.

13.2.4 Responsibility

(1) Construction

Engineering services for the whole system[11] and construction of the irrigation system consisting of diversion facilities, reservoirs, main, secondary and tertiary canals would be done by the public services (MOWRAM). Construction of watercourses would be done by the beneficiaries with the technical guidance of MOWRAM.

(2) Operation and Maintenance

According to the government policy, the irrigation and drainage facilities should be handed over to FWUC, who should conduct the operation and maintenance.

However, for medium to large schemes, it is difficult for the beneficiaries to undertake O&M immediately after completion of the construction.

On-the-job training of FWUC for a certain period (for example 4 years) after construction should be conducted by MOWRAM.

[11] Survey, planning, design, environmental impact assessment for the whole irrigation system consisting of diversion facilities, reservoirs, main and secondary canals, tertiary canals, and drains.

13.3 Approach of Irrigation System Planning

Irrigation systems are generally planned according to the following process.

(1) Hydrological Analyses

Hydrological analyses are done on water availability and floods for providing basic parameters for design of diversion systems and for planning the irrigation system. Half monthly or monthly runoff of 80 % dependability at the proposed intake point is estimated as the available water, and design floods of several recurrence periods are estimated for the design of spillways and gates of reservoirs and drains.

(2) Estimation of Irrigation Water Requirement

Irrigation water requirement is estimated from water consumption use of of proposed crops, which is estimated on the basis of potential evapo-transpiration. Details of the procedure for estimating irrigation water requirement are mentioned in Section 13.4.

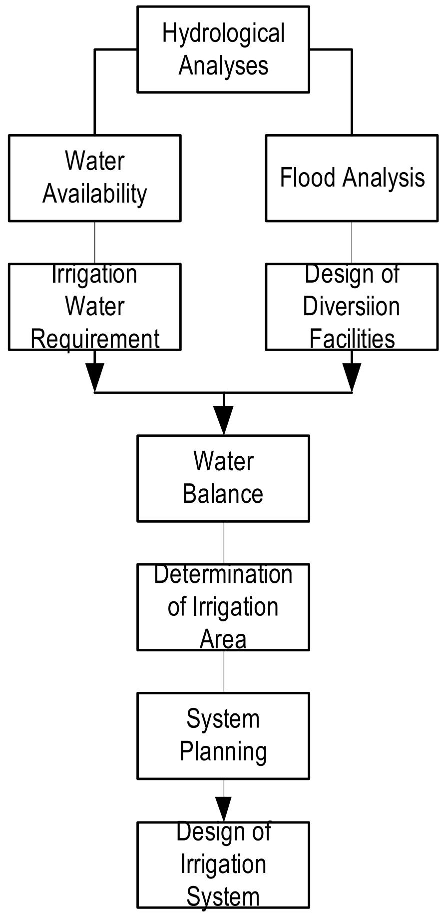


Figure Irrigation System Planning

(3) Water Balance

A water balance is conducted on the basis of the available water and irrigation requirement. Irrigable area is estimated by dividing the quantity of available water by the unit irrigation water requirement. For the irrigation system that includes a reservoir, a simulation of reservoir operation should also be conducted for estimating of the irrigation area. Then the irrigable area of 80 % dependability is regarded as the irrigation area. The water balance procedure is described in detail in Section 13.5.

(4) Determination of Irrigation Area

According to the irrigable area estimated in the water balance study, the irrigation area would be delineated on the map. It should be noted that the irrigable area is the "net area", namely the cultivated area, while "gross area" includes land for canals, bunds of farm fields, inspection roads, etc.

(5) System Planning

According to the irrigation command area delineated on the map, irrigation blocks will be determined for each canal system.

13.4 Irrigation Water Requirement

13.4.1 Field Application System

Irrigation practices at the field level largely influence the irrigation efficiency. In this sub-section, field irrigation methods for paddy rice and diversified crops are discussed prior to estimation of the irrigation water requirements.

(1) Irrigation Method for Paddy Rice Cultivation

1) Ponding Irrigation

Ponding irrigation is the typical irrigation method used for paddy rice cultivation. A farm plot is surrounded by bunds with a height of about 20 cm. The irrigation water is stored on the farm plot, and the paddy rice is planted. The advantage and disadvantages of the ponding irrigation method are as follows:

<u>Advantage</u>

- weed control is easier,
- water management is easier (frequent adjustment is not necessary)
- retards the effect of fertilizer,
- leaches of toxic materials for plants, etc.

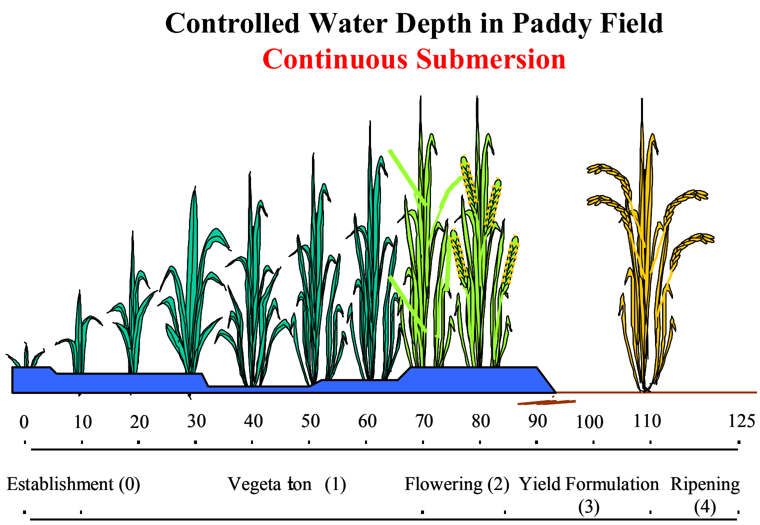


Figure Ponding Irrigation

2) Water Saving Irrigation

Though the ponding irrigation has the above-mentioned advantages, paddy rice itself does not require the ponding biologically. The water saving irrigation method is a procedure to secure the necessary water during the important growing periods such as establishment and flowering, and to supply the minimum water needed to maintain sdequate soil moisture during other growing periods. By applying the method, the yield of rice would be maintained or improved. However, more precise water management would be required for this method.

For example, the peak water requirement was reduced by 25 % by application of the water saving irrigation method for the Upper Slakou River Basin Irrigation Plan.

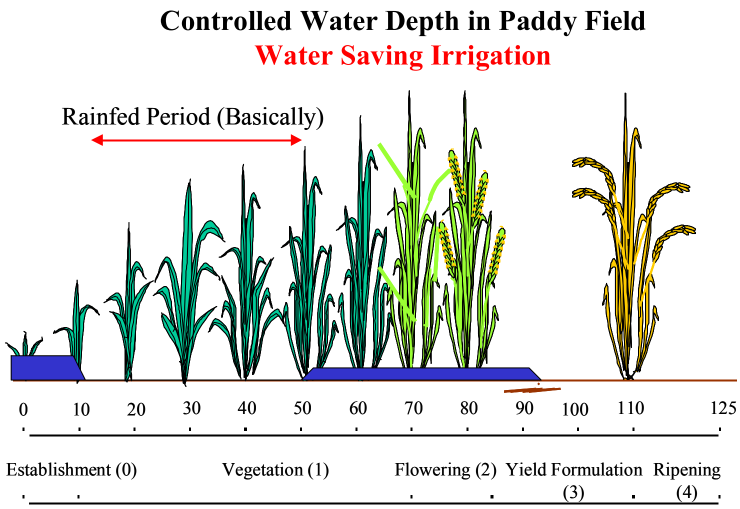


Figure Water Saving Irrigation

Operation by the water saving irrigation method is described in Sub-section 16.1.2 "Operation of Facilities".

3) Plot-to-plot Irrigation

Many existing irrigation systems have poor field irrigation canal network, and the water is distributed from plot to plot. In this case, irrigation water to the end plot is not always guaranteed because the water is not released unless the plots on the upstream are sufficiently irrigated. Application of water by plot-to-plot irrigation is one of the main causes of delay to the cropping schedule and difficulties in water management. Tertiary canal and watercourses should be properly located to reduce the distance of the plot-to-plot distribution as a whole.

(2) Irrigation Method for Diversified Crop Cultivation

1) Furrow Irrigation

Irrigation for diversified crops is generally conducted by furrow irrigation. Secondary crops and vegetables cultivated in the rice field are planted on field ridges formed in the field so that excess soil moisture in the root zone is properly drained. Furrow irrigation is conducted by distributing water through ditches between the ridges. The irrigation efficiency of furrow irrigation is not very high because the water also infiltrates into the soil outside the root zone of crops.

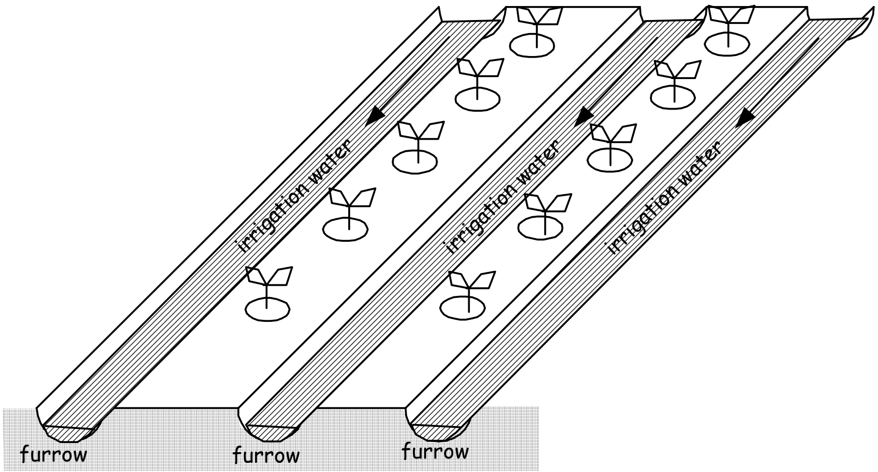


Figure Furrow Irrigation

2) Manual Irrigation

Manual irrigation is conducted by manpower with watering pots. Water is sometimes stored at a field storage site and applied crop by crop. The manual irrigation method is not applicable for large areas, but the irrigation efficiency is quite high.

13.4.2 Net Irrigation Water Requirements

This sub-section explains a method for estimating irrigation water requirements in accordance with Irrigation and Drainage Paper No. 24. For water saving irrigation, FAO Irrigation and Drainage Paper No.33 can be referred to.

(1) Paddy

Fig. 13.5 shows the calculation process of irrigation water requirements for paddy fields.

1) Data and information required

Data and information required are rainfall data, climate data, cropping pattern and percolation loss in paddy fields. Daily rainfall data should be collected. Climate data should consist of temperature, humidity, sunshine hours and wind velocity.

2) Net Irrigation water requirement in nursery bed

$$NIWR_n = LP + CU + P - ER$$

where, $NIWR_n$: net irrigation water requirement in nursery (mm)

LP: water requirement for land preparation (mm).

Water requirement for land preparation usually ranges from 100 mm to 200 mm, depending on soil properties and soil water content. In the early rainy season, soil water content is low and thus water requirement for land preparation is large. In the peak rainy season, around September, the pore space of soil is almost full of water and so the water requirements for land preparation are very low. In habitual inundation area such as downstream area of Thnot Te Reservoir, no water is required for land preparation because the residual water can be utilized in lowland.

Standard water requirement for land preparation

Early rainy season:	150 mm ～ 200 mm
Mid rainy season:	120 mm ～ 150 mm
Peak rainy season:	50 mm ～ 100 mm

Habitual inundation area: no need

CU: consumptive use of water (mm), CU = kc ETo

where, kc: crop coefficient.

The crop coefficient, kc is usually 1.0 in nursery bed.

ETo: potential evapotranspiration (mm) estimated by the modified Penman method that is explained in section (3).

P: percolation loss (mm).

3) Net Irrigation water requirement in main fields

$$NIWR_m = LP + (CU + P + S - ER)$$

where, $NIWR_m$: net irrigation water requirement in main fields (mm)

LP: water requirement for land preparation (mm)

Land preparation for main fields is principally similar to that for nursery beds.

CU: consumptive use of water (mm), CU = kc ETo

where, kc: crop coefficient for paddy growing in the rainy season. supposed to be as follows in accordance with the FAO Irrigation and Drainage Paper 24.

Table kc for medium paddy every half a month

1st	2nd	3rd	4th	5th	6th	7th
1.10	1.10	1.10	1.05	1.05	1.05	0.95

Table kc for early paddy for every half a month

1st	2nd	3rd	4th	5th
1.10	1.10	1.05	1.05	0.95

ETo: potential evapotranspiration (mm) estimated by the modified Penman method, see Section (3)

P: percolation (mm),

Most of soils in the flat plain in Takeo Province fall into “Prey Khmer”and “Preteah Lang” soil groups. According to the experiments carried out in the flat plain along the Slakou River, percolation loss in these soil groups is estimated at around 3 mm/day.

<u>In the estimate of irrigation water requirements, percolation losses should be accounted only during the period of 30 days starting at head initiation till the end of flowering.</u> This water saving irrigation can make water saving of 20 % to 25 % of total net irrigation water requirements made in the lowland where percolation loss is 2 mm to 3 mm/day. Supplemental irrigation for the moderate submergence at head initiation is required, when surface of paddy fields is dry. This amount is supposed to be 30 mm.

ER: effective rainfall (mm),

Effective rainfall is calculated on the following conditions:

When daily rainfall is less than 5 mm, effective rainfall = 0.0.

When daily rainfall ranges from 5 mm to 80 mm, effective rainfall is 80 % of the daily rainfall.

When daily rainfall is more than 80 mm, effective rainfall is 64 mm.

If daily rainfall is not available, monthly effective rainfall will be assumed to be 75 % of the monthly rainfall.

4) Total net irrigation water requirement

$$NIWR_{paddy} = NIWR_n \times Af + NIWR_m$$

where,

$NIWR_{paddy}$: net irrigation water requirements of paddy

Af: area factor. Nursery area is about 5 % of the main paddy field area.

Thus Af = 0.05.

(2) Diversified crops (Upland crops)

Fig. 13.6 shows the calculation process of irrigation water requirements for upland crop fields.

$$NIWR_{crop} = LP + CU - ER$$

where, $NIWR_{crop}$: net irrigation water requirement for upland crops (mm)

LP: water requirements for land preparation (mm),
If soil is dry and hard, water is supplied for land preparation. When upland crops are planted in the late rainy season, November and December or during the rainy season, it is expected that topsoil layer contains a moderate amount of water and plowing can be easily practiced. In the rainy season, therefore, no water is required for land preparation.

CU: consumptive use of water (mm), CU = kc ETo

where, kc: crop coefficient.

The growing period and crop coefficient are different among the various kinds of upland crops actually planted. In case of irrigation planning at master plan and feasibility study stage, the average growing period and average crop coefficient are usually used. The following table shows an example of average crop coefficient of upland crops.

Table kc for every half month

1st	2nd	3rd	4th	5th	6th
0.50	0.55	0.70	0.80	0.90	0.60

ETo: potential evapotranspiration (mm) estimated by the modified Penman method, see Section (3)

ER: effective rainfall (mm),

Effective rainfall for upland crops can be estimated by various methods. One is the evapotranspiration / precipitation ratio method, Table 34 in the FAO Irrigation and Drainage Paper 24, shown as follows.

Table Average Monthly Effective Rainfall as Related to Average Monthly ET crop and Mean Monthly Rainfall (USDA (SCS), 1969)

Mean monthly evapo-transpiration (mm) \ Monthly mean rainfall	12.5	25.0	37.5	50.0	62.5	75.0	87.5	**100**	112.5	125.0	137.5	150.0	162.5	175.0	187.5	200.0
25	8	16	24													
50	8	17	25	32	39	46		Average monthly effective rainfall								
75	9	18	27	34	41	48	56	62	69							
100	9	19	28	35	43	52	59	66	73	80	87	94	100			
125	10	20	30	37	46	54	62	70	76	85	92	98	107	116	120	
150	10	21	31	39	49	57	66	**74**	81	89	97	104	112	119	127	133
175	11	23	32	42	52	61	69	78	86	95	103	111	118	126	134	141
200	11	24	33	44	54	64	73	82	91	100	109	117	125	134	142	150
225	12	25	35	47	57	68	78	87	96	106	115	124	132	141	150	159
250	13	25	38	50	61	72	84	92	102	112	121	132	140	150	158	167

20	25	37.5	50	62.5	75	100	125	150	**175**	200	<-Effective storage in soil (mm)
0.73	0.77	0.86	0.93	0.97	1.00	1.02	1.04	1.06	1.07	1.08	<-Storage factor

CALCULATION OF EFFECTIVE RAINFALL FOR UPLAND CROP

Mean monthly rainfall (mm)	100.0	mm	<- Data Input ! (12.5 - 200.0)
Mean potential evapotranspiration (mm)	150.0	mm	<- Data Input ! (25.0 - 250.0)
Effective storage of soil layer (mm)	175.0	mm	<- Data Input ! (20.0 - 200.0)
Effective rainfall for 75 mm (mm)	74.0	mm	
Storage factor	1.07		
Effective rainfall (mm)	**79.2**	mm	<- This is the result !

When effective rainfall is roughly estimated, or the kinds of crops to be planted are not definitely planned, monthly effective rainfall can be simply assumed to be 75 % of the monthly rainfall.

(3) Potential Evapotranspiration (ETo)

Equation of the modified Penman method is:

$$ETo = c\,[\underbrace{W\,Rn}_{\text{radiation term}} + \underbrace{(1-W)\,f(u)\,(ea-ed)}_{\text{aerodynamic term}}]$$

where, W: temperature-related weighting factor

Rn: net radiation in equivalent evaporation in mm/day

f(u): wind-related function

(ea-ed): difference between the saturation vapor pressure at mean air temperature and the mean actual vapor pressure of the air, both in mbar

c: adjustment factor to compensate for the effect of day and night weather conditions

Table Calculation Sheet of Potential Evapotranspiration by Modified Penman

Pochentong Station (11°North, 10 m in Altitude)

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks
A	Tmean (℃)	26.3	27.6	29.3	30.1	29.9	28.9	28.2	28.2	27.9	27.2	26.5	25.9	Input
B	RHmean (%)	72.9	70.5	70.6	71.4	76.4	78.8	82.3	82.9	85.5	86.0	79.6	75.2	Input
C	ea (mbar)	34.2	36.9	40.7	42.6	42.1	39.9	38.4	38.3	37.5	36.2	34.7	33.4	from Table 5
D	ed (mbar)	24.9	26.0	28.7	30.4	32.2	31.4	31.6	31.8	32.1	31.1	27.6	25.1	D=CxB/100
E	(ea-ed) (mbar)	9.3	10.9	12.0	12.2	9.9	8.5	6.8	6.6	5.4	5.1	7.1	8.3	E=D-C
F	Wind, Vw (m/s)	3.1	3.9	4.1	3.8	4.1	4.6	3.9	5.0	4.3	2.7	3.6	3.7	Input, 12 m above
	Wind, Vw (m/s)	2.1	2.7	2.9	2.6	2.8	3.2	2.7	3.5	3.0	1.9	2.5	2.6	at 2m above GL
G	U (km/day)	184.6	235.4	249.1	227.6	246.2	279.4	234.8	301.5	258.7	164.7	216.9	220.9	
H	f(u)	0.77	0.91	0.94	0.88	0.93	1.02	0.90	1.08	0.97	0.71	0.86	0.87	
I	(1-W) of wind & numidity	0.25	0.24	0.23	0.22	0.23	0.23	0.23	0.23	0.24	0.24	0.25	0.26	Table 8
J	Sunshine, n (hr)	8.7	8.6	8.6	8.3	7.3	6.1	5.8	5.9	5.6	5.8	7.4	8.4	Input
K	W of radiation	0.75	0.76	0.78	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.75	0.74	Table 9
L	Ra (mm/day)	13.00	14.00	15.20	15.70	15.60	15.40	15.40	15.50	15.30	14.60	13.50	12.70	Table 10
M	N (hr)	11.50	11.80	12.00	12.30	12.60	12.70	12.60	12.40	12.10	11.80	11.60	11.50	Table 11
N	n/N	0.76	0.73	0.71	0.68	0.58	0.48	0.46	0.48	0.47	0.49	0.64	0.73	N=J/M
O	Rs (mm/day)	8.2	8.6	9.2	9.2	8.4	7.5	7.4	7.6	7.4	7.2	7.7	7.8	O=(0.25+0.5xN)xL
P	Rns (mm/day)	6.1	6.5	6.9	6.9	6.3	5.7	5.5	5.7	5.5	5.4	5.8	5.9	P=(1-α)xO, α = 0.25
Q	f(Tmean)	15.9	16.2	16.5	16.7	16.6	16.4	16.3	16.3	16.2	16.1	16.0	15.8	Table 13
R	f(ed)	0.12	0.12	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.12	$R=0.34-0.044xD^{0.5}$
S	f(n/N)	0.78	0.76	0.74	0.71	0.62	0.53	0.51	0.53	0.52	0.54	0.67	0.76	S=0.1+0.9xN
T	Rnl (mm/day)	1.5	1.4	1.3	1.1	0.9	0.8	0.8	0.8	0.8	0.8	1.2	1.4	T=QxRxS
U	Rn (mm/day)	4.6	5.0	5.6	5.8	5.4	4.8	4.8	4.9	4.8	4.6	4.6	4.4	U=P-T
V	c	0.99	1.00	1.01	1.00	0.98	0.97	0.97	0.95	0.95	0.98	0.98	0.98	Table 16
W	ETo (mm/day)	5.2	6.2	7.0	6.9	6.2	5.6	4.9	5.1	4.7	4.3	4.9	5.0	W=Vx(KxU+IxHxE)

Sample calculation for estimating ETo by modified Penman Method is shown in the following tables. Details can be obtained from the FAO Irrigation and Drainage Paper No.24.

Tables on the following page are all derived from the above-mentioned paper.

Table Parameters Used in FAO Irrigation and Drainage Paper No.24

Table 5 (page 21)

Tmean	ea	Tmean	ea
20	23.4	21	24.9
21	24.9	22	26.4
22	26.4	23	28.1
23	28.1	24	29.8
24	29.8	25	31.7
25	31.7	26	33.6
26	33.6	27	35.7
27	35.7	28	37.8
28	37.8	29	40.1
29	40.1	30	42.4
30	42.4	31	44.9
31	44.9	32	47.6
32	47.6	33	50.3
33	50.3	34	53.2
34	53.2	35	56.2
35	56.2	36	59.4

Table 8 (page 24)

Tmean	(1-W)
20	0.32
21	0.315
22	0.29
23	0.28
24	0.27
25	0.26
26	0.25
27	0.24
28	0.23
29	0.23
30	0.22
31	0.21
32	0.20
33	0.20
34	0.19
35	0.18

at altitude 0 m

Table 9 (page 24)

Tmean	W
20	0.69
21	0.70
22	0.71
23	0.72
24	0.73
25	0.74
26	0.75
27	0.76
28	0.77
29	0.78
30	0.78
31	0.79
32	0.80
33	0.81
34	0.82
35	0.83

at altitude 0 m

Table 13 (page 27)

Tmean	f(Tmean)	Tmean	f(Tmean)
20.0	14.6	28.0	16.3
20.5	14.7	28.5	16.4
21.0	14.8	29.0	16.5
21.5	14.9	29.5	16.6
22.0	15.0	30.0	16.7
22.5	15.1	30.4	16.8
23.0	15.2	30.8	16.9
23.5	15.3	31.2	17.0
24.0	15.4	31.6	17.1
24.4	15.5	32.0	17.2
24.8	15.6	32.4	17.3
25.2	15.7	32.8	17.4
25.6	15.8	33.2	17.5
26.0	15.9	33.6	17.6
26.5	16.0	34.0	17.7
27.0	16.1	34.5	17.8
27.5	16.2	35.0	17.9

Table 10 (page 25)

Northern Hemisphere

North Lat	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
12	12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5
10	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9

Table 11 (page 26)

North Lat	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
15	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
10	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8

Table 16 (page 28)

	Rhmax=60%				Rhmax=90%			
Rs (mm/day)	3	6	9	12	3	6	9	12
Uday (m/sec)	Uday / Unight = 2.0							
0	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.83	0.91	0.99	1.05	0.89	0.98	1.10	1.14
6	0.70	0.80	0.94	1.02	0.79	0.92	1.05	1.12
9	0.59	0.70	0.84	0.95	0.71	0.81	0.96	1.06
	Uday / Unight = 1.0							
0	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.78	0.86	0.94	0.99	0.85	0.92	1.01	1.05
6	0.62	0.70	0.84	0.93	0.72	0.82	0.95	1.00
9	0.50	0.60	0.75	0.87	0.62	0.72	0.87	0.96

Note: Page in parentheses shows that in Irrigation and Drainage Paper 24, FAO.

13.4.3 Gross Irrigation Water Requirements

Irrigation water requirements are calculated by the following equation.

$$IWR = (NIWR_{paddy} \times A_{paddy} / Ef_{paddy} + NIWR_{uplandcrop} \times A_{uplandcrop} / Ef_{uplandcrop}) / 100{,}000$$

where, IWR: irrigation water requirement (MCM)

NIWR: net irrigation water requirement (mm)
A : planting area (ha)
Ef : irrigation efficiency.

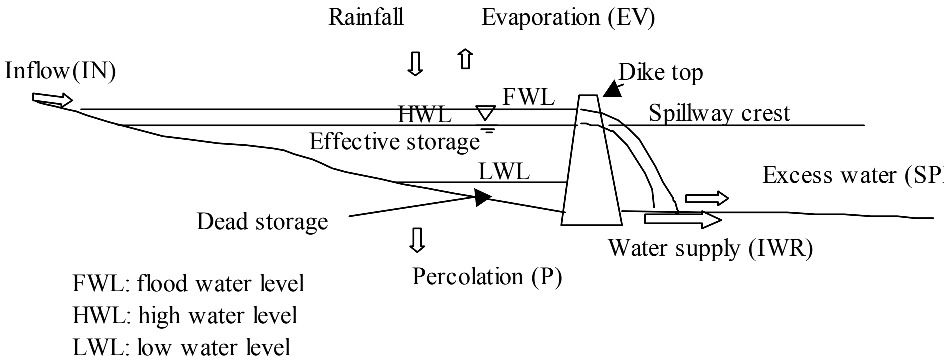
Irrigation efficiency taken for paddy is 0.5 to 0.6 and that for upland crops is 0.5 to 0.55. If the irrigation area is less than 100 ha, and daytime operation can be practiced, a higher irrigation efficiency can be taken into account for estimation of the irrigation water requirements.

13.4.4 Sample Calculation of Irrigation Water Requirements

Table 13.2 shows an example of the calculation of irrigation water requirement.

13.5 Water Balance ~ Reservoir Operation

Water balance calculation between available water resources and irrigation water requirements is made for estimating the area that can be irrigated by the water resources. Key factors on the water balance calculation are river runoff, irrigation water requirement, reservoir capacity, evaporation loss from reservoir, etc. as illustrated below.



The water balance is simply expressed by the following equation.

$$IN + R = IWR + EV + P + SPILL + \Delta S$$

where, IN: inflow,
R: rainfall falling on the reservoir it self,
IWR: water supply,
EV: evaporation loss from reservoir,
P: percolation loss from reservoir,
SPILL: excess water flowing down,
ΔS: storage change volume

13.5.1 Setting of Elevation of Reservoir

Prior to calculating the water balance, a preliminary design of the reservoir and dikes has to be made. In the design, the following items will be decided.

(i) dike top elevation, (ii) flood water level and high water level, (iii) low water level, and (iv) elevation-storage area and elevation-storage volume curves.

Design dike top elevation is generally determined so that the present dike top elevation should not be largely changed. If the storage capacity can be considerably increased by raising the dike a little without causing serious social or engineering problems, a higher dike could also be considered as an alternative of the rehabilitation.

Dead storage capacity is allocated for sedimentation with generation the required volume being simply calculated as a products of the specific catchment' sediment rate and the catchment area. Its volume will be estimated from the experience of sedimentation in existing shallow reservoirs and sedimentation volumes adopted by projects located near the Project. According to past projects in the lowland, 0.1 mm/km^2/year is recommended.

Sample of storage volume and area curves are shown below.

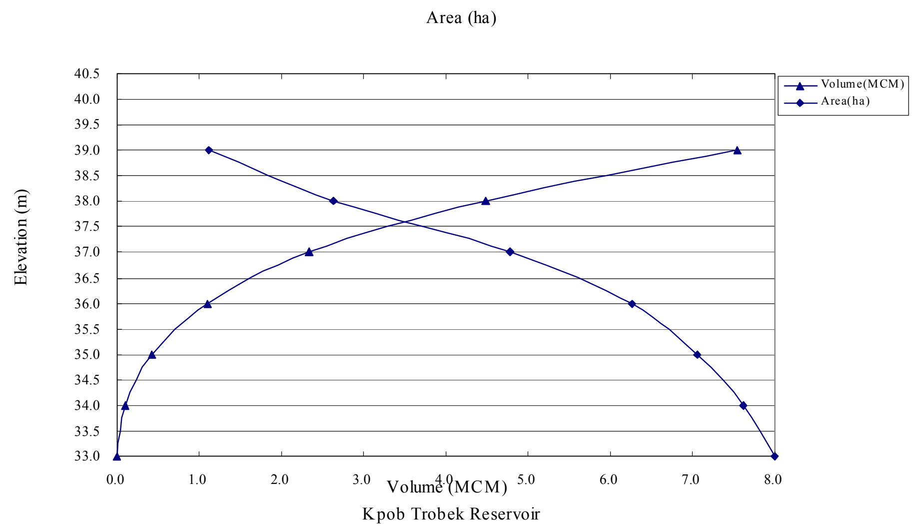


Figure Area and Volume Curve

13.5.2 Calculation Conditions

A water balance calculation for one reservoir system between available water resources and irrigation water requirements is illustrated in the following figure.

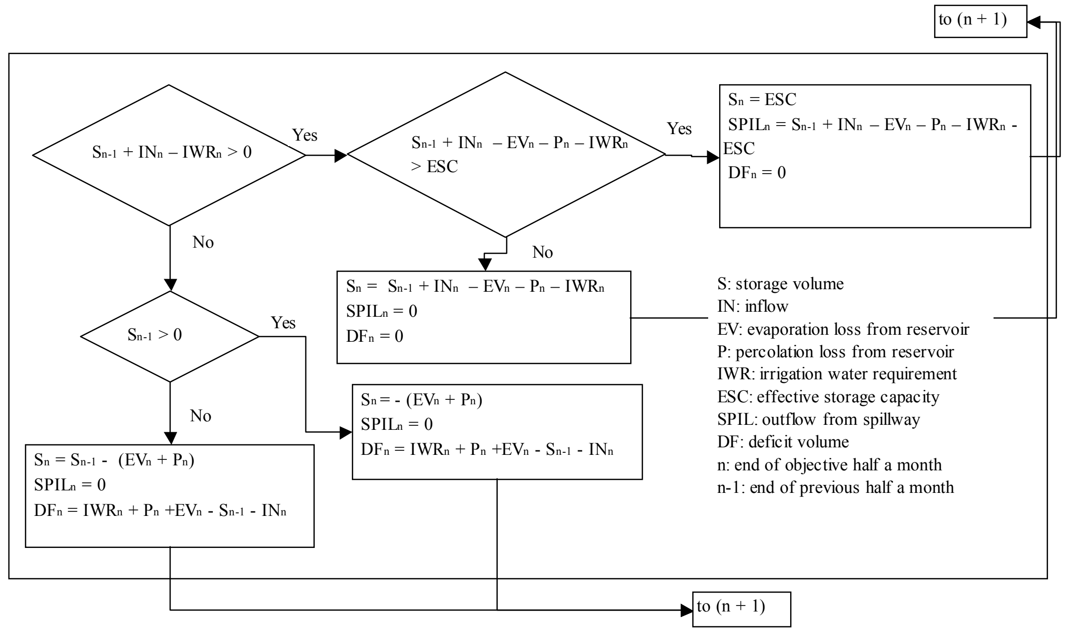


Figure Flow of Water Balance Calculation

Conditions and assumptions for the water balance calculation are summarized as follows:

(1) Calculation period should be as long as possible. Irrigable area at 80 % dependability, or accepting a water deficit once in 5 years has to be estimated. Thus the calculation period should be at least 15 years.

(2) Calculation cycle will be half monthly basis in consideration of data availability.

(3) Estimated monthly runoff will be simply divided into half a the monthly runoff for each half-monthly period.

(4) Judgment of calculation results: The number of times an irrigation water deficit occurs is counted. In principle, N/5 times of water deficit out of N years for each crop was regarded as the level at which irrigation water could be guaranteed to cover the irrigation area at 80 % dependability.

(5) Evaporation loss (Ev) from reservoir:

Evaporation rate is often assumed to be 90 % of ETo. In such a shallow reservoir, evaporation loss is a key factor in the water balance. The evaporation loss is in proportion to the water surface area that considerably changes as water level or storage volume changes. Regression equation for calculating water surface area from storage volume should be incorporated into the water balance calculation.

If the storage area and volume curves can not be developed on the basis of a detailed map, evaporation loss will be estimated for three conditions as follows:

- Storage volume ≧ Full storage capacity,	then Ev = XX MCM/half a month
- Full storage capacity > Storage volume > 0,	then Ev = xxx MCM/half a month
- Storage volume ≦ 0,	then Ev = 0

(6) Percolation loss from reservoir
Percolation rate seems to be small in comparison with evaporation. Some small amount, for example 0.5 mm/days should be considered for shallow reservoirs existing in paddy fields. The percolation loss is also assumed to be in proportion to the water surface area. Thus the loss should be calculated by regression equation for calculating water surface area from storage volume.

(7) Rainfall directly reaching water surface of reservoir
Rainfall falling on the water surface of the reservoir is usually not considered in the water balance study, because it is insignificant compared to the runoff from the broader catchment. However, if the reservoir area occupies more than 10 % of the catchment area, it should be included in the water balance calculation.

(8) In the case of small diversion dams that have no storage capacity, most flood water passes over the weir and cannot be diverted. So, in the water balance calculation, available water resources should be estimated on proper diversion rate as explained in Section 11.1 “Water Availability”.

13.5.3 Sample Calculation

A sample water balance calculation is shown in Table 13.3.

13.6 Irrigation System Planning

In this section, the planning procedures for reconstruction and rehabilitation of gravity irrigation systems of medium to large scale is described. The actual planning procedures from the Upper Slakou River Irrigation Reconstruction Plan (USP) are often used as examples.

13.6.1 Components of Irrigation System

Medium to large irrigation systems such as USP consist of the following system components:

- Diversion system (headworks, free intake, reservoir, diversion canal)
- Conveyance and distribution system (main, secondary, tertiary canals), and
- Field application system (watercourse)

Within the USP, the Tumnup Lok Reservoir is mainly used as a diversion facility while the Kpob Trobek Reservoir mainly used for storage.

13.6.2 Diversion System

(1) Type of Diversion

In the planning of the rehabilitation and reconstruction, the original diversion system should be re-examined. The diversion facilities should be determined according to the characteristics of the water sources. If the runoff is stable and sufficient for the proposed irrigation area, and the main water course does not shift in the river course through a year, a free-intake structure may be the best diversion cum intake facility.

If the runoff is stable and sufficient for the irrigation area, but the water course moves in the river course, a weir structure should be constructed across the river. The headworks are a diversion facilities consisting of the weir and intake structure.

If the long term runoff volume is sufficient, but periodical fluctuation of the runoff limits the irrigation area, the reservoir or dam is required.

(2) Free Intake

The free intake structure consists of an intake gate and canal. The free intake structure has the advantage of low cost but requires a stable water stream both in terms of location and quantity. The free intake structure requires precise gate operation to avoid intrusion of sediment during the flooding period of the river, and to present sedimentation around the gate. Suitable locations for the free intake structure are considered quite limited in Cambodia because fluctuation of the river flow is high and the water level cannot be maintained without a check structure across the river.

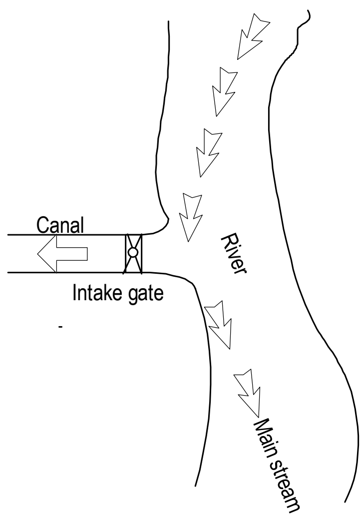


Figure Free Intake

(3) Headworks

The headworks consist of a weir across the river, intake gates, and flush gates to remove sediments around the intake gates. Sediment traps and/or a desilting basin are constructed at the beginning point of the canal to avoid the sediment intrusion to the canal. A "Barrage" is a type of headworks which have a series of gates across the river instead of a fixed weir.

The headworks do not have storage capacity and the water balance should be conducted on the basis of the available runoff of the river. However, a backwater effect to the upstream should be analyzed according to the non-uniform flow analysis so that inundation area on the upstream can be estimated.

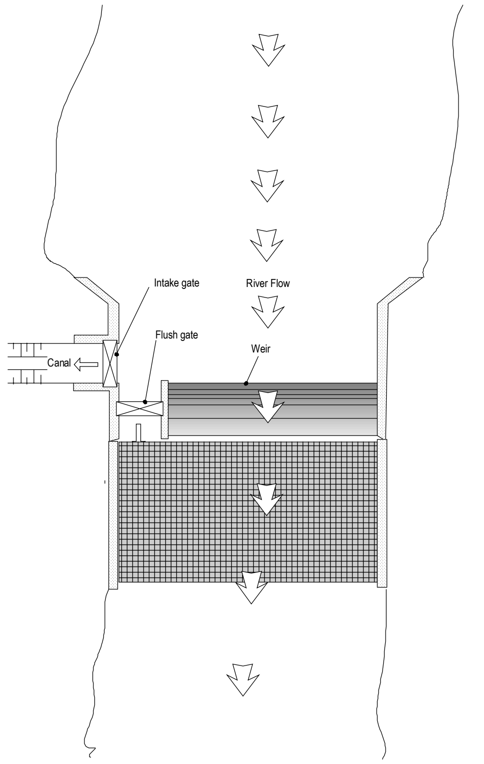


Figure Headworks

(4) Reservoir

In general, a "reservoir" is defined as a dam whose height is less than 15 m. In Cambodia, most reservoirs have homogeneous embankment of local materials and a height of less than 10 m. The effective depth of water that is available for irrigation is less than 1.0 m in many reservoirs. The function of the reservoir expected is as "supplemental irrigation and regulation of water flow in the rainy season".

Planning and design procedures of the reservoir are mentioned in Section 13.7.

(5) Diversion Canal

A diversion canal diverts water at a water source and conveys it to the irrigation area. In general, no off-take structures are constructed on the diversion canal. The diversion canal that connects the water source to a reservoir on the downstream should have sufficient capacity to convey the water to the reservoir promptly. The capacity of the diversion canal should be determined on the basis of simulation of reservoir operation as mentioned in Section 11.1 and 13.5.

13.6.3 Conveyance and Distribution System

An irrigation canal system generally consists of; i) main canal, ii) secondary canal, and iii) tertiary canal. For each canal system, an intake gate, check gate, drop structure, crossing structure, etc. are facilitated so that the planned water distribution can be secured.

(1) Main and Secondary Canal

Canals should be designed to satisfy a range of allowable velocity as mentioned in Sub-section 13.6.7. Accordingly, lining and drop structures would be designed. Structures on the canal would be as follows:

- diversion,
- off-take to the tertiary block,
- drop,
- check gate,
- crossing structure (siphon, aqueduct, pipe or box culvert),
- cross drain,
- bridge (road bridge, foot bridge)
- spillway,
- inlet from drains, and
- inspection road

The main canal is generally designed to distribute irrigation water for 24 hours.

Capacity of the secondary canal is determined by the unit irrigation requirement and watering schedule. In case "rotational irrigation" is planned, the capacity would be larger to distribute the required water volume within a limited period.

(2) Tertiary Block

Tertiary blocks should be planned and designed taking into consideration the following things:

- Size (area) of each tertiary block should be less than 50 ha,
- Each tertiary block should have one or more off-take structure(s) at a secondary canal,
- A tertiary block should be located within the area of only one village,
- A tertiary block should have one or more line(s) of tertiary canal and watercourses (quaternary canals) diverted from the tertiary canal,
- A watercourse should cover a block of about 5 ha, and
- Construction of the watercourse should be done by the beneficiaries themselves getting technical guidance of DWRAM.

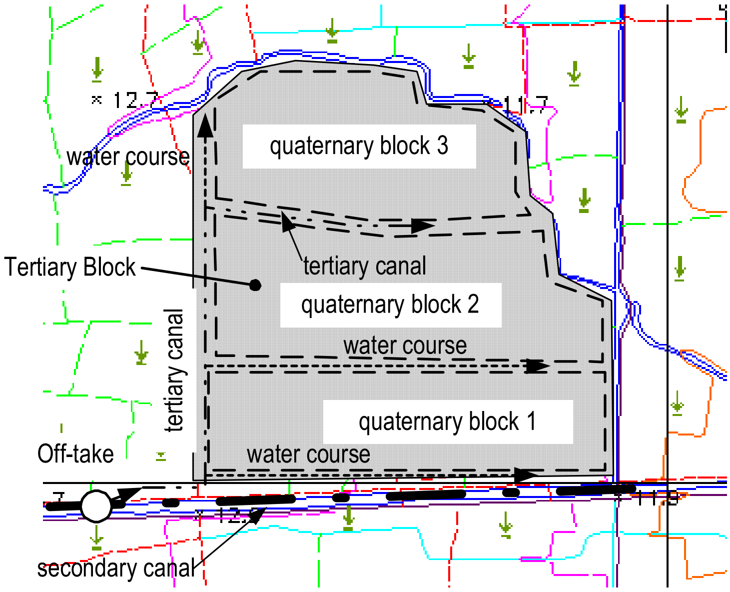


Figure Tertiary Block

13.6.4 Determination of Irrigation Area

According to the irrigable area estimated in the water balance study, the irrigation area would be delineated on the map. It should be noted that the irrigable area is the "net area", namely the cultivated area, while the "gross area" includes land for canal, bund of farm field, inspection road, etc. The ratio of net to gross area depends on scale of maps, but 0.85 is about right for 1 in 10,000 scale map and 0.80 for 1 in 50,000 scale map as there will be more non-farm fields included.

In the delineation of the irrigation area, elevation and alignment of the irrigation canals should be carefully examined. The irrigation area should be lower than the designed water level in the irrigation canal. If the canal water level is EL.35 m, then the irrigation area should be lower than EL.34.8 m taking some head loss into account.

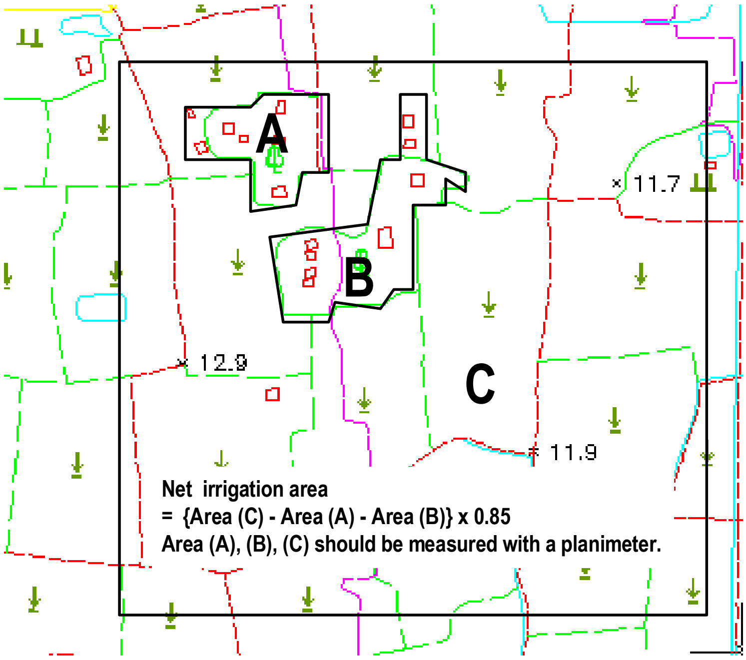


Figure Net Irrigation Area

13.6.5 Irrigation Diagram

Alignment of the irrigation canals should be determined so that the canal network could cover the delineated irrigation area. Then, the tertiary blocks would be delineated on the map to have a command area of 50 ha or less. A code name, the irrigation water requirement, and area of each tertiary block is shown on a schematic irrigation diagram as in the following example.

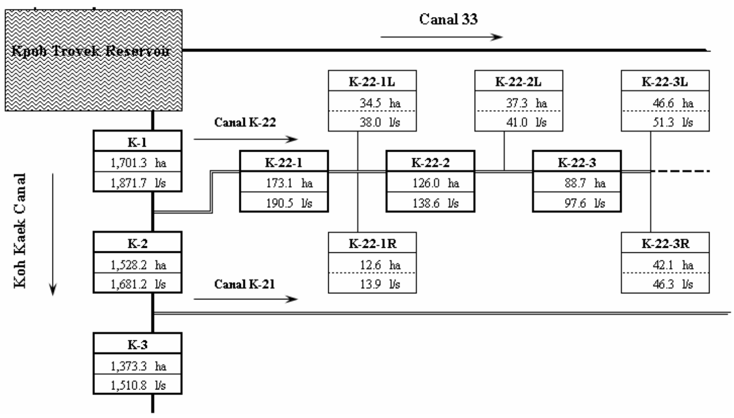


Figure Schematic Irrigation Diagram

13.6.6 Preliminary Design of Canal Systems

(1) Design Capacity

Design capacity of irrigation canals is determined depending on; i) unit irrigation water requirement (lit/s/ha), ii) watering schedule and iii) free board.

If an irrigation scheme has 1000 ha of irrigation area, and the unit water requirement is estimated at 1.1 lit/s/ha, the main canal should have a net capacity of 1.1 m^3/s. For canal systems in which "rotational irrigation" is proposed, the capacity should be increased to supply the required irrigation water within a certain time period. For instance, if a canal irrigates 10 ha every 3 days, the net design capacity should be 3 times, i.e., 33 lit/s.

(2) Freeboard

The freeboard of a canal is determined according to the function of the canal, namely, irrigation canal, drainage canal or both. The freeboard should be calculated by the following two procedures and the larger freeboard of the two should be adopted.

1) Equation for Estimating Freeboard

The following equation is used.

$$F_b = 0.05d + \beta \cdot h_v + h_w$$

where, F_b : freeboard (m)

d : depth of water (m)

β : conversion factor from velocity head to static head (1.0)

h_v : velocity head (m) $h_v = \dfrac{v^2}{2 \cdot g}$

h_w : freeboard for water surface fluctuation (0.15 m)

If, water depth is 2.0 m with a velocity of 0.44 m/s, the freeboard is estimated at 0.26 m.

2) Water Level for 120 % of Capacity

If the design capacity of a canal is 3.5 m^3/s with water depth of 2.0 m, and water depth for 4.2 m^3/s (120 % of 3.5 m^3/s) is 2.15 m, 0.15 m would be regarded as "freeboard".

In the above case, the bigger freeboard of 0.26 m would be adopted.

(3) Dimension of Canals

The dimension of canals should be properly determined using uniform flow analysis by Manning's Formula. Details are mentioned in Sub-section 11.2 "(5) Hydraulic Calculation by Manning Formula".

The ratio of the canal depth to bed width should be 0.8 to 1.0. If the canal bed width is 1.0 m, the designed water depth would be 1.0 m or less.

According to the longitudinal gradient, the ratio of water depth to the canal bed width and allowable design velocity mentioned in the following, canal dimension could be determined.

(4) Design Velocity

Design velocity of the canal would be determined depending on the structure of the canal conforming to the following criteria

1) Minimum Velocity

The minimum flow velocity is determined for the most frequent discharge in the canal. For irrigation canals, the design discharge for normal irrigation period (0.6 to 1.0 lit/s/ha) would be adopted for determining of the minimum velocity. The allowable minimum discharge is set for avoiding sedimentation and weed control at 0.45 m/s to 0.90 m/s. For maintaining the minimum velocity it is necessary to design the canal with a steeper profile or with a lined section. However, the minimum velocity could be reduced to 0.30 m/s if maintenance (desilting and weed cutting) by water users is acceptable.

2) Maximum Velocity

The maximum allowable velocity is to be checked for the maximum designed discharge. The maximum allowable velocity is summarized in the following table.

Table Maximum Allowable Velocity

Type of Canal	Velocity (m/s)
Earth canal (sandy soil)	0.45
Earth canal (sandy loam)	0.60
Earth canal (loam)	0.70
Earth canal (clayey loam)	0.90
Earth canal (clay)	1.00
Earth canal (clay with sand)	1.20
Thick concrete (0.18m)	3.00
Thin concrete (0.10m)	1.50
Masonry	1.50~2.00
Wet masonry	2.50
Concrete pipe	3.00

(5) Hydraulic Loss

Various losses should be considered in the design of the canal system in the form of "head loss" to determine the water level in the canal.

1) Friction Loss

Head loss by friction is estimated by Manning's Formula as follows:

$$h_f = \frac{Q^2 \cdot l}{2}\left(\frac{n_1^{\ 2}}{R_1^{\ 4/3} \cdot A_1^{\ 2}} + \frac{n_2^{\ 2}}{R_2^{\ 4/3} \cdot A_2^{\ 2}}\right) = \frac{1}{2}\left(\frac{n_1^{\ 2} \cdot V_1^{\ 2}}{R_2^{\ 4/3}} + \frac{n_2^{\ 2} \cdot V_2^{\ 2}}{R_2^{\ 4/3}}\right) \cdot l$$

where,

Q : discharge (m^3/s)
A : area of flow (m^2)
h_f : friction head loss (m)
l : distance between the section (m)
R : Radius depth (m)
n : roughness coefficient
V : average velocity (m/s)

2) Other Losses

Other head losses as listed below should be considered.

- head losses at inlet and outlet,
- head loss at transition,
- head loss at screen,
- head loss at bridge pier, and
- bridge pier at curves

The above losses mostly range from 0.02 m to 0.05 m for each location and structure. For big structures and canals of higher velocity, the hydraulic losses should be calculated, but for small canal system, 0.02 to 0.05 m of head losses could be adopted per location or structure as mentioned above.

13.7 Small Reservoir Irrigation System

13.7.1 General

Small Reservoir irrigation system such as SRP consists of the following components:

- Reservoir (storage cum regulation), and
- Canal system (distribution canal)

For most small reservoir irrigation systems, the command area consists of irrigation units that are equivalent to the watercourses of larger irrigation systems. Thus, the development of the canal system of small reservoir irrigation systems is proposed to be undertaken by the beneficiaries.

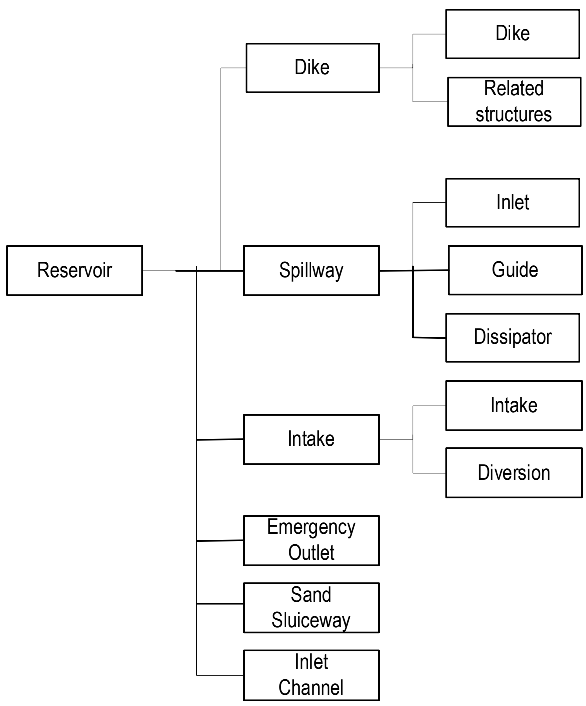


Figure Components of the Reservoir

In this guideline, a reservoir is defined as "a reservoir with earth dike of less than 10 m in height".

Facilities of the reservoir consist of dike, spillway, intake, inlet structure, etc.

13.7.2 Planning

Design of the rehabilitation and reconstruction of the reservoirs should be undertaken in an efficient procedure, taking due consideration of the relationship between the related works.

A standard procedure for planning the rehabilitation of the reservoir is shown in the following:

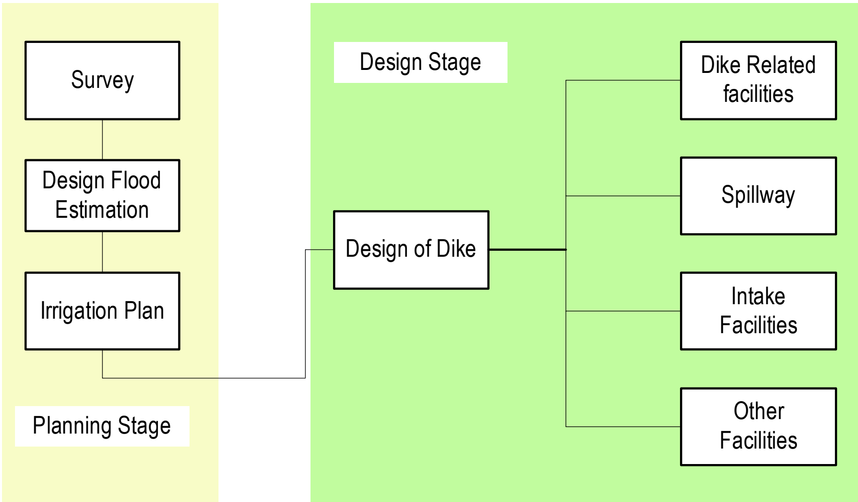


Figure Planning Procedure

(1) Survey

A survey of the existing reservoir should be conducted on the following items:

- leakage from the dike,
- cracks and deformation of the dike,
- insufficient free board,
- instability of the dike due to deterioration,
- malfunctioning of the spillway,
- malfunctioning of intake facilities,
- malfunctioning of the safety control facilities (gate spindle, discharge alerting facilities, etc)

(2) Design Flood Estimation

For the reservoirs, the design floods are adopted from the results of the following procedures:

1) Probability Analysis

If river discharge data are available, probability analysis as explained in Section 11.2 should be adopted. The Recurrence period of the design floods to be adopted is 20 years as explained in Section 13.2.

2) Maximum Flood in the Past

The maximum flood in the past can be estimated on the basis of traces of the floods in the past or from observation by the residents. According to the water level of the observation, the discharge is calculated either by uniform flow analysis or non-uniform flow analysis. A survey of the river profile is required for the analysis.

(3) Irrigation and Drainage System Planning

The irrigable area of the reservoir irrigation system is examined by water balance simulation of the reservoir for several consecutive years. The simulation is explained in detail in Section 13.5 “Water Balance”. The irrigation area and facilities would be planned as described in Section 13.6 “Irrigation System Planning”.

13.7.3 Determination of Dimensions

(1) Elevations

Setting of reservoir elevation is described in Sub-section 13.5.1 “Setting of Elevation of Reservoir”.

(2) Dike

As mentioned in Section 13.2 “Target Level of Rehabilitation and Reconstruction”, Dikes with a height of no more than five (5) meters could follow the standard section as shown in Fig. 13.1. The dike top width should be 5 m, and the slope of the dike should be 1:2.0 ~ 1:3.0 on the reservoir side, and 1:1.5 ~1:2.5 on the downstream side. Existing dikes could be utilized if in a stable condition. Trees on the dike should be removed, including their roots, and replaced with adequate materials. Dikes with a height more than 5 m should be examined by stability analysis after investigating the embankment materials of the existing dikes or proposed quarry.

(3) Spillway

The capacity or dimension of spillways should be determined according to the estimated design flood. In this guideline, an “over flow type” spillway is recommended to avoid “operation failure” during flood times. Discharging capacity of the over-flow type spillway is calculated by the following formula.

$$Q = CBH^{(3/2)}$$

Where, C : discharge coefficient
B : overflow length of crest (m)
H : overflow depth (m)

C-value is an empirical value, but for standard over-flow type spillway, a C-value of 1.9 ~2.2 is adopted. For a broad-crested spillway, a C-value of 1.7 may be adopted for preliminary estimation.

For instance, the design flood of Tumnup Lok Reservoir ($Q=420\ m^3/s$) could be discharged through an overflow type (ogee) spillway as follows:

1) In case overflow depth is 0.80 m, ogee type overflow spillway (C=2.2)

   $B = Q / CH^{(3/2)} = 267$ m

2) In case overflow depth is 1.10 m, ogee type overflow spillway (C=2.2)

   $B = Q / CH^{(3/2)} = 165$ m

3) In case overflow depth is 1.10 m, broad-crested spillway (C=1.7)

   $B = Q / CH^{(3/2)} = 214$ m

(4) Intake Facilities

Intake facilities should be designed to meet the designed discharge of the canals connected to the reservoir.

(5) Maintenance Gate

A maintenance gate should be installed for discharging the stored water in the reservoir to permit reservoir maintenance and to discharge maintenance flow to the river. The discharge capacity of the gate should not be accounted for the discharge of floods. The gate should be installed near the existing river course.

13.8 Pond Irrigation System

13.8.1 General

Pond irrigation system consists of the following components:

- Pond (individual, group, canal), and
- related facilities (ladder, fencing, collector canal, etc.)

The irrigation area is located in the vicinity of the pond, and the watering would be done either by manual application or pumps.

Type of ponds are;

- group pond operated by farmers group,
- individual pond owned and operated by a single owner, and
- canal pond constructed on the canal (public land)

13.8.2 Planning

A Pond irrigation system is generally constructed on private land, so the planning and design should be conducted in close coordination with the beneficiaries. In this guideline, the planning and design of the pond development is proposed to use "survey, planning and design forms".

(1) Identification (**FORM-12**)

Pond development is proposed at the village level. To identify the pond to be developed, the following items are to be clarified.

- Location (coordinate and map),
- Type of pond proposed,
- Member of pond group, and
- Area of land to be irrigated per pond

Prior to the identification, explanation and discussion should be made with the village chief or other representatives of the village such as sub-village (group) leaders.

After collecting basic information for the identification, an explanation meeting on the project, particularly on responsibility of the project and contribution of the beneficiaries, should be held with applicants. Candidate ponds should be nominated after getting consensus of the applicants.

(2) Survey (**FORM-13**)

Survey of the proposed pond and irrigation area would be conducted on the check points as given in **FORM-13**. After surveying, a preliminary design should be conducted immediately to explain the outline of the construction to the beneficiaries. Then, the project policy (contribution of the beneficiaries and responsibility of the project) should be confirmed with each other.

The required contribution of the beneficiaries and responsibility of the project should be determined clearly by the project.

(3) Design (**FORM-14**)

The design of the pond should be done following the parameters given in **FORM-14**. The depth of pond is basically fixed at "3 m" so that groundwater can be utilized to some extent. The construction volume and quantity would be calculated according to the unit cost to be given in the design form (**FORM-14**).

13.9 Drainage

13.9.1 General

As mentioned in Section 13.2, "Target Level of Rehabilitation and Reconstruction", drainage improvement would be considered for area where excess water could be drained using the existing capacity of drains, streams and/or rivers.

If the existing drainage capacity is not sufficient, drainage improvement would not be considered other than to maintain the present drainage condition. In this case, drainage requirement would be equivalent to the irrigation water requirement (about 1.0 L/s/ha) so that irrigation water could be drained properly.

13.9.2 Drainage Requirement

(1) Drainage for Paddy Field

Drainage requirement for paddy field would be considered; to drain the 3-day rainfall of a 1-in-10-year recurrence period within 3 days, allowing a certain depth of inundation.

Drainage water requirement for the paddy field is calculated assuming the following conditions.

- Initial water depth on the paddy field: 50 mm
- Allowable water depth: 150 mm
- Allowable submergence period: 3 days
- 1 in 10 years 3-day rainfall in Takeo: 173 mm

The unit drainage requirement would be determined to meet “3 days” of submergence as shown in Fig. 13.7. Under the above condition, the unit drainage requirement would be determined as 1.6 lit/s/ha.

(2) Drainage for Diversified Crops

The drainage requirement for diversified crops would be considered; to drain 1-day rainfall of 1 in 10 years recurrence period within 1 day without submergence.

The drainage water requirement for upland crops is calculated assuming the following conditions.

- Initial water depth on the paddy field: 0 mm
- Allowable water depth: 0 mm
- Allowable submergence period: 1 days
- 1 in 10 years 1-day rainfall in Takeo: 113 mm

Unit drainage requirement would be determined so that the crops should not be submerged. In most cases, the diversified crops are planted on the paddy field during pre or post rainy seasons, and the drainage system of the paddy fields should be used. Therefore, it is necessary to avoid submergence of diversified crops by adopting “high-ridge cultivation”. Fig. 13.8 shows that a field ridge of 125 mm is required to avoid submergence with the same unit drainage requirement of 1.6 lit/s/ha for paddy rice cultivation.

It is recommended that a high ridge of more than 150 mm should be adopted as shown below:

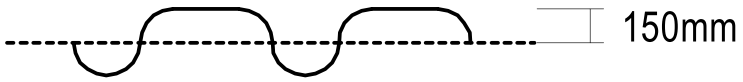


Figure High Ridge Cultivation for Diversified Crops

13.10 Cost Estimate

(1) General

The proposed project will generally be implemented through investment of either domestic budgeting of RGC or foreign funds. Considering the limited funds for development, the economic viability through cost and benefit analysis shall be made for any type of project. Thus, the cost estimate is considered to be one of the most important processes in the planning in terms of checking the economic viability. In this section, the procedure for making the cost estimate for project evaluation is described. The project evaluation procedure is described in detail in Chapter 18.

(2) Type of Project and Contract

Prior to the cost estimate, the fund sources and implementation procedures should be assumed. For instance, large projects that are implemented with foreign loan would generally be contracted through international competitive bidding (ICB), while for minor construction works, the contract would be made through local competitive bidding (LCB). The project cost or unit cost of each construction work for ICB would be higher than that of LCB. Thus, the unit cost should be determined according to the types of contract to be made for the project.

(3) Component of Project Cost

The project cost (financial cost) for the evaluation would consist of the following components:

- Direct construction cost,
- Other direct cost,
- O&M Equipment cost,
- Relocation and land acquisition cost,
- Administration cost,
- Engineering services cost,

- Physical contingency, and
- Price contingency

1) Direct Construction Cost

This is the direct physical cost for the construction works including mobilization and demobilization, machines and man power, preparatory works, temporary works and related activities on the construction. The cost is generally totaled by construction works such as preparatory works, reservoir, main canal, secondary canal, on-farm development, etc.

2) Other Direct Cost

Other direct costs might include institutional development costs, if the project includes a component of capacity building. If the institutional development is executed as part of engineering services, the institutional development cost would be included in the engineering services cost.

3) O&M Equipment Cost

Equipment necessary for O&M works should be procured before completion of the construction works and the necessary cost for the procurement would be included in the initial investment cost. If the O&M works would be done on a contract basis or without equipment, or sufficient O&M equipment is available, it is not necessary to take the cost into account.

4) Relocation and Land Acquisition Cost

If the relocation of houses and land acquisition are necessary for implementing the project, the cost should be estimated.

5) Administration Cost

Administration cost includes the salary and per diem costs of the administrative staff of the project during the implementation period, operation cost of facilities, equipment and related expenditure for the implementation.

6) Engineering Service Cost

The engineering service cost includes; costs for survey, design, supervision and other cost for engineering activities necessary for the implementation of the project. The engineering service cost is generally estimated at a certain percentage (about 10 %) of the direct cost.

7) Physical Contingency

Physical contingency is set at a certain percentage of the total of the above mentioned costs (ex. 10 %) assuming a certain increase in work volume or expenditure that might arise at the implementation stage.

8) Price Contingency

Price contingency is set assuming certain price escalation both for local currency (Riel) and the foreign currency (US dollar) portions. In this Study, price escalation of 2.5 % was adopted for foreign currency portion and 3.0 % was adopted for the local currency portion. The price escalation is set according to the actual changes of the prices in the past.

(4) Currency Portion

Each component of the project cost should be divided into the portion below for project evaluation.

- material cost (local, foreign)
- equipment cost (local, foreign)
- common labor cost (local)
- skilled labor cost (local, foreign)

For example, excavation with machine consists of costs as follows:

Material		Equipment		Labor	
Local	Foreign	Local	Foreign	Common	Skilled
0.9 %	17.5 %	7.6 %	68.6 %	0.0 %	5.3 %

Excavation with machine is carried out with imported machines (equipment) and imported fuel (material) and skilled labor (operator), so the currency and cost portions are allocated as above. On the other hand, excavation by manpower is allocated as follows:

Material		Equipment		Labor	
Local	Foreign	Local	Foreign	Common	Skilled
0.5 %	9.5 %	4.1 %	37.4%	45.5 %	2.9 %

In this case, common labor cost occupies nearly half of the total cost.

The currency potion and cost allocation are determined by work item according to requirement per work.

(5) Disbursement

Disbursement of the project cost should be determined according to the implementation schedule of the project. The initial investment cost would be distributed for the project period (ex. five years).

(6) O&M Cost

The annual operation and maintenance cost of the project facilities includes the salaries of the staff of the Project office, staff of FWUCs, staff of marketing unit, material and labor cost for annual maintenance, the cost of operation, repair and maintenance of transportation equipment, and large scale maintenance on a contract basis every five years.

(7) Replacement Cost

Some project facilities and equipment have a shorter economic life than the project life and will require replacement during the proposed 50 years of the project life. The following table shows the economic life times adopted in the feasibility study on USP.

Table Replacement Period

Description	Economic Life Time
Office / Facilities	30 years
Gates	25 years
Steel Plate	10 years
Transportation Equipment & Generator	10 years
Administrative Equipment	8 years
Marketing Equipment	8 years
Wooden Stoplog	5 years

CHAPTER 14 SUPPORTING PROGRAM

14.1 Planning of Supporting Program

The supporting program for agricultural production in the irrigation project will consist of; i) extension services for dissemination of improved farming technology to the beneficiaries, ii) supply and distribution of required inputs, iii) financial support (credit for purchase of inputs and investment), iv) improvement of farm roads for transportation of outputs and inputs, and v) farmers group activities for participation and self-operation of the support programs. The following figure shows a flow of the planning of the supporting program

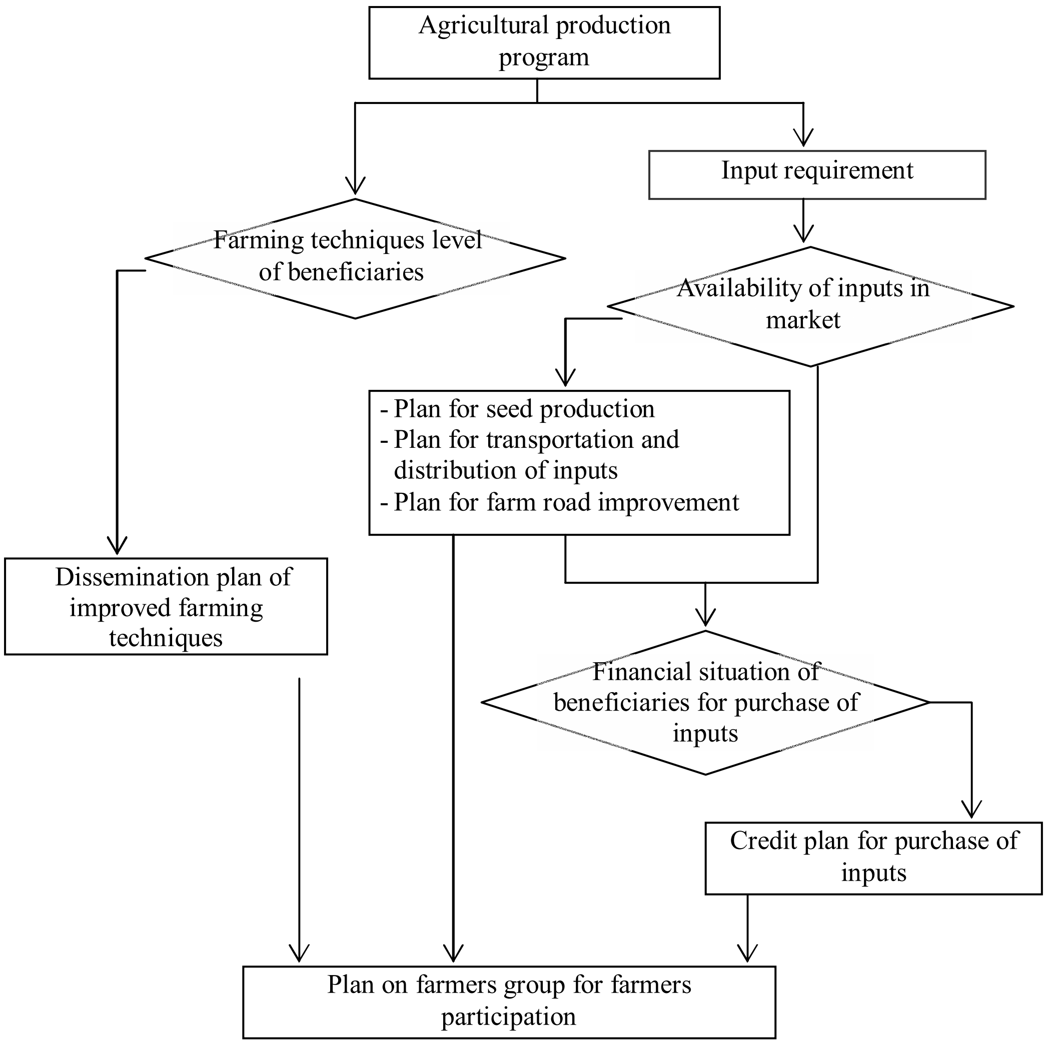


Figure Flow of Planning on Supporting Program

14.2 Extension Services

(1) Dissemination of Improved Farming Techniques

Agricultural extension services are essential to disseminate improved farming techniques to the irrigation beneficiaries and to realize the crop production plan. Irrigation projects should be vigorously supported with extension activities by DAFF. DAFF should perform intensive extension activities in the project area. For this purpose, the project area should be designated as a priority target area of the extension activities.

Farmers Field School (FFS) is an effective extension system in Cambodia. Currently, DAFF under MAFF is providing their extension services including IPM (Integrated Pest Management) through FFS. FFS aims to train trainer-farmers who work in their village as voluntary trainers for villagers under VDC. FFSs provide technical guidance and workshops to participants selected from VDCs. Usually, 25 - 30 farmers participate in a FFS during 16 weeks for every crop (paddy, vegetables or secondary crops) through the cultivation period. Extension workers and IPM trainers provide technical guidance to the participants through FFS. During the period, the FFS is held for one or two day(s) every week. The village activities of the trained farmers by FFS are supported through follow-up and monitoring / evaluation by the extension workers and trainers of DAFF. At least several trained farmers are necessary per village taking into account the number of sub-villages and kinds of target crops.

For the activity of the trained farmers in the village, demonstration farms must be effective for demonstration and verification of the improved farming technology to villagers. The demonstration farms would be set up within a village by target crop with areas of around 0.03 - 0.1 ha per crop.

It is essential that the activities of trained farmers should be well coordinated and cooperated with VDC and FWUC of the irrigation system.

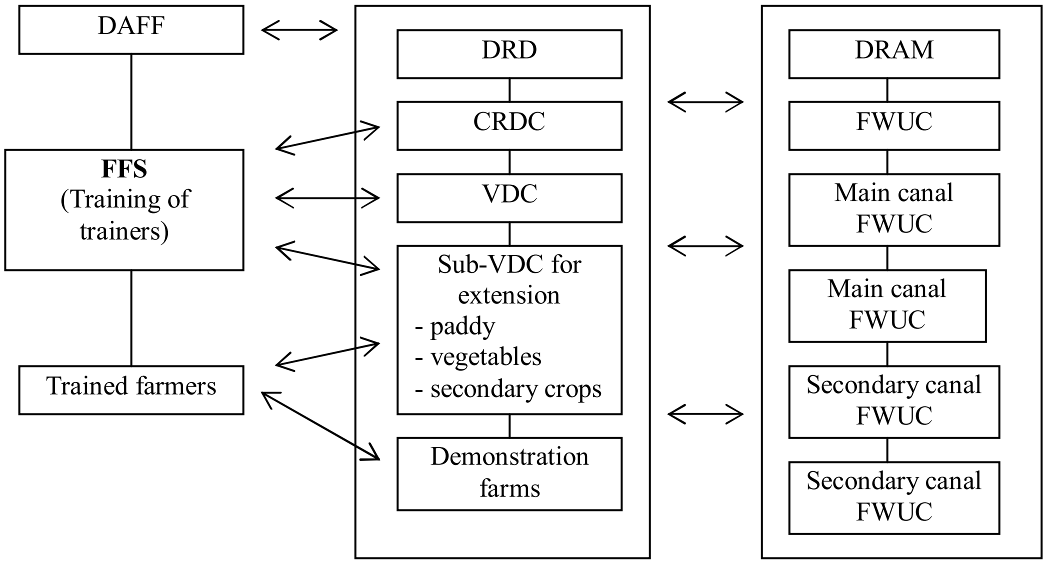


Figure Relations of FFS VDC and FWUC on Extension Activities

(2) Inputs supply

Inputs such as chemical fertilizers and pesticides are imported from the neighboring countries under the marketing economy policy of Cambodia. It seems that these inputs are supplied sufficiently in the country at present. However, in the areas of isolated or poor road condition, the prices are high because of the high transportation cost.

Most farmers can not purchase sufficient input due to their low financial capacity. Consequently, the farmers abandon to purchase inputs or they pay cash or products to input dealers at high interest rates after harvesting their crops .

Considering the above constraints, improvement of market and farm road network and group-purchase by group credit are required. The group-purchase of inputs through credit farmers group under the VDC is mentioned in Sub-section 14.3.

Low availability of improved paddy rice seeds may be a problem in the project area. In this case, the possibility of seed production should be examined in and around the project area considering the following:

- Probability of farmers intension and skill level on the seed production
- Probability of stock seed supply from researchers
- Probability of technical guidance on seed production by DAFF, and
- Seed inspection and processing DAFF or seed-company.

Farmers groups should be organized in a seed production farmers group under VDC or CRDC for effective technical guidance of and planning for seed production.

14.3 Credit

In the agricultural production program under irrigated condition, necessary inputs will increase compared with those under present condition. However, the current financial capacity of farmers is usually insufficient for proper investment in farm inputs. A credit system is required for the purchase of inputs such as seeds, fertilizers, pesticides, and investment in agricultural machinery, marketing of products, storage of products etc.

There is no government-supported institutional credit system in Cambodia. Instead, micro-credit systems handled by NGOs have been developed relatively well in the rural area supported and funded by ADB and other donors. Agricultural credit system in collaboration with NGO is extensively required for financial support to the beneficiaries. Credit farmers groups should be organized under VDC. The farmers group is obliged to collect and repay the credit. The group should be trained in cash/fund management aiming at self-management in the future.

The micro-credit system in the rural area is important not only for agricultural inputs but also for other purposes such as investment for rural business, and improvement of housing and living conditions.

CHAPTER 15 FARMER WATER USER COMMUNITY

15.1 Related Institutions and Laws

The concept of formation of FWUC is relatively new in Cambodia. Since the establishment of MOWRAM in 1999, the following strategy documents related to water resources have been issued:

1) Prakas 306 including Circular No.1 on the Implementation Policy for Sustainable Irrigation Systems, MOWRAM, June 2000;
2) Preparatory Study on the establishment of a new monitoring system for land and water resources management in Cambodia, MOWRAM, January 2000;
3) Strategic Framework for the Water Sector in Cambodia, ADB, March 2001;
4) Draft National Water Resources Strategy, MOWRAM, May 2001;
5) Draft Law on Water Resources Management of the Kingdom of Cambodia.

These Institutions and Laws are to be taken into account for the planning of the formation of FWUCs. The essential points of 1) to 3) are described below.

(1) Prakas 306 including Circular No. 1, Policy for Sustainability of O&M Irrigation System and Steps in the Formation of FWUC

The Circular No.1 describes the role of MOWRAM related to O&M of Irrigation System as follows:

- to review and evaluate all irrigation systems which have the potential for effective development of the national economy;
- to standardize the statutes of FWUCs;
- to carry out feasibility studies and construct irrigation systems to supply water to farmland in an efficient and sustainable manner;
- to cooperate with other concerned Ministries to create sustainable FWUCs.

The Policy for Sustainability of O&M Irrigation System is based on the following basic principles:

- Legal status of FWUC;
- Involvement of FWUC in system development;
- Obligation of farmers in paying the O&M cost and emergency cost of O&M;
- Permanent maintenance and improvement of existing irrigation systems;
- Arranging the water delivery in equality and effect; and
- Receiving support and assistance from the MOWRAM on technical backstopping, managing, monitoring, evaluating, etc.

The Steps in the Formation of FWUC describe the various processes of FWUC formation. This policy is aiming at the transfer of management responsibilities to the FWUCs. The FWUCs should be nonprofit in nature. They are to be operated as service-at-cost communities.

(2) Preparatory Study on the Establishment of a New Monitoring System for Land and Water Resources Management in Cambodia, January 2000

This document was published shortly after the establishment of the MOWRAM and includes a section on the operation and management of irrigation schemes. A classification of irrigation systems is included and management responsibilities are formulated as follows:

Classification of Irrigation Schemes

Small Scale

Less than 200 ha: managed by the District Office. If more than one District is involved, the DWRAM is responsible for the management. O&M are the responsibility of the FWUCs.

Medium Scale

Between 200 and 5,000 ha: managed by DWRAM. If more than one Province is involved, MOWRAM is responsible for the management of the scheme.

Large Scale

More than 5,000 ha: managed by MOWRAM

(3) Strategic Framework for the Water Sector in Cambodia

This Strategic Framework was issued in March 2001 with assistance of the ADB Capacity Building Project. The main issues included are to develop a comprehensive strategy for irrigation and drainage including:

- Promotion of farmer managed schemes,
- Encouraging private sector involvement,
- Improving sustainability,
- Ensuring property rights to land and water,
- Stakeholder participation in O&M of irrigation and drainage,
- Predicting environmental impacts, and
- Water use rights.

15.2 Structure of FWUC

Irrigation development, rehabilitation or extension programs shall be implemented only on the basis of the feasibility and demand of the majority of farmers. During the planning and implementation of irrigation projects, the full participation of organized users shall take place at all levels from the very beginning. Formation of

FWUC shall, therefore, be the primary task leading towards the implementation of an irrigation project. Upon the completion of the project, the responsibility for O&M and emergency repair shall rest with the FWUC through a gradual process of transfer of responsibility.

Based on the capacity of the farmer organizations, the irrigation schemes shall be transferred to the FWUCs for their sustainable operation and maintenance. The right to operate the transferred irrigation scheme and related infrastructures, and the responsibility of its protection shall be with the FWUC recognized by the government. In accordance with the Prakas 306 mentioned in the preceding section, after the scheme has been transferred, the Department of Irrigated Agriculture of MOWRAM shall conclude a necessary agreement with the FWUC for proper utilization of irrigation facilities and related infrastructures.

The FWUC will be managed by its Committee, which is elected by the members of the FWUC. The Committee has basically the following members:

Members of FWUC Committee

- One chairman, in charge of general supervision,
- One first- vice chairman, in charge of maintenance and repair planning
- One second-vice chairman, in charge of water supply distribution and record keeping
- One treasurer, in charge of finance
- All chiefs of the Farmer Water User Groups (FWUGs)

The Committee has the following duties:

Duties of FWUC Committee

- Arranging the work program of the community
- Functioning in accordance with the statutes of the Community that have been jointly approved by the FWUC and MOWRAM
- Organizing the O&M of the irrigation systems for economically optimal water use,
- Dispute resolution among the community members,
- Collection of ISFs as determined by the Community, and
- Determining the level of authority and responsibility of a FWUC for each geographical location and project type as set by the MOWRAM

The FWUC will comprise the farmer representatives from various levels of the irrigation system (watercourse, tertiary, secondary, main canals) or the FWUGs. The FWUG is made up of the farmers who use water in the same irrigated area. The formation of the group will be based on the geographical location of the farmland and the boundary of the irrigation system in that area. Each group should be led by one head elected by all members or representatives and may have other office bearers, if needed.

The FWUGs have the following duties:

FWUG's Duties

- Implementing the work program of the Community,
- To provide data for planning and design
- Coordinating between members of FWUG and Community
- Collecting ISFs from the members according to the terms set by the Community

Fig. 15.1 shows the standard structure of FWUC.

15.3 Formation of FWUC

15.3.1 General

The quality of water services to be provided by a completed irrigation project will gradually deteriorate and eventually fall into disrepair unless adequate maintenance and proper management are provided. During operation, the project faces problems of wastage of water, poor drainage, unauthorized water use by farmers, inequalities in water distribution from head to end, and non-adoption of an adaptable cropping pattern, resulting in deterioration of the infrastructures created at a high cost and low productivity against the anticipated project benefits.

The primary legislative jurisdiction of water resources lies with the Government. The prevailing system of water management does not provide for collective efforts in self-governance by the users. Therefore, with the concept of farmer's participation in irrigation management, the farmers shall form FWUC to manage their affairs.

Under Government policy, the irrigation schemes shall be transferred to the FWUCs for their sustainable operation and maintenance and for the promotion of irrigated agriculture, based on the capacity of the organizations. The FWUC and the government shall jointly manage those irrigation systems that are not fully transferred. The organization of the beneficiaries that take over the operation and maintenance of a system will be called FWUC.

15.3.2 Advantage of FWUC

Advantages of FWUC's beneficiaries are described as follows:

- Assurance and reliability in getting water as per agreement on a long term basis from the irrigation agency/ right of allocation of water;

- Satisfaction of self reliance and a sense of belonging in managing the system themselves;
- Reduction in operation losses and wastage of water, resulting in increase in irrigation efficiency;
- Increase in area under irrigation through water saved and thereby reduction in water fees per ha;
- Equitability in getting water in case of shortage of water on account of less supplement in the system;
- Better conflict management;
- Users at FWUG level are charged for actual use of water per ha based on crop conditions practiced;
- Assurance of getting water by farmers in tail end;
- Collective water management along with crop planning taking into consideration the market situation, existing infrastructure, storage, processing and transport will result in better conditions for the users;
- Members can take joint decision in planning and designing of the system and participate in its construction, repair and maintenance for efficient use of water;
- Members can collectively suggest modifications/ improvements for the main system management and water delivery schedules, and thus participate in decision making at the project level; and
- Through the FWUC, the members can get the services of various departments concerned with agricultural development in a co-ordinated way through their suggestion and guidance.

15.3.3 Formation of FWUC

The jurisdiction of the FWUC will be based on hydraulic boundaries rather than village boundaries. In the rehabilitation of an irrigation scheme, the farmers are basically aware of the irrigated area before the system deteriorated and/or stopped functioning. The focus of organizing activity will be at the tertiary or watercourse level. A single FWUC will be formed to manage the entire tertiary system and the multi-level organization will be organized depending on the size of the irrigation system. According to the Steps in the Formation of a FWUC prepared by MOWRAM, a FWUC is to have a tiered structure and should be organized by the following steps. The MOWRAM through its Department of Irrigated Agriculture will provide for technical and managerial support in the formation of a FWUC.

(1) **Step – 1: "Delineation of Area and Farmers Perception"**

The delineation of the irrigation area is first made according to the available irrigation water and hydraulic boundary. A series of commune or village level forum or public meetings would be conducted to launch the program. In these forums, the aims and objectives of the program as well as the sequence of activities will be informed to farmers. The purposes of the forums are to inform users in detail about these future activities and to make it clear that the irrigation system will be managed by the farmers, and the willingness of the farmer committees will be sought in these meetings.

(2) **Step – 2: "Setting the Levels"**

It is necessary to understand the overall hydraulic configuration of the irrigation system in order to assist the farmers to form a FWUC. The FWUC is responsible for managing the irrigation system from the diversion point to the lower end of the canals. If the irrigation system is quite large, this will generally require the development of smaller affiliated FWUGs at the lower levels.

(3) **Step – 3: "Formation of FWUC Board"**

In the FWUC formation process, the concept of referendum voting by members of a board representing all farmers in the irrigation system is the usual practice. In the large irrigation systems, it is advisable to institute a delegate procedure, for which delegates are elected locally.

The importance of the Board of FWUC is viewed in terms of maintaining the checks and balances in the FWUC activities. The responsibilities of the FWUC are to set water rates, develop and ratify FWUC structure, elect the Committee members of the FWUC, and scrutinize and approve the budget and expenditure.

It is suggested that a statute drafting committee be formed to provide an official status and to eventually register the Committee with the government. A statute drafting committee could be formed from each community under the proposed irrigation area.

(4) **Step – 4: "Selection of Farmer Organizer (FO)"**

Depending on the scale of irrigation system, the entire system will be divided into several irrigation blocks. The FO will be selected from people in the irrigation block (say, 50 to 100 ha). The role of the FO is the formation of FWUC and collection of farmer information and records. The group of FOs selected will be given training regarding their roles and the FWUC formation process, etc.

(5) **Step – 5: "Discussion on the Draft FWUC Statute"**

In order to eventually register the Committee of FWUC with the government, it is proposed to form a FWUC statute drafting committee to enable granting of FWUC status. A statute drafting committee could be formed from each of the regions identified in Step- 4.

Based on the draft statute prepared by the government, the drafting committee will discuss the provision, make necessary modifications and finally submit it for ratification in the Board of FWUC meeting.

(6) **Step – 6: “Formation of the System-wide FWUCs”**

The formation process of FWUC is to be initiated based on hydraulic boundaries of the system from the watercourse and tertiary level to the main canal level. The apex committee is formed with a tier structure system from the lowest level of FWUGs. In this regard, adequate awareness of the process is to be provided to all beneficiaries.

(7) **Step -7: “Final Ratification of the FWUC Status”**

After the Committee and the FWUC Board have been organized, the final draft and ratification of the FWUC status can be addressed with the help of FOs and government staff.

It is essential that the FWUC Board be involved in the ratification process, even though the drafting committee may play a more active role in the actual drafting or modification process.

(8) **Step – 8: “Registration of the Statute and the Committee of FWUC”**

With all the above steps, formation of the FWUC will have been completed at different levels of the irrigation system and possess a Statute. The Committee of FWUC would then apply to the relevant government agency for registration in order to establish the legal status of the FWUC. The Committee of FWUC shall get recommendation from and agreement with MOWRAM. The concerned agencies under MOWRAM after reviewing the Statute and the formation process of FWUC will issue the organization registration certificate to the FWUC Committee. The sequence of formation for FWUCs is shown in Fig. 15.2.

15.4 Irrigation Service Fee (ISF)

According to the policy for Sustainability of Operation and Maintenance of Irrigation Systems, upon the completion of the project, the responsibility of operation and maintenance and the emergency repair shall rest with FWUC in a gradual process as follows:

Gradual Process of ISF Collection	
Year 1:	The Government shares 80% and the farmer members 20%
Year 2:	The Government shares 60% and the farmer members 40%
Year 3:	The Government shares 40% and the farmer members 60%
Year 4:	The Government shares 20% and the farmer members 80%
Year 5:	The Government shares 0% and the farmer members 100%

The above expenditures apply only for the irrigation schemes constructed with Government funds and/or the support from international and national agencies.

The ISF shall be collected from the water user farmers for irrigation service made available from the system by the Committee of FWUC registered with the government. The rate of ISF has to be decided by FWUC according to the following formula.

$$Y = \frac{X_1 + X_2 + X_3 + X_4 + X_5}{\text{Irrigation Service Area}} + 20\% \text{ of Increased Production}$$

Where, Y= ISF per ha
X1= expenditure on maintenance and repair
X2= expenditure on fuel in case of pumping
X3= expenditure on contribution to the Community Board
X4= expenditure on administration
X5= expenditure on contingency

As the O&M cost may vary from system to system and within the system in different years the ISF will vary accordingly and so decided by FWUC. The 20 % of increased production shall remain in the bank account of the FWUC as a fund to cover the emergency repair and maintenance expenditure or the FWUC could spend it on the modernization of the irrigation system or improvement works for farm water management. This should be continued for the first five years, following which depending on the financial situation, the FWUC may reduce the percentage, but not to less than 5 % of the increased production.

The Committee of FWUC collecting ISF in the irrigation system shall have to keep records of the farmers receiving the irrigation facilities.

The income and expenditure incurred by the FWUC shall have to be annually audited by an independent auditor hired by the FWUC and the reports shall have to be presented in the general meeting of the FWUC for approval.

15.5 Training of FWUC

15.5.1 Irrigation Management Transfer

Irrigation management will be transferred to FWUCs only when they are capable of taking over the management. Joint management will be used to establish, register, train, and strengthen the FWUCs in management of O&M of their schemes. After the rehabilitation of a scheme, joint management is proposed to get the system fully operational and to thoroughly strengthen the FWUCs.

It is proposed that the joint management period for medium and large-scale projects is to be about 4 years. For small-scale projects, joint management may be for a shorter period of about 2 to 3 years. During the joint management period, the FWUC will be strengthened to be able to take over the management of O&M, for which MOWRAM is expected to implement the following activities:

- Training for FWUC/FWUG at project level in record-keeping, financial book-keeping, water distribution, maintenance of canal system, meeting arrangement, conflict resolving, etc.;
- Preparing an annual maintenance plan;
- Preparing an O&M manual;
- Assisting in Settling of disputes,
- Assisting in monitoring and evaluation plan.

Costs for O&M will have to be shared as per formula mentioned in the preceding chapter (Prakas 306).

15.5.2 Human Resources Development

In order for the management of the existing irrigation schemes and future development projects to function properly and satisfactorily, strengthening and training the existing staff through seminars and workshops are proposed and additional staff are to be recruited.

In order to smoothly transfer irrigation management to FWUCs, the following activities are required:

1) Strengthening and training of staff, particularly those in charge of FWUCs, and recruiting additional staff in DWRAM for the following responsibility areas;
    - Crop water requirement,
    - Irrigation efficiencies, and
    - Irrigation water application methods;
2) Conducting and training workshops at provincial level,

3) Training and strengthening FWUCs in collaboration with MOWRAM,
4) Technical support to FWUCs in collaboration with MOWRAM,
5) Training on monitoring and evaluation at central and provincial levels.

15.5.3 Training of FWUCs and FWUGs

The representatives of FWUCs and FWUGs need to be trained in capability of operating and managing their system in collaboration with MOWRAM. The major items of training are:

1) Roles and tasks of FWUC Board members and WUG representatives, particularly,
   - Bookkeeping,
   - Administration and documentation,
   - Project planning,
   - O&M of canal and pump (in case of pump scheme), and
   - ISF collection;
2) Operation and maintenance plans;
3) On-farm water management;
4) Budgeting and management of ISF

15.5.4 Training at Field Level

The irrigation schemes need to be well maintained for proper water distribution to the field. Weed growth and silting in the canal and bank erosion will result in low efficiency of the scheme. Therefore, the scheme operator (SO) and ditch rider (FOs in case of FWUG) need to be trained in operation of irrigation structures and routine and periodic maintenance of canals and structures to allow the system to be operated at design capacity as shown in the following major points:

1) Scheme operation
   - Gate setting of diversion facilities and recording of water level,
   - Opening/closing gate of turnout and recording of water level,
   - Monitoring water distribution,
   - Avoiding illegal water use, and
   - Inspection of embankments.
2) Scheme maintenance
   - De-silting canals,
   - Grassing embankments, and
   - Gate repairing and greasing spindles.
3) Emergency repair
   - Collapse of embankment,

- Soil filling, compaction and grassing, and
- Reconstruction of structures damaged.

Basically field staff need to be trained in determining irrigation requirement and water application methods and measuring irrigation water used. These activities are required to evaluate irrigation efficiencies. The farmers are also required to be trained in different water application methods to improve water management in the field so as to improve irrigation efficiency, particularly at the time of shortage of water.

CHAPTER 16 OPERATION AND MAINTENANCE

16.1 Operation

16.1.1 Setting-up of Watering Schedule

(1) Operation Principles

Considering the limited water resources and need to distribution them evenly, the following operating principles are proposed.

1) Water saving irrigation method would be applied.
2) Diversion, main and secondary canals to be operated continuously for 24 hours.
2) Tertiary canals and watercourses would be operated continuously during the rainy season, but rotational irrigation would be applied during the dry season or drought periods in which the available wakes cannot fully meet the demand.
3) The irrigable area in the dry season would be less than that of the rainy season. The irrigation water would be evenly distributed to each tertiary block, and discussion should be discuss by block on how to utilize the limited water for the command area.

(2) Preparation of Water Supply Schedule

The water supply schedule (WSS) would be determined every year before the cultivation starts. Prior to the evaluation of the water requirement, due discussion should be made on the cropping pattern. Board members of FWUC in charge of WSS would consult MOWRAM (DWRAM) regarding the unit irrigation water requirement of the year on a half-monthly basis. Then, according to the unit irrigation water requirements, the watering schedule to each tertiary block (rotation schedule) would be determined by FWUC at the secondary level.

(3) Dissemination and Publicity of Schedules

The importance of wide publicity and dissemination of Water Supply Schedules among the farmers sufficiently in advance of the beginning of the crop season needs strong emphasis. It is therefore essential that water supply schedules are prepared in time and given to farmers so that they are able to plan their crops accordingly.

Setting-up of WSS and flow of operation is shown in Fig. 16.1.

16.1.2 Operation of Facilities

(1) Operation of Diversion System

Principles for the operation rule of the reservoir system are itemized as follows:

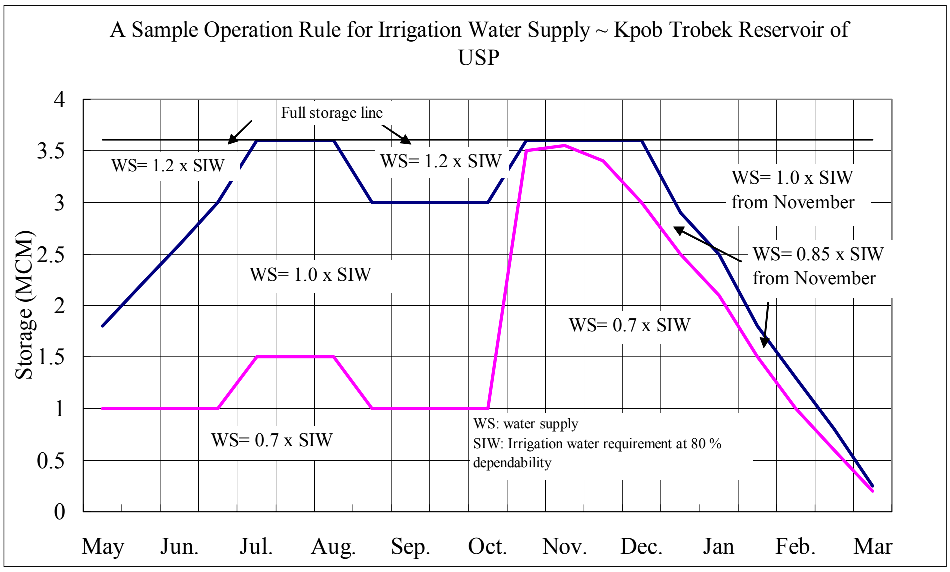
1) Operation for the reservoirs should be simple.
2) Intake gates of the diversion or main canal should be operated so that the diverted flow does not exceed the designed capacity of the canal.
3) Whenever the reservoir is full of water and excess water overflows the spillway, the gates controlling inflow to the reservoir (if any) should be closed.
4) Close communication should be kept between the gate keeper of the reservoir and water users in the command area, especially during large storms and drought.

(2) Operation of Canal System for Irrigation Water Supply and Distribution

Irrigation canal system generally consists of one main canal, secondary canals, and tertiary canals. The main canal originates from a reservoir or a diversion structure on the river. The secondary canals branch off from the main canal and each secondary canal commands 10 to 30 tertiary blocks. Every tertiary block is served by a respective tertiary canal.

Principles and fundamental operation rules for irrigation water supply are suggested as follows.

1) Operation rules for water supply should be simple.
2) Rainfall factor is not taken into account for the operation of irrigation water supply in principle.
   Rainfall is very erratic and so water supply based on the amount of rainfall is not practically possible.
3) The operation rule will be based on the irrigation water requirements estimated at a recurrence period of five years (80 % dependability).
4) Operation will be carried out on half a monthly basis in the irrigation canal system.
5) Only actual reservoir storage volume should be taken into account for the irrigation water supply from the diversion facilities.
   The following operation rule proposed for Kpob Trobek Reservoir of USP shows a good example of reservoir operation. The operation was developed to mitigate irrigation water deficit during droughts as well as to increase of water supply in the high water season.



Irrigation Water Requirement (SIW)

Unit : m^3/sec

May		June		July		August		September		October		November		December		January		February		March	
1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
0.00	0.11	0.22	0.31	0.33	1.41	1.71	1.89	3.06	3.28	1.99	2.27	3.39	2.36	1.36	0.70	0.38	0.44	0.54	0.41	0.30	0.12

For example, at the beginning of the first half month of August, the actual water storage is more than the reservoir storage capacity (water spills out through the reservoir spillway), 1.71 m^3/s x 1.2 times = 2.05 m^3/s will be released to the main canal. In case that the storage is less than 1.5 MCM, 1.71 m^3/s x 0.7 times = 1.20 m^3/s should be released.

During a time of flooding in almost the entire paddy fields, the intake gate of the main canal should be closed.

This rule should be reviewed and revised on a realistic basis at any necessary time during the actual operation stage.

6) The irrigation season is divided into three seasons in accordance with the cropping pattern or irrigation water demands. The first season is two months from May to July when upland crops are planted. In this season, the irrigation water demands are as small as the range from 0.11 m^3/s to 0.33 m^3/s. Middle season is the period from late July to late December when paddy is planted. The irrigation water demands are the largest in this season. Then, the third season is the period from January to March when upland crops are planted. The irrigation water demands in this season ranges from 0.12 m^3/s to 0.54 m^3/s.

The main canal and the secondary canals will apply 24 hours continuous conveyance of water throughout the irrigation seasons. In these first and third seasons when irrigation water demands are very small, check gates on the main canal and/or secondary canals will be fully closed and side overflow sections furnished on check structures will be utilized for water conveyance.

7) Tertiary canals will be operated so as to supply water on a 24-hour continuous conveyance basis during the middle season except small tertiary canals having an irrigation area less than 30 ha. While for the first and third seasons, rotational supply will be applied among all the tertiary canals in each secondary canal. Small tertiary canals will be supplied water in accordance with a rotational supply schedule even in the middle season.

(3) Operation for the Water Saving Irrigation Method

In order to maintain high irrigation application efficiency, irrigation water to paddy fields should be distributed at a certain large discharge. Considering that irrigation water is distributed from a tertiary canal or watercourse to fields and from a paddy plot to a plot, a flow of 10 l/s to 20 l/s is desirable. With this discharge, water supply for land preparation of one hectare of paddy field takes half a day to one day. During the ordinary peak irrigation season, paddy fields of 10 to 20 ha can be irrigated every day.

Puddling works and transplanting works should be carried out immediately after a plot is filled with water.

In the water saving irrigation method, water corresponding to the required amount, less effective rainfall, is supplied during the period after transplanting until the end of tillering and the period of yield formation. In this method, standing water gradually runs out and the ground surface gradually become dry, because no water corresponding to percolation loss is supplied. In such a situation, if water is supplied in small discharge, much of the water is wasted and the water does not carry a long distance. Water should be supplied at rather a large discharge through plots with no standing water plots. Also, paddy plots should be provided with watercourses so as to smoothly convey water to the downstream paddy plots.

It is desirable to keep the soil water content in the root depth at not less than 75 % of full saturation in order to maintain good yields of paddy. In order to attain this requirement at a certain level, irrigation application should be made once a week.

During the period of 30 days starting at head initiation until the end of flowering, the most sensitive period to water deficit, additional water should be supplied so as to keep a moderate level of submergence.

16.2 Maintenance

16.2.1 Responsibility

Maintenance of the irrigation facilities would be conducted substantially by FWUC after completion of the construction works and taking over of the facilities. FWUC would be set up prior to the commencement of the construction works as mentioned in Chapter 15, and MOWRAM and other related government offices should support FWUC for a certain number of years after completion of the construction for realizing proper O&M by FWUC and sustainability of the scheme. The size of a FWUC depends on the scale of the scheme. Several types of FWUCs, which have conformed to the setting-up of FWUC mentioned in Chapter 15, are assumed as shown in Fig. 16.2. Each an FWUC should have FWUC Board[12], which would play a major role in O&M works.

Maintenance of the irrigation facilities would be planned by the FWUC itself. The maintenance procedures for facilities are described in detail in the following sub-section and summarized in Table 16.1.

16.2.2 Maintenance of Large/Medium Scale Irrigation Scheme

(1) Category of Maintenance

Maintenance works would be conducted by four categories consisting of: reservoir; diversion and main canals; secondary canals; and on-farm canals (tertiary canal and water courses). The frequency and magnitude of the maintenance works are; 1) routine inspection and maintenance (every day to once a week as required), 2) periodical inspection and repair (once a year before rainy season), and 3) periodical rehabilitation (once five years). The labor necessary for routine maintenance and periodical repair would be provided by FWUC as contribution, while for periodical rehabilitation, which requires a larger work volume, FWUG members will be hired as laborers on a piece-work basis.

(2) Maintenance of Reservoir

An FWUC Board member in charge of the reservoirs or main system would take responsibility of management of maintenance of reservoirs. The person-in-charge would operate the intake gates and maintenance gates of the reservoirs according to the operation and maintenance plan prepared by FWUC every year. He would also inspect damage on the gates, existence of debris, leakage, then keep

[12] Headquarters of FWUC like FWUC Apex of USP. For smaller FWUC or FWUG, Board of FWUC/FWUG would take part.

maintenance and inspection records, which would be reported and explained to the FWUC Board periodically as part of the routine inspection and maintenance.

Periodical inspection and repair, confirmation of gate function, painting of rust preventive paint, removal of debris, minor repair works of the dike and other facilities by man power would be conducted.

The periodical rehabilitation would involve major repair works of the dike and facilities, removal of sediment in front of the intake and maintenance gates so that smooth water flow to the gates is secured.

(3) Diversion and Main Canals

Maintenance of the diversion canal would be conducted by a member of the FWUC Board in charge of the main canal. In case that trouble such as damage to the structures, blockage of a canal section, illegal extraction or diversion is confirmed, he should keep records and report to the FWUC Board so it can call a meeting and solve the problems.

As for periodical inspection and repair, inspection and repair of intake facilities, crossing structures, such as removal of sediment, painting of the gates, and manual repair of the canals should be done.

The periodical rehabilitation would include rehabilitation of the dike and inspection roads, removal of sediment and debris in the canal, and major repair works of the structures. Necessary costs should be borne by part of ISF.

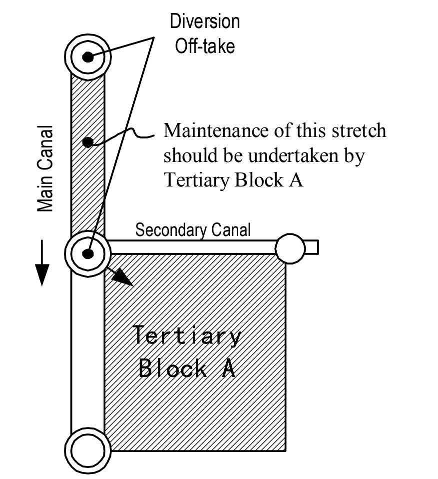


Figure Maintenance of Main Canal

The routine and periodical inspection and maintenance of the main canal would be conducted by FWUG members of the tertiary block of each secondary canal for a stretch between its diversion structure (beginning point of the secondary canal) and the upper diversion structure as shown on the right. Items of the inspection and maintenance would be similar to those of the diversion canal.

(4) Secondary Canal

The inspection and repair for the periodical and routine maintenance would be carried out by man power. The routine inspection and repair would basically be conducted by FWUC, but the actual works such as grass cutting and/or sediment removal will be carried out by FWUG members adjacent to the canal. FWUG members of a tertiary block should be responsible for the maintenance works between their off-take structure and the next upstream off-take as shown on the right.

Repair of minor damage to the secondary canals that would affect several tertiary blocks would properly be repaired as a part of periodical repair works. The works should be substantially organized by FWUGs. For the repair works, all tertiary blocks commanded by the secondary canals should provide the labor, and necessary materials and equipment would be procured by FWUGs by using funds from the ISF.

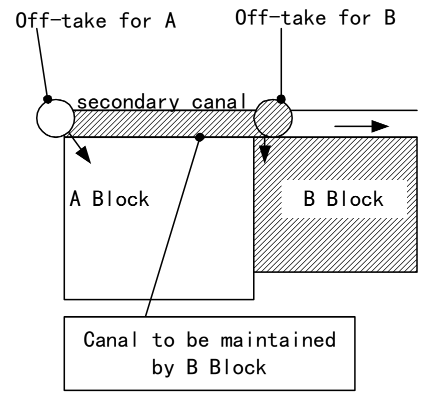


Figure Maintenance of Secondary Canal

The periodical rehabilitation (every five years) would be conducted for major repair of the canals and structures on the piece work basis by using reserved ISF.

(5) Tertiary Canal and Water Courses

Maintenance works of the tertiary canals and water courses would be carried out by Farmer Organizers (FO) whose role is mentioned in Sub-section 15.3.3 "Formation of FWUC". The routine inspection would be done by FOs and maintenance works would be done by the FWUG members. The periodical repair should be done before the rainy season spending about 10 days by all the members. Major works would consist of removal of sediment, painting of the gates, etc. and materials or cost for purchase them would be claimed by FOs to FWUC.

16.2.3 Maintenance of Small or Micro Scale Irrigation Scheme

Operation and maintenance of small reservoirs should be conducted by Farmer Water User Group (FWUG). Water depth of the reservoir is generally shallow and subject to the influence of sediment. However, no particular facilities for flushing the sediment are considered, and removal of sediment around the intake structures should be undertaken periodically.

As for the dike, routine inspection and maintenance should be done on the erosion of the slope by wave and rain water. Rust preventive material should be painted every year and removal of sediment from the pipe culvert should also be done periodically. It is desirable to fix the period of intensive maintenance works in a year, and all the FWUG members should participate in the works.

CHAPTER 17 ENVIRONMENTAL ASSESSMENT

17.1 Initial Environmental Examination

17.1.1 General

As mentioned in Chapter 9, the official EIA procedure as per Sub-decree is not required for projects of size/capacity less than the standards shown in the table in Section 9.2. However, it is recommended to conduct an Initial Environmental Examination (IEE) in order to confirm and highlight the impacts to be examined and monitored further.

IEE consists of three (3) parts, namely, i) project description and screening, ii) site description, and iii) initial evaluation.

The project description and screening aims to identify the project activities and related components to be examined.

The site description summarizes the present socio-economic status, natural conditions, area under specific designation, and other information.

The initial evaluation is conducted to examine the magnitude and extent of the impacts by each project activity/component to relevant environmental elements.

17.1.2 Project Description and Screening

Screening of the major project components should be done through specifying scale and characteristics of each component, in order to determine the components to be examined. If the scale is considered small enough not to affect the identified environmental conditions, the project component would be screened out. The screening is conducted with **FORM-15** in Attachment-1. A sample of the screening results is given in Table 17.1.

17.1.3 Site Description

(1) Present Socio-economic Status of the Project Area

The following items should be briefly described:

- land ownership and land use
- economic activities
- customs (water right, etc.)
- host people or community
- health and sanitation
- population

(2) Natural Conditions of the Project Area

As for the agricultural development projects, the following items should be briefly described:

- climate
- topography
- hydrology and drainage

- soil
- forest and vegetation
- rare species or fragile ecology
- water quality

(3) Area under Specific Designation

Existence of the following areas should be specified in/around the project area.

- fauna and flora in CITES,
- wetland designated in the Ramsar Convention,
- heritage sites under World Heritage Convention,
- Protected areas (national park, wildlife sanctuaries, etc.), and
- others (forest concession area, reforestation project area, etc.)

(4) Other Information

Other social and natural sensitive issues identified in the project area should be itemized and briefly described here.

The site description should be summarized in **FORM-16** in Attachment-1. A sample of the site description is given in Table 17.2.

17.1.4 Initial Evaluation

Initial evaluation is done with a matrix between the main components of the project identified in the screening process (Section 17.1.2) and environmental elements which might be affected by the components. Magnitude of the impacts anticipated is evaluated in five classifications as follows:

A: Relatively high magnitude of impact is anticipated,
B: Relatively moderate magnitude of impact is anticipated,
C: Relatively low magnitude of impact is anticipated,
X: No effect is expected, and
*: No relation

The impact or effect is divided into two categories, namely;

+: Positive effect is expected, and
-; Negative effect is anticipated.

The initial evaluation should be examined for socio-economic issues and natural environmental issues. The issues to be examined are given in **FORM-17** in Attachment-1. Samples of the initial evaluation are given in Table 17.3.

17.2 Environmental Impact Assessment

17.2.1 Detailed Investigation

In case that i) the important environmental conditions are identified (Section 9.3), or ii) the high magnitude of environmental impacts is expected (Section 17.1), it is recommended to carry out the detailed investigation. The detailed investigation is conducted focusing on the environmental conditions/elements identified specifically, taking heed of the following. It is better that the investigation results are presented along with maps, sketches, charts, and tables. The investigation methods and parameters adopted should also be clarified.

(1) Definition of Spatial Limit of Investigation

The geographic area subject to potential environmental impacts by the project should be defined prior to the commencement of the detailed investigation. The definition of the area to be investigated is dependent on many physical factors, for example:

- Scale of the project and type of the project activities,
- Areas directly affected by the project itself and areas indirectly affected
- Sensitivity of the surroundings from the natural or socio-economic viewpoint, and
- Ecological diversity in/around the project site.

These factors are to be considered for definition of the investigation area.

(2) Time Requirement for the Investigation

Some investigation works require consideration of period in a year. For example, where there are distinct rainy and dry seasons, investigation should comes the two seasons, and examination of the two transitional seasons might also be required. Species, such as migratory birds would only be present during a certain season. The factors of these time requirement are to be considered.

17.2.2 Impact Prediction and Assessment

Based on the results of the detailed investigation, it is important to predict the future potential impacts on specific environmental conditions/elements quantitatively or qualitatively, in order to develop the mitigation measures against impacts. In predicting the impacts, the following factors are to be considered.

- Intensity
- Extent
- Continuity
- Frequency
- Irreversibility
- Time-frame and delays
- Probability
- Direct or indirect impacts
- Uncertainty
- Cross linkage
- Visible or invisible impacts

Assessments are basically to evaluate the predicted impacts by means of the following methods.

1) "Absolute evaluation" is based on the comparison of the results of predicted impacts with environmental targets or standards (i.e. water quality standards, effluent standards, etc.)
2) "Relative evaluation" is based on comparison of the results of predicted impacts with the existing environmental levels.

In addition, it is better to consult with such the stakeholders as the local authorities, communities, and NGOs about the assessments of the predicted impacts.

17.3 Environmental Conservation Program

It is recommendable to establish an environmental conservation program, in case that:

i) The predicted impacts are assessed as exceeding the standards/targets of absolute evaluation,
ii) The predicted impacts are assessed as causing a serious and unavoidable deterioration to the existing environment according to relative evaluation, and
iii) Minimization of impacts is recognized to be preferable even though a high magnitude of impacts is not anticipated in IEE stage.

The environmental conservation program includes mitigation measures and monitoring. The contract document for construction often includes a component for environmental conservation so as to specifically address how the contractors are to incorporate environmental consideration into their work.

Cooperation and collaboration with other agencies and organization (MAFF, MRD, MOE, NGOs, local authorities, communities, etc.) are occasionally indispensable in order to ensure the effectiveness of the environmental conservation program.

(1) Mitigation Measures

Based on the magnitude of the impacts identified in the process of IEE or impact prediction and assessment, mitigation measures are considered to reduce the impacts. The measures should, to the greatest extent possible, provide details of the proposed work items and schedules. The following table is the basic strategy for developing measures (NEPA/USA).

Table Basic Strategy for Developing Mitigation Measures

Avoidance	Avoiding the impact altogether by not taking a certain action or parts of an action.
Minimization	Minimizing impacts by limiting the degree or magnitude of an action and its implementation.
Rectifying	Rectifying the impact by repairing, rehabilitating, or restoring the effect in the environment.
Reduction / Elimination	Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
Compensation	Compensating for the impact by replacing or providing substitute resources or environment.

Feasible and cost-effective measures that may reduce the environmental impacts should be selected and developed. They should be prioritized according to their relative importance, their capital and recurrent cost, and their institutional and training requirements. The approaches of measures or their examples are shown in Table 17.4.

(2) Monitoring

A monitoring plan should be developed, considering the following two viewpoints.

1) “Compliance monitoring” to confirm the implementation of mitigation measures.
2) “Effects monitoring” to determine whether the proposed mitigation measures serve their intended functions and effectiveness.

The monitoring activities, methods, schedules, responsibilities, and cost should be clarified to the greatest extent possible.

17.4 Implementation of Environmental Conservation Program

The mitigation measures and monitoring should be performed in compliance with the environmental conservation program, after the project is started (i.e. detailed design, construction work, and operation and maintenance stage).

In case that i) the mitigation measures are not as effective as expected, or ii) unanticipated environmental impacts occur, the cause should be identified, and proper countermeasure should be developed and implemented if necessary.

CHAPTER 18 PROJECT EVALUATION

18.1 General

Project evaluation is made for economic and financial assessment of the project in parallel with the technical justification of the project. The project specifically for irrigation and drainage development is evaluated by economic values to assess the economic viability of the project for comparison with alternative investment opportunities. In addition, the project is assessed by financial change and sustainability of household economy and relevant organizations compared to present and future conditions under with and without project implementation. The procedures for the project evaluation is summarized as follows:

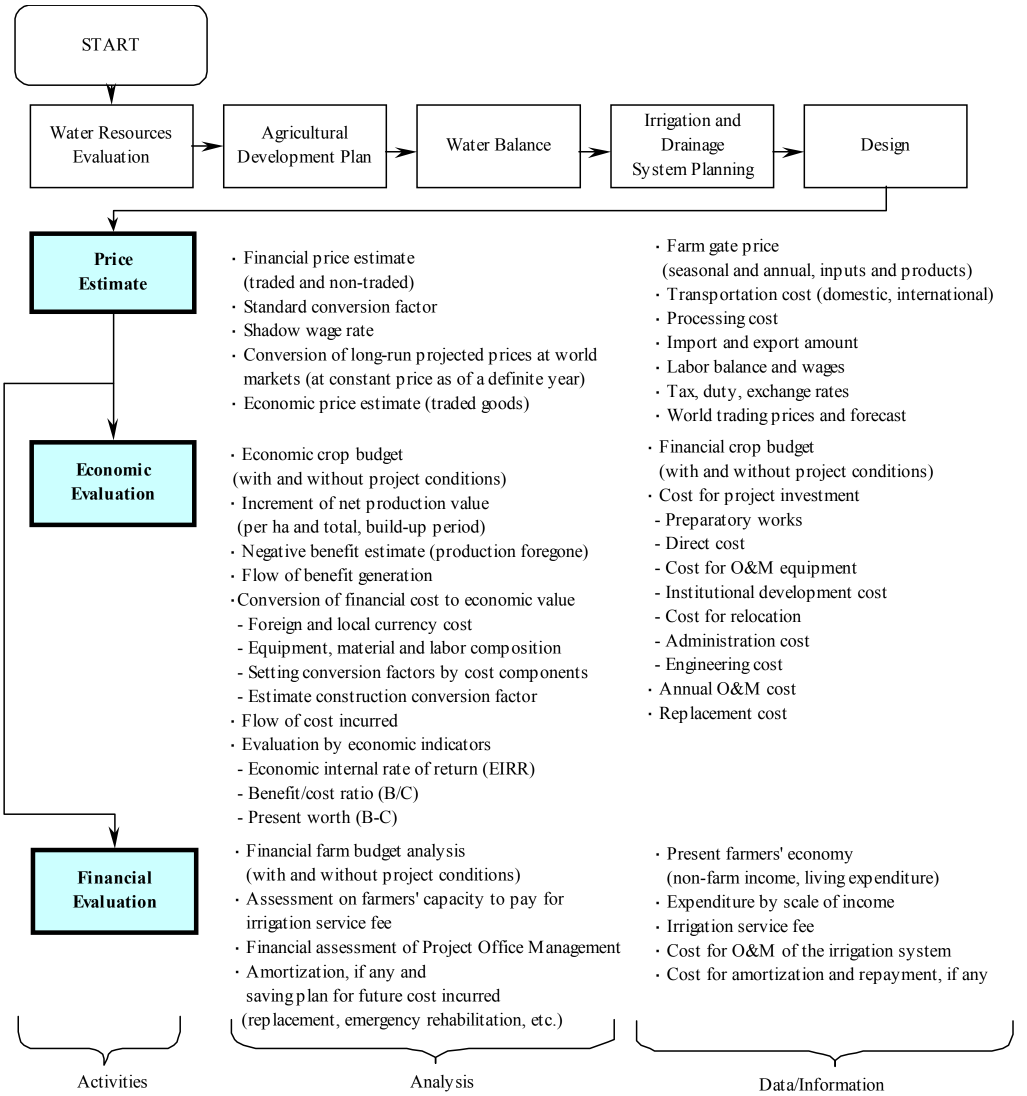


Figure Project Evaluation Flow

18.2 Price Estimate

18.2.1 Financial Farm Gate Prices

Farm gate prices of farm products usually fluctuate by season and method of sale. Determination of farm gate prices of farm products is made as follows:

1. Verification of prevailing trading practices of farmers in the area and their quantity:
   1) Method: selling to dealers along the road or the house, local markets, etc.
   2) Time: harvesting seasons, lean months, etc.
2. Verification of prevailing trading prices by season and place
3. Assessment of farm gate prices according to the sales quantity by season and place (weighted average)

Prices of farm inputs such as fertilizer, seeds, farm tools and equipment will be collected at the local shops, while the farmers usually procure the inputs and pay the transportation cost by them. The farm gate prices of farm inputs are defined as the sales prices at the markets and their transportation cost between the farmers' house and the markets.

A questionnaire survey needs to be implemented to collect actual price information, farmers' sales practices, source of inputs, means of transportation, quantity of sales and procurement prices. The data collected is analyzed for determination of representative farm gate prices of farm produces and inputs.

18.2.2 Economic Farm Gate Prices

(1) Information Required for Economic Price Estimate

The following information is required for assessment of economic prices of traded goods:

1. Transportation cost per unit in the country (the major terminal markets, international trading ports and boarder gateways, and the project area), and between the domestic international trading points and world market sites,
2. Processing cost per unit of products, i.e. rice from paddy, sugar from sugarcane,
3. Prices of by-products, i.e. rice bran, broken rice, rice straw, corn stalk, etc.,
4. Import and export quantity of traded goods related to the project in order

to determine the parity prices of goods,

5. Total import and export value,
6. Tariff rate, value-added tax, other taxes for trade and business activities,
7. Import and export subsidy,
8. Annual available labor force for farming and labor requirement without and with project conditions,
9. Long-run projected prices based on the World Bank Commodity Price Forecasts, and
10. Standard conversion factor based on the data of item 5, 6 and 7 (Ref. Table 18.1).

(2) Economic Price Estimate

Economic farm gate prices of traded farm inputs and outputs are estimated by using the information of the World Bank Commodity Price Forecast. The long-run projected prices are determined taking the year of realization of project benefits according to the project implementation schedule into consideration, i.e. at least after the completion of construction works, but not for too long as forecasts become unreliable beyond 10 years. Economic prices for traded goods are estimated according to the following formula (Ref. Table 18.2):

Table Estimation Formula for Economic Price of Traded Goods

Item	Import Parity Price		Export Parity Price	
1.Border Price				
Projected World Price				
Constant Price in 1990 price	=	100.0	=	100.0
Factor of Munufacturing Unit Value Index	x 1.01		x 1.01	
Constant Price in the project year		101.0		101.0
2.Quality Ajustment	x 0.9	90.9	x 0.9	90.9
3.International Shipping and Handling, if any	+	20.0	-	20.0
4.CIF/FOB Price at the Port	=	110.9	=	70.9
5.Port Charge, Handling and Warehousing	+	5.0	-	5.0
6.Price at the Port	=	115.9	=	65.9
7.Transportation Cost between the Port and the Major City	+	5.0	-	5.0
8.Wholesale Price in the Major City	=	120.9	=	60.9
9.Transportation Cost between the Project Area and the Major City or the Port	-	10.0	-	10.0
10.Price in the Project Area	=	110.9	=	50.9
11. Processing Cost	-	3.0	-	3.0
12.Transportation Cost from Farm Gate	-	2.0	-	2.0
13. Farm Gate Price	=	105.9	=	45.9
Share of Import and Export Quantity	50%		50%	
14.Weighted average economic farm gate price		75.9		

The cost of transportation for import and export parity prices is calculated according to the following nodes of commodity trading:

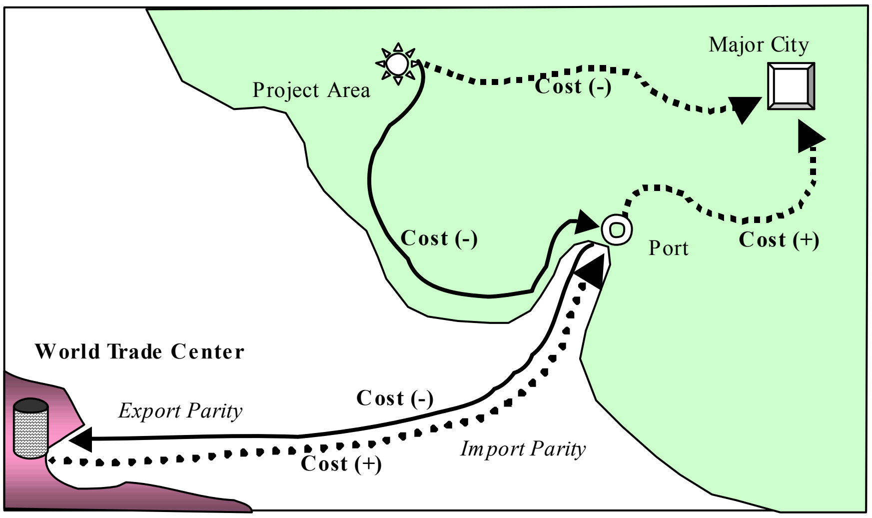


Figure Export and Import Parity Price Estimate

Labor market in the countryside is usually surplus under the less opportunity of employment and engagement of farm works, i.e. underemployment condition. The prevailing financial rate of unskilled farm labor needs to be converted to opportunity cost of labor (shadow wage rate in economic value) taking the actual demand and availability of farm labor into consideration. The shadow wage factor (ratio of shadow wage to financial price of farm labor force) might be changed by the irrigation and drainage development through the increase in farm labor requirement and also increase in the area population. The labor balance study is made on the basis of demographic data, farm labor requirement, and cultivation area under the without and with project conditions. The shadow wage rate is determined by multiplication of a shadow wage factor and a standard conversion factor (Ref. Table 18.3).

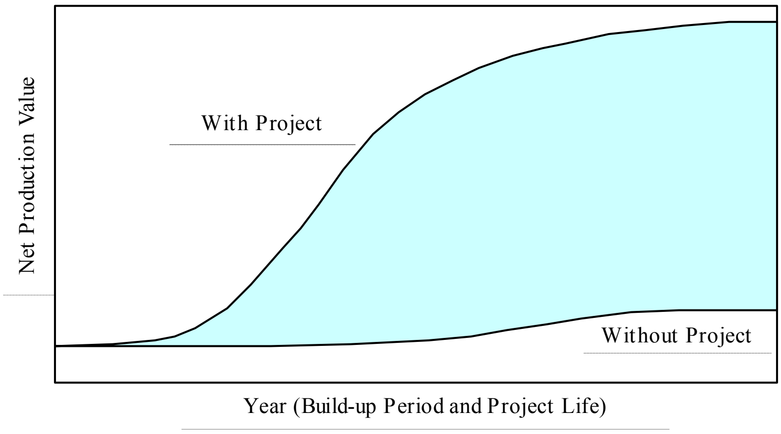
18.3 Economic Evaluation

18.3.1 Economic Crop Budget and Increment of Net Production Value (NPV)

Based on the financial crop budget, the economic crop budget is prepared under the with and without project conditions by applying requirements for farm inputs and total labor, unit crop yield, and their economic prices. The anticipated yield is assumed to be increased under the without project condition or set at the same level based on the past trend of yield and local condition (Ref. Table 18.4).

Direct irrigation and drainage benefits will be accrued from increases in cropping areas and productivity of target crops of the project. The economic benefit is estimated as the increment in Net Production Value (NPV) between the future with and without project conditions. The increment of the benefit will gradually increase year by year and reach full benefit several years after the initiation of the irrigation water supply and other support activities, i.e. usually assumed at three to five years depending on the beneficiaries' capacity and the project assistance. The increase of the benefit is illustrated as follows:

Figure Net Production Value, With and Without Project Condition



The economic irrigation and drainage benefit at full development stage (increment of NPV) is summarized as follows:

Table Economic Irrigation and Drainage Benefit

Project	Project Area (ha)	Cropping Intensity (%) Without Project	Cropping Intensity (%) With Project	Net Production Value (Riel Million) Without Project	Net Production Value (Riel Million) With Project	Net Production Value (Riel Million) Increment
	3,500	92	137	2,106.3	8,149.6	6,043.3
List up alternative and/or related project name		Show the change by the project		Sum of NPVs comprising various crops according to their areas		NPV (With - Withou)

18.3.2 Negative Benefit

Existing farmlands will be acquired and used for the construction of irrigation and drainage facilities. The value of production in the acquired area will be lost by the project implementation. The agricultural production foregone defined as the annual net production value under the without project is accounted for as negative benefit in the economic evaluation.

18.3.3 Economic Cost Estimate

The economic cost for the irrigation and drainage project comprises (i) cost for project investment, (ii) O&M cost, and (iii) replacement cost. The economic cost is estimated by applying relevant conversion factors to the respective components of financial foreign and local currency cost comprising equipment, materials and labor.

The economic cost of project investment is classified by (i) direct construction cost, (ii) O&M equipment cost, (iii) institutional development cost, (iv) administration cost, (v) engineering cost, and (vi) physical contingency. The price contingency is not included in the economic evaluation. The respective cost components are allocated according to the project implementation schedule (Ref. Table 18.5).

The financial O&M and replacement costs are converted to economic value by applying the same conversion factors concerned as for the cost of project investment. Those costs are allocated to the respective years based on the progress of irrigation development and the useful life of the project facilities such as the gates and O&M equipment (Ref. Table 18.6 and 18.7).

18.3.4 Economic Evaluation

The economic cost and benefit stream comprising (i) the cost for project investment, O&M and replacement, and (ii) irrigation and drainage, and negative benefit is prepared for the economic life of the respective projects. Economic internal rate of return (EIRR) is the discount rate at which the net present value (balance of present value between the economic benefit and cost) is zero. The benefit/cost ratio (B/C) and the present worth (B-C) at a specific discount rate are also calculated for assessment of economic efficiency of the projects (Ref. Table 18.8).

Table Economic Efficiency of the Projects

Item	Project A	Project B			Project C		
		B-1	B-2	B-3	C-1	C-2	C-3
EIRR (%)	10.8	10.2	10.7	7.2	9.9	13.1	7.6
NPV (Riel Million) (6.5% discount rate)							
Benefit	64,044	450	450	214	105	110	101
Cost	40,780	302	291	197	72	60	89
B - C	23,263	148	159	17	33	50	12
B / C	1.6	1.5	1.5	1.1	1.5	1.8	1.1

18.4 Financial Evaluation

18.4.1 Farm Budget Analysis

Farm budget is analyzed by assuming the anticipated change in income and expenditure for a representative farm household. A median size farm operation based on the farm survey and/or aland holding statistics can be applied for the farm budget analysis. In case a distortion in land holding observed in the project area, three classifications of farm budget, i.e. small, median and large scale farm operation, need to be assessed.

Other farm and non-farm income and living expenditure are assumed to be the same for both with and without project conditions in order to enable assessment of the direct impact on the farm economy of the projects (Ref. Table 18.9).

Table Farm Budget Assessment (Median Scale Farmer)

(Unit : Riel '000)

Item	Project A & B	Project C
Without Project		
Income	789.2	789.2
Expenditure	784.6	784.6
Net Reserve	4.6	4.6
With Project		
Income	2,011.6	923.1
Expenditure	1,081.6	804.4
Net Reserve	930.0	118.7
Increase (%)		
Income	155	17
Expenditure	38	3
Net Reserve	20,117	2,480

18.4.2 Capacity to Pay for O&M Cost

The increase in farm income will be spent for additional living expenditure, savings, and O&M cost for the irrigation and drainage facilities. The annual requirement of O&M cost of the projects is estimated and compared with the increment of net farm income. In the case shown in the following table, the O&M cost requirement is below 10 % of the increment of net income for the project A and B, and below 20 % for the project D.

Table O&M Cost Requirement and Share to Net Reserve

Project	O&M Cost (Financial)		
	Per ha (Riel '000)	Per 0.8 ha (Riel '000)	Share to Incremental Net Reserve(%)
Project A	76.7	61.4	7
Project B			
B-1	96.0	76.8	8
B-2	96.0	76.8	8
B-3	96.0	76.8	8
Project D		(0.07 ha)*	
D-1	152.0	10.6	9
D-2	268.0	18.8	16
D-3	258.0	18.1	16

Note : * Irrigated area per median farmer (0.8 ha)

18.4.3 Financial Assessment of O&M Organization

The financial sustainability of O&M activities to be implemented by Farmer Water User Committee (FWUC) and Project O&M office is assessed on basis of the revenues and expenditure. The revenue is accrued from the Irrigation Service Fee (ISF) comprising (i) regular O&M work and (ii) savings for emergency works and facility replacement, and other income. Expenditure for O&M activities comprises cost for personnel, maintenance of the facilities, equipment to be procured, replacement of facilities, capacity building program, etc. Annual balance of the revenue and expenditure needed to be saved in order to supplement expenditure for emergency repairs and facility replacement. The financial assessment of O&M organization is shown as follows:

Table Financial Cash Flow for O&M Activities

(Unit : Riel Million)

Year	Revenue				Expenditure							Balance	Cumulative
	Regular ISF	Saving ISF	Others	Total	Personnel Cost	Mainte-nance Cost	Equipment (Newly Procured)	Recurrent Cost	Replace-ment Cost	Capacity Building Program	Total		
1 2 3 4 5 6 7 8 9 10 .	ISF for annual regular expenditu	ISF for saving emergency repair & replacement	Other income from pre- and post-harvest activities		Salary/ incentives for FWUCs' regular staff	Cost for materials and labor		Running cost for office (water, electricity, supplies, etc.) vehicles, motorbike, etc.	Irri.& drainage facilities, buildings, vehicle, motorbike, equipment, etc.	Cost for refresh training, workshop, etc. for the FWUC staff		Balance of total revenue and expenditur	Cumulative amount of annual balance

CHAPTER 19 PARTICIPATORY PLANNING APPROACHES

19.1 General

Although the participatory planning approaches are not common in Cambodia, a project planner should accept the opinions and requests of the stakeholders in the project area as much as possible, and make/modify the plan. For this, meetings particularly informal ones with stakeholders such a beneficiaries and the disadvantaged, would give good suggestions for making the plan more attractive and acceptable to them.

An interview survey of all the stakeholders can be properly conducted for small projects. But for medium or large-scale projects, it will be more appropriate to adapt the interview survey to a sample basis to make the survey process and results more efficient and equitable. “Rapid Rural Appraisal” (RRA) is a comprehensive participatory planning procedure which would provide a clear understanding on the selected households or communities in a comparatively short period.

A public hearing meeting held in the form of “Participatory Rural Appraisal” (PRA) would help the stakeholders in understanding the draft project plan and giving their comments for finalizing the plan.

Agreement of the stakeholders of the project would be essential for its successful implementation and sustainable development. For this, the stakeholders should participate in the planning process and hold a common understanding of their status, as either advantaged or disadvantaged. It is also important that all stakeholders should be kept independent through the course of the participatory planning process so that any bias and state power of the influential person should be avoided.

The participatory approach promotes beneficiaries to develop awareness as the “owner of the project”. And also it will be an important step for them to receive technical and fund input from outside. The conditions of the inputs should satisfy the beneficiaries’ needs. The government that promotes the project would also have to understand that it would require sustainable effort to maintain project efficiency and sustainability by getting participation of the beneficiaries.

The first approach to be taken is to have a clear understanding of the circumstances of the assumed beneficiaries, to evoke them to participate in the project smoothly.

In some cases, conflicts among the stakeholders might affect the function of the community due to the advantages and disadvantages that would be brought by the project into the community. Expectation on beneficiaries' participation by the project would often make the beneficiaries reluctant to get involved in the project. It should be noted that the project planner should always keep a sense of neutrality and regard for equity for all the stakeholders.

19.2 Rapid Rural Appraisal

The "Rapid Rural Appraisal (RRA)" consists of two approaches, namely, ① Key Informant Interview and ② Individual Interview. The Key Informant Interview is directed at community leaders who have various kinds of knowledge, experience and opinion, while the Individual Interview targets individuals who have representative or typical attributes in the project area. The "Semi-structured Interview" (SSI) is applied for both of the above interview surveys. The SSI has only main topics to discuss with the interviewees. The sequence of topics might be changed incidentally in an ad hoc manner. Also, detailed questions on each topic might be asked as required. The Structured Interview has detailed points to be asked to the interviewees, and the survey points might be subject to the bias of the persons that prepared the questions. Purposes of SSI are to prevent such bias and to allow flexible interview based on the interviewers' judgment and the responses of the interviewees.

Both interview surveys should be conducted by organizing a group consisting of specialists of different fields. Differences of specialties would supplement each other. An example of question subjects for Key Informant Interview and Individual Interview is shown in the following page. Secondary data should be prepared prior to the interview survey. The secondary data are statistical data and maps. Results of the questionnaire survey should also be analyzed if it is conducted. A session of RRA requires more than three (3) days: the first day is for preparation of the secondary data, the second day for the Key Informant Interview and the last day for the Individual Interview. Summarization of each interview should be conducted in the same day not to spoil the interview results that may be forgotten as time goes by. A report on the meeting should be prepared if several teams are organized to execute several surveys at a time. Sharing of information and understanding of problems found on the surveys with all the participants is important. The report on the results of RRA will assist the understanding of other planners that could not participate in the RRA survey. Sample of the RRA report is shown in Table 19.1.

(1) Key Informant Interviews

Map	
Physical layout:	Village boundary, Neighborhood distribution, Road, Water resources, Common land, Village settlement, and others
Topography:	Major land types and land use pattern.
Soil:	Soil types, distribution and problems. Changes in soil fertility and soil management.
Water resource:	Sources of water for human and agricultural uses, Seasonal and long-term variability in water supply, Water management practices, Problems and opportunities.
Land use:	Area, Type, Availability, Utilization and Management.
Infrastructure:	Infrastructure map (Household distribution, Road, Public amenities), School, Temple, Electricity and Transportation

Crops	
Crops:	Type and varieties (crop inventory), Objectives of planting each crop, Crop calendar
Practices:	Pre-planting, planting, harvesting and post-harvesting (fertilizer and insecticide use)
Pattern of land and labor use	
Products and product distribution	
Problems:	Limiting factors for major crop production and opportunities

Livestock and Fisheries	
Types and breeds/ species	
Use of livestock:	Consumption, economic and rituals
Cultural practices:	Feeding, shelters and disease control
Livestock calendar	
Technology acceptance	
Problems:	Limiting factors for livestock production and opportunities

Economic Data	
Occupation, Income and Expenditure:	Type of occupation (No of HHs involved in each activities)
Labor Utilization Pattern:	Labor calendar
Marketing and Credits:	Markets for products, inputs, goods and labor. Exchange of goods. Formal and informal credits (range of credits). Flow diagram
Land Tenure:	Distribution of land holdings. Land ownership. Land inheritance system.
Social Stratification:	Criteria used to classify social stratification. Characteristics and no. of households in each strata. Wealth ranking

Groups and Kinship	
Groups:	No of important groups (Formal and informal groups). Groups forming and objectives. Group activities. Leader and committee. Relationship with other groups (Exchange information, capitals, labors, supplies, advices and others). Intra-village. Inter-village.
Kinship:	The primary kinship that founded the village (which kinship). Where did they come from? Relationship between kinship (kinship diagram). Name of kinships. Inter-kinship marriage. Kinship zoning in village, migration. Relationship of family group in the village. Which kinship contributes mostly on the village development?

Socio-Cultural Data	
History of the Village:	History of the village settlement. Major events in the village/ outside the village (time line).
Population:	No. of household, no of population, sex ratio, ethnic groups, birth rate, migration (seasonal and permanent).
Festival Calendar:	Beliefs and Taboos (in relation to resource utilization).
Development Project in the Village:	Types of agencies and activities.
Social Infrastructure:	Education (formal and informal education, perceptions of parents about education of their children). Health (Health services; modern and traditional medicine, Common disease, Malnutrition. Infant mortality rate. Sanitation). Religion (Role of monks in the village)

(2) Individual Informant Interviews

Family Structure
No of Family Member, Age, Sex and Job of all member, No of Worker (Full-time and part-time respectively), Seasonal differences (Study in the other place, Migrant work), Health Condition

Land
Distribution (Location) of Land (Draw his/ her house), Area, Land Tenure (Ownership), Utilization (Kinds of crops, Yield), Water Sources for Crops and it's Condition

Farming Practices
Varieties of Crops, Purpose of each Crops (Self-consumption, Purchase), Farming Practices (Seeding, Harvesting and post-harvesting, Rotation of crops), Work Inputs (Family labor, Employment labor, Work sharing), Usage of Agro-Chemicals, Fertilizer, Manure, Tractor, Pomp, Yield, Marketing Channel

Livestock and Fishery
Raising Pattern, Varieties of Livestock and Fish, Purpose of raising, Condition and Location of Raising Farm, Disease Control

Non-agricultural Income
Types of Non-agricultural Work (Handicraft, Peddling, Farm Labor, Migrant work), Purpose, Income

Cash Income and Expenditure
Cash Income Sources (Sources and amount), Money Flow, Assets (Savings, Fixed property, Mobile phone, Motorbike, Tractor, TV, Refrigerator)

Savings and Debt
Formal Debt, Informal Debt (Private money lender), Interests for debt, Propose for Debt

Decision Maker and Troubles
Decision Maker for Expenditure (Usual expenditure and expensive expenditure), Troubles for living (Stress and domestic troubles)

19.3 Participatory Rural Appraisal ~ Public Hearing Meeting

The draft project plan formulated by the planner by using various information and site surveys, should properly be opened to the public or stakeholders prior to the implementation so that the planner could reply questions, receive comments and opinions, and modify the draft plan as the final plan by adopting such comments. However, it is not sufficient for attaining the project purposes that the planner distributes explanatory paper on the project to the stakeholders or holds a meeting only to explain the plan.

Most of assumed beneficiaries in rural areas are not familiar with such meetings, and it is rather difficult for such beneficiaries to understand the intention or purpose of the project and to provide the necessary information that the planner requires, or express their problems and needs. Thus a "public hearing meeting" is recommended to make the beneficiaries participation in the planning process easier and more productive.

The public hearing meeting has to be organized by well-trained facilitators who can flexibly change and adjust the contents of questions according to the participants' understanding and generate an atmosphere so that the participants feel free to join the discussion. If the literacy rate of the participants is low, visual materials which explain the project outline or others should be prepared. Preferably, the facilitators for the public hearing meeting should have had training in the PRA.

The PRA is one of a series of procedures that are used for study stage of the project aiming at local people and outsiders to learn from each other. On the other hand, most of advantages of PRA could be applied for the public hearing meeting at the planning stage.

Other than facilitators, planner(s) should also participate in the meeting because detailed questions about the project might be asked. The planners who participate in the meeting should understand the whole plan of the project. Meetings with the chiefs of public administration such as at the province, district and commune level should be held separately without other stakeholders so that participants can express their opinions freely. In some cases, the village chief would not be invited to the meeting for the same purpose. The likelihood of such an atmosphere can be discovered through preliminary survey like RRA.

Although all of stakeholders should have a chance to participate in the public hearing meeting and to express their own opinions on or requests for the draft plan, it will be impossible to hold a meeting inviting all the stakeholders, which sometimes number over one thousand, for large-scale projects. As the purposes of the meeting are to grasp the problems of the draft plan for stakeholders and to listen to their requests, the meeting should be held with representatives of each group as categorized by the planner. The stakeholders will be divided into these groups as shown below.

(1) Group that will lose land and/or other assets by rehabilitation or reconstruction of reservoir and/or irrigation facilities,
(2) Beneficiaries group that will receive some or sufficient irrigation water,
(3) Women's group including woman headed household,
(4) Group of large paddy field cultivators who operate more than 2 ha,
(5) Group of small paddy cultivating farmers who operates less than 0.2 ha,
(6) Village chief and president of VDC,
(7) Local administration such as commune, district and province, and
(8) Related NGO and IO group.

However, it is indispensable to get the cooperation of the commune chief and village chief to reach agreement on the project from all the stakeholders. Thus a number of meetings by participatory approaches with the various stakeholders are required.

19.4 Other Participatory Approaches

"Participatory Evaluation" of the project by the planner, beneficiaries and other persons concerned with the project should be conducted to evaluate their activities compared with planned activities. Evaluation by outsider might also be effective.. The results of evaluation should be fed back to the project to improve the draft plan. However, if some results evaluated by the outsider have negative points that reject the project itself, such results would not be acceptable for the persons concerned with the project,

For improvement and sustainable development of the project, it is important that the people concerned with the project should participate in the evaluation, analyze problems and work out countermeasures. Those concerned with the project will get more skills for evaluation and applying countermeasures against the problems from such experience of evaluation. They would also increase their awareness of the project thorough participation in the evaluation process.

Purposes of the Participatory Evaluation are, (1) strengthening of management ability, (2) strengthening of ownership awareness, (3) effective feed back and (4) improvement of accountability.

Stakeholders, including beneficiaries, should participate in the evaluation, preparation of the evaluation plan, supplying, collecting and analyzing of information, and modification of original plan as much as possible. The evaluation would be done not only at the end of project, but also at the beginning (pre-evaluation), and monitoring the on-going project is considered as one of the evaluation activities.

"Project Design Matrix (PDM)" is used for "Project Cycle Management (PCM)". The PCM is a procedure for participatory planning, monitoring and evaluation. The PDM is used for all steps of PCM. "Project Purpose", "Activities", "Inputs" and "Important Assumption" are arranged in one sheet (PDM), and these are linked each other. Sample of PDM is attached in Table 19.2. PCM is a logical framework procedure.

(1) Participatory Planning Approach

Stakeholders of a project (related administrations, beneficiaries, working agencies and planners such as consultants) will participate in PCM workshop and formulate a plan. In the workshop, "Participation Analysis", "Problem Analysis", "Objective Analysis" and "Project Selection", PDM and activation plan will be made. The PDM will be made at the final stage of the workshop with all the participants, and a detailed activation plan will be made by the planners.

(2) Monitoring and Evaluation

The purposes of monitoring the project using PCM procedure are; i) to check whether the project conforms to the original plan, and ii) to modify the plan and PDM in accordance with progress. The purposes of the evaluation are to check any on-going and completed projects on five points of evaluation* so that suggestions for the projects future and lessons for other projects can be applied.